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T H E  
B O O K of N A T U R E;  
O R, T H E  
H I S T O R Y OF I N S E C T S:

Reduced to distinct CLASSES, confirmed by particular INSTANCES,  
Displayed in the Anatomical Analysis of many SPECIES,

A N D

ILLUSTRATED with COPPER-PLATES,

INCLUDING

The Generation of the FROG, the History of the EPHEMERUS, the Changes of FLIES,  
BUTTERFLIES, and BEETLES;

WITH THE

Original Discovery of the MILK-VESSELS of the CUTTLE-FISH, and many other curious Particulars.

By J O H N S W A M M E R D A M, M. D.

WITH

The LIFE of the AUTHOR, by HERMAN BOERHAAVE, M. D.

Translated from the DUTCH and LATIN Original Edition,

By T H O M A S F L L O Y D.

Revised and improved by NOTES from REAUMUR and others,

By J O H N H I L L, M. D.



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MDCCLVIII.

BOOK & TABLE

1877

THE HISTORY OF THE  
ROYAL SOCIETY OF MEDICINE  
AND THE ARTS  
IN GREAT BRITAIN  
FROM THE YEAR 1662 TO 1800

BY  
JOHN HENRY CLAPHAM

IN TWO VOLUMES  
LONDON  
PRINTED BY RICHARD CLAY AND COMPANY, LTD.  
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1917



THE HISTORY OF THE  
ROYAL SOCIETY OF MEDICINE  
AND THE ARTS  
IN GREAT BRITAIN  
FROM THE YEAR 1662 TO 1800





TO THE RIGHT HONOURABLE

GEORGE

EARL OF MACCLESFIELD,

PRESIDENT

OF THE ROYAL SOCIETY,

This WORK

Is most Humbly Inscribed,

By His LORDSHIP'S

Most Devoted Humble Servant,

The EDITOR.



T H E

L I F E

O F

# JOHN SWAMMERDAM.

**J**AMES Theodorus was born in Swammerdamme, a village of Holland situated upon the Rhine, between Leyden and Woerden; and removing afterwards to Amsterdam, where he carried on the timber trade, obtained the surname of Swammerdam from the place of his nativity. In this last place heaven blessed him on the last day of January in the year MDCVI, with a son, who was called John James Swammerdam, who followed in that famous city the business of an apothecary. As this John was very studious of natural history, and very well skilled in several branches of it, so he diligently improved every opportunity of cultivating it, which his residence and way of life afforded; and for fifty years together spared neither pains or expence in procuring proper materials for that purpose. And indeed his collection was very magnificent, his house being full of animals, insects especially, vegetables, and fossils, though without the least confusion, every thing being disposed in its proper place and order. But the chief ornaments of his museum were curiosities from both the Indies, and particularly the porcelain of China and Japan. Both citizens and strangers viewed this collection with admiration; and the greatest princes, that passed through Amsterdam, visited it, as one of the things best worth their attention in that famous city. Many of these, delighted with the sight of so beautiful a spectacle, offered to purchase it, but were surpris'd at the price, the possessor valuing it at sixty thousand Dutch florins; though after his death, when his curiosities were sold publickly in single lots, they scarce fetched one sixth of that price.

This great naturalist, and Barentje Corver, daughter of John Janfz Corver, were the parents of John Swammerdam, who was born at Amsterdam the twelfth of February MDCXXXVII, and lived to be the celebrated author of this valuable work.

His father intended him for the church, and with this view took care to procure him early instructions in Latin and Greek; but our author, after a serious examination of his own disposition and talents, thought himself unequal to so important a task, and brought his father to change his former intention, who thereupon consented to his son's applying himself to physic; but as he kept him at home till he should be properly qualified to engage in that study, he frequently employed him in cleaning his curiosities, and putting every thing in its proper place. This occupation inspired our author in

a manner from his childhood, with a taste for natural history, so that not content with the survey of those curiosities that his father had purchased, he soon began to make a collection of his own by catching some, and buying or bartering for others, all which he disposed in certain classes; and compared with the accounts given of them by the best writers. However, when grown up, he very seriously attended to his anatomical and medical studies, but all the while with a mind bent on attempts of the greatest importance. Accordingly he spent both day and night in discovering, catching, and examining, the flying insects proper to those two different times, not only in the province of Holland, but in that of Gueldres, and in the the province of Utrecht. He ransacked with this view the air, the land, and the water; fields, meadows, pastures, corn grounds, downs, wastes, sand hills; rivers, ponds, wells, lakes, seas, and their shores and banks; trees, plants, ruins, caves, uninhabited places, and even bog-houses, in search of Eggs, Worms, Nymphs, and Butterflies; in order to make himself acquainted with the nests of insects, their food, manner of living, disorders, changes or mutations, and their several ways or methods of propagation; and, indeed, while yet a very young man, he had made more discoveries in regard to all these particulars, and obtained more certainty, than the known authors of all the preceding ages put together. This, however incredible it may appear to some, is notwithstanding matter of fact. Persons properly qualified to judge of his success, have honoured it with the same testimony.

Our author, thus initiated in natural history, came to Leyden in the year MDCLI, to pursue his studies in the Dutch university, of which he was admitted a member the eleventh of October, and attended assiduously for two years together the lectures in surgery of the celebrated John Van Horne, and those in physic of Francis Sylvius de la Boe; and his progress in those noble studies was so answerable to his diligence, that on the eleventh of October MDCLXIII, he was admitted a candidate of physic in that famous university, after undergoing the examinations prescribed on that occasion. Our author, on his arrival at Leyden, contracted a friendship with that great anatomist Nicholas Steno, and ever after lived with him in the greatest intimacy. He likewise commenced a friendship with Rynier de Graaf, another eminent anatomist; but emulation, or rather envy, afterwards changed it to an inveterate hatred. The curiosities of anatomy now began to make a considerable impression on our author, formed it seems by nature herself for the cultivation and improvement of that noble science; so that having gone through his courses with the most sudden and unexpected success, he immediately began to consider how the parts of the body prepared by dissection, could be preserved and kept in constant order and readiness for anatomical demonstrations; as such a discovery would free him not only from the trouble of repeated dissections, but likewise from the difficulty of obtaining fresh subjects, and the disagreeable necessity of inspecting such as were already putrefied. And herein he succeeded, as he had done before, in his nice contrivances to dissect and otherwise manage the minutest insects. Sylvius, the most diligent anatomist of his time, made good use of this our author's great art and indefatigable industry; but was chiefly delighted at his extraordinary skill in dissecting Frogs; for Swammerdam had demonstrated to him by actual experiment, so early as the fifteenth of January of this year, that in this animal the air at the time of inspiration could be derived to the artery and pulmonary vein, and thence to both regions of the heart. See Sylv. Disp. Med. VII. §. LXXIX. — LXXXVIII.

After

After this our author made a journey into France, where he spent some time at Saumur, in the house of Tanaquil Faber, and made a variety of observations upon insects. It was there, that on the nineteenth of June MDC LXIV, he discovered, by means of very slender tubes, the valves of the lymphatic vessels, which he immediately sent, on the twenty-eighth, delineated with his own hand, to his friend Steno, who he then thought resided at Copenhagen. See his treatise on Respiration, page 90, 91. He afterwards wrote to Thevenot on the twenty-fourth of September in the year following, that perhaps the famous Frederick Ruysh might have seen those paintings before he published his own on the same subject: this he mentioned to Thevenot, on occasion of his sending him from Paris to Amsterdam, the little treatise on those valves which Ruysh published the same year at the Hague. But Swammerdam barely hinted this, without directly charging Ruysh with plagiarism, which he owns it is impossible for him to prove; on the contrary, he expresses a great deal of affection for his rival in this discovery, and says, he is sincerely rejoiced at his having the honour of it. And no doubt Swammerdam did no more than justice to Ruysh's merit on this occasion, as this last, long before the edition of his book, had shewed these valves to others, and even to Bilis. But the letters directed to Steno at Copenhagen, could not reach his hands in Holland, where he then resided, but very late; and if Ruysh had seen them, how could he have had the assurance to publish the drawings taken notice of, without mentioning Swammerdam, who was then living, and even on the spot. Among other things, our author, during his stay in the neighbourhood of the Loire, observed and described the flying insect called Libella or Dragon Fly, and likewise some Hemerobia or Day Flies. From Saumur he went to Paris, where he lived in the same house, and in the greatest friendship with Steno. He likewise contracted an intimacy with Melchisedec Thevenot, a very worthy gentleman, and formerly the French king's minister at Genoa, who most hospitably received and entertained him and Steno at his pleasant country seat of Yssi, at a few miles distance from Paris, and thereby afforded our author an opportunity of making further observations upon the insect creation. Not satisfied with this piece of politeness, he in consideration of Swammerdam's singular abilities, and the great pains he had taken to cultivate them, made him a most liberal offer of every thing he thought requisite to promote his studies. Our author ever retained a grateful memory of those favours, and others which he afterwards from time to time constantly received from this great respecter of merit; and a little before his death owns in one of his letters, that he had never found in any other person, so true, faithful, and sure a friend. Thevenot introduced his guest to a great many other gentlemen, who met frequently at his house with a view of cultivating the arts and sciences; but in all their assemblies our author continued for a long time, notwithstanding all the company's entreaties, a silent auditor only, till his modesty being at last overcome by repeated importunities, he found himself obliged to give one and then another specimen of his manner of dissecting insects, and of shewing their inward parts; by which he gained great applause, as by his tacit skill he effectually silenced the talkative ignorance of others. Thevenot, moreover, strenuously recommended our author's skill to that great man Conrad Van Beuningen, a senator and burgomaster of Amsterdam, and at that time that republick's minister at the court of France; who obtained leave for Swammerdam at his return home, to dissect the bodies of such patients as should happen to die in the hospital of that city: and our author improved himself

himself greatly in anatomy, by making the proper use of so favourable an opportunity.

But this was not the only opportunity which providence threw in our author's way at this time, as the principal physicians of Amsterdam had formed a college, and had agreed to meet together every other week in order to confer on medical, but chiefly anatomical subjects, and to make experiments relative thereto. The observations of this society of learned men were afterwards published by Casper Commelin, in the year MDCCLXVI and LXVII, before Swammerdam had been created doctor of physic; notwithstanding which, he was the first to furnish materials for it. It was he, and he alone, that made in the said college, with his own hand, a drawing of the spinal marrow, published by Blasius at the same place; and on this occasion he wrote to Thevenot the following particulars. I. That the spinal marrow consists entirely of fibres. II. That those distinct fibres meet and terminate in some part of the brain. III. That there issue fibrous nerves from the fibres of the spinal marrow. IV. That the pia mater is altogether extended into hollow sheaths. V. That all these things may be easily seen, by suddenly placing the yet warm spinal marrow along with the vertebræ containing it, in cold water, and breaking the vertebræ with great caution from the marrow, after having suffered both to remain in that situation during the space of a day and a night. This letter was written the first of April MDCCLXVI; our author at the same time tried many experiments by injecting the vessels of living animals with various liquids. See de Resp. page 103 and 107. He even made some chemical experiments on the cold fermentation produced by mixing together the salt of urine, and the spirit of glauber salts, *ibid.* p. 111. He then too composed that laborious essay on respiration, which he was to maintain on his declaiming for his degrees in physic. We may be convinced by reading this performance, that he only pursued such things as he thought of in his own way, and of whose truth he had satisfied himself, and could convince others by experiments, without borrowing any assistance from other writers. Having finished this dissertation, he came back to Leyden to take out his degrees; and took occasion of his stay there to cultivate a most intimate friendship with the famous Van Horne, who had been formerly his preceptor in the study of anatomy. With this gentleman he then practised this useful art, and prepared a great many things in many various ways, while both publickly owned a community of sentiments and discoveries. The professor most liberally supplied all kinds of materials, the other directed the work, and at the same time made with his own hands the most masterly drawings of each discovery, which he immediately forwarded with suitable observations to Matthew Slade. Nothing here was wanting to carry on so laudable an undertaking. Van Horne's liberality contributed the subjects, the instruments, and every other expence; and Swammerdam's wonderful skill was day and night employed in making proper use of them. It was at this time, and on the twenty-second of January MDCCLXVII, that in Van Horne's own house, Swammerdam first injected the uterine vessels of a human subject with a ceraceous matter, which most useful attempt he afterwards improved and perfected. The twenty-second of February of the same year, he was admitted to his degrees as doctor of physic, after having publickly maintained his diatriba or thesis on respiration; which was then conceived but in short and contracted arguments, but appeared the March following with considerable additions in a volume from the printing-house of Gasbekios, with a dedication to the illustrious Thevenot, and adorned with a frontispiece of a most elegant figure

figure of the reciprocal copulation of the hermaphrodite house Snail. John Baptist Van Lamsweerde published in opposition to this of Swammerdam another most vehement dissertation, which he entitled, “An Expiration of Swammerdam’s System of Respiration;” but this attempt fell short of its author’s expectation: for though Swammerdam’s book may contain some things out of the way, they will be readily excused by equitable judges, in consideration of the many curious and just observations that are to be met with in every part of that work. Another occupation of Swammerdam’s at this time was to blow up with air the parts of the body first properly evacuated and cleansed, that by drying in this situation they might afterwards retain it, and so at all times afford an opportunity of observing and describing them. This certainly must be allowed one of the most useful inventions in anatomy, as by it we can erect and stiffen parts, which would putrefy on lying one upon another, and which if injected with wax would be rendered obscure and confused. It was thus our author cultivated anatomy with the greatest art and labour, in conjunction with the celebrated Van Horne; but a quartan ague, which attacked him this year, brought him so very low, that he found himself under a necessity of discontinuing his anatomical studies, which on his recovery he entirely neglected, in order to give himself up to the study of insects. In the year MDCLXVIII the great duke of Tuscany being then in Holland with Mr. Thevenot, in order to see the curiosities of the country, came to view those of our author and his father, and surveyed them with the greatest delight, and his usual taste and attention for natural history. On this occasion Swammerdam made some anatomical dissections of insects in the presence of that great prince, who was both a lover and a most skilful judge of such things, and who was struck with admiration at our author’s great skill in managing them, especially at his proving that the future Butterfly lay with all its parts neatly folded up, in a Caterpillar, by actually removing the integuments that covered the former, and extricating and distinctly exhibiting all its parts, however minute, with incredible ingenuity, and by means of instruments of an unconceivable fineness. On this occasion his serene highness offered our author twelve thousand florins for his share of the collection, on condition of his removing them himself into Tuscany, and coming to live at the court of Florence. In this certainly the prince acted very wisely, as those curiosities would be in the greatest danger of being lost or becoming useless, if not preserved and shewn by the great genius that had collected them, and who was alone capable of shewing every article, and exhibiting them to the greatest advantage; but Swammerdam, who hated a court life above all things, rejected his highness’s proposal. Besides, he could not put up with the least restraint in religious matters, either in point of speech or practice. In the mean time, he had the happiness of discovering in the dissection of an overgrown Acipenser, a very large pancreas, which, by discharging its fluid contents into the first intestine through a great many spacious and open-mouthed channels, gave a most satisfactory opportunity of examining this, at that time, so famous and much-talked-of fluid, in which, on the strictest examination, he could discover no acid taste, but rather a bitterish rankness, resembling that of gaurus, or pickle made of fish.

This our author affirmed publickly, contrary to what had been before advanced by de Graaf and Sylvius. He also made some observations in the hospital, but merely as supplementary additions to his other inquiries; for he now made the nature and properties of insects his chief study, and pursued it with infinite diligence, and without the least relaxation; so that in the year MDCLXIX, he published a general history of them, a work equally remarkable for

the author's great boldness in the attempt, and happy success in the execution. This performance he dedicated to the honourable the burgomasters of Amsterdam. But as he was entirely bent on perfecting this work, and collecting of insects from every quarter of the world, and then disposing them in separate boxes in order to form a complete catalogue, which was attended with great and constant expences, without the least return. Our author's father, who had always kept him at home, and supplied all his expences, began to take offence at his proceedings; for though he was now above thirty years old, and consequently had spent the best years of his life, he had not as yet engaged in any business that could serve to render him easy and independent. His father on this account omitted no opportunity of reproving his son for this his thoughtless way of acting, which he would have had him change for the practice of physic; but instead of prevailing on him by his remonstrances, they only served to make him redouble his endeavours according to his disposition, that he might the sooner finish the great task in which he had so courageously, though perhaps unadvisedly, engaged; all the while striving to divert his father's anger, by promising him, that as soon as he had completed his undertaking, he would in good earnest apply himself to the practice of physic. But his father seeing no probability of his son's accomplishing his purpose, nor yet of being able to divert him from it by fair means, threatened him severely that if he did not immediately exert his talents as a physician, but obstinately persisted in his anatomical studies, his expensive researches after insects, and his experiments of that kind, he would neither supply him with money or cloaths; and to shew he was in earnest, he immediately deprived him of the means of pursuing what he had begun. Our author therefore, though exhausted with continual labours, and moreover afflicted with a continual bad state of health, at last consented to take his father's advice, the justness of which he now began to perceive; but his bad health rendered him quite unfit to bear the fatigues usually attending the practice of physic, so that he thought it was proper that he should retire into the country for some time, in order to recover his strength, and with a view of returning to his business with new force and spirits. But he was scarce settled in his country retirement, when in the month of June MDC LXX, he relapsed into his former occupation, the torrent of his genius that way being so much favoured by the solitariness of the place, and the favourable opportunity of examining insects in their very haunts and scenes of propagation. Thevenot, in the mean time, informed by his correspondents in Holland of the disagreement between our author and his father, and the bad consequences that might probably attend it, did all that lay in his power to engage the former to retire into France, where he most generously offered to provide him with every thing requisite for the pursuit of his favourite studies. But whatever impression this proposal might have made on the son, the father forbid him to accept of it, as appears by a letter of his to Mr. Thevenot, dated the thirtieth of October of the same year. The son upon this, to oblige and appease his incensed father, made an accurate survey of every curiosity in the latter's grand and numerous collection, put all things in their proper places, and composed a most exact catalogue of them with infinite pains and labour, and a considerable loss of time, which he ever after severely regretted. The year following, MDC LXXI, having gone through this tedious and disagreeable task, he was about publishing his treatise on the Chameleon and Hemorobion, or Day-Fly; but afterwards thought proper to defer the publication of those pieces, so that they did not appear till the year LXXV,

though



though he had formerly printed some part of them in Ruylenburgh, and even in France, so early as the year MDCLXVII.

On the first of May LXXII he sent to the Royal Society of London three plates and six figures, in which he had represented the womb of a human subject, dedicating them at the same time to that learned body. To them he added some most curious drawings of the spermatic vessels, the tube of the womb, and the ovary. All these curious pieces had been sketched out in professor Van Horne's house by the twenty-first of January, MDCLXVII, though not finished or illustrated with proper explanations till the seventh of May MDCLXXI. Thus for the first time was published a specimen of a method, by which both arteries and veins, and their finest ramifications, can be filled with a ceraceous matter, which not only renders those parts perfectly visible, but even incorruptible: and our author, to procure due credit to his drawing, sent with them the uterus itself prepared according to this his new method. His motive in all this proceeding, was to have the opinion of learned and equitable judges of such kind of performances. Another thing he had in view, was to convince the world that it was indebted to him as the first inventor, for the discoveries relating to the spermatic vessels, which the celebrated Van Horne had before published in his *Prodromus*. But above all things, he by this means endeavoured to refute what Regnier de Graaf had written against him, with the greatest bitterness, concerning some discoveries in regard to the organs of generation; and for this purpose he appealed to the judgment of the members of the Royal Society, to whom, as far as it concerned him, he gave full power and authority to decide the controversy.

About this time he made a great many other very useful anatomical discoveries: in particular he dissected a great number of fishes, with a view chiefly of discovering their liver, pancreas and melt; and in the course of his inquiries very often found in some a very large pancreas, with a great number of spacious and wide-mouthed ducts opening into the intestines: but above all things he applied himself with the greatest diligence to find out by every trial that promised any success, the true nature and properties of the pancreatic fluid, of which he sent many bottles full to the celebrated Charles Drelincourt, then professor of anatomy and physic in the university of Leyden. All these particulars may be seen in the second part of the *Private College of Amsterdam*, published by C. Commelin in the year MDCLXXIII; for there is scarce any thing in all that performance, for which the world is not indebted to our author; who there very mildly and modestly refutes de Graaf and Sylvius's accounts of the pancreatic fluid, though he formerly used to treat with great harshness those who contradicted his sentiments, as appears in the literary controversies he before this had maintained with de Graaf, Gasper, Bartholin, and others. But religion and piety had by this time got the better of our author's warm and stubborn temper. Happening to read some books which the then famous Antonia Bourignon had a little before published, they made so great an impression upon him, that a strict compliance with all the duties of a good christian was now become his principal concern. He began to hate and shun all those things which men most covet and run after, but bent his endeavours more particularly to suppress the unruly passions of the mind, and above all that insatiable ambition which makes us so desirous of a superiority over others, and which therefore, as the root of all evil, he was desirous utterly to extirpate and destroy. All this time Antonia Bourignon happened to be in Holstein, accompanied by John Tielens,  
a native

a native of Amsterdam, with whom Swammerdam had been long acquainted. He therefore writ to his friend the eighteenth of March MDC LXXIII, to beg he might procure him Antonia's good will, and leave to write to her on his spiritual concerns; and having obtained this favour, he accordingly writ to her the twenty-ninth of April following, and received an answer to his letter dated the seventeenth of August. Her advice wrought so great a change in him, that at that time he thought of nothing but of obtaining from God a holy peace of mind, sincerely grieving that he had lost so much time in the service of the world. After this he writ many more letters to Antonia, who very graciously answered them. About this time he was, if I am not mistaken, the first that discovered a thing of very great importance, for he found that the hernia in both men and women never proceeds from a rupture of the peritoneum, but that the peritoneum alone is extended over the part where the feminal vessels, enclosed in one case or sheath, but which before this lay close under the peritoneum, fall from it towards the scrotum. Now, if in this case the peritoneum happens to insinuate itself into that wide passage, by which the spermatic cord falls down towards the testes, it there, whatever cause may press it, forms a sacculus cæcus, or blind bag, on account of its wonderful extensibility, and the smoothness of the cavity made for it by the descent of the spermatic cord. The ecphyfis once formed, grows larger and larger, as the cause which first produced it increases; and continuing to keep close to the spermatic cord, follows it towards the scrotum, above the os pubis, and along the outside of the muscles. If this ecphyfis stops at the groin, it forms what is called a bubonocœles; but if it descends to the scrotum, an oscheocœles; besides which, it obtains a variety of other names, from the different substances that may happen to fall into it, such as the omentum, the intestine, air or water. The same is the case in women, except that the descent is made along the femoral vessels, (See Schraderi, Observ. Decad. II. Observ. IV. v.) where there is a very exact drawing to represent the nature of this disorder. Many eminent persons have since made pretensions to the honour of this discovery, but the account I have given of it appears the most probable. In this book too there is another observation of our author equally important; for he there mentions his having seen two cicatrices in the ovary of a woman, that had been brought to bed of twins; which it is duely to be remarked happened at the same time. In the same collection there is our author's contrivance for preserving the parts, or anatomical preparations in balsam. For all these reasons, the editor thought proper to dedicate this work, published in MDC LXXIV, to Swammerdam, who was the chief contributor to it. Our author, moreover, in the year MDC LXXIII, had exhibited to the illustrious Arnold Syen, professor of botany in the university of Leyden, the feminal little bags of Fern, and the delineations he had made of them. I intreat the reader to view and consider attentively the descriptions and figures contained in this book, and compare them with those given a long time after by some of the greatest botanists. There cannot be a greater resemblance between two eggs, than there is between our author's performance this way, and those that followed. The same things might have been seen in France, nor is it impossible that they might have been described there too. The last day of September of this year, our author finished his treatise on Bees, which proved so fatiguing a performance, that he never after recovered even the appearance of his former health and vigour: and indeed it was an undertaking too great for the strongest constitution, to be continually employed by day in making observations, and  
almost

almost as constantly engaged by night in recording them by drawings, and suitable explanations. This being summer work, his daily labour began at six in the morning, when the sun afforded him light enough to survey such minute objects; and from that hour till twelve he continued without interruption, all the while exposed in the open air to the scorching heat of the sun, bearheaded, for fear of interrupting the sight, and his head in a manner dissolving into sweat under the irresistible ardors of that powerful luminary. And if he desisted at noon, it was only because the strength of his eyes was too much weakened, by the extraordinary afflux of light and the use of microscopes, to continue any longer upon such small objects, though as discernible in the postmeridian, as they had before been in the antemeridian hours.

This fatigue our author submitted to for a whole month together, without any interruption, merely to examine, describe, and represent the intestines of Bees, besides many months more bestowed upon the other parts; during which time he spent whole days in making observations, as long as there was sufficient light to make any; and whole nights in registering his observations, till at last he brought his treatise of Bees to the wished-for perfection: a work which all the ages from the commencement of natural history to our own times, have produced nothing to equal, nothing to compare with it. Read and consider it, and then judge for yourself. Our author, the better to accomplish his vast unlimited views, often wished for a year of perpetual heat and light to perfect his inquiries, with a polar night to reap all the advantages of them by proper drawings and descriptions. In his essay on the Hemorobion, or Day Fly, he ingenuously owns that this his treatise of Bees was formed amidst a thousand torments and agonies of heart and mind, and self-reproaches, natural to a mind full of devotion and piety. On one hand his genius urged him to examine the miracles of the great Creator in his natural productions, whilst on the other, the love of that same all-perfect Being deeply rooted in his heart, struggled hard to persuade him, that God alone, and not his creatures, was worthy of his researches, love and attention. The distress of mind our author felt upon this occasion, was so severe that as soon as he had finished his book upon Bees, he put it into the hands of another, without knowing or giving himself the least concern about what might become of it. It appears however, that he at the same time wrote two letters to Paul Boccone, on the construction of salt water or sea stones and corals, which are to be found in the nineteenth and twentieth letters of the said Boccone's natural observations. After this Swammerdam grew almost altogether careless of the arts he had been hitherto fondest of. He had conceived this distaste for worldly affairs above two years before, though he had struggled against it in favour of his book on Bees; but now he could no longer allow his mind any other occupation besides that of loving and adoring the Sovereign Good, to whose honour alone he openly declared, he began and directed his many and great labours in the cultivation of natural history, from which he now entirely desisted merely to devote all the little uncertain portion of life that remained, to the sincere practice of every christian virtue. His temperament was of the melancholy kind, which physicians have observed to be very firm in its purposes, and our author's natural disposition was increased by a quartan ague, so that he persevered in his resolution, in which the authority and advice of Antonia Bourignon fixed him beyond a possibility of relapsing into his former worldly way of thinking. He therefore resolved to withdraw himself entirely from all conversation with

the world, but had first the prudence seriously to examine, what would be necessary to maintain him in his retirement. This he found to amount yearly to four hundred Dutch florins or gilders, without having any thing but his curiosities to raise such an income by. These therefore he immediately resolved to sell, in hopes the produce of them put out to interest, would be sufficient to answer his demands. The first he applied to on this occasion, and the only person perhaps who knew any thing of our author's private intentions, was Thevenot, whom he requested to publish and forward the sale of those things, which he had spent so much time and labour in collecting, and formerly so much loved. Thevenot did all that lay in his power to serve his friend, but to no purpose; for however valuable the treasure, no one was to be found in France willing to purchase it, though our author was often flattered with the hopes of its selling to advantage. This disappointment made Swammerdam apply to another friend. This was Nicholas Steno, who having renounced the religion of his country, was become a member of the church of Rome, had obtained a bishopric as a reward for his change, and to induce him to continue in it, and now lived at the court of Florence. Swammerdam wrote to him to know if the grand duke was now as willing, as he had formerly been, to purchase his curiosities. In answer to this letter, the new convert's zeal made him use every argument he could think of to make our author, after his own example, conform to the church of Rome, and remove with his collection into Tuscany, promising him for certain, that the great duke would let him have for his curiosities the price of twelve thousand florins, which his highness had formerly offered, and let him want for nothing, that could make life easy and agreeable. But our author looked upon these conditional offers as the greatest indignity that could be offered him, and accordingly bitterly reproached his friend Steno for endeavouring to prevail upon him in a manner he utterly detested, telling him withal that his soul was not venal; and Bourignon being consulted on the occasion, advised him by all means to reject Steno's proposals. Our author agitated by such a series of hopes and disappointments, made use of the little leisure that remained on his hands, in arranging and adorning his curiosities; rendering them as durable as possible, and composing a complete catalogue of them, so that in his museum thus settled, the materials and the contrivance, the dignity of the subjects, and the vast pains taken in procuring, preparing, and exhibiting them, vied together for the preference. These treasures consisted chiefly of insects and anatomical preparations from human subjects. The former our author set the highest value upon, and no wonder, as he had spent sixteen years in collecting and preparing them, with infinite pains and expence. The sight of his museum was alone sufficient to prove, that what all former authors had published on this branch of natural history, amounted to nothing more than a dry catalogue of names, and some external figures, without affording any certain and useful knowledge. Whereas our author alone had collected near three thousand species of insects, that had no relation one to the other, and had examined every one of them, and disposed them all in classes according to their real and natural characters; he had even dissected many of them with that skill and dexterity peculiar to himself, and having with unwearied diligence traced them through every the least period of their changes from the egg to the Butterfly, faithfully recording all his observations, taking care at the same to prepare and keep by him the minute originals as incontestable vouchers of his indefatigable industry in examining them, and his scrupulous veracity, relating  
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what he had discovered. Nay, that nothing should be wanting to perfect his discoveries, he used himself to hatch, in a manner found out by, and only known to himself, the little eggs of insects, in order to discover the obscure manner of the existence of their first rudiments, the progress of these rudiments to life, the first motions of the infant animalcula, and by what endeavours they at last broke their eggs, and opened themselves a passage into the world. While thus employed, he at length published at Amsterdam the twelfth day of July MDCCLXXV, his history of the Ephemerus, or Day-Fly; which he began in France in the year LXIV, continued in Guelderland in the year LXVII, but did not perfect till this time, that he made it public. However even this, he did not attempt without Bourignon's approbation. This was the last offspring of our author's great genius and application, after which he entirely renounced all thoughts of human affairs, to think of nothing but his spiritual concerns, which he imagined he could not so well promote in any other manner, as by going to confer personally with Bourignon. Accordingly, having first obtained her leave for that purpose, he set out the autumn following from Amsterdam for Sleswick in Holstein, where she then resided, arrived there the thirtieth of September, and spent some time in her house. Mean while the Lutheran divines of that country, utterly averse to Bourignon's undertakings, were for making her quit Holstein, which made her think of asking the king of Denmark's leave to take shelter in his regal dominions. Swammerdam having taken upon him to execute this commission, set out for Copenhagen, in company with another of her disciples, the twenty-fifth of March, MDCCLXXVI. Here he saw Steno's mother, now far advanced in years, but reaped no other benefit by his journey, his Danish majesty not thinking proper to grant Bourignon's request. After this our author made but a short stay at Sleswick, from whence he set out for Amsterdam the sixteenth of June following. On his coming home, he had the mortification of finding that his father's displeasure at his past conduct, instead of being appeased, was grown more violent on account of his late undertakings. Another and greater subject of affliction was, the marriage of his sister Joanna, who had hitherto kept house for her father since he had buried his wife; for the father on this occasion had resolved to break up house-keeping, and to live for the future with his son-in-law. Our author therefore now found himself under the sad necessity of shifting for himself by the month of May following. How great, alas! must have been his distress! He had neither money nor any thing of value except his museum, which he had already so often endeavoured in vain to dispose of; and his father did not propose to allow him more than two hundred florins a year. On this occasion he formed a design of retiring into the country, and flattered himself with the hopes of being able to provide for himself that way. The most noble John Ort of Nieuwenrode Breukele, &c. had contracted a friendship of a very long standing with our author, and had often entertained him at his pleasant country seat with the greatest hospitality and politeness, and even invited him to remain there for good and all, and pursue his studies without interruption. But Swammerdam never till now found himself under a necessity of putting his friend's sincerity to the test; however he little expected the refusal he now met with, and which, as it convinced him of the little dependance to be had on the promises of men, greatly contributed to increase his former anxiety. But his father dying this year put an end to his troubles, by leaving him a sufficiency to live, in a manner suitable to his own inclinations, for now he saw himself freed from all  
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business, but that of serving God, which alone he delighted in. But his joy was soon interrupted, when the father's fortune came to be divided, and his museum to be disposed of, the sister claiming more of the inheritance than came to her share, and the chief direction of the sale, while Swammerdam for the sake of peace and quietness, and in order to get the sooner into his long wished for retirement, submitted to her unjust pretensions. Nevertheless, the vexation attending this family strife, joined to the uninterrupted fervour of his devotion, brought a tedious disorder upon him. This was a double tertian ague, which afterwards continued without intermission, and then changed in different manners. Whilst this fit of sickness continued, he got up but seldom in the day time, and for three months together that the slow fever continued, he never went out of his house; he was even a whole twelve month without making a single experiment. At last his disorder, again changing to a tertian ague, seemed to abate, and then entirely left him for some days. His friends nevertheless, and among them doctor Matthew Slade, a most learned physician, and one whose advice had the greatest weight with our author, could never prevail upon him to stir from his bed-chamber. He would often excuse himself by saying that solitude and retirement could alone extirpate the relics of his disorder; when Slade, Ruysh, Schrader, Hotton and Guenellon, who all of them frequently visited him in the quality both of friends and physicians, attempted to persuade him to the use of medicines and fresh air for the recovery of his former strength and vigour. But he at last put a stop to their importunities by an obstinate silence. However as the things he formerly took most delight in, were now become odious to him, and he had no further hopes of being able to dispose of them in France, he wrote to his friend Thevenot, who had again invited him to his house, that he would accept of his kind offer, provided he would immediately dispose of his curiosities for him, and permit him to live quite unknown and retired. But here too our author was again disappointed, so that at last he advertised a fixed day in the month of May following, MDCCLXXX, for the sale of his curiosities, article by article, to the best bidder; so great a desire he had of getting rid of them, notwithstanding that he had seen that his father's museum, when sold in single lots, had not produced above a sixth part of what his executors expected it would have sold for. But whilst our author was taken up in this manner, his old disorder broke out anew with worse symptoms than had hitherto appeared, an emaciated countenance, hollow eyes, a slow continued fever which eating always increased, and a swelling in his feet, legs, thighs and belly, attended with constant and uninterrupted pains. All this time his friends durst not make the least mention before him of his former studies, nor did he himself ever speak a word of them; for he now utterly detested as vain and insignificant the things he formerly most delighted in. Thevenot, informed of the languishing condition he was in, offered him the jesuit's bark, then greatly talked of for its efficacy in curing fevers, and Swammerdam desired he might send him some of it, and some specific against the dropsy, if he knew of any. But at last finding himself grow worse and worse, he made his will the twenty-fifth of January MDCCLXXX, and left Melchisedeck Thevenot, formerly the French king's minister at Genoa, all his original manuscripts belonging to the natural and anatomical history of Bees and Butterflies, with fifty-two plates belonging to them, and ordered all those valuable papers then laid up in the house of Herman Wingendorp at Leyden, to be delivered to the legatee within a year after his death; but earnestly recommended that his treatise on

Bees should be published in Dutch as well as Latin, as displaying the wisdom and power of God in so particular a manner. The little portion of life, that he enjoyed after this disposal of his worldly concerns, he gave entirely to his spiritual ones, spending his whole time in acts of love and adoration of the Supreme Being, and thus ended his course the seventeenth of February following. He constituted Magaret Volckers, wife of Daniel de Hoest, doctor of physic, his heiress, and her and Christopher Van Wyland his executors, but Van Wyland dying soon after, the trust devolved wholly into the hands of Madam Volckers.

As soon as our author's executors had performed the last rites due to their deceased friend, Mr. Ort at their request gave Mr. Thevenot notice of the legacy left him in Wingendorp's hands; for Swammerdam being little versed in the Latin, in which notwithstanding he was desirous of seeing all his works published, had given them to Wingendorp to translate into that language, as he had before done our author's writings on the uterus. Thevenot on this wrote several times to doctor de Hoest, to desire he should immediately cause his legacy to be delivered him; but Wingendorp, who was poor, and lived by his translations into various languages, after endeavouring by a thousand frivolous pretexts to make a property of what he had only been entrusted with, at last openly declared he would return nothing till compelled to it by due course of law. Upon this therefore a tedious and troublesome lawsuit ensued, in which however Thevenot at last obtained a decree in his favour in May MDCLXXXII, when Swammerdam's papers in the hands of Wingendorp were delivered to Burcher de Volder, a celebrated professor of anatomy and mathematics, whom Thevenot had engaged as a friend to take his interest in hand, and without whose diligence and prudent management, it is possible that Thevenot would have lost his legacy. As soon as Thevenot heard of his friend's success, he gave orders to have the writings in question published in Dutch, but soon altered his opinion, and sent for them. He then attempted some alterations in them, as I could discover by the erasements made here and there with his own hand; but in this he fell short of answering Swammerdam's intentions, though probably only for want of abilities suitable to such a task. Be that as it will, this valuable treasure, after Thevenot's death, was purchased by Joubert the king's painter, whose heirs afterwards sold it at the inconsiderable price of fifty French crowns to the illustrious Joseph du Verney, with whom they lay hid and disregarded for a long time. At last a report prevailing that the anatomy of insects was coming into great vogue, and that a history of this part of the creation, composed by the great anatomist just now spoken of, was upon the point of appearing at Paris, I requested William Sherard my guest at that time, and most intimate friend, to obtain some certainty for me in regard to this report, as he was then about making a journey into France. Accordingly on his arrival at Paris, he wrote that Swammerdam's works were in the hands of Monsieur du Verney, and even sent me some copper-plates after the drawings of our author, which when I examined, served only to excite my ambition of asserting the right of my country to the honour of having produced the originals, and making without loss of time all the inquiries I judged necessary for that important end. At last, by the assistance of the reverend Mark Guitton, and the eminent William Roell, professor of anatomy at Amsterdam, both then residing in Paris, I so far succeeded, that they were purchased for me the twenty-sixth of

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March, MDCCXXVII, at the price of one thousand five hundred French florins, and I received them complete the same summer. As soon as I had got them, I read them; and having diligently examined them more than once, I carefully digested them, and had the satisfaction of seeing that nothing was wanting except a few pages of the text in the treatise of Bees, which a note in the margin observed was not to be repaired; however, on looking narrowly for them, I had the good fortune of finding them elsewhere. Upon this, I should have published them directly, but for the insatiable avarice, and unbounded audaciousness of the printers, who make nothing of reprinting things as soon as they appear, to the great loss of the first publishers. However, I have at last succeeded in guarding against such foul treatment, and return my hearty thanks to all those who so generously contributed their assistance on this occasion. And now I must own, that it is with the greatest pleasure I find myself enabled by this valuable work to challenge all those nations, who so liberally reproach us Dutchmen with a dullness that requires the inventions of others to sharpen it, to produce before able judges, any thing equal to this performance of one of our countrymen. This instance will, I believe, be sufficient to convince mankind that we have among us uncommon geniuses, who have made the most important discoveries, and spider-like, have furnished themselves alone both the workmanship and materials. However I must in justice own, there is now in France such another bright sun, who by his light not only shews, but adds grace and dignity to every object he is pleased to shine upon. I mean that prodigy of our age, and glory of his country, the illustrious Reaumur. God grant this great man life to go through, and many years to survive, his great undertaking.

I examined with the greatest care and attention all the letters, and other writings of Swammerdam, that I could lay my hands on, in order to find out the methods taken by him to perfect those beautiful discoveries, by which he has so far exceeded all authors in the same way; and I shall here candidly relate the fruits of my perquisition. For dissecting of very minute subjects, he had a brass table made on purpose by that ingenious artist Samuel Musschenbroek. To this table were fastened two brass arms, moveable at pleasure to any part of it, and the upper portions of these arms were likewise so contrived as to be susceptible of a very slow vertical motion, by which means the operator could readily alter their height as he saw most convenient to his purpose. The office of one of these arms was to hold the little corpuscle, and that of the other to apply the microscope. His microscopes were of various sizes and curvatures; his microscopical glasses being of various diameters and focuses, and from the least to the greatest, the best that could be procured, in regard to the exactness of the workmanship, and the transparency of the substance. His way was to begin his surveys with the smallest magnifiers, and from thence proceed by degrees to the greatest; and by nature and use was so incomparably dexterous in the management of these useful instruments, that he made every observation subservient to the next, and all tend to confirm each other, and complete the description. These no doubt were talents very uncommon, though no less requisite in an observer of such things. But the constructing of very fine scissors, and giving them an extreme sharpness, seems to have been his chief secret. These he made use of to cut very minute objects, because



because they dissected them equably; whereas knives and lancets, let them be ever so fine and sharp, are apt to disorder delicate substances, as in going through them they generally draw after them, and displace, some of the filaments: his knives, lancets, and styles were so very fine, that he could not see to sharpen them without the assistance of the microscope; but with them he could dissect the intestines of Bees with the same accuracy and distinctness, that others do those of large animals. He was particularly dextrous in the management of small tubes of glass no thicker than a bristle, drawn to a very fine point at one end, but thicker at the other. These he made use of whenever he had a mind to shew, and blow up the smallest vessels discovered by the microscope; to trace, distinguish, and separate their courses and communications, or to inject them with very subtil coloured liquors. As to the insects themselves, he used to suffocate them in alcohol or spirit of wine, in water, or spirit of turpentine, and likewise preserved them for some time in these liquids, by which means he kept the parts from putrefying, and consequently collapsing and mixing together; and added to them, besides, such strength and firmness, as could not fail of making the dissections far more easy and agreeable. When he had divided transversely with his fine scissors the little creature he intended to examine, and had carefully noted every thing that appeared without further dissection, he proceeded to extract the viscera in a very cautious leisurely manner, with other instruments of equal subtilty; but first took care to wash away and separate with very fine pencils the fat with which insects are most plentifully supplied, and which always occasions some damage to the internal parts, before they can be extracted. This last operation is best performed upon insects whilst in the Nymph state. Sometimes he put into water the delicate viscera of the insects he had suffocated, and then shaking them gently, procured himself an opportunity of examining them, especially the air vessels, which by this means he could separate from all the other parts whole and entire, to the great admiration of all those who beheld them; as these vessels are not to be distinctly seen in any other manner, or indeed seen at all without damaging them. He often made use of water injected by a syringe, to cleanse thoroughly the internal parts of his insects, then blew them up with air and dried them; by which means he rendered them durable, and fit for examination, at a proper opportunity. Sometimes he has examined with the greatest success, and made the most important discoveries in insects that he had preserved in balsam, and kept for years together in that condition. Again, he has frequently made punctures with a fine needle in other insects, and after squeezing out all their moisture through the holes made in this manner, filled them with air by means of very slender glass tubes, then dried them in the shade, and last of all anointed them with oil of spike, in which a little resin had been dissolved, by which means they retain their proper forms for a very long time. He had so singular a secret for preserving the very nerves of insects, that they used to continue as limber and as perspicuous as ever they had been. As to Worms in particular, his way was to make a small puncture or incision in them towards the tail, and after having very gently, and with great patience squeezed out all their humours, and great part of their viscera, inject them with wax, so as to give and continue to them all the appearances of living, healthy, and vigorous creatures. He discovered that the fat of all insects was perfectly dissoluble

in oil of turpentine, and that they could not be preserved in balsam: and this discovery he always made the greatest secret of, because the fat of insects when melted, and then dried, looks like lime scattered over the parts, so as to obscure the viscera, and make it utterly impossible to examine them; but then, however confused and immersed they might have been before, they shew themselves after this process very plainly and distinctly, on being long and thoroughly washed with fair water. Very often he spent whole days in cleansing of its fat in this manner, the body of a single Caterpillar, in order to discover the true construction of that insect's heart. His singular sagacity in stripping off the skin of Caterpillars that were upon the point of spinning their nests, deserves particular notice. This he effected by letting them drop by their threads into scalding water, and suddenly withdrawing them, for by this means the epidermis peeled off very easily; and when this was done, he put them into distilled vinegar and spirit of wine mixed together in equal portions, which, by giving firmness to the parts, gave an opportunity of separating them with very little trouble from the exuviae or skins, without any damage to the viscera, so that by this contrivance the Nymph could be shewn wrapped up in the Caterpillar, and the Butterfly in the Nymph. All these wonders he performed by the light of the brightest mid-day sun, and had brought his arts to such perfection, that he could exhibit whenever he thought proper, the manner in which insects were enclosed in insects, and were to be extricated from their enclosures. He could at last change the Caterpillar to a Chrysalis at his pleasure, and also could as he pleased forward, stop, and regulate its motions. He affirmed nothing but what he saw, and was able to demonstrate every thing he affirmed. He in good earnest followed Lord Bacon's advice; for his opinions were the fruit of his experience, and he could effect the very things, whose existence he maintained. Observations alone, made with the most wonderful patience by experienced senses, assisted with the fittest instruments, led him into the method followed by nature in all her operations; and he so scrupulously adhered to that great guide, that whenever he formed a rule from particular observations, he did it with so much caution, as to let it include those particulars only, from which he had deduced it, and extracted his canon. In explaining the works of nature, he used to reason by comparing his observations with one another, and never admitted the use of a general application of them upon any other occasion. Thus he began, carried forward, and perfected without any assistance, in a private and middling station of life, more discoveries than all the writers of all the preceding ages. By these means he found there were little creatures that breathe at the tail, and others that govern themselves in the water by the help of a little bubble of air, which they expand at pleasure to ascend to the surface, and compress in like manner, when desirous to sink to the bottom; and can regulate it in such a certain manner, that they can suspend themselves in any part of the water they choose. Some again he discovered, who have their legs fixed to their jaws; and others in which the penis of the male receives in copulation the vulva of the female, and a few which are of both sexes at once, and act reciprocally upon each other as such at one and the same time. In fine, from such an infinite number of new and uncommon observations, he formed a system superior by many degrees to any thing of the kind that had as yet appeared. He even collected the materials upon which this system was founded, rendered them durable, and digested them, in order to have always at hand undeniable vouchers for the truth of every

every thing he advanced. Such a fabrick had never been raised before, yet it was raised by him in so masterly a manner, that it might have stood ages. But, O hard fate of industry! after having been driven himself to offer his curiosities to sale more like a beggar that had nothing to give, than like a man who offered infinitely more than he asked, and this too without success; his heirs, after his decease, made proposals of selling them all, his anatomical preparations, his insects, and his instruments, for the trifling sum of five thousand florins, without finding any one intelligent enough to buy them for his own use, or generous enough to purchase them for that of the public. Alas, what a loss was this, never to be repaired! These wonders of art and nature, by being separated and scattered into different hands, lost all their value, to the irretrievable dishonour of an age, the most remarkable of any that had as yet ever been for studies of this nature. As for you, my readers, I must inform you of the obligations you owe, on the present occasion, to the great Gaubius, who from his sincere love to the republic of letters, translated all the works I now present you, from the original Dutch into Latin, that the curious of all nations might have the better chance of reading them; and perhaps it would have been a hard matter, if not impossible, to find another translator equal to the task. The facts I have here related are collected from the history of the times, from a repeated perusal of Swammerdam's works, and from the letters written or received by him. An accurate and well-digested collection of all these papers supplied me with materials for writing his life, and I intend to deposit them all, as well as the original drawings made by his own hand in the most elegant and masterly manner, in the public library of the university, there to remain as an eternal monument of our author's merit, and of my exactness and integrity in writing his life, and publishing his labours; and, in fine, that such as take delight in things of this kind, may by this means have an easy opportunity of satisfying their curiosity. It was thus I acted in regard to the posthumous works of the celebrated Vailant. Farewel reader.

LEYDEN, 17<sup>th</sup> 1735.

HERMAN BOERHAAVE.



T H E

## AUTHOR'S PREFACE.

**C**URIOS reader, before I proceed to lay my observations before you, I must most humbly request, that you will not be displeas'd, if in all this work I have only made use of my own observations, as a solid and immoveable foundation to build upon, and that from them I have deduced certain conclusions, solid theorems, and classes digested in due order. For as long as neither nature herself exhibits any thing in opposition to these theorems, nor other writers produce experiments to contradict them; we may rest assured of the truth of what I have deliver'd; but then we must not wander beyond the limits of such observations, nor by straining them too much, make them extend to things not as yet sufficiently discovered. Otherwise, as nature is utterly inexhaustible, we should be in danger of falling into errors; and indeed it is generally our own fault that things of themselves sufficiently clear and evident, become obscure, and even impenetrable to us. Thus a person would be guilty of a great mistake, who, after running over all the animals he knew, never to be at once male and female, should from thence conclude, that both sexes are never found in one and the same subject; whereas the contrary appears in Snails, which are all capable of impregnating as males, and conceiving as females, but with this restriction, that the same Snail cannot act upon itself; so that a mutual intercourse of two is requisite to carry on the business of propagation, as I many years ago demonstrat'd before a numerous company. As therefore all the experiments I have hitherto made, agree perfectly together, and mutually support each other, there is the less reason, till something appears in the nature of things to break the thread of my system, to be startled at the objections of others, who never made the same observations, and are not perhaps properly qualified to make the same experiments. But if hereafter any thing should occur, that I may have reason to think deserves to be added to what I have already advanced, or exceeds the bounds to which I have confin'd myself, or appears repugnant to my former observations; I promise faithfully to publish them, though they should absolutely destroy the principles I have laid down, provided that they serve to confirm and illustrate the truth. And I moreover earnestly request all those who love truth as I do, and are equally anxious to find it out, to assist me on this occasion with their favour and advice.

But as the most eminent amongst the ancient writers on this branch of natural history, have propos'd two different manners in which insects undergo their mutations; one known by the name of Nymph, and the other by that of Chrysalis, calling Nymph that change of the Worm, under which it exhibits the form of the insect that is to issue from it; and Chrysalis, that other change which shews no signs of the future insect; I must forewarn

forewarn my readers that I shall by no means admit two different species of changes, as I can plainly and distinctly discover in the Chrysalis, as well as in the Nymph, all the parts of the future insect, and can even give ocular proof of their existence. And as to the parts not appearing externally in the Chrysalis as clearly as they do in the Nymph, and the former having a gold colour, which I never observed in the latter, it is not a thing of consequence enough to make me alter my opinion.

But perhaps the reader, as yet a novice in the history of insects, may not rightly understand what I mean by the words Nymph and Chrysalis, I must refer him to the figures of this work, where he will find the Nymph of the Ant represented under number v. Tab. XVI. and the Chrysalis of the nocturnal Butterfly, under the same number v. Tab. XXXIII. For the sake of greater perspicuity, I observe the same order in Tab. I. XII. and XXXVIII. where I place before my readers other species of Nymphs that shall be described in their proper places, and afterwards summed up under one view, in the general comparison of mutations, with which I intend to conclude this work. Farewell.

# E L E G I A

I N H O N O R E M

D. JOANNIS SWAMMERDAMII, M.D.

Naturæ Insectorum Indagatoris indefessi, incomparabilis.

Allocutio ad Harveum ῥ πάλυ.

**F**LOROS & honos Angliæ gentis, quo, judice Phœbo,  
Nil quicquam eximius terra Britannia tulit ;  
Artis delictium nostræ, quo sospite quondam  
Sidera tangebatur vertice celsa suo ;  
Desine jam gemitus, tua jam suspiria cessent,  
Quod multa abstulerit ter scelerata manus,  
Quæis miranda tibi levium spectacula rerum  
Scripta, atque in varios corpora versa modos :  
Quæis tibi Nympharum & fulvæ Chryfallidos ortus  
Depicti, & Gryllus papilioque fuit :  
Ecce alium, data damna tibi qui sarciet olim,  
Inventisque addet non tibi visa tuis.  
Non hunc parva latet magni Formica laboris,  
Angusto quamvis tramite carpat iter.  
Hic quis amor, quis Hymen illis, quæque oscula novit,  
Quâ foveant natos sedulitate suos :  
Non fugit hunc misera & male nata Diaria, quamvis  
Vix detur medium vivere posse diem ;  
Quæ postquam teneris volitavit in ære pennis,  
Sævis præda avibus, piscibus esca cadit.  
Nec Scarabæus aquæ, seu pervolat ille paludem,  
Seu celer, ad fundum, mox rediturus, abit ;  
Sed bullâ, mirum visu ! rediturus inani,  
Quam villosa intus caudula clusa tegit.  
Nec tu, dire Culex, mediis seu degis in undis,  
Aëra seu pinna liberiore petis.  
Novit Apum sexus, ortus, connubia, novit  
Quam telam in cera sedula fingat Apis.  
Et negat ulla novas Insecta assumere formas,  
At vermi inclusas delituisse docet.  
Quam stupui, quando narrantis ab ore pependi,  
Cum mihi monstraret plurima quam stupui !  
Gaude, Vegta, tuis illum quod vexeris undis,  
Et quod capta tuo flumine præda fuit.  
Non Aldrovandos jam clara Bononia jactet,  
Nec mihi Mousetos Anglus ad ferat :  
Gesneros etiam fileat Germania tellus,  
Nescio quid majus Terra Batava dabit.

Cecini amico amicus

MATTHÆUS SLADUS, M. D.

ἜΙΣ ΣΩΑΜΜΕΡΔΑΜΟΝ περὶ Ἐφημέριε ἐντόμου

βιβλίον ἐκδιδόντα.

Πρὸς ἀναγνώστην.

Τὴν δ' ὅταν γνῶης ἢ ἀναγνῶης, φίλε, βίβλον,  
Σουαμμερδάμος τῆν τέκεν εὐφραδέως,  
Ἐντόμου ἢ σε φυὴν ἀλλοιώσεις τε δίδάσκει  
Ἦμαρ τῷ σφείερον δώκεν ἐπωνυμίην.  
Μὴ καταγινώσκῃς πόνον αὐτοῦ. ἀλλὰ σεαυτὸν  
Γινῶσι, ἢ αὐτοῦ ἐὼν μάθησαν Ἐφημέριος.

*Idem utcunque Latine redditum.*

*Ad Lectorem.*

*Videris ut, Lector, librum & perlegeris, ingens  
Quem Swammerdammi cura laborque dedit;  
Quo tibi natura Insecti moresque patefcunt,  
Unica cui nomen donat habere dies.  
Negligere illius curam fuge. Noscere at ipsum  
Te cupe, quamque fugax ipse brevisque fies.*

M. SLADUS, M. D.

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T H E

B O O K of N A T U R E ;

O R, T H E

H I S T O R Y of I N S E C T S.

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C H A P. I.

*The design and distribution of the work.*

**A**FTER an attentive examination of the nature and fabrick of the least and largest animals, I cannot but allow the less an equal, or perhaps superior degree in dignity. Whoever duly considers the conduct and instinct of the one, with the manners and actions of the other, must acknowledge all are under the direction and controul of a supreme and singular intelligence; which, as in the largest, it extends beyond the limits of our comprehension, escapes our researches in the smallest. If, while we dissect with care the larger animals, we are filled with wonder at the elegant disposition of their limbs, the inimitable order of their muscles, and the regular direction of their veins, arteries, and nerves; to what an height is our astonishment raised, when we discover all these parts arranged in the least, in the same regular manner. How is it possible but we must stand amazed when we reflect that those animalcules, \* whose little bodies are smaller than the finest point of our dissecting knife, have muscles, veins, arteries, and every other part common to the larger animals? Creatures so very diminutive, that our hands are not delicate enough to manage, or our eyes sufficiently acute to see, them; inasmuch that we are almost excluded from anatomizing their parts, in order to come at the knowledge of their interior construction. Thus, what we know of the fabrick of those creatures reaches no farther than to a simple enumeration of the parts which we have before observed in larger creatures. We are not only thus in the dark, in attempting a discovery of the construction of the least animalcules, but we even gain very little knowledge of the wonderful texture of the viscera of the largest

animals: for as the point of our dissecting knife is not minute enough to separate the tender parts of the small animals, it is not less unfit to be used in discovering the extremities of the nerves and veins in the larger.

As our knowledge of both species of animals is so far limited by our ignorance, and as we have not hitherto had such a sufficient number of experiments as are necessary to form a proper judgment of their elegant structure, and the admirable disposition of their parts, we may easily see how rash and precipitate their opinion is, who esteem the larger creatures only as perfect, and the less as scarce worthy to be classed with animals; but, as they say, produced by chance, or generated from putrefaction; rendering, by such reasoning, the constant order of nature subject to chance. But as it happens to the smallest of animals, for instance, to those produced from the egg of the *Acarus* which is so minute, as scarcely to be visible, so also it is with the largest animals; their origin is not more obvious or more visible, perhaps it is rather more obscure, and they derive their being from a less visible beginning. Nor let any man imagine that I say this without conviction, since I have found by diligent inquiry that the largest animal is not in its first formation bigger than the rudiment of an Ant; and therefore, unless the Great Creator had set certain bounds to the growth of every kind, which it cannot exceed, I see no reason why the Ant might not surpass in bulk the largest. Perhaps, their sizes proceed in proportion to the greater or less strength of the heart, by which the parts must be extended, against the pressure of the atmosphere. Notwithstanding the smallness of

\* We are accustomed to use the word animalcule, to express those minute creatures in particular, which are only seen by the assistance of microscopes; this author applies it to small animals in general, which was its original, and is its more proper, meaning.

Ants, nothing hinders our preferring them to the largest animals, if we consider either their unwearied diligence, their wonderful strength, or their inimitable propensity to labour; or, to say all in one word, their amazing and incomprehensible love to their young, whom they not only carry daily to such places as may afford them food, but, if by accident they are killed, and even cut into pieces, they, with the utmost tenderness, will carry them away piecemeal in their arms. Who can shew such an example among the largest animals, which are dignified with the title of perfect? Who can find an instance in any other creature, that may come in competition with this? But in the entrance of this work it is not my intention to explain the form and wonderful propagation of animalcules, which seem to be exanguious or to have no blood: I shall treat in general of the manner of their surprising metamorphoses; and at the same time shew, that they not only resemble other animals in the increase of their parts, but that they exceed them by infinite degrees. This being done, the particular observations concerning those animalcules shall be fully explained in their proper order and place. But before I proceed to them, it will be necessary to prefix a general dissertation on their nature.

That I may make good the promise which, twelve years ago, I made to the public in the preface to my book of Respiration, (and which I have been unhappily hitherto hindered from fulfilling by sickness, and other impediments,) I am now to shew the particular change of the Caterpillar into a Chrysalis; as also, the nature and various forms of those animalcules, which are said to be exanguious, before and after their change into Nymphs: but I judge it extremely necessary to establish first some certain propositions, and to explain the order of their changes. This, fully understood, will contribute to a clear and distinct perception of the irregular and various appearances of insects; supplying the place of a pencil, and representing, as it were, in their true colours, the variations of them; setting each in a just light, and in their native dress. Thus some certain and fixed principles will be supplied to the ingenious, who are curious in these things; and the observations, of which I shall give a considerable number, will remain as a firm foundation and sure support for all those experiments that shall be made concerning them, or all that possibly can be made. Nor does it appear to me a matter of small moment to have discovered rules and theorems in the nature of things, by the assistance of which all those

metamorphoses of insects, which have the appearance of fiction and fancy, and differ in form and structure infinitely from each other, are reduced to one foundation and kind only; including in three or four orders of changes all the various species. This may be perceived in the first rudiments of those creatures which appear to us under the form of eggs.

The true nature of the metamorphoses of these animalcules seems to have been subject to the fate of some valuable picture, which, by length of time, being soiled and clouded with dirt, no longer shews the true form of its figures, but has an appearance altogether different; so that it must be cleaned, and its original lustre restored, if we would discover its true appearance. In the same manner here, before we can explain the positions and the series of the changes, and illustrate them by particular examples, it is necessary we should restore this excellent appearance, or, if I may so speak, that curious picture, exhibiting the natural forms of insects: which, by the learned as well as others, through length of time, has been so soiled and obscured, that the beautiful and genuine changes of those animalcules do not appear properly what they are, but rather somewhat else, or at least, are seen in a confused manner. These must therefore be cleared from the false traditions of philosophers, by our theorems, as by the genuine tinct of nature, and restored to their native beauty.

We shall now proceed to the four distinct things which are to be treated of in this work. In the first place, we shall consider the Nymph as the original ground of all the transformations of insects, or exanguious animals; but, lest any one should mistake the use of the word transformation, I here add, that both in this, and in every other part of the ensuing work, I intend no more by that term, than the gradual and natural growth of those creatures. Secondly, we shall shew by what means it has happened, that the knowledge of the Nymph, or original ground of those natural changes, has been so obscured and darkened. This we shall take care to clear up and restore to its former state. Thirdly, we shall establish four series or orders of those changes, taken from nature, to which all the metamorphoses of the exanguious animalcule may be referred, as depending only upon one foundation. Lastly, the order of the natural changes of their parts will be confirmed by particular examples in the insects themselves, together with the figures of them, and the whole clearly and distinctly explained.



## C H A P. II.

*The single foundation of the changes observable in the known insects shewn to be the Nymph; with an explanation of the manner in which worms and Caterpillars become Nymphs.*

**T**HOUGH, amongst all the mutations of nature which deserve our attention, none appears more surprizing to the generality of mankind, than that by which a Caterpillar assumes the form of a winged animal, it in reality deserves no more admiration, than any other change in the forms of Bees, or the transformation observable in plants. This will evidently appear to any one, who, having examined the real nature of such metamorphoses, will observe how exactly they agree, not only with the growth of animals which undergo no such change; but also with the shooting or budding out of plants and flowers. Whatever difficulty we find in this, is merely an effect of our own mistaken notions; and our admiration arises from our ignorance of the nature of the Nymph or Chrysalis. In this the little animal lies, like the flower in its bud. Before I proceed farther on this head, it may be proper to observe, that these words, Nymph and Chrysalis, signify the same thing, and that there is no difference in the nature of the subjects to which they are applied.

To advance toward my purpose, I must repeat, that the reader is to take particular notice; that to acquire a satisfactory knowledge of the mutations which happen in the eggs of insects in general, as well as in the worms or Caterpillars in particular hatched from them, he must first clearly and distinctly comprehend the nature of the Nymph, Necydis, Chrysalis, or Aurelia. Though we must allow that there appears, as it is generally called, some accidental difference between the plain unadorned Nymph, and that form of it, which, from its bright gold colour, is called an Aurelia, or Chrysalis; upon mature consideration, this will be found merely accidental; without any difference in the internal constitution of their parts, sufficient to alter in them what is commonly called the essence of things. This great truth being once understood of insects in general, may be afterwards applied to every particular species of them: for instance, to the Silk-worm, whose Nymph or Necydis is never called Nymph by naturalists; but only Necydis and Chrysalis, though it is in fact a Nymph, and is called Chrysalis merely on account of the external difference in colour.

That we may succeed the better in examining the nature of this Nymph, or Chrysalis, upon which, as upon an immovable basis, the doctrine of all the changes observable in insects is so evidently founded, that the jarring opinions of all the naturalists who have hitherto wrote upon the subject, must appear utterly vain; it is necessary to observe, that the Nymph, or Chrysalis, is nothing more than a change of the

Caterpillar or worm; or, to speak more properly, an accretion, growth, or budding of the limbs and parts of the Caterpillar or worm, containing the embryo of the winged animal that is to proceed from it. The Nymph, or Chrysalis, may even be considered as the winged animal itself hid under this particular form. From whence it follows, that in reality the Caterpillar, or worm, is not changed into a Nymph or Chrysalis; nor, to go a step further, the Nymph or Chrysalis into a winged animal; but that the same worm or Caterpillar, which, on casting its skin, assumes the form of a Nymph or Chrysalis, becomes afterwards a winged animal. Nor, indeed, can it be said that there happens any other change on this occasion; than what is observed in chickens, from eggs which are not transformed into cock or hens, but grow to be such by the expansion of parts already formed. In the same manner the Tad-pole is not changed into a Frog, but becomes a Frog, by an unfolding and increasing of some of its parts.

Hence it follows, that in the Aurelia, and more particularly in the Nymph, so called by Aristotle\* with the greatest propriety, there are not only all the parts and limbs of the little winged animal itself; but, what is more surprizing, though till now unnoticed by any author I have met with, all these parts; or limbs, are to be discovered, and may be shewn in the worm itself; on stripping off its skin in a careful manner. If therefore we retain the name of Nymph; used by Aristotle, the worm at this period may be considered as marriagable, and, if we may make use of these expressions, entering into the conjugal state. We may further shew this, by considering that the worms; after the manner of the brides in Holland, shut themselves up for a time, as it were to prepare, and render themselves more amiable, when they are to meet the other sex in the field of Hymen. Since therefore the word Nymph expresses the nature of the thing better than any other, as will more clearly appear hereafter, we shall adopt it on this occasion to avoid confusion, and to be the better understood: for though the words Chrysalis and Aurelia are employed to express the same thing, they properly imply some external differences, which we have already named, and shall hereafter treat of more at large.

That elegant disposition, and distinct framing of parts, which I have mentioned, is particularly observable in the Nymphs of Ants, Tab. XVI. No. v. Flies, Tab. XLI. fig. 11, and Bees, Tab. XXV. fig. vi. as will appear upon inspecting their figures in Tab. XVI. XLI. and XXV. For some accidents, as they are

\* Hist. Anim. Lib. V. cap. 19.

called, such as colour, firmness of the parts, and the like excepted, these Nymphs represent exactly, and in a surprising manner, the little winged animals they are to produce; and even in the space of two or three days after they have cast a very thin skin, all those parts appear in most of them.

This accurate agreement, or rather this sameness of the Nymph with the little animal it covers in the present form, has given room to some who have written on this subject, to call the Nymphs of Ants, Flies, and Bees, by the names of Ant-shaped, Fly-shaped, and Bee-shaped Nymphs. This we see in Aristotle, in the place above cited: He says, "When they have received the out lines of the shape which they are afterwards to wear, at this period they are called Nymphs." Even the learned Mouffet, though in his book of Insects he bestows a particular chapter upon the Chrysalis, there denies that any distinct parts are to be observed in it, yet is not to be understood as including the Nymph in that assertion; he does not even make the least mention of it: and, indeed, those distinct parts are so evident in the Nymphs of insects, as scarce to leave the least room in any to doubt, but that they are the very animal which they so evidently represent. This certainly must be the reason why the Nymphs are often call'd Chrysalides and Aureliæ by the same author, in the course of his work; though no description is given of them in the chapter we have here named.

As errors never are confined to those who first fall into them, the incomparable Harvey\*, by committing the same mistake with Mouffet in his notions concerning the nature of the Chrysalis, has ranked the Nymphs of the Bees in the number of them. With the same Mouffet, Aristotle and Aldrovandus have explained the difficulties which occur in following, by a nice examination, the transmutations of this class of insects, by a system more ingenious and subtil, than agreeable to truth and the nature of things; since both he and Aristotle†, Aldrovandus, and numbers of other authors, have imagined, that the Nymphs of Bees are so far from containing the parts of the future insects; that they can only be looked upon as the eggs which are to produce them.

Tho' there are some slight external differences between the Nymph and Chrysalis, which we have already observed, the Chrysalis notwithstanding ought to be considered as a Nymph; there are also some external differences amongst the Nymphs themselves, which it is likewise proper to take notice of in this place. Thus, there is by far a greater agreement between the Nymph of the common Ant and the Ant itself, than there is between the Nymphs of Bees, or of Flies, and these winged insects respectively; so that there appears the same disagreement between Nymphs of one kind and another, as between these and Chrysalides. But as all these differences are merely accidental, as will hereafter more plainly appear, little regard is to be paid to them; notwithstanding Aristotle, who at the same time that he asserts a similitude, in point of shape, between

the Nymphs and the little animals to be expected from them, so far denies such a property in the Chrysalides, that he represents them merely as the eggs of those insects to which they belong‡.

That we may treat more accurately of the Chrysalis, or Aurelia, which is indeed nothing more than a gold-coloured or gilded Nymph, and neither is nor ought to be called specifically or distinctly by this name; nor can at all times, seeing all the Nymphs which are called Chrysalides have not this bright outside; this Chrysalis, I say, in the same manner as has been shewn of the nymph, "not only contains all the parts of the future animal, but is indeed that animal itself". This truth, however, is contradicted among the antients by Aristotle, and among the moderns by Harvey, and numberless other writers. As we have observed that the Nymph of the Ant differs from that of the Bee; and this last from the Nymph of the Fly; we remarked also, that the Nymph generally known by the name of a Chrysalis, differs from all those beforementioned. That this may appear the plainer, for example, in the case of the Butterfly's Chrysalis, Tab. XXXV. fig. VI. and VII. it will be proper regularly to demonstrate, not only the differences by which the Nymphs of the Ant, Bee and Fly may be distinguished from one another's, but those variations likewise by which the Butterfly's Chrysalis is distinguished from these Nymphs; and the differences also, by which all these Nymphs and Chrysalides vary from the insects they are to produce. By this means we shall be enabled to attain a perfect idea of that most remarkable property, by which they perfectly agree with each other. This property we affirm to consist in an exact representation of the future animal, and of all its parts.

The first property then, by which the Nymph of the Ant, Tab. XVI. No. v. agrees better with the Ant, than the Nymphs of Flies, Bees, or Butterflies, do with those insects respectively, and by which property, of course, the Nymph of the Ant differs from the Nymphs of the three other insects before-mentioned, consists in this; that the common Ant, which has no wings, but only antennæ, or horns, and legs, affords as clear and distinct a representation of those parts, when hid under the form of a Nymph, as when it afterwards appears in its own proper and perfect shape; excepting only, that the legs and horns, which in the Nymph are folded up in a delicate manner, shew themselves at large, and in another situation, in the Ant itself. So that the different disposition of these parts, in the ant and its Nymph, which every one must allow to be an article of little consequence, constitutes all the difference that there is between them. Nevertheless, the overlooking of this truth, the most important of all in the theory of insects, in the case of their Chrysalides, has been the great reason why the true knowledge of the nature of this species of Nymph has been buried to this time in obscurity, to give way to a fancied metamorphosis.

\* In Lib. Gener. Anim. Exerc. 1.

† In Lib. ii. Cap. 5. de Chrysalide.

‡ Hist. An. Lib. v. Cap. 19.

The other difference, or that which is remarkable in shape between the Fly, Tab. XLI. fig. II. and its Nymph, and between the other insects already mentioned, and theirs, consists chiefly in this, that the wings which in the common, or more scarce Fly, appear stretched out and expanded over the body, are folded up in the Nymph, and lie close along its sides, and between its legs. This is also the case in the common Ant; whereas both in the Fly and its Nymph, the horns, and proboscis or trunk, are almost the same in every respect.

The third difference, or that which is observed between the Bee and its Nymph, Tab. XXV. fig. VI. and the insects already named, and their Nymphs, is this, that the legs and Nymph of the Bee, which, besides horns, has four wings, and a little trunk turned up towards its body, carries those parts in a different position, from that wherein they are seen in the Bee itself, and in a manner which makes it difficult to discern them. The wings, like those of the common Fly, Tab. XXXVIII. fig. IV. are folded up, and lie close along its sides, and between its legs; but the little trunk, so difficult to be observed in the common Fly and its Nymph, is very conspicuous in that of the Bee, where it lies delicately disposed between the contracted legs of the embryo.

As therefore all the parts of these Nymphs may be easily distinguished in them, though occasionally with some accidental differences; so one thing is equally common to all of them, namely, that each of them clearly expresses the insect which is to be expected from it, or is rather already that very insect; which in the manner of the Caterpillar, the better to explain the difference between the Nymph and the future insect, is now preparing to cast off a skin, to become from a Nymph, a winged animal; in the same manner as it had cast one off before, from a Worm, to become a Nymph. These operations of nature Libavius\* has sufficiently explained in the Silk Worm, and faithfully represented in his elegant drawings.

It is, moreover, worthy to be observed, that the legs, wings, trunk, horns, and every other part of the animal, are covered with a membrane of equal thickness, in every place where they do not lie upon each other. This is the reason why, in the Nymphs of insects, almost all the members appear free, flexible, and capable of motion; for there is a space between all these parts accessible to the air; and they neither touch, nor can adhere to one another. This also is the reason, why the free space produces a slight shade between some of the parts, affording the curious eye an opportunity of determining exactly the figure of the insect's little body, and all its limbs; to this cause also, we are to attribute, that the Nymphs become of a particular colour, as soon as they have gone through their necessary change, and appear of a perfect milky whiteness.

In the Chrysalides, some of which, like the other Nymphs, assume this milky hue at the time of their change, but afterwards become spotted with gold, or entirely cloathed in that rich colour, it is a more difficult matter, on a bare survey of their outsides, to distinguish the parts of the insect one from another. Their legs, wings, and the rest are folded up, and as it were packed together in a most intricate manner: and this difficulty has been the cause, as will be hereafter shewn, of the principal mistakes of writers on this subject.

It is likewise worthy to be observed, that the Nymphs of all the three insects we have here taken notice of, the Ant, the Fly, and the Bee, immediately after their change become tender and flexible, and indeed fluid, in a manner like water itself; so that they lose all their former strength and vigour: this made Gaza, with great reason, call them invalids, as the learned Aldrovandus has observed, since they remain in this condition almost to the end of this period of their life. Mouffet seems to have taken notice of this softness in some Chrysalides, the cause of which we shall explain in its due place, with the necessity there is for it. That author's words are, † “When Pliny says that “the body of the Chrysalis is hard, I imagine he “means the Caterpillar.” The skins which are thrown off by the Nymphs here mentioned, are so twisted and folded together, that, without a delicate hand, and a great deal of experience, it is a hard task to display them properly; this will appear when we come to relate our observations upon Bees, the curiosity of which has a right to command the admiration of mankind.

We now proceed to the fourth difference, or that which belongs peculiarly to the Chrysalis, and, like the rest, is only accidental, though a great deal more remarkable. That the reader may know what Chrysalis we are about to compare with its Butterfly, and afterwards with the Nymphs of the Ant, and the Fly and the Bee, and, lastly, with these insects themselves; we are to inform him, that we shall take for our present example that Chrysalis, of which Mouffet ‡ gives a drawing in number XII of his diurnal Butterflies, which is the same with that described by Goedaert, in the twenty-first experiment of his first part, and which I have represented several ways in Tab. XXXV of this work.

The difference between this Butterfly and its Chrysalis, as well as between the other Nymphs heretofore mentioned, and their animacules, is as follows. The wings, which in the Butterfly arise from the shoulders, are very large, and hang over the back of its body, in the Chrysalis, Tab. XXV. fig. VII. are gathered up and folded into the shape and size of half the nail of a man's little finger, and are turned in towards the belly, against which they lie of an equal thickness, *mm*.

\* Obs. Hist. Bomb L. I. C. 21.

† Inf. Th. L. II. C. 36. de Aurel.

‡ Inf. Th. L. I. C. 14.

The trunk, which in the Butterfly is contracted and curled up into the size and shape of the head of a small pin, and lies between its wings, appears in the Chrysalis beautifully expanded along its belly, between the two wings *dd*. In the Chrysalis also, the legs, *ff*, *g g*, by a most inimitable contrivance, the cause of which, with the reasons for it, we shall hereafter deliver in our select experiments, which are placed on both sides close to the trunk, quite otherwise than in the Butterfly; and finally, to compleat this scene of wonders, the horns, *ii*, which in the Butterfly are stretched out at full length over the eyes, lie over the legs in the Chrysalis; so that upon the whole, all the parts of the insect, the body, wings, horns, legs, and trunk, are to be found as well in the Chrysalis, as in the Nymph, in the former, indeed, the feet are less discernable than in the latter; but the same difference is equally observable in the respective insects.

The skin which contains the Chrysalis, is much thicker in those parts which cover the limbs on the outside, than in those which serve only to keep them asunder; besides, all these parts are so evenly and elegantly fastened as it were to and upon one another, that they exhibit an uniform and equable contiguity of parts. For this reason they are, with the greatest difficulty, to be distinguished from one another, and that only by a singular method, which I shall explain to the reader in its proper place. This difficulty not only prevented Mouffet from giving us an accurate representation of the Chrysalis in the place just cited\*, but induced him to deny, with Aristotle, that there are any parts in the Chrysalis discernable by our senses. He says, "the Chrysalis has neither mouth, nor any other part of the succeeding insect, that can be perceived."

Libavius, is under as great a mistake on this subject †; for, though in treating of the *Necydalis*, he allows it some traces of wings, and also of horns, he denies that any distinct limbs are observable in it; his words are these, "On the fore part there are marks of legs and horns; and on the back part, towards the sides, some faint representations of wings." But a little afterwards he says, "You cannot perceive any distinct limbs."

Goedaert is as much at a loss as these authors, about the true nature of the Chrysalis. He is at great pains to make out in it some resemblance of the human face; and he gives a drawing of it, under this idea, in his figures of *chrysalides*. He should rather have given us that elegant form, which really appears in the Chrysalis, than have endeavoured to amuse his reader with idle speculations, the more productions of his own fancy. Nor is this all his error; he gives us an unnatural representation of the caterpillar itself, in the place already

cited; for that Caterpillar is not covered with hair, but with little prickles, and is very nearly of the figure represented in his 26th experiment.

As the limbs of the Chrysalis, fastened together in the manner already mentioned, harden by degrees, or its skin, which at first was soft and tender, gradually dries up, and becomes, as it were, of a horny substance, it gradually also changes the greenish hue which it had before, for a gold colour, and all the parts lose their motion; till at last this Chrysalis, or properly the Butterfly, which has lain its time under the form of this Chrysalis, casting off its hardened skin, breaks forth in the very shape in which it lay hid under it, without having suffered any change during its confinement, unless this, that its tender parts, which were fluid like water, and immoveable, through an excess of humidity, have with time acquired firmness and strength; just as it happens in the Nymphs already described.

When the Chrysalis has cast off its skin, the wings visibly expand to their true dimensions in a most surprising manner; and the legs and other limbs unfold themselves, and assume the direction and form we see in the Butterfly ‡.

This expansion of the wings being very sudden, and therefore difficult to be justly observed, or understood as it deserves, unless by persons accustomed to experiments of this kind; it is no wonder that the most happy geniuses, the immortal Harvey, for example, and numberless others, should have fallen into an error on the occasion, affirming that this metamorphosis is not external, or occasioned by any growth in the wings of the Chrysalis; but that it is altogether internal, not only in regard to the wings, but to all the other limbs; inasmuch that Harvey takes upon him to say, that the Chrysalis assumes a new form in every respect, and therefore calls it a perfect egg. The truth is, this supposed transformation does not take place either internally or externally in the Chrysalis; this is proved by the most careful experiments, with which his doctrine totally disagrees. Nor does he succeed better in explaining, than he had, in imagining this metamorphosis, which by his denying any growth of the parts, and substituting an imagination of his own, becomes utterly incomprehensible. These remarks are to be considered here as occasionally introduced; for as we intend to describe in our select experiments, the manner in which these wings and the other limbs grow, and to demonstrate also what changes happen from day to day in the egg and Chrysalis of the insect, both of which we have found to be of the same nature, till the Caterpillar issues from the former, and the Butterfly from the latter, we shall at present enter no further on this subject.

\* Inf. Th. L. II. Cap. 36. de Aurel.

† Obs. Hist. Bomb. L. I. Cap. 21.

‡ The time in which a Butterfly remains in the Chrysalis state, is not limited by nature to any particular period, but depends on external accidents. Reaumur fancied that he could keep the Chrysalis entire many months beyond the usual time of the disclosure of the insect, and thus add to the length of the creature's life, though in a condition wherein it had little enjoyment.

Let any one attentively consider these accidental differences, by which the Nymphs of insects differ amongst themselves; the Chrysalis from its Butterfly, and the other Nymphs from their respective insects heretofore mentioned; as also, those qualities by which the Nymphs agree both with their animalcules, and amongst themselves; and he will plainly perceive, that the Nymph and Chrysalis do not differ in the least in this nature, or as to the interior constitution of their parts, since both distinctly and exactly represent the form of the insect, which is to be expected from them. We allow this representation to be more distinct and observable in the Nymph, than in the Chrysalis; but even this depends in a great measure upon the good sight and dexterity of the observer. An indefatigable examiner must at last reach the deepest mysteries of this science; and thus an assiduous application has rendered it familiar to me to exhibit, in every species of Chrysalis, all the parts of the succeeding insect. But, lest any opposer should take it into his thoughts to object with the great Harvey, that there is in this case a perfect egg, which time may transform, and to which it may give limbs, we can answer, that we can perform this operation equally at different times, in the very instant of the change, or in the beginning, as easily as in the middle and end of it; and even on the very Worm, before it becomes a Chrysalis. There is no kind of Chrysalis, (however strange, unnatural and ludicrous the figures may be, which Goedaert and others have found out for them, in the wild fallies of their imaginations) in which we are not able to demonstrate all the parts of the future insect; and this as evidently, as in the true Nymph. It appears therefore to be beyond all doubt, that the Chrysalis differs from the Nymph only in colour, and the disposition of its parts, or, as the philosophers term it, *per accidens*.

But it will be asked, perhaps, how it happens that limbs should be more conspicuous in the Nymph, which is evidently the very insect itself, than in the Chrysalis, though equally worthy of that name? and why, in the latter, the parts are not so fastened, as it were, to each other, as in the former. It may be demanded also, for what reason the skins cast by the Nymph should be much thinner, than those thrown off by the Chrysalides, which part with theirs in the same manner that the chicken leaves the shell of its egg. To all this I can only answer, that these things are hardly, if at all explicable; the nature of them depending entirely on the pleasure of their Creator; and the reasons of this variation being hidden in his impenetrable wisdom, whose providence has bestowed on his animal productions as great a variety of cloathing, as it has pleased him to form distinct species of such beings. It appears therefore that in these and other as true re-

searches, we should endeavour, by all means, to explain difficulties by reasons drawn from the nature of things themselves, not from the scanty storehouse of our imaginations. Otherwise, by deviating though ever so little from that rule and order, which is firmly established throughout the whole creation by the all-wise, and powerful author of it, it is impossible we should not go astray at every step, and lose ourselves at last in the wrong paths, directed by our own feeble and imperfect reason.

As the foregoing questions deserve great attention, I shall propose that solution of them, which nature herself seems to authorize and support. We may observe, that the Nymph of Ants, Flies, and Bees have a much slenderer body than the Chrysalis before spoken of; and from this it appears reasonable to suppose, they should have a much tenderer skin. The Nymphs, besides this, are always confined to moist places, where their exterior covering cannot readily harden: do not the Nymphs of Ants lie hid under the earth? and those of Flies in putrid flesh, the excrements of animals, and other moist places. As for the Nymphs of Bees, they are always found surrounded with moisture, inclosed in wax, and covered besides, like Silkworms, with a thin membrane: besides this the Nymphs of Bees, at the time when they enter upon their period of change, have all their parts so excessively moist, that sometimes they weigh twice as much as the Bees that are produced from them.

It is observable, indeed surprising, that the humours constituting this moisture must be dissipated by insensible perspiration, before the milky limbs of the insect can move themselves in the least; and all this while the creature discharges no excrement. This Aristotle has remarked in express words\*.

On the other hand, the Chrysalides of diurnal Butterflies (I speak here in general, and do not confine myself to one kind of Chrysalis) go through their changes in the open air, with the greatest part of their bodies destitute of any web to protect them against the inclemencies of the weather; for this reason their outer skin will naturally grow hard, and therefore may be cast off, as has been already taken notice of, without being liable to shrink up, or lose any thing of its original form. Besides, the skin of the Horned Beetle, Tab. XXVIII. fig. VI, VII, VIII, which is likewise found under the earth, is so very fine, that in point of thickness it is greatly exceeded by the coat of the common Chrysalis.

If any one should ask, if it is for the same reason that the Chrysalis itself grows hard, and the Nymph continues in its former state of softness? and why, on the one hand, the Nymph is covered with a thin skin, and its limbs adhere but little to each other; whereas, on the other hand, the Chrysalis is surrounded by a kind of hard shell, and all its

\* Hist. Anim. Lib. V. Cap. 19.

parts are in a manner fastened together, so as to form one substance? I must acknowledge, that I cannot satisfy his curiosity. For as the Nymphs of Bees, when exposed to the open air, die as soon as it begins to harden their skin; and on the contrary, the Chrysalides fare no better when confined to a moist situation; I cannot be brought to think, that things, which are produced by nature every year, in a most wise, regular, and constant manner, should be left so dependant upon chance, and the state of the air and weather: I willingly grant, however, that it is moisture alone which hinders the Nymphs from growing hard, and that the Chrysalides cannot but harden in an open, airy, and dry situation. But if, after all, we consider, that the skin in which the Chrysalis is wrapped up, is not throughout of the same strength, but thicker in those parts which are exposed to the air, than in those which are out of the reach of its influence, as serving only to cover the inner surfaces of its members; whereas it is the reverse in the Nymphs, whose covering is throughout nearly of the same thickness, and therefore less able to protect the enclosed insect from the drying qua-

lity of the air; these things, I say, being duly considered, I cannot by any means allow; that the preservation of moisture, or the hardening of the Nymphs and Chrysalides, just taken notice of, depend at all upon chance; unless I should be satisfied to give up my reason so far as to imagine, that the very being of these little animals depends upon chance likewise; and that they spring spontaneously from corruption; and in this blind manner wilfully doubt of nature's great attention and wisdom, so conspicuous in her manner of preserving and cloathing this part of the creation. I conclude, from all this, that there is no essential difference between the Nymph and the Chrysalis; and that the variation which appears, consists only in this, that the skin of the former is more thin and tender, and that of the latter thicker and harder; to which I may add, that in the Nymph all the parts of the future insect may be easily seen, whereas in the Chrysalis they are less distinct. That these are the principal differences, will appear evidently hereafter, when I treat those subjects separately, and in a more ample manner.

*The manner in which Worms and Caterpillars become Nymphs.*

**H**AVING laid down the sole foundation of all those changes which are observable in insects, and shewn that this consists in nothing but the Nymph, into which, at their proper seasons, all the Worms of flying insects and Caterpillars are changed, or, to speak more properly, from which they shoot out or bud; a change which appears in all, except such insects as remain in their eggs, till, without passing through any intermediate state, they have acquired their full vigour, and attained their proper degree of perfection; to which may be added, those insects also, which, hiding the real shape of the Nymph under the resemblance of an egg, issue from it complete animals, as shall be hereafter explained. These things being proved, it appears necessary that, before we pass to the other propositions, we should enter upon and explain the manner in which this change is produced, illustrating it with the figures of those insects that are the subjects of it.

But as in the forms of those insects which shoot out or bud into Nymphs, there is not only an amazing, but in a manner an infinite variety; and consequently it would be impracticable here to describe them all; I shall particularize only those, which differ most remarkably from each other, and consider them as they have, or have not legs.

We observe, that of those insects which become Nymphs or Chrysalides, some have no legs, Tab. XVI. fig. II. some have six, Tab. XXVII. fig. v. and others a greater number, Tab. XXXIV. fig. II. and Tab. XLIV. fig. III. And as this difference between the various

species of insects is particularly remarkable, if we compare them together; so there occurs a no less obvious difference on account of the various number of legs in those we have ranked under the third species, viz. that of insects which have more than six: but in these many footed insects, the six foremost deserve our chief attention, as does in the insects that have no legs, that part of their body, which in other animals is called the chest.

That it may appear upon what grounds we have adopted this method of classing insects, according to their having or not having legs, and according to their having six or more, it will be very proper to observe, that in those Worms which have no legs, that part of them, which we have called their chest, never undergoes any change, or alters its situation; and that in the Worms and Caterpillars which have legs, be the number more or less, the six foremost never come off, or change their places in any sensible manner; Goedaert, in direct opposition to truth, would have us believe they do, but experiments shew the contrary. In most Worms and Caterpillars, not to say in all, the six foremost legs are constantly preserved by the insect, and that without the least change in their position: and what is yet more surprising, in several Worms which have six legs, the alteration in their legs is so small at the time that they shoot out into Nymphs, Tab. XX. fig. v. that it cannot by any means be distinguished or observed, whatever metamorphoses the former naturalists, without any exception that I know of, have idly and extravagantly imagined on this occasion.

As therefore the experiments we have made, have, like the rising sun, dissipated this thick and dark cloud of imaginary metamorphoses, the whole truth thereby appearing in the clearest and most evident light; in the same manner, by pursuing the same cause, with that readiness and confidence which such guidances deserve, we shall readily understand the most obscure and difficult changes which happen in those insects that have no legs. As we have resolved in this work not to depend upon inductions of one thing from another to prove the assertions, we shall abide firmly to the chain of our experiments, and, in consequence of this method, advance, that the wings, horns, and other parts which Worms without legs seem to acquire about their chests, at the time of their mutation, are not truly produced, during the period of mutation, or, to speak more agreeably to truth, during the time of the limbs shooting or budding out; but that they have grown there by degrees under the skin, and as the Worm itself has grown by a kind of accretion of parts, and will make their appearance in it upon breaking the skin on its head or its back, and thereby give it the figure of a Nymph, which it would afterwards of itself assume, Tab. XXV. fig. v.

Hence it is, that we can with little trouble produce the legs, wings, horns, and other parts of an insect, which lie hid under its skin while in the shape of a naked worm, which has neither legs nor any other limbs. This we have shewn in the presence of the celebrated Mr. Thevenot, a gentleman whose unusual sagacity, in every branch of polite learning, is above praise. We had the good fortune of changing before him the Worm of a Bee into a Nymph, by breaking the skin upon its head, upon which all the parts hid under it made their appearance; and we since have had equal success in demonstrating to the same gentleman, and the illustrious Lawrence Magellotti, a curious searcher into the secrets of nature, all the parts of the Butterfly clearly and distinctly in the original Caterpillar. We have since discovered also a method of changing, at pleasure, the Caterpillar into a Chrysalis.

To comprehend in a few words the reasons, foundation, and manner of these natural changes, and at the same time to illustrate them by a palpable similitude, I need only briefly remark, that "the Nymph or Chrysalis" (I here speak only of insects without legs, the change that happens in the rest, being, as will hereafter appear, so easily understood as to require no explication) "is nothing more than a little Worm, which, the growth of legs, wings, and other limbs hid under its skin being perfected by time, at last bursts that skin, and casting it off, gives us a clear and distinct view of all those parts." This change, which has been preposterously called a transformation, or metamorphosis, and by some a death and resurrection, is no more mysterious or surprising, than what happens, when "one

"of the meanest plants, despised and trodden under foot, gradually swells on every side; and after producing a bud, by bursting the little case containing it, presents an elegant and beautiful flower."

We might likewise compare, in this place, the sanguiferous animals with insects; as in respect to the accretion of their limbs there is not the least difference to be found between these large creatures, and the little worm we have compared with vegetable substances: but amongst all the animals of that tribe, none agree so exactly or obviously in these changes with the insect tribe, as Frogs. These creatures are changed into a true Nymph, known by the name of a Tadpole; as will more fully appear hereafter, in the explanation of our plates, and in comparing together the Tadpole, the Nymphs of Worms, and the little case in which flowers are produced, Tab. XLVI.

The same changes therefore, which we observe in vegetative animals, are equally observable in sensitive ones, so as to afford us in all God's works the most manifest proofs of his infinite wisdom and power, which man can neither imitate nor comprehend: for as the foundations of all created beings are few and simple, so the agreement between them is most surprisingly regular and harmonious, every thing conspiring equally to fill us with sentiments of admiration and reverence for the great Author of nature.

The serious consideration of the preceding truths, will set in a just light the great error of those, who, from these natural and intelligible changes in bodies, have endeavoured to explain the resurrection of the dead; whereas that great operation not only far surpasses the powers which we see in nature, but has not any thing in common with the natural changes of which we have been speaking: the resurrection is a subject of faith only, which gives a certain and undoubted knowledge of things beyond the reach of our senses. These animalcules do not die, as man does, in order to rise again; all that happens to them is, that their limbs become improveable at the time of their transmutation, which, however, happens in so surprising a manner, that it is no wonder observers, at first sight, should take the production to be a real resurrection from a dead animal. This is all that can be offered from what we know of insects, in proof of the resurrection of the dead; which is altogether another thing, than that idle and imaginary death of those animalcules, or the transformation, as it is called, of their limbs. Nor are those authors less mistaken, who, from these natural changes, which they idly call metamorphoses, have endeavoured to ascertain the transformation of metals; as amongst others, the most learned Sir Theodore Mayerne has not feared to advance this absurd notion in the dedicatory epistle prefixed to Mouffet's treatise on insects. His words are: "Moreover, if

“ animals are transmuted, why may not metals be transmutable?”

To finish this inquiry, as it is much more easy to comprehend the change of the six-legged Worms, than that of the Worms without legs, of which we have hitherto been speaking; seeing the former only acquire wings, Tab. XLV. fig. xxiv, xxv. and its limbs are seen to shoot or bud out, in the same clear, distinct, and gradual manner with the corresponding parts of plants and flowers, so as to agree more perfectly with such vegetation, and with the change spoken of in Frogs; than what happens in the Worm without legs; so it cannot but appear surprising, that men of the greatest sense, learning and experience, who have at all times been indefatigable in observing these changes, should have so long continued under a mistake, in regard to the true manner in

which they are performed; substituting all along, to a simple but elegant scene of wonders, the wild flights of their unnatural fancies. Hence it is, that the doctrine of insects remains to this day buried in the profoundest obscurity, so as that not only those look upon it as a mystery, who have few opportunities of being acquainted with such subjects, but even those also who have made this study their regular employment, and were the best qualified to pursue it with success, such as Aldrovandus, Mouffet, Libavius, and Goedaert; indeed, I might say all who have hitherto applied themselves this way, have been so far deceived as not only to doubt and waver in their opinions; but influenced by prejudices obstinately to remain insensible to the strongest conviction, that the most obvious and convincing experiments could afford.

### C H A P. III.

*The manner in which the true knowledge of the Nymph, the real foundation of all the natural changes observable in insects, has been obscured and corrupted; with an illustration of the subject, and an entire restitution of its original truth.*

HAVING manifestly proved in the preceding pages, that the Nymph, or Chrysalis, is nothing but the very insect which may one day be expected from it; and having proved beyond contradiction, that the former lies hid within the worm, or its skin, in the same manner as the tender and growing flower is wrapped up in its bud; so that as the flower breaks from the surrounding cup, the limbs of the enclosed insect, by the power which swells and shoots them forth, must, in the same manner, at last burst their prison, and make their appearance, which appearance alone constitutes the nature of the Nymph, or the knowledge of the foundation upon which all those natural mutations depend. All these things, I say, having been abundantly demonstrated, I can have no pleasure in giving a long and pompous catalogue of those authors, who have entertained different opinions of the matter, nor in refuting those strange fancies with which they have obscured and perplexed this most valuable branch of natural history. Besides, what purpose could such a discussion serve, but to lead us still further from the conclusion of this our second proposition, since the simple explanation of truth, is the best method of opposing and overturning falsehood?

However, as Mouffet's elaborate performance on this subject, is in a manner universally read by those who study the nature and the changes of insects, and is not only founded on the experiments of the author himself, and of his learned friends Wotton, Gesner, and Penn; but in part extracted also from upwards of forty authors, of which the learned Aldrovan-

dus is one; and as the author follows so scrupulously the rules laid down by Aristotle, that he scarce ever deviates from them, it is incumbent upon us to mention what he proposes in his elaborate treatise, where he lays down the changes that occur in the Silkworm, as an example of those which happen in all other insects; and gives such an account of those changes, as neither reason nor experiment can warrant. His words are these: \* “ It is very remarkable that in this metamorphosis which is performed by means of an Aurclia, the Silkworm's head becomes the Butterfly's tail; and the head of this last the tail of the former; and the same thing happens in all the other Caterpillars, that become Aurclia.” In another part of the same † performance, where he treats purposely of the Chrysalis, he says as follows: “ It has neither a mouth, nor any distinct limb.” Now as all these notions are directly opposite to the clear and distinct observations we have made, and already delivered, it would be spending time to little purpose to dwell any longer upon them; they have been already sufficiently refuted. We need not be now surprised that this learned Englishman, who could be guilty of so great an error (which some eminent countrymen of his own have before taken notice of in a performance called, “ A catalogue of the plants that grow in the neighbourhood of Cambridge,”) should not have taken the least notice of the manner in which such fanciful changes are performed, though in the same chapter he with great reason affirms, contrary to Aristotle's opinion, that

\* Inf. The. Lib. II. C. 1.

† Inf. The. Lib. II. C. 36.



the Chrysalis is not the egg of the Caterpillar. His words are: "To conclude, what is there here in common between an egg and an Aurelia? The former has neither life nor motion, and is discharged from another animal; the latter is not discharged by any animal, but is only changed from one thing into another." However, though Mouffet denies that the Aurelia is an egg, he has not courage enough to call it an animal; he considers it only as a kind of medium, or mean condition, between two animals; or as a third being between the Caterpillar and the Butterfly; saying, "It appears nevertheless by what I have already said, that the Aurelia is not an egg; the truth is, that it is to be called a kind of transmutation, and not a generation of the Caterpillar into an Aurelia, and of the aurelia into a Butterfly." But as this difficulty, contrived by his own imagination, has rendered utterly inexplicable what otherwise might be very easily explained, he has recourse, as is usual in such cases, to the immense power of the Creator, and after this concludes the subject in the following words: "I well know how the Aristotilians perplex themselves in this case with a wonderful transformation, and at last are obliged to refer us to God's indeterminate power."

But we leave to the wildness of their own genius, those learned men, who rashly affirm that the true notions of every thing that appear in insects, as well as in other bodies, are to be found in the eminent writers of antiquity. Nature, that indulgent parent, exhibits, all that relates to them, to us, every summer, in the plainest and simplest manner; nay, she gives us an opportunity of demonstrating those her proceedings, and that in the most satisfactory manner, in the very depth of winter, by the help of the artificial heat of a stove, or any like continuance. Let us rather take a specimen or two of the unworthy manner, by which the genuine representations of these changes, which are no more than the natural shootings of the limbs, that at last thereby come to make their appearance, have been confounded and obscured, even by men who have spent their whole lives in researches into the nature of animal generation in general; and have applied themselves more particularly to find out the nature of those changes observable in insects.

The first I shall mention, is that second Democritus, the celebrated Harvey, who, against the current of the most convincing experiments, boldly affirms with Aristotle, that the Chrysalis (though it be indeed the very insect) is a perfect egg, from which of course the insect may, by the help of transformation, be afterwards expected to spring. Take his own words: \* "Such are likewise the seeds of many insects, (called worms by Aristotle) which being at first produced in an imperfect state, search out their food; by which being

"nourished and increased, from a Caterpillar they become an Aurelia, and a perfect egg and seed from an imperfect one." By this, he not only with Aristotle calls the Chrysalis a perfect egg, which, according to the same author, is neither a Caterpillar nor a Butterfly, but seems to give into Mouffet's false and absurd opinion, who affirms, that the Chrysalis is a kind of medium, or middle being between the Caterpillar and the Butterfly. This passage of Harvey's shews us, that he was not acquainted with those insects which proceed immediately from an egg in a state of perfection, without ever appearing in the form of worms, Caterpillars, or Nymphs; or at least that he imagined the mutation they undergo is performed within the egg; and that therefore their generation is the same in all respects with that which he has described as proper to Chickens within the egg of the Hen; or with that other generation which he attributes to the worms of insects †, which spring from eggs, and which he represents as perfectly agreeing with the generation of Chickens.

But although this great philosopher calls the Chrysalis a perfect egg, he nevertheless does not assert that the insect proceeds from the chrysalis, as from an internal and hidden principle, in the same manner that he affirms the chicken springs from the Hen's egg, or that the insect is formed by one part of egg, while it only receives the matter of its increase from the other part; which he says is the case in the generation of Chickens. Nay, his opinion on this occasion is far more rational and solid, for he admits it, with Aristotle, as an axiom: ‡ "That the animal is not made out of the worm, as out of an egg, from a part of it; but that the whole worm grows, and becomes an articulated animal," without considering that Aristotle calls the Aurelia an egg. Now if we compare the passage which Harvey has adopted from him, with the scene which nature every year presents to us, we shall find the words contain a true definition of the Nymph: but as both Harvey § and Aristotle \*\* have here besides fancied a metamorphosis, which they call "a distribution of one thing that is to be altered into many;" and which in another place †† Harvey has expressed by the following periphrasis: "In the generation that is performed by a metamorphosis, things are produced as it were by the impression of a seal, upon the matter of them, or by this matter's being cast into a mould, the whole of it entirely transformed." This account is not only false, but altogether degrades and darkens the true system of those natural mutations: no satisfactory explication can be drawn from it, of any manner in which these fancied metamorphoses, and imaginary transformations, can be said to happen.

But the better to understand Harvey's doctrine of insects, which, however, does not

\* Lib. de Gen. Anim. Exerc. II.  
§ Exerc. LXXII. de Hum. Primig.

† Lib. de Gen. Anim. Exerc. LVII.  
\*\* Lib. II. de Gen. Anim. C. I.

‡ Lib. de Gen. Anim. Exerc. XVIII.  
†† Exerc. XIV. de Gen. Anim.

reach the outer limits of this branch of natural history; and at the same time, to shew what egregious mistakes we are apt to commit, the moment we abandon the solid arguments furnished by experiments, to follow the false lights struck out by our weak and imperfect reason, I shall here give his imaginary account of this matter, as I find it in his book upon this subject \*, in his own terms,

“ There are two ways,” says he, “ in which  
 “ we observe one thing to be made out of  
 “ another (as out of matter) both in art and  
 “ in nature, especially in the generation of  
 “ animals; one is, when a thing is made  
 “ out of another, already in being, as a bed  
 “ out of wood, and a statue out of stone;  
 “ when, for example, all the subject-matter  
 “ of the workmanship exists, before the work-  
 “ man begins the work, or attempts to give  
 “ give it any form. The other way is, when  
 “ the stuff receives both being and form  
 “ at the same time. As therefore the works  
 “ of art are performed two ways; the one  
 “ by the workman’s dividing, cutting and par-  
 “ ing away the matter prepared for those ope-  
 “ rations, so as to leave behind, like a statuary,  
 “ the figure of the thing he intends to make:  
 “ the other, by the workman’s adding and  
 “ moulding, as well as paring away, the mate-  
 “ rials, and at the same time tempering the  
 “ matter itself, so as to produce. like a potter,  
 “ the figure; which, for this reason, may be  
 “ said to be made, rather than formed. In the  
 “ same manner it happens in the generation  
 “ of animals; some of which are formed and  
 “ and transfigured out of matter already di-  
 “ gested and encreased for this purpose, all the  
 “ parts springing out together distinctly, by a  
 “ kind of metamorphosis; and thus forming a  
 “ perfect animal, while other animals are made  
 “ piece by piece, at first deficient both as to  
 “ size and shape, afterwards receive both by  
 “ degrees, from the same matter out of which  
 “ they were originally formed. In these last  
 “ animals, one part is made first, and the other  
 “ parts, by means of this first, as the princi-  
 “ ple of the animal’s existence. This process  
 “ of nature, we call an epigenesis, or accretion  
 “ of parts, on account of her forming the parts  
 “ gradually one after another; and this is more  
 “ properly called generation than the other.

“ The generation of insects is performed  
 “ after the first manner:” when the worm, by  
 a metamorphosis, proceeds from the egg; or  
 the rudiments are formed out of matter in a  
 state of putrefaction (by growing too dry or  
 too moist) “ and these rudiments produce, as  
 “ by a metamorphosis, a Caterpillar grown to  
 “ its full size, or an Aurelia, a Butterfly or  
 “ a common Fly of its full size, so as never to  
 “ grow bigger. But the more perfect sangui-  
 “ ferous animals are formed by an epigenesis,  
 “ or a superaddition of parts; and after their  
 “ birth, grow to a state of adolescence, and  
 “ arrive at their perfection. Chance or for-

“ tune seems chiefly to pride in the production  
 “ of those animals, which owe their form to  
 “ the power of a pre-existent matter; which  
 “ matter is the first cause of their generation,  
 “ rather than any external efficient; for which  
 “ reason those animals are more imperfect,  
 “ and perpetuate themselves less, both as to  
 “ number and likeness, than sanguiferous land  
 “ or water animals; which, by deriving their  
 “ being from an univocal principle, (that is,  
 “ from other animals of the same kind) keep  
 “ up an eternal succession; and the cause of  
 “ of this we attribute to nature, and a vegi-  
 “ tative power.

“ Some animals, therefore, are produced of  
 “ themselves from matter digested spontane-  
 “ ously, or by mere chance, as Aristotle seems  
 “ to advance in the sixth book of his metaphy-  
 “ sicks, chap. 9. Those animals, to wit,  
 “ whose original matter can give itself motion,  
 “ such a motion, by accident, as the seed gives  
 “ itself in the generation of other animals. And  
 “ the same thing happens in the generation of  
 “ animals, that is observable in the works of  
 “ art; for some things which are produced  
 “ by art, are likewise brought about by acci-  
 “ dent, as health; other things that are made by  
 “ art, are never made otherwise, as a house.

“ Bees, Wasps, Hornets, or Butterflies, and  
 “ whatever other animals are generated by  
 “ metamorphosis from a creeping insect, are  
 “ said to be the offspring of chance, and there-  
 “ fore never to keep up their species. But the  
 “ Lion or Cock are never produced spontane-  
 “ ously or by chance, but are the work of  
 “ nature; wherefore they do not require a  
 “ suitable matter, or some other divine power,  
 “ so much as a similar form.

“ In the generation by metamorphosis, ani-  
 “ mals are fashioned as it were by the im-  
 “ pression of a seal, or framed in a curious  
 “ mould, all the matter of which they consist  
 “ being transformed; whereas the animal which  
 “ is produced by way of epigenesis, or accre-  
 “ tion, at once attracts, prepares, digests, and  
 “ makes use of the ready matter; it at once  
 “ grows and acquires its form. In the former,  
 “ the plastic power divides the same similar  
 “ matter, arranges it when divided, and re-  
 “ duces it into limbs; from similar making it  
 “ dissimilar, or forming dissimilar organs with  
 “ a similar substance. But in the latter, whilst  
 “ it produces in order different parts, and those  
 “ parts differently disposed, it requires and  
 “ makes different substances; and substances are  
 “ variously disposed, the better to suit the dif-  
 “ ferent parts that are to be generated.”

This is the doctrine of Harvey; and this  
 his dissertation contains almost as many errors  
 as words. This may appear surprising in one  
 so well versed in enquiries of this kind, where  
 truth can only be ascertained by experiment:  
 notwithstanding all his errors, we must do his  
 great merit in other respects justice; his dili-  
 gence in studying nature was very great, and

\* Lib. de Gen. An. Exerc. XLV.

he therefore deserves not only our praises, but those of all mankind; and the candid manner in which he usually offers his opinions, is yet more praise-worthy; for he thus most ingenuously speaks, in the preface to that performance I have been just now mentioning: "Therefore, (generous reader) I do not expect you should take my word as to the manner in which the generation of animals is performed: I appeal to your own eyes as witnesses and judges of what I advance. For as all perfect science is built upon such principles, as are derived from the observations of sense; you ought strenuously to endeavour, if you have a mind to become thoroughly acquainted with what relates to animals, to attain this knowledge, by frequent dissections of them. If you proceed otherwise, you can only acquire a specious and wavering opinion, but no certain and solid science."

To conclude, it is not our intention to refute one by one, in this place, all this ingenious but mistaken author's propositions; seeing this is abundantly done already, by the evident truths we have produced; neither will the dignity of so great a name, easily admit of such a censure, (in abstaining from which, we only follow the example himself has given us in the case of that famous anatomist Fabricius ab Aquapendente, whom he spares in the same manner, and on the same account.) Nevertheless, I cannot avoid again inculcating at least one principle; that whereas the Nymph is indeed the animal itself, and by no means the egg, the whole and only mutation which happens here, is nothing more than a slow evaporation of the superfluous moisture; for by this all Nymphs are necessarily changed.

Thus it happens, that during this evaporation, before explained in the Nymph of the Bee, the limbs which were before tender, weak, and fluid like water, are freed from the superfluous moisture which deprived them of motion; whereby the latent insect is enabled to force its exterior covering, and, having cast it off as the Bee does, or forsaken it as is done by the Butterfly, to make use of the moisture which remains, to expand its wings and other parts.

The Nymph therefore, during the first days of its change, resembles a man who has lost the use of his limbs, by a collection of saline or other humours about his joints, and does not recover them, till such hurtful moisture is dissipated by nature, or by art. Nature and art have the same effect upon tumified members, and upon what we call Nymphs; so that on evaporating the superfluous humidity of these last, by the means of nature, or by an artificial heat, they may be brought forth in the form of insects, even in the depth of winter.

In fine, as it is utterly erroneous to suppose, that the whole mass of the Worm is transformed into the Nymph, and after this the Nymph into a winged land or water animal; so, on the

other hand, nothing is more certain, than that all the limbs of the Butterfly, the common Fly, and such other insects, do actually grow in the Worm, in the same manner as the limbs of other animals: so that nothing can be more repugnant to truth, or be so little supportable by any solid arguments, as this notion of a metamorphosis: for it is not in the Nymph alone, but in the very Worm, or Caterpillar: Tab. XXXVII. fig. II. III. and IV. we can lay before the eye all the parts of the future insect. Those parts are by no means generated suddenly and all at once, as has been supposed; but grow leisurely one after another, till all of them having arrived at a state of perfection, the Worm gives itself motion, and breaks its skin; the inclosed limbs having generated by degrees, from the motion of the moisture, and their own contraction, swell and easily casts its skin, and suddenly discloses all its limbs to our view. In this inflation, (shooting out, budding, or vegetation; and, as it were, changing of the nutriment of the new limbs, which have gradually grown, or have been produced by an epigenesis, or accretion of the parts, and not at all by a metamorphosis) consists the sole foundation of all the changes which we remark in insects. We call the creature in the state of this natural mutation a Nymph, because this kind of insect, on casting its skin, may be said to resemble a bride or Nymph, who, in many countries, leisurely prepares and adorns her person for her intended spouse. But we utterly deny what Goedaert has in several places advanced, that there is any resemblance between the Nymph and an infant in its swathing clothes; as also its likeness to any other figure than that of the future insect; for the Nymph not only represents clearly and distinctly all the parts of the future insect, but is, in reality, the insect itself; and this, not dead or buried, but, as Libavius has already observed of the *Necydalis*, actually living and feeling, though unable to give any indications of life, except by the motion of its tail or belly; for in many we find these parts are not affected with any moisture, nor undergo any change, but what arises from the casting off a very thin skin, so that they cannot lose their former power to move.

Allowing therefore as a certain truth, as it really is, what has been already advanced in this work concerning insects, not only all that Harvey says upon the same subject, in the extracts we have given, and all the errors that flow from thence, fall to the ground; but likewise that common opinion of philosophers, that the generation of insects is fortuitous, and which Goedaert's editors seem to have fathered, or rather to have forced upon him, appears utterly groundless; seeing it has no other foundation, than that idle and imaginary metamorphosis, which neither exists in nature, nor can fairly be deduced from Harvey's (in many places) contradictory arguments. This great man must have easily seen the weakness of his

own repugnant notions, had he not been too much prejudiced in favour of the opinions which they were calculated to support or explain, if the respect we owe him will, after all, permit us to think he really gave into this absurd notion. Perhaps we may with more justice assure ourselves, that he proceeded on this occasion, in the manner that people generally proceed in considering things that are difficult to be understood and accounted for; that is, by fancying something, which seems, on mature deliberation, best to agree with the nature of things, as Aristotle had long since directed, in his treating of the generation of Bees \*; his words are, "That the generation of Bees is performed in this manner, seems not only agreeable to reason, but to what appears to happen in the generation of other insects of this kind; however, the observations hitherto made are not sufficient to give us a certain knowledge of what it is that really happens. When we have acquired that certain knowledge, we must trust our senses, rather than our reason, by which we are to be guided, as far only as what it demonstrates, agrees with what our senses ascertain." Daily experience shews us, how many and how great errors this method of philosophising hath produced; so that an author would do much better to own his ignorance ingenuously, than to lead astray, by unnatural phantoms, those multitudes of credulous readers, who, idly thinking that all true learning is to be found in books, never give themselves the trouble of immediately consulting nature herself: perhaps we ought rather to pronounce such idle followers of knowledge well worthy of this punishment, for neglecting the opportunities of finding it in the things themselves with which they are desirous to be acquainted.

Having shewn in some measure on how uncertain a foundation Harvey's account of the natural mutations of insects is erected, it remains to consider with what gross errors, and palpable falsehoods, Goedaert has defiled them: but at the same time we own with satisfaction, that this author alone observed and discovered, in the space of a very few years, more singularities in the Caterpillar kind, than had been done by all the learned men who treated the same subject before him. Notwithstanding this, we cannot help saying, that not only he was not free from mistakes, but that he has made some such important ones, as can scarcely, if at all, be excused: not to mention his not having had the least notion of the true nature of the Nymph. But as we have resolved to examine on a succeeding occasion, separately, all the errors of this author, we shall produce at present only two of the most glaring; upon which, as upon a frail and slippery foundation of ice, all his experiments are built. Nor shall we do this with any other view than that of making truth appear the more strong and plain, by being compared with falsehood; for the more

naked truth is proposed, the more powerful it is to subdue errors.

In the first place Goedaert is under a very great mistake, when he advances, that the Caterpillar can be changed, before it has reached the full term of its growth; adding also, what is still more apt to lead people astray, that the mutation effected in this manner is very incomplete and unnatural. But let us attend to his own words, in the first volume of his singular observations on the wonderful mutations that happen in the Caterpillars, page 12 of the Dutch edition. "I have besides observed," says he, "that, whenever the Caterpillars effect a mutation, before they have been sufficiently fed for that purpose, and have reached the full term of their growth, they never receive a perfect form in consequence of such premature change, but are misshapen and miserable, with short and shrivelled wings, like a piece of scorched parchment; whereas otherwise, in less than half an hour, these useful parts expand themselves, and acquire their proper beauty, with a variety of elegant colours. Hence it happens, that the unhappy insect, not being able to make any use of those imperfect wings, is much more miserable than it was before its change, being obliged to creep upon the ground, where it at last perishes for want of proper nourishment." Afterwards, in his twenty-eighth experiment, it appears, that on the strength of the foregoing hypothesis, having for several days supplied a Caterpillar with food, though all the time preparing for its mutation, he breaks out into the following words: "If I omitted giving it food, but for one day, it immediately set about changing; for which reason I took care not to make it fast any longer, as so premature a change was likely to produce but an imperfect Butterfly; for it is remarkable of all Caterpillars in general, that as soon as they find their food fail, they prepare for a mutation; but if it fails of its food before the term appointed by nature, the insect produced is both imperfect and tender; so that to have a succession of complete Butterflies, the Caterpillars must be provided with food, till they refuse it of their own accord, in order to enter upon the business of mutation." At length, after having given in the eighth experiment on the strength of a mere conjecture, the example of a nocturnal Butterfly, which was, in his judgment, the weaker, because its Caterpillar had been deprived sooner than it ought of its ordinary food; in the fifty-ninth experiment of the first volume, and afterwards in the thirtieth of the second, he in a manner opens the source from which he derived all those his mistakes; for after describing a very miserable animal, that was neither a Caterpillar nor a Butterfly, according to the idea he had idly formed of it in his own fancy, he adds, "The reason of all this is, that the Caterpillar had entered upon the business

\* Gen. Anim. Lib. III. C. 10.

“of mutation, before it had taken its proper quantity of nourishment.” As this argument appeared to him most incontestible and evident, he afterwards, in the twenty-ninth and thirtieth experiments of his second volume, where he describes such another imperfect animal, and one with wings; does not mention one word of this false proposition, but passes it over in silence, as if sufficiently proved, and not liable to contradiction.

Since in the places here cited two animals are exhibited, one of which, namely, the female, is always, by an invariable law of nature, transmuted without wings, Tab. XXXIII. fig. VI: whilst the other, which is the male, never appears without them. No. VI. not only the genuine foundation of all natural mutations is overturned, and rendered obnoxious to chance, by the idle comments which we have extracted from Goedaert, but the road to truth is also rendered impracticable, at least to the unskilful.

Goedaert himself could not avoid the consequences of such rash and idle fictions; he has thence fallen into two other mistakes. The first is seen in the pains he must have been at to supply his Caterpillars with food as long as they required it. The second, his omitting, on this account, some very curious experiments; for, infatuated with his own prejudices, he neglected the true knowledge he might have acquired by his experiments, to adopt a false reasoning; so that he could never afterwards by his experiments come to know, that the species of Caterpillars he describes, are never changed after any other manner; the male Caterpillar becoming constantly a tender insect, furnished with wings, and the female a coarse and big-bellied one without any.

The observation made in the place here cited appears to be of the utmost importance, viz. “That the male of the nocturnal Butterfly is always provided with wings, whereas the female never has any;” so that the male can enjoy the sweet refreshments which the free air affords, and ramble at pleasure over the smiling fields and fragrant flowers, when, on the other hand, the care at home, and management of the fruits of wedlock, are committed to the female only; for which reason, she is always found with the hinder part of her body thrust out, in order, as it were, to induce the male to do his duty; nor does the male seem indisposed to perpetuate his species. Nature, therefore, intended to afford us in these insects the most striking examples of an affectionate mother, and a careful father; and perhaps, as the slothful were formerly referred to the ant, as a pattern of industry, married people, that neglect the duties of their state, may, with equal propriety, be desired to consider this other little insect as a model of conjugal sollicitude.

As it sufficiently appears from our experiments, which contradict those of Goedaert, (though that very observant author has taken the right method in making them, and hath

given tolerably accurate figures) what false consequences he has deduced from thence, and, by that means, rendered the strongest basis of the origin of insects wholly subject to chance; we shall now restore this foundation, whereon, as on a rock, depends the whole fabrick of the transmutations of insects, and shall lay down the following as undoubted axioms. First, that the Caterpillar cannot be changed before the time appointed by nature, that is, the last moment of its growth. Secondly, that although Caterpillars may be transformed before they leave off feeding, yet this has no effect to cause any change in their form. We must however acknowledge that some difference in size may arise from hence, which we must observe hath not been noticed by Goedaert, nor, hitherto, by any other person. Wherefore, thirdly, we by no means think it necessary that the Caterpillar should be fed until it ceases to eat of its own accord; for at the time when it is to undergo a change, the business of feeding is not only unnecessary and difficult, but entirely useless. Consequently, the conclusions of Goedaert before mentioned, have not been drawn from the nature of things, but from his own false and chimerical notions. For he, not having examined his experiments with deliberation and diligence, deceived himself and others.

We may take it for granted, that as soon as the Caterpillars have arrived at their utmost growth, that is, when all the limbs under the skin have grown to a proper size, they have not only power and ability, but also, if I may be allowed the expression, a free and absolute will to begin their mutation, with this restriction only, that they cannot omit or avoid it; since the budding limbs, which demand, as it were, to be changed into the Nymph, in process of time, bursts the skin, though they can feed for a considerable time afterwards: but then, as I have before observed, this further feeding is of no other use but to make the creature larger or smaller, for from that time not even the least of their limbs is increased in length. This Harvey hath also remarked, in his treatise of the generation of animals. From hence it also follows, that these animalcules, now grown to perfection, attaining the age of maturity, and fit for the copulative state, apply themselves solely to propagating their species, in the execution whereof some particulars are so astonishing, that they deserve everlasting admiration.

Nature performs the whole process of generation in these insects in so clear and open a manner, that by the assistance thereof it should seem as if we could penetrate into the true foundations (though hitherto buried in darkness) of the generation of other animals, which we shall evidently demonstrate, when we have time and opportunity for further experiments.

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That we may give our opinion on this head in a few words, it seems very probable, that in the whole nature of things there is no generation that can be properly so called, nor can any thing else be observed in this process, than the continuation, as it were, of the generation already performed, or an increase of, or addition to, the limbs, which totally excludes the doctrine of fortuitous propagation. Having established this principle, it is easy to explain the reason that a man, deprived of hands and feet, may have a sound and perfect offspring. Hence, also, we may determine that famous question, whether, in order to produce a complete issue, a seminal particle drawn from every member of the body be absolutely necessary. Moreover, the reason is evident, how Levi, being yet in his father's loins, paid tythes long before he was born: for he was in his father's loins, when Melchisedeck met Abraham. Lastly, even original sin (in the opinion of a very learned man, to whom we have occasionally communicated the mysteries of our experiments) may stand on this principle as on a firm foundation, since all mankind have been laid up originally in the loins of their first parents. But, since others claim the right of explaining such mysteries, we shall enter no further into this matter, but come to another error of Goedaert, intending to discuss the rest, when we have occasion to examine any more of his experiments; for it is not our intention to build on another's foundation.

A further error of Goedaert appears in the 77th experiment of the first part, in the words following: "What is more particularly worthy of our notice in these insects is, that wherever the legs are situated in the Caterpillar, there is placed the back of the animalcule that is to arise by transmutation: and on the contrary, where the back of the Caterpillar was, there, are the legs in the animalcule to be produced from thence. This metamorphosis, adds he, (which renders him the more blameable) is performed in a short space of time, so that it may be distinctly seen; because immediately after shedding its skin, this change appears to the eye." From hence may arise a proper opportunity of explaining accurately and carefully the true transmutation of the Caterpillar into the Chrysalis; but as this matter is (as far as hitherto is necessary to be explained) very evident, from what we have on several preceding occasions said thereon, we shall here pass it over in silence; and the rather, because we have determined to treat this matter professedly in the following sheets; for we shall shew from reason, and illustrate by figures, after what manner, and in what place, every limb of the Nymph and Butterfly are disposed and arranged, which we have before actually laid before the eye, in the presence of Magalloti and Thevenot, by shewing all the limbs of the Butterfly in the Caterpillar. There-

fore, to prove the falsity of what we have cited out of Goedaert, it is sufficient only to repeat, that the six fore legs of the Caterpillar are never changed or transposed in any remarkable manner. And though Goedaert thought himself superior, with respect to the sharpness of his sight, to Mouffet, Harvey, and others (whose thoughts on this subject were conjectural) and has asserted the contrary to their doctrine, yet nothing is more certain than that not only he, but those who boast to have seen it, were grossly deceived. This deception may possibly arise from two causes: the first is the swift shedding of the skin; whence it happens, that the limbs, hitherto hidden, suddenly appear, and are disposed in a form quite different from what they were in the Worm: the second may be owing to some protuberances and swellings, which are on the back of the Caterpillar, and, as soon as the skin is shed, have the resemblance of legs. Indeed, a person more quick-sighted than Goedaert, may be deceived by this, since the change of the skin happens suddenly, and, as it were in the twinkling of an eye: wherefore, even the more modern authors, who wrote most accurately on this subject, have discovered nothing else, than that the skin is first broken on the head and back. This is plain from that very elaborate treatise of the generation of these insects, published by Francis Redus, principal physician to the grand duke of Tuscany, in his own language, in the year 1668; wherein he has proved, by the strongest arguments, that no insects are generated by putrefaction. This doctrine we shall not only willingly grant this eminent physician, but further we scruple not to assert, that putrefaction is, in a great measure, produced by those very insects which are supposed to arise from it: but of this matter more at large hereafter.

In order to shew the origin of those swellings on the back of the Caterpillar which imposed on Goedaert, as so many signals of changing their legs, it must be observed, that many of the Caterpillars, whilst they are changing, cast off from those hairs wherewith their bodies were before roughened and bristly, a very tender, and, as it were, membranous sheath; after which, the finer part of those hairs appear like so many linen threads in the Chrysalis. But since this Caterpillar of Goedaert's is covered with hairs which are more like bristles than linen thread, it follows, those hairs and the rest of the body having shed their skin, form in the Chrysalis the figure before mentioned, and appeared as if the legs were transposed. This is what led Goedaert into another error: for if he had known these several particulars, he might have easily investigated the origin of those silken yellow threads, which he tells us he saw in the Chrysalis, and which are described in the 20th experiment of the first part.

It is not only very certain that the change of the Caterpillar into a Chrysalis may be perceived by the eye, but our experiments proceed

so far, that, by following nature, we are able to produce the Chrysalis from the Caterpillar state. Nay, it is in our power to keep back this transmutation, or to retard the same to any degree we think proper, though it happens so swiftly and suddenly, and therefore, undoubted credit ought to be given to the several matters we publish here concerning this change. Hence it is, that we can now exhibit to public view many Chrysalides, reduced to almost one half; this, among several other mysteries of nature, we have shewn before his serene highness Cosmus the third, grand duke of Tuscany, when he, by a special mark of distinction, was graciously pleased to visit us, and to approve of our experiments.

But to have done with the errors of Goedaert, which we have hitherto been setting right, we shall lay down the following as undoubted truths. First, that the legs of the Caterpillar, or Worm, are never transposed to the back. Secondly, that the Caterpillar is not changed into another animal, though, in process of time, the legs themselves grow in the same

manner, as the wings of a young bird, or feet of a Tadpole. Thirdly, that no natural transformation happens in these insects; but that this whole change, (in finding out the nature whereof, authors have committed so many errors, and proceeded, as it were, blind-fold, like the combatants of old) consists only in this, that the limbs of the Caterpillar, or Worm, by an accretion of the parts, grow insensibly under its skin; and when the latter is shed, the former appear plainly and distinctly to the sight, but they cannot be moved at first by the little animal; the reason of which is, because they are fluid like water, and cannot acquire sufficient strength, unless they evaporate it for some days before.

But this does not hold in all Worms, since there are many which lose no part of their motion. To render this matter the more clear, we shall now proceed to the third proposition, desiring the reader to consider it attentively, as it is a matter of the greatest importance, and of very great extent.

## C H A P. IV.

*Of the four orders of natural changes, to which we refer nearly all the species of insects, as having the same sole principle of change.*

**H**AVING hitherto, from the nature of things, examined and drawn, as it were, a just and elegant picture of the true origin of these appearances, or, as they may be called, sudden buddings and shootings into limbs in insects, and by that means, shewn how this subject hath been disgraced and obscured by chimerical notions, and the idle traditions concerning these changes; having likewise cleared the subject from the impurities wherein it was involved, by establishing it on a strong and firm foundation, which cannot be shaken by any force; and in our opinion, can no more be set aside in favour of fortuitous chance, than a Lamb can be generated by a Wolf, or an Eagle by a Dove, we shall now proceed to the positions themselves, or to the several orders of these changes; whereby, as with the genuine tinct of nature, we shall endeavour to illustrate the picture before us, and restore the amazing and wonderful appearances of insects to their true splendor and native beauty. Thus shall we more clearly be sensible of, and, with greater devotion and more humble reverence, meditate on the omnipotent wisdom and superlative goodness of God in the accretion, sustenance, and change of the minutest animalcules, which form a celestial host as the angels.

If we diligently attend to this true basis of all the changes of insects, that is the Nymph, it will be easy to comprehend the reason why all the species, tho' so many in number, together with their changes, agree and terminate in this one particular; wherefore it seems super-

fluous to dwell longer on the explanation of them. If again we more seriously consider after what various ways this Nymph hides itself under the manifold forms of those insects, so as to elude the sharpest eye; it will become necessary to view this Nymph in every light, under all its accidental appearances. And herein we shall not follow as a guide the delusive traces of our own ingenuity, or admit the inventions of fancy, but pursue only the various and natural phenomena of the Nymph. There are four orders which comprehend the whole class of insects, so that we cannot see one, which may not be referred to one or other of them, especially if we can see its change.

The first order will comprehend those insects, which, with all their limbs and parts, proceed instantly out of the egg, and grow insensibly, until they attain a proper size; after which they are changed into the Nymph, which undergoes no other change but that of its skin.

Of the second order are those hatched with six legs, and which, when the wings are gradually perfected, are also changed into Nymphs.

The third order is, when the Worm or Caterpillar comes forth from the egg either without any legs, or with six or more, and its limbs afterwards grow under the skin, in a manner imperceptible to our sight, until at length it casts that skin and resembles the Nymph, or Chrysalis.

The fourth order is, when the Worm likewise proceed from the egg, either without  
F any,

any, or with six, or more legs, and in an invisible manner grows in its limbs and parts under the skin, and does not shed this skin, but acquires the form of a Nymph under it.

Having laid down these general propositions,

I shall hereafter distinctly and at large, describe the Nymph under these four different orders; and at the same time shall lay it before the eye by particular examples, illustrating every description; but in the first place, I shall enumerate the insects which belong to each order.

## The F I R S T O R D E R.

*Of the natural changes, or slow accretion, of the limbs.*

AS on the one hand it appears, from the nicest experiments, that all insects proceed from an egg, that is laid by an insect of the same species, with whatever warmth some philosophers have maintained the contrary; so on the other it must be observed, that some insects issue therefrom instantaneously, and, as it is said, perfect in all their parts, as almost all the kinds of Spiders, and many more. Others, on the contrary, undergo some changes before their parts are finished, which is the property of a great number of Worms and Caterpillars; for when these insects assume the form of a Nymph or Chrysalis, under this shape they suffer another change, or rather, the same evaporation of the superfluous moisture which the animalcule suffers in the egg when it issues from thence, or which they themselves have also suffered in their egg, before they underwent this change,

Hence it is, that as some insects come from the egg perfect in all their parts, Tab. I. fig. II. *a.* so, on the contrary, others are forced from thence imperfect as it were in their several limbs. But as the former often change their skin, though they be not afterwards transformed into Nymphs, which are discoverable by certain new limbs, before they grow mature, and are rendered fit for generation, so the latter sometimes cast their skins, and when they throw off the last, under which they acquire the form of a Nymph, and are furnished with new limbs, Tab. XVI. they likewise attain to maturity; after which neither the former nor the latter insects cast their skin or grow, but apply themselves, with all their strength, to the business of generation; and then, pleased as it were with their past employment, they die in peace, unless it be so ordered by nature, that they are obliged to feed their young, and for that purpose must necessarily live somewhat longer. Indeed, most insects are found of such a nature, as scarcely to live more than four hours after the time of their last change, and the business of generation is over: so that nature seems to exert her utmost strength upon this occasion, and the beginning of life in one little animal is the end of it in another, as we see every day in the motion of the weights affixed to clocks, one of which descends whilst the other ascends. But we shall treat more fully of these matters in their proper place.

To explain our observations on the egg somewhat more amply, and as far as may be

proper in this place, we must add, that we have remarked, that the insects which proceed instantaneously, or perfect, from the egg, as well as those which issue from thence in the form of Worms, are disposed and placed in the same egg as close as can be, and without any food in their power, in the same manner as the Worm and Caterpillar lie still and composed, without the least food, when they have put on the form of a Nymph, as we have observed. This will be clearer when we come to the fourth order of transmutation.

Further, as the Worms and Caterpillars beforementioned, when changed into Nymphs, are fluid like water, and swollen on account of their limbs being extended by a superfluous moisture; and as they cannot move, although they live and breathe; so we have found, that our animalcules lying in their egg, and being also fluid like water, are incapable of the least motion. Wherefore, as the insect formed from the Nymph, or rather the insects themselves, hidden under the form of Nymphs, do not appear, till these redundant humours have been dissipated, and their limbs have acquired sufficient strength to burst the outward skin; so likewise these animalcules, which are protruded from the egg, either perfect or imperfect, do not part with these their eggs or coverings, before the superfluous moisture is expelled, and their feeble limbs have acquired sufficient strength, so as to be able to break through the outmost skin, wherein they are involved as in a shell, and to quit it, as soon as it is burst or perforated.

If we attentively consider what has been hitherto advanced, which is indeed of great moment, and productive of many useful conclusions, we shall be inclined to determine, that those eggs, wherein the animalcules lie still without food, in the figure of Nymphs, and which, for that reason, often have the form of the animalcules that are to proceed from them, ought not, properly speaking, to be called eggs, but Nymphs in the form of eggs, or oviform Nymphs. The former insect, for this reason, though yet in the egg, may not be improperly called a Nymph-animal oviform, or in the appearance of an egg; as the latter may be denominated an oviform Nymph-vermicle, or Worm-Nymph. Nay, the egg, as it is called, or rather, the coat wherein they are wrapped up, ought to have the appellation of their skin, rather than that of the shell or egg,



egg wherein they are to be generated or formed: but we have already touched upon these observations concerning the skin in the foregoing pages, when we treated of the Nymphs and Chrysalides casting their skin.

As our intention is to offer some rules and orders of transmutation, which comprehend all the changes that happen in the insects known to us; we shall fix our eyes first on the changes of those insects, which issue instantaneously, as it is said, out of the egg, and which have already gone through the whole process of their change, or accretion, of their limbs in their mother's womb; that is, when by the continual increase of their invisible yet essential parts, as they are called, they have become perfect animals in the egg, they have undergone no other change out of it, except only the evaporation before mentioned; nor are they to be afterwards subject to any other change or accretion into a Nymph, which is also performed only by evaporation.

This we shall offer as the first, simplest, and plainest method of change in insects, and from this we shall proceed by degrees to such as are more obscure, complete, and difficult of comprehension, mentioning some so intricate, that, it seems to many, they cannot be explained at all. This notion hath been so established by custom, that for want of a more proper term, the bodies have been called eggs; since to a person, who views them slightly and superficially, not even the least vestige of any distinct limb appears in them.

The first order of change then, according to our system, is, when the insect, lying in the egg or skin without food, after some days evaporation and dissipation of the superfluous moisture, creeps out of it, perfect in all its parts, so that afterwards it is not changed into a Nymph, nor undergoes any other remarkable mutation. But since this insect, before it hath arrived to its full bigness and proper growth, by means of the food that is given it, is sometimes obliged to cast its skin, like the Worms or Caterpillars that are changed into Nymphs; and since, under the last change of the skin, its limbs also undergo some transmutation; it is therefore the insect ought to be considered as a real Nymph, at the time it is in its last skin; for when this is cast, it is observed to be fit for generation, and to have come to its maturity and full vigour, and not before.

Since therefore some insects are changed after they have cast the last skin, which may be exemplified in the long-legg'd Spider described by Goedaert; we shall, for this reason, consider this insect as a kind of Nymph, and for distinction sake call it a Nymph-animal. Not that we would have any person tied down to make use of the terms we have offered, being satisfied, if the orders of these changes be as diligently, accurately and distinctly observed as they are in nature, for in this lies the principal and only knowledge.

If we further seriously attend to this change, we shall plainly see, that it not only agrees

with the accretion of the limbs in sanguiferous animals, but also with that epigenesis, or super-addition, observable in plants or vegetables; this therefore we would have understood of the orders of changes, and shall accordingly make the like application.

To give some instances of what happens in sanguiferous animals, none seems more proper for that purpose, than the accretion of the limbs in a Frog, Tab. XLVI. *a.* for as the young Frog is very visible, by means of the black spot which we see in the egg, so we find that this is nothing but the very animal, in the same manner as we have shewn in insects. But as the insects are not produced with their food, so no other difference can be discovered in this case, than that the young Frog issues forth with its proper aliment; and it is also found to be wrapt up in a certain membrane like the insect, though it still feeds for five days within it.

Further, as the Frog, immediately after the bursting of this membrane, finds matter to feed upon, for it lies in the midst of it, so likewise are the insects readily supplied with nourishment, when their eggs are broken; since some of them are placed within, and the rest without, and upon the substance on which they are to feed.

To pursue the analogy, as the Frog proceeds from its egg without legs; so we see a great many insects creep out of their skins without them. And as the legs and the rest of the Frogs limbs increase in process of time, some within, and others without the skin, so that at length it resembles a Nymph of the second order, in the same manner we see, that all the limbs of insects, as well those that are in, as those that are out of the skin, grow by degrees, until they are changed into real Nymphs.

Lastly, as the Nymph of the Frog before-mentioned casts its skin in process of time, and exposes to open view its hidden limbs, which we saw through the skin before, and by degrees attains its full maturity and ability for generation: so, after the same manner, we observe, that the Nymphs of insects after some time cast their skins, and shew their covered limbs, and, like the frogs, are rendered capable of propagating their species.

But we shall treat this matter more at large in the following sheets, when we lay before the reader our own most remarkable experiments on Frogs; the principal part whereof has been performed before the grand duke of Tuscany, the sublimity of whose noble and accomplished mind, is inspired with a generous and benevolent affection for the liberal arts and sciences.

Let us now consider the vegetable kinds, Tab. XLVI. *a.* for as we see these grow from a seed, which infolds some leaves, or a very tender sprout; in like manner, we find that insects ripen into a fuller and stronger habit from their feed, which contains all their limbs, or rather the animal itself wrapt up in the skin.

For the same reason that plants come in time to maturity, and swell under the cover wherein the flower lies, as the insect does in the Nymph: so likewise we observe, that insects insensibly approach to a more perfect maturity, and by slow degrees spring in their covering, or the Nymph, in which are all their limbs, as the flower is placed in its proper covering: this we shall hereafter demonstrate in the Clove Julyflower, Tab. XLVI. *b*.

Lastly, as flowers at length break out from their husks, and become capable of producing new ones by generation and running up into seed; in like manner insects proceed from their Nymph, as the flower from the husk, and are also rendered fit for generation and repositing

their sperm. And as propagation is performed in plants, by the union of their seed with the moisture of the earth's womb, insects perform the act of generation, by the conjunction of the fruitful, and, as it were invisible particles of the male's sperm, with the conspicuous, vivifick, and sensitive seed in the female. This seed of the female continues and perfects the life, motion and sense which it enjoys, when the spermatic virtue of the male is thrown into it; and it is in this continuance of motion that the fruitful conception of the seed is properly said to consist: but we shall hereafter explain this matter more at large, by particular examples.

*A catalogue of the insects which are referred to in the first order of natural changes, called the Nymph-animal.*

HAVING explained our first and most simple order of changes, in which we have considered the animalcule, which comes perfect from the egg, as a real Nymph when it is about to cast its last skin; it now remains, that we should give a catalogue of insects which belong to this order: and upon this occasion we shall briefly enumerate such of them as we have in our custody, as we shall do also with regard to the Nymphs, Chrysalides, and distinct specimens of the four orders, together with several other things not unworthy the speculation of the curious, which we preserve in our cabinet, and by the assistance of which we are able to demonstrate to the eye every thing hitherto, and that shall hereafter be, advanced.

To the first order of transmutations belongs the Spider \*, which proceeds immediately from its egg, and has no vermicular state; this has been also observed by the most accurate Martin Lister, who in his elaborate treatise on Spiders says, "These are hatched from the eggs, perfect and complete in all their parts." Chap. II. Of the generation of Spiders.

I keep, for this purpose, the largest of all Spiders, that is, the venomous, Brasilian kind, which has crooked, black, very sharp and big claws, or rather darts, and also has two arms, which are in all respects like shanks or legs.

I also have the great downy Phalangium, or Tarantula.

Also a very remarkable Spider which Dr. Padbrugge sent me from the Cape of Good Hope. It is of the colour of scarlet velvet, and covered thick with a fine down, in which is the colour. It is as big as a grain of a small French bean, with an oblong body, and broad breast; it has short legs, except the two foremost pair, which are very long; the second pair

are somewhat shorter; the third is very short; but the fourth or last is somewhat longer, and all of them are covered thick with red hair. The breast is so closely united to the belly, that they cannot be separated from one another; therefore this Spider is in that respect like a Lobster; it has two short arms, and two ruddy transparent stings or darts, but its eyes can't be seen on account of the thickness of the hair.

I have also the American species of Spiders, which has rough, thick, and very long legs in comparison of the body; the belly is somewhat swelled and bristly, its darts are very much bent and crooked like claws, but the arms are short in comparison of the legs, being not above a third part of the length of the fore pair. It has eight eyes, which are neatly ranged in two rows; its breast is like an oval shield; it turns the eyes to the extreme parts, and bends itself a little on the inside, behind the joint of each leg or shank, in the same manner as the skin sinks between the ribs in lean and thin people; but this is common to a great many Spiders big and little.

I have also one of the Holland spinning Spiders, which, in colour and figure, resembles Mouffet's largest spinner, but it is not half so large. I have observed in this species, that each of its eight legs consists of seven joints; thus the first joint at the breast is very short; the second is much shorter and formed like a ball; the third is the longest of all; and it is for the sake of this only, that the other joint seems to have been made, that this third joint may be moved with the greater ease and expedition; the fourth is somewhat bent, and by degrees grows thicker; the fifth is the longest except the third; the sixth and seventh decrease in proportion, whereof the latter is provided

\* The generical characters of the Spider kind, as established by Linnaeus, are, that they have eight legs, and the same number of eyes, placed on the back part of the thorax. The common house Spider, the water Spider, Tarantula, and others, are of this genus; and these distinctive marks exclude some insects, called by others by the same name, placing them under other heads. The long-legged Spider having but two eyes, is properly an Acarus.

with two large, crooked, black claws, accompanied by others of a smaller size\*. The animal makes use of all these to run down the web, and to guide and govern it.

I cannot determine, whether the English Spiders have the same properties, as Lister says positively, "All Spiders have three joints in their legs." But since this gentleman thinks that all Spiders have two antennæ, or horns, which are inserted in the head next to, and above the darts, I should not agree with him in this assertion; for though I have never seen the English Spider, yet I can easily see from other foreign kinds, and their limbs, that this is repugnant to the nature of Spiders. In order to solve this difficulty, I shall briefly relate what I have observed, concerning this matter, in my Spinner. By examining the Spider before described, I found that those two joints, and all the other legs, are fixed to the breast; but with this difference, that the place of their connection with the breast is higher, on account of the thickness of the hair; and this I judged to have been done, lest they should impede the action of the limbs, wherewith the spicula or darts are united, and that these joints may move with more ease. I have also observed, that they consist of six, or perhaps of seven joints, which I shall not positively affirm; wherefore they are, for this reason, like legs, as Dr. Lister has also observed, where he says, "These, like feet, consist of certain joints."

But what deserves the greatest attention, is, that every one of these has a claw fixed to the end of it, that is somewhat crooked and blackish: wherefore, these may very properly be called the fifth pair of legs; and the rather, because they have their muscles on the inside, as the other legs have, and are rough with hair and prickly bristles. However, many reasons induce me to think, that they ought not to be reckoned among the legs, since in the whole tribe of Spiders they are not shaped in this manner, but in a great many they resemble the claws of Lobsters and Scorpions. This is visible in the Flea-Spider, in which these limbs very nearly resemble a pair of tongs or pincers, only that they want the great toe, as appears by one now in my custody; I am obliged to refer to this, as nothing remarkable or useful can be observed at this time, for I am writing this in the month of December; but I can demonstrate this so clearly, in another spinning Spider I have, that there can be no room for doubting: for first, we may see two darts or arrows in this; then, these arms are formed with such wonderful art, as not to be inferior to the inimitable workmanship which we admire in our own hands.

These arms are divided into different joints, at the end of which we see a small concave and convex part, covered with hair: this re-

sembles, in aspect, a piece of the white of an egg divided into four parts. At the end of this small part, there is in every arm a little rising somewhat like a finger. There are also on these small hairy parts, others worthy our observation, each of which is joined on the inward concave side, to the basis of these hairy parts, so as that the latter may protect, and, for the greater safety, hide the former. The first of these parts is divided into two joints placed one upon the other, to the lower of which is joined a real but obtuse forceps, of a mixed light red and blackish colour, whereby the arms are connected together. To the other joint, which is somewhat higher, is joined an obtuse or blunt little claw, of a colour inclining to a bright red. We further find, that another small, and, as it were, blunted part, is articulated at the root of the first part, whereon lies the forceps; on the end of this are three small toes or crooked claws, which are not placed, nor formed, in the same manner, and whose moving muscles are hidden in the small blunted part. Thus it is plain, that these arms are differently framed, according to the different kind of the Spider.

From these instances, therefore, it is clear as the light at noon day, that these limbs or members ought not to be called antennæ, feelers or horns, but real arms, and that neither Spiders nor Scorpions have any horns. But as the brachia, or arms, before described, are formed with amazing art, I have therefore thought proper to preserve them dried; in order to have them ready to shew on any occasion.

I likewise observe, that the long-footed Spider has no feelers or horns, but its arms are provided with, at least, one crooked black claw, that reaches beyond the end of the arm. The legs, with respect to the joints, are like the legs of the spinner before described; and what is properly called the foot, seems to be divided into two several joints, that have two claws at the end of them. But I cannot further investigate these matters at this time, being now in the midst of winter, and having no Spiders, but such as are dried and preserved; in which, but especially in the large venomous ones, that I keep, it is very evident that Spiders have no horns or feelers.

I also have Lister's small crimson Spider, but as this is also dried, we cannot discover the proportion of the ends of the arms, but we may see that they are somewhat thicker than the legs.

I observe in the green, small, and long-bellied Spider, of that illustrious Englishman, that these arms have likewise a plain claw at the end of them. The same is observable in other Spiders which I have, nor is there any that has not the fore joint armed in the manner before-mentioned.

\* There is a remarkable property in the Crab, in breaking off a wounded limb at a particular joint. This has been exemplified at large in the Philosophical Transactions. If the last joint of a leg be wounded, the Crab, by a peculiar motion, breaks off the limb at a peculiar place above, and a new one grows in its place. The same happens in some species of the Spider.

I think, I observe a very remarkable texture in the arms of the Wolf Spider, which I cannot now thoroughly investigate.

As to the Spider's teeth, I do not find that they have been hitherto described by any author, since the parts supposed to be teeth, are, in reality, the creatures weapons or darts, by which it takes and kills little animals, afterwards sucking their blood. But to speak first of the darts, it is to be observed, that they are two crooked, kind of horny, and sharp parts, like the claws of birds of prey, and are situated in Spiders immediately under the eyes: but they are articulated with two strong, firm, kind of horny and muscular substances, which are observed to be fixed under the bottom of the breast, in which the eyes are placed. I have seen clearly in my Spinning Spider, which is like that of Mouffet, as I before observed, that these firm little bones grew on the inside, like certain blackish eminences or juttings like teeth, between which the spicula, or darts, were securely and safely inclosed, as the moveable blade of a knife is in the groove of its handle.

I have not, on the narrowest inspection, been able to find the least opening in these darts, by which the insect might eject any venomous liquid; such an opening as we see in the teeth or stings of the Worm called the Sica, or Sicarius, or Assassins, or such as it is said are to be seen in the teeth of Vipers. I have not even been able to find any apertures in the stings of the biggest venomous Spider called Phalangium, though as long as half a joint of the first finger.

Neither could I ever perceive that Spiders, however irritated, discharged any virulent matter, though I have spared no pains or attention to observe them. Doctor Lister also seems to have made the same remark, and I shall willingly subscribe to his opinion; till experience may inform me otherwise.

It is very surprising, that such strong and solid muscles should be contained in the horny substance of those parts, to which the stings are fastened. I have a method of extracting these muscles entire, in anatomizing the insect; and the same may be observed of the muscles serving to move the claws of Crabs. No doubt, these parts agree much with the internal claws or pinchers of Scorpions, who likewise carry them under their eyes; and was it true that Spiders, on wounding any animal with their darts, discharged a poisonous liquor along them into the wound so made, we might then say, that the darts of this insect and that of the Scorpion were perfectly alike; excepting this, that the Spider's weapons are placed on the fore part of its body about the mouth and breast, whereas that of the Scorpion is fixed to its tail; besides, the Spider has two darts, and the Scorpion only one. But it is above all things worthy observation, that in the Spider with two eyes, these darts are joined and formed into real forceps, as the indefati-

gable Lister has observed, and I have myself discovered this to be the case in some long footed ones which I dried: so far therefore these parts agree in make with the internal forceps of Scorpions.

As to the true and proper teeth, I have found them situated forward on the lower part of the thorax, immediately under the points of the darts, where they shut one close to another; in the same manner that I have observed in the little crabs, and as may be seen in the Cray-Fish. They are also fashioned in the same manner, but of a substance not so horny. On pulling out these teeth, it appears that they are united with certain other little pieces; which may not improperly be called articulated bristles. We have here therefore a satisfactory solution of the phenomenon, so judiciously observed by doctor Lister, viz. that there may be found in the excrements of Spiders, some particles of the Flies they have devoured. His words are, "You would imagine they only lived by sucking the juices of the Flies they catch, if you were to view nothing but the dead carcasses of those Flies; but if you attentively examine the excrements of the Spiders, you will find in them particles of their skin or coat." Spiders, therefore, actually devour some parts of their prey, and suck the juices from other parts of it, which they can easily and conveniently do, when they squeeze it between the denticular process of those parts, where their darts are inserted, and draw in its blood and juices. They are able to do this the more easily, as their darts terminate opposite to their teeth; for under the teeth there may be observed a little piece like a lip, and this process covers some part of them.

As to what regards the eyes of these creatures, I cannot at present examine them to my satisfaction, the days being short, and the weather very cold and cloudy; besides which, I have but one of these Spiders in my cabinet, placed there for the sake of observing, whether the severest frost would not entirely stiffen it, as is the case with Butterflies, and common Flies. But as I had doctor Lister's work, it induced me to undertake the dissecting of this single Spider, though I had at first intended to say nothing of Spiders in particular at this time. I discovered that its two uppermost eyes were somewhat bigger than the others. This difference is very striking in the Flea-Spider, as it was evident from a drawing I formerly took of this last insect; in which I have represented its ten eyes. But neither can I now examine that kind of Spider so accurately as I could wish. Which way soever the fact may lie, I find the two eyes that are placed above the eight others, are represented very small in my drawing.

I have carefully examined also, whether in the *asperæ arteriæ* of the Spider, there were any openings; but I could find none in the thorax, nor any which ran into the belly: I only discovered in this kind of web Spider an oblong member,

member, like the penis of many animals, situated in the middle of its belly, on the outside of its body, on a very prominent place near the thorax; and near this member there were two yellowish spots in the form of moons, covered with a softer skin than the other parts of the belly.

But not to dwell too long upon these parts, the following are the principal of the others, which occurred to me on examining this Spider; besides eight eyes situated in the head and thorax, and on the fore part under the eyes, the darts with their joints; behind and under those darts in the thorax, appeared its mouth and teeth; then beyond these were two arms with their claws, and after these eight legs, each with seven joints and two claws at their extremities; add to these the belly, with its peniform member, and the down, and sharp bristly hairs, with which the skin both of the body and legs are all over covered.

I cannot yet say much of the internal parts, but I may affirm, that I saw very distinctly the muscles of the legs, claws and darts; I could likewise perceive that the thorax was quite full of muscles, so as hardly to contain any thing besides the mouth, heart, and spinal marrow; but I have not observed these muscles of the thorax distinctly enough, to be able to affirm any thing certain concerning them.

The muscular integument of the belly was very easily separated from the intestines which it contained; and under this there appeared an elegant piece of net-work, like an omentum or cawl, consisting of globules delicately fixed to one another, and of a whitish purple colour.

On opening this omentum, I thought I could perceive the abdomen, which was shaped like the tendril of the vine; then first appeared pretty distinctly the intestines, through which there ran here and there whitish vessels, which I took for productions of the aspera arteria. Next there came in sight a transparent yellowish mass of a globular figure, which might be taken for a string of eggs, if the peniform particle or member already observed had not indicated the creature to be male; and consequently this something else.

The little bag, in which the Spider carried the stuff for its web, like soft glue, was twisted into many coils of an agate colour; and upon breaking it, the contents were easily drawn out into threads: but as I made all these observations in haste, and in the first dissection of a Spider that I ever set myself about with attention, I neither can, or dare vouch, for the perfect certainty of them all. I refer to some other opportunity a more careful survey of this most curious subject.

In the mean time, we have great reason to be concerned that doctor Lister did not think proper to finish his excellent work with the anatomy of all these parts; which would certainly have been a most valuable addition to science. He has laboured strenuously in the

other parts, every where giving proofs that he wrote his history in an accurate and regular manner from his own observations. This is the reverse of what the generality of modern writers practise, who do nothing but plunder each other, and then, like Æsop's crow, adorned with the feathers of other birds, and weakly glorying in their borrowed finery, persuade themselves that what they have pillaged from others, is the offspring of their own brain, though they do not so much as understand it. We may the more readily excuse such high notions in them, when we know they are no more than the monstrous productions of a heated imagination.

Of the Flea Spider I preserve two kinds. These seize their prey by a sudden leap, and therefore nature has provided them, as well as other Spiders, with eight eyes, and a most acute sight: it is more difficult to judge of this sight in the Spiders that make webs; for so far from taking notice of a finger put close to their eyes, they neither express any concern at it, nor attempt to run away; whereas, let the most minute animal fall into their nets, they immediately perceive, and lay hold of it. This apparent insensibility on the one hand, and readiness of perception on the other, has made some philosophers think the web Spiders had no eyes, but received information only concerning their prey, by the tremulous motion of their web. When these gentlemen further consider, that what look like eyes in Spiders, never appear when viewed with the microscope of a reticular form, as is the case in the Scorpion: they more roundly deny that they have any eyes. But it by no means follows from the web Spider's never leaping upon its prey, or from its never running to it, unless when taken in its net, that it has no eyes; and this conclusion must appear yet weaker, on considering that eyes are as distinctly perceivable in this kind, as in the Flea Spider, and withal are disposed in the same manner. As to the argument drawn from the parts which look like eyes in web Spiders, not being formed in the reticular manner, as in other insects, it is equally unsatisfactory: for what difference is there between its eyes being placed singly in different parts on the surface of the body, as in the Flea Spider, and their being gathered into one net as in other insects? besides, the eyes of Spiders thus scattered, are much larger than those which form the netted eyes in other insects; so that, every thing duly considered, there is reason to affirm, that Spiders have a more perfect sight than the generality of other insects, except the Libella or Dragon Fly, which appears to have very large, or very numerous complex eyes, so as to afford an opportunity of trying upon it many curious experiments. Thus, has nature displayed her wonders, even in those little animals, which, at first sight, appear to many beneath their notice; at the same time that she ordains the largest animals to proceed originally from principles

principles, or eggs, as little conspicuous as those from which these minute insects derive their beings: this we have already observed.

But let us return to the Flea Spider, in which the providence of nature is very conspicuous, having supplied it with a thread by which it may swing, and be secured from any sudden fall; if at any time it should fail in the springs it makes: however, this thread becomes an obstacle to its catching any, except very little, animals, when it has remained any time in the same place. Though this insect makes use of no net to catch its prey, it spins itself, like many other Spiders, a web to fly to, and to hide in, on being pursued. Another thing worthy our notice in the Flea Spider, is, that on pointing your finger to it at a distance, it wheels and turns itself about every way you move and turn about the finger; and runs off, on your putting the finger nearer. Lastly, as I have already observed, there are amongst the Flea Spiders which I keep in my cabinet, some, the extremities of whose claws are found like the forceps of Scorpions, except that they are not jointed, but shut in a manner like the forceps of the Cray-Fish.

I have besides these a Hedge Spider, which, to hatch its eggs the better, carries them about, as it were, in a case, with wonderful sollicitude and affection; insomuch, that when the skin forming this case, which hangs to the hinder part of its body, is by any accident broke off, the little insect seeks after it with as much earnestness and industry, as a Hen for her lost Chickens; and when found, fastens it again to its place with the greatest marks of joy. A description of this Spider may be seen in Harvey's Treatise on the Generation of animals, and more perfectly in doctor Lister, who with great propriety calls it the Wolf Spider\*.

I preserve also in my collection, some bags in the shape of eggs or pearls, in which Spiders put up their eggs, and hang them, as in a basket, to the beams and floors of houses. I have sometimes observed small Flies to come from these nets, and have by me some of the Flies thus produced. It would demand too much compass, for this place, to enlarge at present on this subject as much as it deserves.

To conclude, I preserve likewise that species of long-legged Spiders, which Goedaert, to whom the learned world are obliged for the drawing of about four hundred insects, has exactly described, in the forty-ninth experiment of his second volume. He there, in the drawing of this insect, most evidently demonstrates, that it is a true Nymph at the time when it is about to throw off its skin for the last time; for its legs at this period are lengthened in a very remarkable and surprising manner. The accurate Lister has also remarked, that Spiders sometimes are not fit to enter upon the business of generation, till they are almost

two years old; which, no doubt, proceeds from this, that nature intends they should so long continue growing, before they part with their last skin, and with it, the form of a Nymph. Before this time they are not fit for generation, and after they are, they never change their skin.

We are likewise greatly obliged to the late accurate James Hoefnagel, painter to the emperor Rudolphus, who has left us the drawings of thirty-five Spiders, and of about three hundred other insects of different kinds; which drawings, taken after the life, have been since published from copper-plates, with the privilege of his imperial majesty, and are in no respect inferior to those of Goedaert.

Wenceslaus Hollaar has also applied himself to this study, and deserved well of the publick, by his most exact drawings of the insects preserved in the Arundel Museum. It were greatly to be wished, that all those who would be thought to have any extraordinary knowledge of insects, did the same, that by their joint labours this branch of natural philosophy, which is by no means of the least account, may be brought to perfection. A thorough acquaintance with the dispositions and actions of these little animals, would enable us to form the better judgment of the dispositions and manners of innumerable others.

Before I quit the consideration of Spiders, I think it will be agreeable to shew in what manner those kinds which spin webs, or live upon Flies, get from one tree to another, which they will do; even when separated by a running water. It will be first proper to mention, that the Spider's thread is by no means single, but almost always double, and sometimes even ten or twelve fold. This may be easily seen by throwing down a Spider, and immediately examining the thread to which it hangs. Or it may be observed, with still greater ease and certainty, by separating the hinder part of a Spider from its fore part, and then drawing out the thread, and afterwards examining it. As therefore the Spider's thread is generally made up of two or more parts, after descending by such thread, it ascends by one only, and is thus enabled to waft itself from one height or tree to another, even across running waters; the thread it leaves loose behind it, being driven about by the wind, and so fixed to some other body. This opinion of Spiders making use of a double thread, has already been advanced by Henricus Regius, professor of medicine at Utrecht, and that eminent naturalist Franciscus Redus.

But the accurate doctor Lister produces some different observations on this subject; he says, that Spiders, in this case, shoot out their threads. His words are as follow: "Some Spiders shoot out their threads in the same manner that Porcupines do their quills, with this difference only, that whereas the quills

\* The Wolf Spider makes no web, but lives at large upon dry banks and heaths, pursuing his prey or seizing them by surprise; and is very nimble and very bold.

“ of the latter are entirely separated from their bodies when thus shot out, the threads of the former remain fixed to their anus; as the sun’s rays to its body.” And in another place, “ Spiders that are middle-aged, or of a moderate bigness, trust themselves to gentle winds by means of a thread, and thus endeavour, as it were, to ascend into the clouds, and the upper regions of the atmosphere.” As to the first of doctor Lister’s assertions, I cannot at present take upon me either to countenance or contradict it; I only wish he had explained himself more clearly; for how is it possible that the thread of a Spider, which is so fine and slender, should be shot out with force enough to divide and pass through the air? Is it not rather probable that the air would stop its progress, and so entangle it, and fit it rather to perplex and obstruct the Spider’s operations? I know very well, that a man may drive out his urine to a considerable distance, in the form of a slender thread; but this urine is a liquid, which is not the case with the Spider’s thread; besides, it does not appear that the Spider carries all the matter of which it composes its threads, in a single cavity, so as to be able to throw it so far, if it could do it, even in a solid form. Moreover, there seems requisite for this purpose a great strength of muscles, and a considerable exertion of such strength; whereas that part of the Spider from which its thread issues, does not appear to have any muscles: these are conjectures only, which time will overthrow or confirm.

As to doctor Lister’s last assertion, there is no great difficulty in comprehending it. I have myself often observed small Spiders supported and driven about in the air, by means of a thread, in the same manner with that little paper machine called a kite, with which children divert themselves. If therefore doctor Lister, in saying that Spiders when come to their full growth shoot their thread, means only, that they let it fall loose from their bodies, to be taken hold of by the wind, and lengthen it by a continual sending out of the matter that composes it, there can be no objection to his doctrine. For my part, nothing more as yet appears to me on this occasion, than that all Spider’s threads are drawn from the insect’s body, by its own weight or effort, without any compression while it descends or moves forward, as the threads of the Silk-Worm are drawn, and by no means ejected, from the bags in which the matter forming them is lodged. I can yet more easily comprehend how, Spiders without giving themselves any

motion, may, by only compressing their anus, spin out a thread, which being driven by the wind, may serve to waft them from one place to another.

The dart of the Tarantula is said to occasion a peculiar frenzy\*, which the same authors say is cured by musick, but this seems an imposition. A very curious gentleman lately arrived here from Italy, has assured me, that it is looked upon as a mere fable, even in the country where the creature is most common; and that none but the lower sort of people, beggars and vagabonds, pretend, on being hurt by those venomous creatures, to find any relief from musick. They pretend this, that by imposing on the credulous, they may live without betaking themselves to honest labour. And thus we see amongst ourselves, the people called Gypsies, by setting up for prophets, prey upon the ignorant and illiterate.

To finish what I have to say in this place concerning Spiders: I am to observe, that doctor Lister very accurately divides them into what he calls fowlers, viz. such as take their game in nets, or by stinging it, and into hunters with eight eyes, which he distinguishes from those with two eyes and long legs. Doctor Hooke has favoured us with very curious drawings of the best kind, and I intend to publish dissections of them on some succeeding occasion; that so the history of these insects may, by our joint labour, be brought to the perfection it deserves, and supply us with new motives to love and reverence God, the author of all the miracles we observe in them: this should be the sole end of all our endeavours and studies.

I shall next refer the Acarus † to the first order of mutations, as it issues from its egg, perfect in every thing but size, which it afterwards acquires by degrees.

In the same order too I shall place the common Louse ‡, which has a Nit for its egg; but as this issues very suddenly from its egg, or rather, as what we call the egg is in reality the Louse itself, which only waits to be freed from the superfluous moisture that surrounds it, to escape from its cover; it is an easy matter to conceive, how this little insect can multiply so fast, that people say in sport, but it is no more than a jest, that a Louse may see its fourth generation in the space of twenty-four hours §. These Nits must be laid in a place that is warm, and moderately moist, to produce any thing. This is the reason that many Nits laid on the hairs in the night-time, are destroyed by the cold of the succeeding day, and so stick for several months,

\* Bonone mentions a large Spider in Sardinia, whose bite proves mortal in a few hours.

† The generical characters of the Acarus, are, that it has eight legs, and in each leg eight joints, and has only two eyes. According to this distinction, established by Linnæus, and now adopted by all naturalists, the long-legged Spider, and many of the creatures infesting birds and beasts, and commonly called Lice and Fleas, are truly Acari.

‡ The generical characters of the Louse, according to the Linnæan system are these: it has six legs, contrived for walking, not for leaping as in the Flea; the eyes are two, and they are of a simple structure; and the body is divided by indentings into several lobes.

§ Lewenhoeck, who put a male and female Louse under a stocking which he wore night and day to favour their breeding, found that the female lays from fifty to a hundred eggs; and computing the natural increase from what he had seen, says, that in eight weeks, one Louse may see five thousand of its descendants.

till they at last come to lose even their external form.

In examining a Louse by the microscope, its white veins and other internal parts appear, as likewise a most wonderful motion in its intestines, on account of the transparency of the internal parts of this insect. When the Louse feeds, the blood is seen to rush like a torrent into the stomach, and its greediness is so great, that the excrements contained in the intestines, are ejected at the same time, to make room for this new supply. But I shall treat of these insects in particular, as soon as I shall have finished what I propose saying in general of these that belong to the first order.

What I have already mentioned is but by way of parenthesis, that my countrymen might know something of the stupendous actions and constructions of so small an animal, and be thereby incited to praise the author of nature, who has here placed in one point of view so many and so great wonders. The great usefulness of the microscope will also appear from the preceding observations, since, by discovering to us the muscles, vessels, and internal parts of so small an insect, it acquaints us with the incomprehensible perfections of that great being, who could not only create, but impart life and motion to so minute organs. There is another advantage also in microscopes, viz. that in transparent animals, they give us a much more perfect knowledge of the motion of their intestines, than any we can obtain in other creatures by dissecting them. This benefit of the microscope has been already taken notice of by the illustrious Hooke, in his *Micrographia*, or collection of observations made with microscopes, a work lately published in English, and dedicated to his Britannick majesty.

I have reason to believe, but for want of sufficient experiments I dare not as yet affirm, that the Lice of other sanguiferous animals, and the Lice of insects, with those that live upon plants, or ramble about the fields, belong to the last mentioned order or class \*. Mean time it will appear evident, in treating of the fourth class, that there are some tree Lice, described by me under the title of animalcules,

found in the excrescences of the black poplar, which belong to the second order.

Neither can I affirm, that the Tick, or Ricinus of Aldrovandus, though placed by me in this class, does really belong to it; though I have in my collection a good specimen of this insect.

I likewise refer the Bug which lies in bedsteads and furniture to this first class; as also the Crab-Louse, though I have not as yet made experiments sufficient to determine perfectly the nature of this last insect.

I have also in my collection the Louse of the Whale, which is almost an inch long, and half an inch broad, of a very singular form, and all over covered with a shell †.

After these, I rank the Flea ‡ in the first class. This insect also springs from a Nit, in the which it elegantly changes to a red colour, like other insects in the Nymph state; the changes it undergoes, while as yet in the state of the Nit, and the manner in which it from white becomes black, are easily discernable by the help of the microscope: nor are these observations of little use or importance, as I shall hereafter prove at a proper season. I have been told that Doctor Lewenhoeck observed a Flea at Delft, which, about the end of summer, issued from an egg in form of a Worm, and then shut itself up in a case till the ensuing month of March; but I shall not as yet affirm the certainty of this observation; neither shall I determine whether the Flea wore in its case the figure of a Chrysalis, or a Nymph; if it did, the insect must belong to the third, and by no means to the first order. I shall use the first opportunity of exactly observing this insect, so as to know the certainty of what has been advanced concerning it, as such enquiry cannot be attended with any great trouble §.

I likewise place in this first class an insect which is generally found in cisterns where rain water is kept, and which Goedaert has described by the name of the Water-Louse, as may be seen in the third volume, letter X. But as the structure and dispositions of this little animal differ greatly from those of the com-

\* Redi, who very accurately examined this subject, found Lice upon the Lion and the Tiger. He calls all those on quadrupeds by this name; and those on birds, Fleas; but he is in this mistaken, the distinctive characters are to be found in the structure of the parts, not on the creatures whereon they feed. The same author observes, that the Lice bear no proportion to the bigness of the creature on which they live, the Starling having a Louse as large as that of the Swan.

† The common Fly is subject to a particular insect which lives upon his head; this is so minute that few have observed it; its size is calculated by La Hire of the French academy, to be not more than a four thousandth part of that of the head of the Fly. This is of the *Acarus* kind, having eight legs.

The Crab-Louse upon the human body is of the same genus with the common one of the head, but a different species. It is destroyed by mixtures with water, in which crude mercury is boiled.

Even the Snail is subject to be infested with a kind of Louse, but in a very singular manner; for this creature, which has eight legs, and is of the *Acarus* kind, lives equally on the surface of the body, and within the intestines, running in and out at its pleasure. It is usually seen alive in the intestines, when they are examined by the microscope.

‡ The common Flea is an extremely singular insect, there being no other species properly of its kind: the generical characters are these; it has six legs formed for leaping, the eyes are only two, the organ which serves for a mouth is bent downwards, and the belly is roundish and compressed. Only the Flea of the human body has these characters; what is called the *Pulex Sturni* is an *Acarus*, and the rest of the insects which have received this name from inaccurate observations, belong to other genera.

§ Though the Flea is peculiar in the human kind, it is not so with the Louse. Multitudes of animals, birds and beasts, are infested with Lice, and though of different species upon most kinds, they all have the characters here described, and are properly of the *Pediculus* or Louse kind. Insects have also lesser insects living upon them, particularly the Beetle; but though these are called Lice, from their living on other animals, they are not of that kind. The Louse of the Beetle, as it is commonly called, has eight legs, whereas the proper Louse has but six: this creature is properly an *Acarus*, and so of the other.



mon Louse, though it be at the same time equally singular and remarkable, I have given drawings of it, both of its natural size, and as the microscope represents it, in the special treatises on insects of this first class, under the name of the water arborefcnt Flea \*. These drawings are exhibited in Tab. XXXI, and a complete description of the insect immediately follows that of the Louse.

I now pass to the Afellus, or wood Louse, which is found of all sizes †, and may, partly for that reason, and partly for others, be ranked in this first class. I have in my collection three kinds of this insect; the first is the common ground Afellus; the second has great, black, prominent eyes, a distinct head, and a thorax like a hood; the third kind is very remarkable for folding itself into a ball when handled, and remaining for some time in that posture.

I likewise preserve several skins thrown off by Afelli, sloughs or dead skins, which still exhibit the exact figure of the insect. These sloughs produce a great fermentation, when mixed with acids; whence we may justly infer, that they contain a great deal of alkaline salt, and therefore may be of great service in curing the dropsy, stone, and gravel in the kidneys.

I likewise have in my collection some sea Afelli. I give them this name, because they are found in salt-waters. The largest of these is one that measures two inches and a quarter in length, and one inch and a quarter in breadth; it consists of eight rings, of a firm and bony substance. I have likewise a very small Afellus of the same kind, which I caught in the North sea near Petten. Doctor Padbrugge sent me from the island of Ternate, another species of Afellus, under the name of the sea Louse. It is almost half an inch long, consists likewise of eight rings somewhat coloured, and, like the Sea Hedge-hog, or Echinus, has a border of small prickles; but these insects have no legs.

I preserve also some other kinds of sea Afelli, more curious than these already mentioned, amongst which there are four, whose shape is like that of the Shrimp. The first of these, which is the biggest, is an inch long, has a slender body, seven legs on each side, like the ground Afellus, and large horns which meet in a sharp point; the last ring of the body in this species is much longer than the rest, and running out into a three-pointed extremity. The second and third kinds are much smaller, but almost of the same structure. The fourth differs from the three kinds already mentioned in this, that its fore legs are much longer than its whole body, and these are divided into four very distinct joints. It is likewise the smallest of the four kinds, not ex-

ceeding half an inch in length, even when its claws are stretched out to their greatest extent.

I preserve also a broad sea Afellus, sent to me from Iceland; it is an inch long, half an inch broad, and composed of seven rings, including the head and tail. Its antennæ or horns are sharp and short, its eyes are brown, its six foremost legs are armed with sharp and crooked claws, and near its tail, on both sides, are two flat fins. Olaus Borrichius observes, that the whole body of this insect appears to be supported by a simple bone, not unlike in shape to a small date, but of a horny or cartilaginous substance. I have some of the same, kind but very small, which I took in the salt-water river that runs by Amsterdam. I can also shew a very uncommon kind of sea Afellus, which I caught near Petten; it is scarce an half inch long, of a globular but somewhat oblong form, resembling a pear, with a pretty long tail, and some fins. I preserve with these some Scrophulæ, which belong to the genus of Afelli. The first of these I caught on the coast of the North sea; it is very small, always runs, and sometimes swims slantingly, and when ashore leaps as the Flea does.

Amongst the Scrophulæ which I have taken in the fresh waters and rivers of Holland, is to be mentioned, that kind which is called Snel. This has a pretty way of running slantingly, and if we may believe the tales of fishermen, it readily kills the Perch, by running itself suddenly into the gills of that fish. We have no experience to confirm this tradition. I know, indeed, that this little animal is furnished with arms sufficient for the purpose: being held in the hand, it excites a kind of tingling: now the gills of Perches, and indeed of all fish, are so tender and delicate, that it is almost impossible they should not die on receiving wounds in that part, through which all the blood of fish is circulated, in the same manner that the blood of other animals is all circulated through their lungs. This kind of Scrophula is found equally in fresh and salt waters.

After these follows properly the Worms, which some have called the intestines of the earth. These proceed immediately from the egg, and do not afterwards undergo any change, coming forth at their full perfection. The females, from their first hatching, have their little eggs, which are very distinct and perceptible. I observe, that this genus may be divided into many species.

Though it is no hard task to distinguish in several kinds of Worms and Caterpillars the males from the females, by carefully examining them, but chiefly by dissection, to see if they have any eggs within them, yet they sel-

\* Latter distinctions do not permit us to give this singular creature the name Pudex or Flea. It is of the monoculous kind, the characters of which, according to Linnæus, are, that the fore feet are branched, and are found equal for swimming or for leaping; that the eye is single, but composed of three, and that the head has a crustaceous covering.

† The characters of the Afellus are, that the body approaches to an oval form, and the tail is simple, and not foliated. The number of legs is uncertain, ten, fourteen or sixteen. The genus is now called Oniscus. The plain tail distinguishes it from the Shrimp kind; and some others which approach to it in many respects, but by their leafy or foliated tails are referred, though small, to the Crab kind.

dom copulate while in the Worm state; so that Goedaert seems to advance a paradox; when, in the seventy-fourth experiment of his first part, he represents as a male Worm, an insect which he afterwards, on its having undergone the usual change, calls a female, in the seventy-fifth experiment. This is the same as if an infant, who we called a boy, we should afterwards, on his arriving at the state of maturity, denominate a woman. But I shall speak more of this hereafter. In the mean time I must remark, that my reason for animadverting thus freely on the mistakes of others, is, that succeeding writers may take the same liberty with me, by which means truth will at length universally triumph; for I am well aware how much we are apt to be pleased with our own conceits, and how often deceived by that fondness, so as to take them for the true representations of nature. However, I have no great reason, I think, to dread the severest inquiry into my observations, so that I with pleasure give them up to the examination of those who shall think it worth their while to compare them with the things themselves, which is the only method of coming to a certainty, in investigating what belongs to the animals of which I have been treating. Nevertheless I must candidly own, that many of the particulars I have mentioned as yet, appear so obscure to me, that I can at most but consider myself as a novice in this business; besides, that words are wanting often to express the wonders which occur in the study of insects.

Scorpions\* belong to this class of the insect kind; they are produced from an egg like the Louse, as will appear in the account I shall give of them in particular, after the history of the water arboresecent Flea.

I am of opinion also, that the Leech † is to be arranged in this class, though I have no particular experiments to confirm that opinion, except its being found of almost all sizes. It is very remarkable how firmly this insect will fasten itself to the sides of the glass vessels in which it is kept, so as not to be separated from them without the greatest difficulty. This, I apprehend, it effects by pressing its body close to the glass, and then swelling it in the middle, so as to repel the water in which it swims. Thus, if we apply to a stone a round piece of leather, with a string fixed to the center of it, and then pull this string, the stone and leather unite very firmly together ‡.

I refer also the Scolopendra, or Centipes, to this class, as I have met with this insect of all sizes, and could never yet discover that it chang-

ed its form. I have got one of the largest kind, which is even a span long, and was sent me from the East Indies. I preserve also other kinds of this insect, as the Lybian Scolopendra of Mouffet, and the water Scolopendra, and in fine, some Juli, or Gally Worms, which we ought to rank with this kind.

After these insects follows the Snail, as proceeding directly from an egg, and not being liable afterwards to any change. I preserve a sort of Snail, in which, on cutting off the head, is found a stone, called the snail stone, said to be serviceable in the gravel and strangury. Under this stone we always find the heart, which retains a pulsation, and is, with the vessels that spring from it, of a very white colour. As on cutting off the Snail's head, this stone is always to be met with, it seems probable, that it serves for the same use as the Os Sterni does in other animals: it is further observable, that nature has formed Snails in such a manner, that they void their excrements at their neck, breathe at their neck, and have there also all the parts subservient to generation. I have observed also, that every Snail is both male and female; in a word, a perfect hermaphrodite: the penis is formed like that of the Whale, and is of a surprising length. But I shall hereafter treat of all these particulars more at large. The English authors, who published a catalogue of the plants that grow in the neighbourhood of Cambridge, have already observed, that Snails are hermaphrodites.

To come to a conclusion, I preserve also in my cabinet the teeth of Snails, which are flexible, and of a horny substance; as likewise the heart of a Snail with its auricles, preserved in a balsam, and properly infected.

All the insects hitherto mentioned issue directly perfect into light, and are never changed into motionless Nymphs; for their eggs, without any intermediate state, afford young insects exactly like the old ones, which grow to their due bigness in time, whilst their limbs acquire firmness and strength. Nor do they in this respect differ from those other animals, which Harvey tells us proceed from a perfect egg, though before they attain their full growth, they may be obliged to change their skins, and some of them in their last change of their skin undergo some further changes: for this reason I have considered them as Nymph animals. Besides, some of them, like mankind and quadrupedes, hatch their eggs within their bodies, and are therefore viviparous. This is the case with Scorpions, and some species of Snails.

\* The generical characters of the Scorpion, as now established by Linnaeus, are, that it has eight legs, with claws on the forehead; eight eyes, two on the upper part of the thorax, and six at the sides, with a tail armed with its sting.

† The Leech, like the Earth Worm, constitutes a particular genus of insects; the characters are few and plain; the body is simple, and is expanded into breadth at each end: we have two kinds common in shallow waters, the Leech used for bleeding, and the cylindrick kind.

‡ Morand, in the memoirs of the academy of sciences at Paris, has accurately described the mouth of the Leech; it consists of five parts, two lips, a hollow for receiving the blood, an instrument to pierce the skin, which is composed of three sharp points, and an Oesophagus for swallowing the blood. The Leech will live in oil, which is destructive of most other insects, if only rubbed upon their skins. The Leech, when taken out of oil and put again into water, casts a thin and very delicate skin.

*The natural changes of the first class or order of insects, exemplified in the Louse; with an explanation of what relates in general to the other three classes.*

THAT I may give a singular and satisfactory specimen of the first class of insects, I shall here insert a letter, formerly wrote with great care to Mr. Thevenot, as it contains a complete and exact account of the limbs and parts of a Louse, both internal and external. This example, by which I propose to illustrate the first class of insects, and the examples I shall give, in their due places, for the other three classes, will enable the reader to form a competent judgment of the changes, which all other insects undergo, according to the different classes to which they belong. It must be allowed, however, that whatsoever pains we may take to arrange them, there will still remain, even amongst those of the same class, very remarkable differences; and some of those differences will be in the mutations they undergo. This will most clearly appear from our experiments relating to the fourth class, in the case of the worm-like Nymph of the Afilus Fly, and in the egg-like Nymph of the common Fly; between which there is no small difference, though they belong to the same class, and are liable afterwards to the same changes. This accidental difference may also be seen on looking over the figures of animalcules, which I have given under each kind in the special histories of the three other classes. It appears very strikingly in the Cryfallides of Caterpillars, as they are exhibited in the designs of the indefatigable Goedaert; for though they all belong to the second mode of our third class, yet one Chrysalis differs in many particulars from another: this difference is, however, far from being what is called essential, it only consists in some part of the external forms.

From the first class of our changes, we shall now select the Louse as an example, and represent by figures, the changes which happen in its parts, till it comes to its full growth. The Libella, or Dragon Fly, will serve us for the second class; and the Ant for the first mode of the third; the nocturnal Butterfly for the second. Lastly, we shall give the common Fly as a specimen of the fourth class; and I shall afterwards illustrate these several changes by the accretion of the limbs in a Frog, and the budding out, or shooting, of the parts of a flower.

Though the foregoing natural changes, and the comparisons of others which will be made in treating of them, may be thought sufficient for giving a clear idea of the practices of the insects contained under the four classes, into which I have arranged them, and of the differences between each class; nevertheless, I shall add to the first class, a separate and satisfactory account of the manner wherein the parts of Snails grow and are changed. I shall

do the same by the Ephemeron, or Fly of one day, in the second class. In the third class I shall exhibit, according to the first mode, all the changes of the Bee, with a complete dissection of that insect and the horned Beetle; and the same both in descriptions and by figures of the common day Butterfly, according to the second mode of the third class. Lastly, I shall give in the fourth class an account of all the changes which the Afilus, or Gad Fly is subject to, and illustrate them with plates. I shall, besides these, insert various other histories, all which will not only throw a light upon each other, and represent clearly and distinctly the changes of the four classes in the exact manner wherein they happen, but, what is much more advantageous in this kind of study, they will display such miracles of wisdom, power, and goodness in the great Creator, as cannot fail powerfully to incite us to love and adore him. This, indeed, is the great purpose I propose to myself in my inquiries concerning these natural mutations.

To set forth clearly and distinctly the orders of the transmutations in the Louse and Dragon Fly, the nocturnal Butterfly, and common Fly, and to exhibit more plainly the changes of each of them; as also that I may be able to demonstrate those, wherein the orders of the changes agree or disagree among themselves: I shall use the same number, and observe the same rule in explaining the five respective figures. For though there be not the same necessity to proceed in the same manner in setting forth all the figures of the changes and accretions observable in those insects; as for example in the change of the Louse, which is only a simple augmentation; yet, since we see five distinct changes in the Libella, or Dragon Fly, and other insects, whose figures we exhibit before they attain their full age, and are rendered fit for generation, we have been, as it were, obliged to treat the Louse in the same regular manner, in order to render the whole more exact and uniform, as we have before done in comparing the Frog with the flower or vegetable increase.

We have not observed that method also in the particular histories of Bees and the rest, as well because their anatomy are subjoined to those accounts, as that the classes we have advanced, seemed calculated to exhibit a certain general rule, whereby all the changes of insects produced by nature may be tried and examined.

Finally, every thing marked in numbers in the explanations of the figures, is delineated in its natural bigness; but the Animalcules, to whose figures the numbers 1, 2, 3, &c. are affixed, are represented as they are magnified by the microscope; while some others that are

characterized by 1, 2, 3, are represented to the life. This has appeared to me the proper method of proceeding in this affair, for two reasons; first, lest the order of the number should be broke by increasing or diminishing the figure; secondly, because some of these insects are so large of themselves, that there is no need of a microscope to delineate them.

To follow nature as near as we could, we have put the white animalcules, or little animals of our four classes on a black ground, which we have not done with respect to the other coloured ones. This appeared the more necessary, as Goedaert represented a bristly Caterpillar, the figure whereof we have in one

of our tables, without any hair at all, which error was probably owing to his not laying it on a black ground, whence its white hairs were not discernible.

To make the rule of our four classes the stronger, we have also been careful to select animalcules that are so well known, that there is no necessity to illuminate them with colours. And we are confident, that our figures are so accurately executed, that it would be unpardonable to daub them with paint. We come now to treat of the Louse, which I now intend to do, comprehending the whole doctrine concerning it in the form of a letter.

TO THE MOST ILLUSTRIOUS

Mr. T H E V E N O T,

Formerly embassador from the king of FRANCE to the republick of GENOA.

MOST ILLUSTRIOUS SIR,

**T**HE omnipotent finger of God is presented to you in the following sheets, in the anatomy of a vulgar and loathed insect, the Louse; wherein you will indeed find miracles heaped on miracles, and will be amazed at the wisdom of God, most clearly manifested in a minute point. Let the world admire the masterly strokes of Apelles: here you will find the complete fabrick of the viscera of all the animals in the world, formed with the most exquisite workmanship, and abridged, as it were, in a particle of a line in measure. What mortal, illustrious sir, can attain to this by reason? what other hand, but that of God, can investigate and frame such things? The spirit and grace of God, which he bestowed on mankind, has rendered some capable of searching into such sub-

lime miracles and secrets, and to lay them open to the view of others. Though the Ægyptian Magi could imitate the other miracles which God performed by Moses, they were not able to produce these animalcules by their magick art, as the sacred writings testify. \* “Aaron stretched out his hand with his rod, and smote the dust of the earth, and it became lice in man and in beast; the magicians did so with their enchantments to bring forth lice, but they could not; then the magicians said to Pharaoh, this is the finger of God.” I cannot so properly, illustrious sir, offer these observations to any other as to you, since I know no other that sets a due value on such things, according to their dignity.

The E X T E R N A L P A R T S.

**B**EFORE I exhibit the internal parts visible in this small and despised animal, I shall describe its external parts, and shall shew every thing remarkable in the head, thorax and abdomen.

The shape of the fore part of the head is somewhat oblong, that of the hind part somewhat round; the skin is hard, and being stretched, is transparent like parchment, and has here and there bristly hairs. At the extremity of the fore part is the proboscis, or sucker, Tab. I. fig. iv. a. seldom visible, since it is always drawn to the inside; I shall therefore describe it when I come to the throat and stomach. On each side of the head are the antennæ or horns bb, which are also covered with a skin like parchment.

Each of these is divided into five joints, elegantly covered with bristly hair, and several white vessels are seen through these horns. Behind these are the eyes cc, which seem to want those hexagonal divisions observable in other insects, and they appear to be encompassed with some few hairs.

The neck is very short, the breast is divided, as it were, into three parts; in the middle of which, on the back side, appears, as it were, a small shield. On each side are placed six legs dd, each of which consists of six joints, some larger than others: they are very delicately adorned with bristly hairs, and many whitish vessels are seen through them. The ends of their legs are armed with a smaller and larger ruddy and

\* Exod. viii. 17, 18.

pellucid claws *ee*, serving these insects in place of a finger and thumb; for by the former they take hold of a person's hair, and by the latter, they are able to ascend and run nimbly. Under, at, and upon the breast, where it is joined to the legs, and, as it were in the very center of it, there appears a short whitish groove or channel, which is conspicuous through the middle of the abdomen, appears of a brownish colour, fig. v. vi. and has very strong motions. On either side of this groove or channel are two bright little parts, like the larger before described, whose appendages they are, and which rise considerably on the inside of the breast, and are there also transparent.

The abdomen is divided into six parts, and at the end of it, on the under part, the body terminates as it were in a cloven tail. Besides

these in the middle of the lower part of the belly, there is to be observed a whitish spot like a point, which is also transparent, and moves distinctly up and down. On the sides and extremities of the belly, which is all over hairy, are observed some pellucid, ruddy, little bodies; and over the whole belly, a great number of white vessels are visible, fig. iv. gg. The like are discernable in the back and breast. The skin of the abdomen is made like the ends of our fingers, consisting of small grooves, but this structure does not hold through the whole, and not at all at the extremities of the abdomen; for there, as well as in the whole body, it is somewhat firm, like clear parchment, and when roughly pressed, it makes a noise and breaks.

### The anatomy of the INTERNAL PARTS.

TO obtain a perfect knowledge of all those parts, which I have hitherto mentioned in general, there is no other way but to dissect the creature. I shall therefore now give an exact description of all the minutiae relating to the internal parts; for by this means we shall have a complete idea of the external also.

If we begin the dissection in the upper part of the abdomen, and cautiously open the skin there, blood immediately issues from the wound, and this being received into a small glass tube, Tab. II. fig. 1. *aa*, and viewed with a powerful microscope, is seen to consist of transparent globules, as cows milk: the same has been likewise discovered in the human blood for several years; it is found to consist of ruddy globules swimming in a clear liquor.

It is, however, a matter of doubt, whether the blood in its vessels has any globules, for when drawn from them it may easily acquire that figure; this may at least be asserted of the ruddy part of the blood. I have therefore often resolved to put a small glass tube into the artery of a dog, and with a microscope to view the flowing blood. For thus, by analogy, it may be possible to determine with some certainty, whether the human blood, before it is taken out of its vessels, contain any globules. I am the more in doubt concerning this matter, because there are vessels discovered in the body, which appear much finer than the globules themselves visible in the blood. By this means also may be known the true difference between the arterial and venal blood; for in the latter only, I have hitherto observed these globules, having never examined the former: Nor shall I positively assert, that there are originally globules in the Louse's blood, for they may be easily formed by the intermixture of the blood with the fat, and some wounded particles of the viscera or bowels, which consist of a congeries or heap as it were, of globular parts; as I shall shew in its proper place. Wherefore, more time ought to be spent in

this anatomy, than I can devote to it at present, being engaged in many other studies.

Tab. II. fig. 11. Immediately under the skin are certain muscular fibres, which move the annular divisions of the abdomen. I have observed three distinct kinds of these muscles, some a little broader *a*, others narrower *b*, and a third sort with two bodies *c*. One may see that these muscles extend themselves from one annular division to another, and that some are much shorter than others. This little animal is very full of muscles, particularly at the extremities of the abdomen; since the motion is strongest in that place, and the respiratory points or orifices for respiration are placed there, by the assistance of which the Louse takes in the air, and by a manifest act of inspiration and expiration, draws it into the body, and again discharges it. When these muscles are drawn from the body, they seem as if they consisted of but one fibre, but if they are dried upon a thin and clear glass, and washed with spirit of wine, which takes off the impure fat that adheres to them, their fibres and joints appear distinctly to be made up of globules.

Under these muscles the fat and the tracheæ, or air vessels, come in view; nor could I ever hitherto discover any vestige of a heart in this upper part of the abdomen, as is usual in other insects, wherein the heart is always placed in the upper part of the abdomen and back; but I found clearly by this dissection, that the Louse otherwise agrees in all its parts with other insects, as will hereafter plainly appear; therefore I have more diligently sought for the heart, but in vain: this may probably be owing to its extreme smallness, since it is very difficult to find it in the larger insects, as in the Horse-Fly. There is also another impediment, which is, the strong and continual agitation of the stomach in this insect, being hardly a moment at rest, from which there arises an unavoidable inconvenience in investigating the heart.

The particles which I take to be the fat of the Louse, are for the most part very small, but extremely numerous, though we may discover it in a larger species or kind of fat particles; the figure of the smallest kind of particles is usually globular, but that of the greater is more irregular. They are of a clear transparent colour, like gelly, but all the other parts of this animal are not of that colour.

The ramifications of the trachea, aspera arteria, or windpipe, constitute the principal part of this insect; a very considerable number of them are found in the head, breast, belly, legs; nay, and in the antennæ or horns. We may likewise observe, that they are connected and supported by the fat, as I have found in other insects: and these are the white vessels which are seen through the transparent body, as I have observed in the history of the external parts. The reason that these pulmonary pipes are seen through the skin, is, that they are of a silver colour, or light bright mother of pearl, and therefore afford a very agreeable sight, whilst the animal lives. They constantly keep this colour, nor will they ever fade, for their structure is such, that they remain always open.

As to their composition, it consists of a double matter; a part is composed of rings, which resemble the cartilages of the trachea, or windpipe, in man. It appears very distinctly by the microscope, that these rings often bend themselves round, in order to form a cavity and open pipe, Tab. I. fig. VII. *a*; but this does not happen so often as in other insects, because the rings of the Louse are shorter: they are also more curled and twined *b*, in likeness of a Serpent, and seem every where interrupted *c*. It may also be observed, that where the aspera arteria, or wind-pipe, is divided into branches, there these rings are largest *d*, but they are afterwards insensibly divided into smaller *e*. The other part of these vessels is membranaceous, and is situated in the interstices of those rings; and by its assistance the rings may conveniently bend and turn themselves, as is known to happen, particularly in those wonderful motions of the stomach, which is surrounded by a great number of air-pipes.

I have hitherto omitted examining whether these pulmonary pipes within the body, likewise shed a little skin at the time the Louse casts its coat, as I have observed to have happened in the Bombyx, or Silkworm, and in almost all other insects. However, the smaller these pulmonary pipes are, the fewer rings they have, until at length they appear like more membranaceous threads.

I may venture to affirm, that the pulmonary pipes cannot be more conveniently viewed in any species of animals that I have hitherto known, without dissection; so that we cannot contemplate their situation and course, with greater admiration, in any animal than in the Louse. But I have by me a very curious and familiar apparatus, by the assistance of which, I

can at any time demonstrate it with the greatest certainty.

Tab. I. fig. IV. The orifices of the XIV pulmonary pipes are seen in the outward skin of the Louse; one (1) of which is on either side of the breast; and on each side, on the extremities of the abdomen are placed six, 2, 4, 3, 5, 6, 7, which I exhibit in the figure in one side only. I have also thought I sometimes saw one pair of air orifices between the second and third pair of legs; however, I will not be positive in this matter.

Tab. I. fig. VIII. These orifices are the respiratory points, one of which is situated on one side, between the first and second pair of legs, and six on the extremity of the belly, 1, 2, 3, &c. these points swell a little there, like a small nipple *aa*, and in their circumference, seem to have a slight rim or border, which appears somewhat ruddy and transparent as the place itself wherein they are fixed is also of a light red and bright colour; they are a little bent towards the inside, and immediately after the tegument of the extremity of the abdomen swells out. All the points are like that which I have observed to be placed in the breast. *b*.

Tab. I. fig. IV. From every respiratory point there issues a branch of the trachea *bbb*, which soon after forms a visible anastomosis or inosculation with some branch of the trachea, that proceeds from another point, and both close into one canal: the same holds also in all the XIV apertures of the lungs; so that the air, which is drawn into the body by one respiratory point, may be spread through the whole. Nor is it there only that the pulmonary pipes unite, but this holds equally in those which are in the back, belly, and breast; which last is distinguished by three manifest ramifications that are joined together underneath. This matter hath been already elegantly delineated by doctor Hooke, in his incomparable Micrography; however, he could have no knowledge of these ramifications by any other means, but that they appear visible through the body.

I am further instructed by the dissection, that the pulmonary pipes may be discovered not only in the head, breast and abdomen, but they reach also to the intestines, the ovary, spinal marrow, brain, and, in fine, to all the internal parts of the body of this animal; all which, as I have distinctly seen, so I can demonstrate them to others, with the assistance of certain experiments which God enabled me to invent in the study of anatomy, that the miracles of his works might be known: for we have not even the least thing from ourselves, for it is God that giveth us ingenuity.

These things being well understood, I might proceed to describe the other parts; as first, the ovary, which appears next after the former, being a part placed upon the stomach itself: but since method requires us to treat, before these, of those parts which assist digestion, and tend to the nourishment and preservation of the body, and afterwards of those which serve for generation.

generation. I shall now describe the proboscis, or sucker, the throat, stomach, intestines, and other adjacent parts. I shall after these treat of the ovary, brain and nerves, and then add something concerning the outward skin, with which I shall conclude this anatomical description.

The Louse has neither beak, teeth, nor any kind of mouth, as doctor Hooke described it, for the entrance into the gullet is absolutely closed: in the place of all these, it has a proboscis or trunk, or, as it may be otherwise called, a pointed and hollow aculeus or sucker, with which it pierces the skin, and sucks the human blood, taking it for its food into the body. But this proboscis cannot be shewn, on account of its extreme smallness; nor can it be distinguished, unless a person happens to see it by chance.

At the extreme point of the head, when pressed out artificially, and with a particular attention, there appears an obtuse prominence, Tab. II. fig. III. *a*. which being hollow in the middle of the inside, bends back into itself, and goes into the body, but has no aperture or opening. From this the proboscis *b*, or sucker, is observed sometimes to proceed, and wherefore this part is, as it were, the sheath or case of it, wherein it is laid up.

I cannot illustrate this structure or machinery by a more proper example, than by that of the horn of a snail, which is likewise turned into itself on the inside, and is again stretched out, but there is no perforation: wherefore, if the proboscis or sucker was placed at the end of it in this insect, instead of the real eye which we see in the snail; one might in some measure form an idea how the proboscis, or sucker, is wrought in this insect, and worked up with admirable art by the supreme architect of the universe.

If the whole little sheath or case be afterwards examined, Tab. II. fig. IV. *c*. it is observable, that the upper end of it is thicker than the lower, and is swollen like a mushroom; so that it appears from hence, that the little foot on which it stands is smaller than its top. When one presses the proboscis, or sucker, and its sheath on the outside, we shall find that the end of the latter is absolutely blunt and resembles the head of a pollard willow tree, having all its branches cut off; we see also that there are here and there certain pointed parts or claws *d* in it, which, as well as the sheath, and the proboscis or sucker, are of a light brown colour, and are transparent. I shall presently shew the use of these claws; there is also a crooked proboscis or sucker *e* in the middle of them. The outward skin of the sheath which is annexed to the proboscis, and from which its head is prominent, is of the same texture with the rest of the skin that covers the Louse; for it consists of grooves and pellucid globules, as I shall explain hereafter, when I treat of the skin.

If we examine that part of a Louse's head at the time when it is seeking out some pore of sweat in the hand, wherein to fix its proboscis or sucker, a small line of a pale brown colour is then presented to us, which appears visible through the head, and has its fore part more deeply coloured. This little line is nothing else but the sheath itself, with the proboscis hidden in the inside.

But before I explain the use of this proboscis or sucker, and its manner of rising, it seems necessary to describe the figure, situation, colour, texture and motion of the gullet, stomach, and intestines: for thus the method whereby the proboscis performs its suction, will be more easily understood. The œsophagus or throat is a very small canal, fig. III. *f*, which one cannot see at any other time, but when the blood ascends through the proboscis or sucker into the mouth, and passes through this into the stomach. It is situated a little behind the eyes, and seems to be carried up above the brain: the reason that I think so is, because it appears there very clearly at the time of suction; so that probably it runs immediately under the skin of the head. In the neck it is somewhat enlarged *g*, and afterwards it grows small again in the back *h*, until it terminates in the stomach, near which I have observed it, like a very small, clear, and transparent thread, wherein a person that dissects it sometimes observes blood, and some other substance, which appears like the contents of the stomach. I discovered the whole gullet, in the action of sucking, as before described; for it is a very difficult matter to discover it in any other manner, because in the upper part of the back, and also in the head and neck, it is very strongly connected with the adjacent parts.

The stomach, fig. III. *ii*, is lodged partly in the breast and back, but the greatest portion of it is in the abdomen. When swollen with blood it appears of a dark brown colour, which is visible through the skin, and is either a faint red, or a full or bright brown, as the contents of the stomach are more or less changed. Where the stomach joins the breast above, its figure resembles a fork with two teeth; these are two hidden appendages of *kk* the stomach, which go deep into the breast, and on either side near the gullet and spinal marrow, and reach to the first pair of legs. These are those two blackish, transparent and coloured parts, which I have mentioned in general in the history of the external parts.

The part of the stomach connected with the abdomen deserves particular consideration; it is formed like an oblong bag, which is here and there continually contracted and again extended. When it is empty, it is colourless, and the stomach and its appendages are transparent. But as the stomach fills, the colour is seen plainly through the outward skin. It manifestly consists of two coats, the outward is thicker, the inner very thin, as it is in all

insects. Nay, it is probable that it has three coats, and that the third is muscular.

The outward coat of the stomach is furnished with so great a number of pulmonary *llll* pipes as can hardly be expressed in words. The larger branches are very conspicuous in it, but the smallest cannot be discovered, except by the assistance of the best microscopes. On the contrary, the inward coat is very thin; the third, which, I suppose to be situated between the two former, comprehends without doubt, the muscular fibres of the stomach, by the help of which it performs its wonderful motions. The coats of the stomach, especially the outmost, appear to consist of very many globular little grains, which are very irregular in form; but whether these little grains properly belong to the texture of the stomach, or whether they are rather particles of fat, which cover the stomach, whereby the pulmonary pipes are gently moved, I could not well discern; only this I know, that the greatest part of them, when often touched, retire from the stomach.

Underneath, in the abdomen, on a little rising or prominence, nearly in the middle of the stomach, there is seen a certain little part *m*, which doctor Hooke apprehends may be the liver; but I should rather take it to be the pancreas, or sweet-bread, though there want sufficient arguments to prove it. Its colour is not properly whitish, but somewhat inclining to yellow; and it is so strongly connected with the stomach, that it cannot be easily separated from it. If this be laid before the microscope, it may easily be divided into many little grains like glands, but these are not very transparent. When it is accurately viewed by the microscope, the pulmonary pipes also appear in it. The substance of this little part is more firm than that of the rest, for when it is extracted from the body and dried, it is but little diminished. It is of a very irregular figure, and is formed divers ways in almost every Louse, being sometimes greater and sometimes less; but it is always finished in the same general manner, by reason of its bendings and situation over the stomach, as is evident from the five different figures of these little parts, which I have delineated to the life from the microscope, in fig. v. 1, 2, 3, 4, 5, of Tab. II.

At the lower region of the stomach is seen the pylorus, fig. III. *n*. and immediately from this, the intestinum tenue or small gut *oo*, which is extended on each side, and formed like the stomach: this is also provided with a great many pulmonary pipes. At the end of this small gut, which is for the greatest part bent in a serpentine manner, or like the letter S, are discovered four small vessels *pppp*, which the sagacious and excellent anatomist Marcellus Malpighius, has called the swollen vessels in Silk-Worms; but these are straighter and less inflected in the Louse; they are considerably long, and of the same texture with the intestines. These four little vessels are properly four intestina cæca, or blind guts, which I have

found in all insects; wherefore, by inference, I call them here by this name, though I never have had the fortune to see their extremities. They open into the intestine, from whence they arise at the place just mentioned. After these appears the little intestine colon *q*, and at the end of that, there is a manifest dilatation or extension *rr*, which is the cloaca, or place where the excrements acquire their figure; for they are very irregular, and not like those of other insects, which are usually formed in a singular and regular manner. Within this dilatation appears the intestinum rectum *s*, which shews its aperture, as the anus situated upon the belly between the division of the tail *t*; and just under this the skin is very bristly.

As to the motion of the stomach, it is truly admirable; insomuch that one might suppose it an animal within an animal, by reason of the strong agitations, contractions, dilatations, corrugations and expansions, all which belong to it, and strike one with amazement, the whole being plainly seen through the body. These appear plainly at the time when the stomach is full of food, but they are best of all seen, when the blood passes into it at the time of sucking; for then it is sometimes observed, that the remainder of the old aliment is mixed with the new, and is shaken and agitated up and down, and on every side, in the stomach. This may be seen the more distinctly, as the colour of the contents is more dark.

Hence one may easily conceive what strange changes and emotions the pulmonary pipes on the stomach undergo at that time, and after what various ways the air contained in them is pressed, moved, propelled, and so purified; changed from its first nature, and rarified within the creature. But who can discover, by the most diligent researches, the use of the air in that place? surely no one. Yet very wonderful motions are observed on this occasion, particularly in that little part which I called the pancreas or sweet-bread; for this being connected with the stomach, must obey all its motions. That any person may form to himself an idea of the motion of the stomach, I have drawn three figures of it. When contracted, it is seen as at number 3, fig. VI. Number 2 shews how its contractions are changed, and after what manner it dilates, is apparent from number 1. These motions are continually repeated by turns, and undergo an infinite number of variations.

As to the method whereby the Louse sucks the blood, and conveys that nourishment into the stomach, it is performed thus, by the assistance of the proboscis, and its aculeus or point. First, if the Louse has abstained from food two or three days, it becomes very hungry, which is discoverable from the empty stomach, and because the creature is then wholly transparent; in this case, immediately as soon as he is placed on the hand, he seeks for food, which he will the sooner and more readily find, if the hand be first rubbed until it grows red.

Then



Then the Louse turns his head; which lies between the two fore legs, to the skin, and diligently searches for some pore of sweat: when he finds it, he fixes his aculeus, or sucker, therein; a little after this, the blood is observed, through the microscope, to ascend to the head, in a very rapid, and, as it were, frightful stream.

The Louse has at that time matter enough to feed on in any posture, for if it finds any hairs on the hand, by which it does not desire to descend, it stays in that posture, and sucks with its head down, and its tail elevated. I have likewise observed that it sometimes sucked with its belly upward, that is, when the hair it took hold of was bent down; and then the motion of the stomach, and pancreas, or sweet bread, might be seen most beautifully by the help of a microscope.

But I should think the principal use of the claws, which I have described to be situated at the end of the sheath or case of the aculeus or sucker, is to assist the creature in sucking, and that the aculeus serves for this purpose; for whilst these are strongly fixed in the superficies of the inner skin, and in the extremities of the pores, they enable the Louse to use its aculeus the more freely, and to move it at discretion, when the end of its sheath is placed firm and immovable.

Sometimes, whilst the Louse was sucking, I have strongly pulled the skin of my hand aside, that by this means the sheath, or rather its claws, together with the aculeus or sucker, might be bound fast in the skin, and the Louse could not disengage itself. This affords indeed a very agreeable sight. This I did with a design, that if I could thrust the Louse out of its place, I might the more plainly see the aculeus: but I could never accomplish my desire in this particular, though I had then almost wished to have three hands, that I might the better find what I wanted. There are some speculations and researches in anatomy that will not bear writing, since they almost distract the mind.

When the Louse is employed in sucking, a very small rivulet, Fig. III. *u* of blood immediately appears behind the aculeus or sucker, which is seen through the transparent head. Between and before its eyes, on the middle of the head, there is observed also a considerable dilatation *x*, for the jaws are there remarkably expanded, by the blood continually ascending. These parts are so swiftly contracted again, that there scarce remains the least sign of blood after a moment, and both are performed with such velocity, that the dilatation can hardly be distinguished from the contraction; wherefore I do not know how to explain this matter more properly, than by the sudden oscillation of the pendulum of a clock. Behind the eyes, a small rivulet of blood is likewise observed to run down within the head: this passage may be properly called the œsophagus or gullet, fig. III. *f*, which lies behind the jaws, and grows wide again in

the Louse's neck as has been shewn before *g*. I have chosen to exhibit all these as one continued canal, that my description may be the more clear.

After the blood has ascended to the jaws, and comes to the gullet, we observe that it is immediately conveyed to the stomach, and that the bifurcated appendages, as well as the stomach itself, are at once filled with it. The motions of the stomach are then remarkably increased, its muscular parts being distended; for as these muscular parts are then stretched, they have an opportunity of contracting themselves again. Wherefore it is immediately observed, that the excrements in the large guts begin likewise to move; nay, it usually happens that the Louse discharges them during the sucking.

The food being thus received into the stomach, is agitated about in a wonderful manner; it is moved up and down, and by contractions and dilatations, which are not to be described, then performed by the stomach, is, as it were sifted. After this, it is seen, that the contents first begin to divide into parts in the back or hinder portion of the stomach, and they then appear like raisins preserved in jars, and are thus distributed through the body. However, this is a false appearance; it arises from hence, that the skin being divided into many grooves, is not equally transparent every where, and that some difference is in this respect seen through it, because the grooves are not equally transparent with the intermediate parts. Nay, the particles of the internal fat not being uniformly visible through the skin, and obscuring the brightness of the skin, conduce likewise to deceive the sight, as if the retreating blood entered into many peculiar vessels. To this may be added, that the blood has not at that time a homogeneous or equal colour, for its parts separate from each other. From these appearances, before I had accurately examined things, I thought that the blood was distributed out of the stomach, through various vessels, into the other parts of the body; but I afterwards observed that this phenomenon arose, as well from the blood itself, as from the different colours of the parts through which it was seen, and which I then took to be vessels. Perhaps others, especially doctor Hooke, who first prejudiced me in favour of this opinion, have split on the same rock. I have not as yet made this experiment in the smallest Lice, in which more peculiarities may probably be seen, than in the larger kind.

I have likewise resolved to receive the blood, when changed in the stomach, into a glass tube, and then to view it in the open air, or in some dark place by candle light; but this I have not hitherto done, being hindered from making this, as well as many other experiments which I had a mind to try. In some hours after feeding, the contents of the stomach are observed to become insensibly more brown or blackish, and

to diminish slowly: wherefore the intestines are afterwards seen to be more and more distended with excrements, which sometimes lie in them regularly divided, as it were, into globules. The reason of this is, that the intestines do not, at one and the same time, contract themselves about the fæces, and therefore they cast or extrude them out of the body at different times. I have already treated of the muscles of the abdomen in this insect, I shall now proceed to the parts of the breast.

In this part, and in the back, are seen several muscles, which move the legs and head; and herein are also visible the appendages of the stomach, and a great number of pulmonary pipes and particles of fat. In the same view is also seen the gullet and spinal marrow, together with the nerves arising from thence, of which I shall now speak distinctly.

In the middle of the back is seen a certain tendinous point, under the small shield there situated, where the skin does not appear to be so transparent as in the rest of the body. This shield seems there to be hollow, being thrust down into a little pit. At this point almost all the muscular fibres are seen to concur, and their motion and contraction are here very visible. As to the appendages of the stomach, and other parts of the breast and back, we have before treated of them at large.

The spinal marrow is properly situated in the breast, and therein reaches to the insertion of the last pair of legs. When this is discovered, it is easy to judge what that short whitish groove is, which appears through the breast, between the appendages of the stomach; for these appendages are placed on both sides of the spinal marrow.

The structure of the spinal marrow itself, does not differ much from that found in the Worm, from which the *Scarabæus Nasicornis*, or Horned Beetle, by the ancients consecrated to Mercury, is produced, as is manifest from the history and figures of the latter. It consists of three remarkable swellings, expansions or dilatations, fig. VII. *aaa*, from which, on either side, we observe three nerves *bbb* to arise, which reach to the muscles of the six legs; but underneath, or in the hinder part of it, I distinguished six nerves *cc* issuing, which doubtless are distributed through the rest of the viscera, to give them life, sense and motion. The lowest of those little knots, whereof the spinal marrow is composed, is formed in a different manner from the upper ones, which are alike.

The membrane which covers the marrow is interwoven with a great many pulmonary pipes, and seems to be composed of irregular and globular little parts *dd*, in the same manner as we have shewn in respect of the coat of the stomach: and this texture, together with the great number of pulmonary pipes belonging to the part, afford a very agreeable sight in the living insect.

I could discover no fibres in the nerves, which arise from the posterior part of the marrow, though I viewed them fresh with the

microscope; they seemed indeed to be made up of a homogeneous, bright and transparent matter, and at their sides were hung a great many pulmonary pipes; with particles of fat.

The origin of the marrow, where it is connected with the brain, is seen like a fine thread *e*. But in all other insects this beginning of the marrow is perforated, and through its aperture or cavity the gullet passes.

The brain of the Louse is shaped like a pear *ff*, and is divided into a right and left part. The dura mater, surrounding it, is formed like the membrane that covers the marrow, and is provided with pulmonary pipes and particles of fat *gg*. I can very easily at any time shew the marrow, but the demonstration of the brain must be obtained rather by chance, than with any premeditated design or art; it is clearly seen when by any accident it happens to be stript of the parts wherewith it is covered.

The optic nerves *hh* are short, and the eyes *ii*, which are connected to them, are so small, that I could not dissect them to my satisfaction; as well because this operation is but awkwardly performed under microscopes, which magnify objects so much, that all instruments are too coarse for this purpose. Thus much, however, I distinctly saw, that this black part in the eyes might be separated or lifted up from them; which part in other insects I call the tunica uvea, not being situated on the bottom, but on the superficies of the eye; after this appears the tunica cornea; this seemed divided as it were into hexagons, as it is in other insects, though the other was not: but that I would not affirm for certain, for we are not to suppose or imagine, but to pursue by our senses, and discover the actions and productions of nature. This opinion, however, does not please some anatomists, who therefore esteem all comments on the brain merely as ingenious fancies. The younger Bartholinus, who, speaking of the fiction that silkworms had no brain, expresses himself thus: "Behold, how many are pleased  
" with their own blindness! who, although  
" they are blind, and shall for ever remain so,  
" yet cry aloud they can see, since these their  
" contemptible works, which ought to be re-  
" moved from their eyes, and buried in obli-  
" vion, are lasting monuments of their cloudy  
" arrogance; for by this means they might  
" afterwards seek for the light of truth."

Whether Lice are distinguished by the parts of generation, into males and females, as other insects are, I could not discover. Heretofore, indeed, I had sometime remarked that Lice get upon each other; but this I could not observe while employed in this dissection. I found an ovary in every one of forty, which I dissected; this almost inclined me to think that these little animals are Hermaphrodites; and perhaps they really have in each animal a penis and an ovary together, in the same body, as I have found in snails. Whether indeed it be so, is still a secret to me, for though I saw the ovary very distinctly, I could discover no penis, notwithstanding

standing the great hopes I had of finding it, from having observed that all kinds of insects have very large organs of generation.

The ovary is extended through the whole cavity of the abdomen, so that with its appendages it reaches even to the breast. It has an opening distinct from the end of the intestines, for as the upper part of the fundament is placed in the division of the tail, in which the abdomen ends; so on the contrary the vagina or mouth of the ovary opens into the lower part of the abdomen, where the body is divided as it were into two parts, Tab. II. fig. VIII. as may be seen in doctor Hooke's figure. The ends or extreme appendages of the oviduct or egg-passage are like two tubes *bbbb*, naturally joined in one point; this I have shewn in the figure by one side: In the oviduct *c* are seen at once perfect eggs *d*, and their rudiments *e* or principles; so that in one ovary I have counted ten larger and forty four smaller eggs, together making fifty-four. In the uterus I saw one perfect egg, which was fallen down ready for birth; at that time these little eggs are called Nits. In my figure of the ovary there are fifty-one eggs.

The ovary is double *ff* in all Lice, and every part of it is subdivided into five oviducts *gg*, which on each side end in one common canal; next comes in sight the uterus *h*, in which the egg *i* acquires its full perfection. Where the uterus ends, is seen a sacculus or bag full of a glutinous matter *kk*, opening in that part into the uterus; this is designed for fastening the eggs, whilst they are laying; the same may be likewise observed in many other insects, and particularly in Bees. I must acknowledge that I have not seen the glutinous matter contained in this bag; but I infer, from the situation and structure of the part, that the bag was designed for keeping such a substance. After this appears the neck of the uterus *l*, and therein is a small dilatation or expansion; by means of which, the ovary immediately opens itself into the outward womb, as may be seen at the letters *aa*.

The oviducts embrace the eggs so closely, that scarce any difference is observed between them *m*, nor can we separate the oviducts from the eggs, without great labour; when we do this, a great many bags of fat issue from thence, which obstruct the sight. It therefore has appeared to me, that the structure of the oviduct is the same with that of the stomach and intestines; though the texture of this part is nevertheless more delicate, and that the glo-

bular particles proceed from thence with greater ease, than in the other viscera. The oviducts are provided with many pulmonary pipes *n*, of which, as we have already observed, this little animal has a very large number, though no bigger than a point; its structure and viscera, which excel all human art, the greatest geniuses ought to be amazed at, as I have here, though briefly; yet clearly; explained and demonstrated. I am persuaded that I might make many more discoveries in it, if I had more time for that purpose, since I have completed this dissection, and discovered these remarkable miracles in this microcosm or little world, in the space of six days. If the learned Daniel Heinsius had searched for these things in nature herself, and not in his own fancy, and in books, he would not have written so poor an encomium on this insect.

As to the structure of the external skin of the Louse, it affords many particulars worthy of observation, nor is there any thing that bears a greater likeness to it, than stiff and transparent parchment: it is in several places marked with small grooves or channels, in the same manner as the ends of our fingers; which, when viewed with the best microscopes, really seem to be so many divisions of pulmonary pipes. But the lens of the microscope must, for this purpose, be carefully managed, for as it is turned one way or another, different things are seen: one cannot bring the lens nearer, or remove it further, by the least distance, but something is immediately perceived by the sight, which was not observed before. Globular particles, fig. IX. *a*, sometimes appear in the place of channels, or oblong pipes *bb*, though the eye is always fixed on the same part; then between the grooves themselves, where the skin is simply membranaceous, globular particles *c* are likewise observed. In other places, as in the extremities of the abdomen, the structure of the skin is different, for there it seems to be composed as it were of irregular squares; Tab. II. fig. x. *d*, wherein circular grooves *e* may be seen in one part; in another globules *f*; in a third, both globules and grooves *g*, nay sometimes the plain transparent skin only is seen full of points *bb*; all which, as we have before observed of the oblong grooves, are represented according to the transparency of the parts, which have not been yet totally separated from the inner surface of the skin; or just as the microscope is moved, somewhat nearer to, or further from the skin.

### Conclusion to Mr. THEVENOT.

All these things, most illustrious sir, while I viewed them. I have carefully delineated with my own hand, as you may see by the figures annexed. I shall now leave you to judge, whether chance, by any right, can claim even

the least part in the most artful structure of the small point of the universe, which is here exhibited; since so many and such different miracles jointly proclaim in it the divine omnipotence. Wherefore though this animal is

of no advantage to the body, yet it is able to raise our thoughts to God; so that by seriously contemplating the divine Majesty, and the glittering rays of his miracles, in this little animal, we may, with the most submissive humility, change and contract our vain pride into as small a point.

Then we shall observe the finger of God in these things, and shall obtain an effect, which none of the forcerers can imitate, or reduce into act: for the most small and humble may drive away the devil, and rob him of his strength.

The miracles of God are magnificent in every thing he has created; and even the smallest of them are the host of the Lord of

Israel; wherewith he does service to his people by chastising them, when their sins are grown to an height; that they may repent and acknowledge the supreme hand, which punishes our offences, as we are taught at large in the sacred writings. I shall conclude this discourse with observing, and shall always firmly maintain, that the miracles of nature are open books, whereby we are all reduced to our eternal origin, nor are we ever elevated above nature and created beings, until we constantly love God, and renounce all that is not God.

*The end of the wonderful anatomy of the Louse.*

## T A B. I.

*Explains the changes of the first order or class, which are laid before the eye, by the assistance of figures; for which purpose the Louse is produced for an example.*

N. B. The numeral letters distinctly shew, after what manner the transmutations succeed each other: some of the figures are exhibited as they are magnified with the microscope; and let the reader observe in general, that we have likewise followed the same rule in the examples of the second, third, and fourth orders or classes of our changes of insects.

No. I. Is the Nit or little egg of the Louse delineated in its natural size, wherein the Louse is contained, being yet cloathed in its first coat or skin. The same may be seen in fig. I. as magnified with the microscope.

II. The empty shell of the egg, or the Nit's coat, cast off by the Louse, after it has crept out of it. It is represented magnified in fig. II.

III. The Louse itself just excluded from its egg, or coat, where it is evident, how this animal has crept out of the membrane wherewith it was covered, in a state of perfection; so that it is not obliged to undergo any other change, but afterwards grows to a larger size, and must often change its skin. Wherefore we have called the Louse in this form, an oviform Nymph animal; because it comes from its coat perfect in all its members.

IV. We represent the same Louse somewhat larger, and cloathed as it were in its third or fourth skin, which is likewise to be cast off soon after.

V. The Louse, having attained the full term of its increase; in which period we have considered it as a Nymph animal; because it is then in the last skin that it will cast, and indeed we find some insects in this first order, which are still somewhat changed about the time of casting their last skin; which is sufficiently evident, among other examples, in the longipede or long-legged Spider; the legs of which grow much longer, at the time it is casting its last skin. After this is cast, the insects of this first order grow no more, nor are they any ways changed; as may be more

easily understood from the figures of the subsequent examples of the four orders, under the same numbers v and vi.

VI. The Louse, having attained its perfect maturity and full growth, so that is now fit for generation, and is arrived to the state of puberty. Fig. III. represents it magnified by the microscope.

### FIG. I.

*The Nit or egg of the Louse delineated with a microscope.*

*a.* An oviform border or extremity, which surrounds the Nit's head; within which are seen certain small cups, like *uvulæ*, of no exact or determinate figure. These little cups are somewhat bent, and they again swell in the middle, as it were into a whitish top. It is observed also that these little cups do not entirely fill the inward parts of the border or circle that surrounds the head.

*bb.* Two tender little swellings or pimples, wherein the Louse's eyes, whilst its limbs are yet moist and soft, are situated. These eyes grow insensibly browner, and become visible through the skin, and at length grow entirely black.

*c.* A certain white pellucid little part, situated in the middle of the Nit, which we have often observed to beat regularly like the heart; and this is the little part represented by the letter *b.* in figure vi. and called by us the pancreas, as it moves up and down with the stomach.

FIG. II.

*The egg-shell, or empty Nit, and the first skin cast by the Louse.*

*a.* The border or extremity of the head burst asunder with its little cups, and driven back by the Louse creeping out at the upper end.

*b.* The other part of the cast and empty skin of the Nit, from which the border of the head was separated; so that it resembles an empty tankard, having its aperculum or cover taken off.

FIG. III.

*The Louse lying on its belly, and magnified with the microscope.*

On its head is seen a shining skin, together with some little holes and divisions. On the

breast or back is an elegant delineation of a shield, which is painted in the middle; and the glittering skin is also observed to be here variegated with little holes. The legs, which are fixed to the breast, are full of little swellings or pimples, like shagreen skin, but they are lost by degrees towards the end of the legs. There are many hairs between the claws of the legs. It hath been discovered by the microscope, that at the extremity of the abdomen, the skin likewise appears painted and rugged, with little grains like shagreen as before mentioned; but I have at length discovered with the best microscope, that the skin really consists of irregular squares, globules, &c.

### *Of the Arboreſcent Water Flea\*.*

After the Louse I have likewise in this first order, placed the Arboreſcent Flea, whereof I now intend to treat particularly. This insect, which I here delineate larger than the life, Tab. XXXI. fig. 1. *a.* is the same that in fig. 11. I have represented also larger, yet in a side view. In this, besides the outward form of the body, which is square as it were, I shew an eye in one side of the head, fig. 11. *a.* and under it a sharp beak *c.* On the breast are seen arms, divided into branches *bb* like the boughs of trees; and in the abdomen there is a transparent substance, with the legs and tail; and in the hinder part of the body, its legs appear placed as it were on the middle of the back.

But if this animal be represented in the form wherein it shews itself to the naked sight, you would say it had only one eye; for the eyes, by reason of the smallness of the head, seem to be joined to each other. They are situated in the beak of this insect, and this beak is likewise very small and sharp-pointed. The structure of the eye is seen by the microscope, to be reticulated, or made like a net, such as we see in the eyes of other insects, and the beak is not only small and sharp, but also transparent: and it seems probable, that this little animal sucks in its food, by the help of this little part, as is usual with other aquatic insects, which feed themselves with their hollow beak, or tubular aculeus or sucker.

Of all the parts of this animal, its branching arms, and the motion it makes with them in the water, deserve out greatest attention. They arise undivided from two, as it were, simple trunks, which, like the shoulder bones, spring from the shoulder blades, and are each divided into two branches; each of these is again subdivided into three different joints. At the first and second joint, reckoning from the single trunk, there arise on each side a little branch, almost like a hair; and at the third or extreme joint, three such buds or shootings are placed, which also seem to be again divided into other joints.

But though these arms are very remarkable, and worthy of consideration, the motion produced with them by this insect deserve yet greater notice. For this is threefold; first, the little creature can, with their assistance, move in a straight line; whilst it constantly waves its ramified arms, as a bird its wings in the air, sometimes upward, sometimes downward, and sometimes on one side, and all the while moves forward in a straight line.

A second motion is like that of the sparrow, for as these, by expanding and again contracting their wings, pass with an uneven motion through the air, and sometimes descend, and immediately after are carried aloft again; so this little animal, by striking the water now and then with its branching arms, obtains a like unequal motion, and sometimes dives as it were to the bottom, and again rises up to the surface. These arise from the alternate ceasing and repetition of the motion; the animal by this means moving in a different manner. Since, therefore, the motion of this little creature is not at that time very irregular, it happens that it is continually seen to jump in the water, its head always tending towards the surface, and its tail stretched downward.

I cannot find a more proper example of the third kind of motion in this animal, than the whirling or turning about of that kind of pigeons, which, from this whirling or gyration of the body, are called tumblers. For as these tumblers, when whirled about in the air like a ball, seem for a time to be deprived of their motion, and fall as it were downward towards the earth; so this little creature, inclining its head down into the water, and at the same time raising the hinder part of its body upwards, moves itself as it were in a circle, without any interruption in the motion of its arms, which it uses upon this occasion as oars. Hence it happens, that the parts of its body, though in perpetual motion, and naturally always sunk into the water, are sometimes seen under and sometimes above it; which is a very pleasant

\* This insect is frequent with us in shallow and standing waters, as in the ditches at Tothill-fields.

fight, and may be compared to the turning of a wheel about the axle-tree of a chariot.

In regard, therefore, of the motions before explained, by which this little animal seems to approach rather to the nature of Fleas than Lice; and on account of its wonderful arms, which are made like the boughs of a tree, I think it may be properly called, as I have named it, the Arboreſcent Flea.

The ſtructure of this infect's belly likewise deſerves as much conſideration as its breaſt and arms: if we view it on the outside, it will ſeem to be of a rhomboidal form; but in reality, the part which reſembles the belly, is nothing more than a transparent ſkin full of ſcales or ſhells, fig. II, *d*, which is joined together in the back or poſterior part of the body, but in the fore part is divided into two ſegments which open from each other; and thus it forms, as it were, a little open caſement, through which the animal can move his real belly and tail in and out. Therefore this rhomboidal ſkin which covers the infect, is only its ſhell, through which its real body is ſeen, as this ſhell is transparent. This ſo far agrees with the teſtaceous animals; but it differs from them widely with reſpect to its diſtinctly viſible motions, which it has with the abdomen and tail. I have often obſerved that it ſtretched out its tail through the opening in its ſkin or ſhell beforementioned, and pulled it in again. This ſubſtance, or the body and tail, are waved and turned round like the letter S; in the middle is ſeen a ſmall transparent inteſtine, and in the fore part are ſeen feet which are transparent, formed almoſt in the ſame manner as the articulated bristles in Shrimps, and having the like, as it were, tremulous or jumping motion, wherewith this animal, as well as the Shrimp, can change its place; though this office is performed in general by its arms, to which, however, the legs ſeem to be ſomewhat aſſiſtant. The extremity of the tail is divided into two ſharp and ſtiff briftly hairs *f*, on which, at a little diſtance, grow two other ſimilar ones. The eggs *b* are placed on the back of the body, which I affirm as certain for this reaſon, becauſe, ſoon after this infect hath caſt them out, very ſmall whitish infects are ſeen ſwimming in the water, which are of the ſame nature with the full grown ones, nor do they undergo any other change, except that they grow bigger; as I have ſhewn to happen to Lice, in the example of the changes of the firſt order.

In figure III I ſhew all the parts hitherto deſcribed, except only the eggs which are caſt out, with this difference, that a little of the fore part of the body, which was before repreſented laterally, is here delineated; ſo that the motion of the inward body and tail through the rhomboidal ſhell, or ſkin, may be ſeen the more exactly. The feet alſo may, by this means, be ſeen more plainly, being here ſtretched out beyond one ſide of the ſkin; which I ſhall make more clear, and explain more particularly hereafter by letters.

The colour of this infect inclines ſomewhat to red in the full grown; and is like that of beef, which has been ſome time ſteeped in water. The outward ſtructure of the ſkin that covers it agrees, in ſome meaſure, with the reticulated and chequered ſhell ſkin of the ſcaly fiſh; though I could hitherto ſee no ſcales in it, having never viewed it through microſcopes, which, in the moſt powerful manner, magnify the bulk of objects: but it is transparent like the ſkin of the Shrimp, or as the ſhells of very ſmall Muſcles and young Cockles. The extreme part of the branching arms is like Hen's feet, but their diviſions are not ſo diſtinct.

I have frequently the infect I have been hitherto deſcribing, in ciſterns of rain water, when no rain hath fallen for a long time; but when theſe infects have plenty of rain, they can ſcarcely be ſeen, becauſe they divide themſelves here and there to every quarter. I have found them likewise in running water, and in mooriſh or fenny ditches, wherever any of the clear water has ſtag-nated on the ſediment at the bottom. They ſometimes remain ſeveral days on the ſurface of the water, and ſometimes are ſeen at the bottom only; but we ſeldom or never ſee them at reſt. They change their ſkin like Lice, and the caſt ſkin reſembles the infect itſelf ſo exactly, that you would ſay, you ſaw it alive. I keep by me ſome ſkins of this ſort, which are very curious.

I remember when I was in France, in the foreſt of Vincennes, that I ſaw ſo great a number of theſe infects in a watering-place for horſes, that the water appeared as if changed into blood; which, indeed, terrified me at firſt, but it afterwards gave me an opportunity of inveſtigating the nature of theſe infects more accurately, and made me cautious not to paſs too raſh a judgment on things that are obvious and familiar to us; for this leads us into innumerable errors and prejudices. It is not impoſſible that thoſe who affirm that bloody rain has fallen, have been deceived in the ſame manner. Is it not poſſible, that ſuch red drops might iſſue from infects, at the time they come freſh from the Nymphs, which diſtil a bloody fluid? This ſeems to happen, eſpecially when ſuch infects are more than ordinarily multiplied in any particular year, as we often experience in the Butterflies, Flies, Gnats, and others.

The celebrated Florence Schuyt, who was profeſſor of phyſic in the univerſity of Leyden, long after this incident communicated to me the like obſervation concerning bloody rains. He informed me, that being once intent on his ſtudy, he heard a noiſe, of which, as it increaſed by degrees, he was deſirous to know the cauſe; and that he was ſoon ſatiſfied in this particular, for that one of the maid-ſervants ran up to him, and told him, in an interrupted ſobbing tone of voice, that the waters of Leyden were turned into blood. Upon  
this,

this, he went directly in a small bark to the places he had mentioned, put some of the bloody water into a glass, and, upon viewing it carefully, observed that it was common water, and abounded with little red animals. Thus his sudden fright was changed into a lasting admiration. Before I treat of other matters, I shall disclose a method, to the diligent searchers into nature, by which I have discovered these and such like aquatic insects in water, which, when found, may be examined more accurately.

To find single insects in water, I know nothing more proper than the glass vessel commonly called an urinal; for if its empty belly be somewhat narrow, the smallest animal swimming in it must be seen by us, since the water itself contained in it supplies the place of a microscope. As the glass, therefore, is wider or narrower, so we see the little animal represented less or greater. But it must be observed, that this augmentation is not visible, except only when the animal swims on the opposite side of the glass. When the insects are once obtained, they may be removed into smaller glass bottles, wherein the parts may be seen much more distinctly: nay, the microscope, consisting of only one convex glass, may upon this occasion be used to advantage. Besides these, we have likewise other helps to magnify these little creatures: we have caused very small round bowls to be made of glass with divisions, in which we have, by the help

of a microscope, viewed the insect, having only a little water, to the utmost advantage; and gained a very distinct knowledge of all its parts. It may likewise be very conveniently examined by the microscope, if it be placed in a small drop of water, dropped upon white paper; provided one takes care to avoid the brightness produced by the water. If the insect should happen not to be distinctly seen upon a white ground, we may change the white into yellow, green, blue, or any other colour: we have, for this purpose, put our little glass bowls before mentioned, into a cake or composition of starch and blue, into foot, vermilion, and other paints; and by this means our endeavours have been crowned with a fortunate event. Since, therefore, the method we have been hitherto explaining, has been very useful to ourselves in discovering a great many water insects, and viewing their parts with the help of a microscope, we no longer desire to conceal it, but communicate it for the service of the public. To this we shall add, that among all the kinds of microscopes which have been invented, none is better than that which has only one lens. But since we owe the benefit of this instrument or contrivance to that very great and incomparable mathematician, Mr. John Hudden, senator of the city of Amsterdam, we esteem it our duty to do this renowned gentleman honour; and to give him public thanks for the favour he has done us in this respect.

*A particular treatise on the Scorpion, which likewise belongs to the first class or order of natural changes.*

NEXT in order under this head, come the Scorpions, which are viviparous, according to the observation of Dr. Francis Redi; his words are these: "The thoughts of the great Aristotle were just, who is of opinion that Scorpions are generated by the conjunction of the male and female; the Scorpion not laying eggs, like other insects, but bringing forth little Scorpions alive and perfect in their species: and of this opinion are also Pliny, Lib. II. Cap. xxv. and Ælian, Lib. VI. Cap. xx; and the same thing has been accurately observed by Thomas Furenius, and by the very learned John Rhodius, in their medical observations.

"As, therefore, I had nothing to follow or avoid, I began at once my experiments; and having brought a large quantity of Scorpions from the mountains of Pistoia, in Tuscany, I selected some of the females, which, by their size and roughness, are easily distinguished from the males, and on the 20th of July put them in separate glass vessels, and kept them without food; some of them died before they brought forth their young. But one of those on the 5th of August brought forth, not eleven, as Pliny

"and Aristotle have imagined, but thirty-eight Scorpions, well shaped and of a milk-white colour, which every day changed more and more into a dark rusty hue. Another female in a different vessel brought forth twenty-seven of the same colour, on the 6th of the same month; and the latter, as well as the former, seemed fixed, as it were, to the back and belly of the female. On the 19th all these young ones were living, but afterwards some of them died daily, so that I lost all soon after, except two which survived until the 24th of August, and then they died also.

"In the mean time, I had a mind to see how these insects were placed in the parent's womb before their birth. Having, therefore, opened some of them, I found different numbers, yet never less than twenty-six, nor more than forty; all which hung on an oblong thread, and were covered with a very fine and delicate membrane, in which one Scorpion was very clearly distinguished from another, by a certain partition resembling a fine film." Thus far Dr. Redi, in Exp. Circa Gener. Insect. But the description given by him does not at all satisfy

fatisfy me, since his description of the uterus and its oviducts is not sufficiently exact; nor does he take any notice of the place where the oviducts are connected with the uterus, and form one common excretory duct. I should likewise be glad that the extremities of the oviducts had been examined by him, and that he had described the rudiments of the eggs contained in them. He should have told us, what that oblong thread is of which he makes mention, and which was doubtless one of the oviducts. The membrane, likewise, which separated the Scorpions from one another in the oviduct, could be no other than the membrane which covers the foetus of this insect, and ought indeed to be called the proper egg of the Scorpions. It is probable that he found this egg in the extremities of two oviducts; though his words import, that there was only one oviduct, which he calls an oblong thread; which seems to me scarce probable, since we are taught the contrary from the analogy there is between the uterus and oviducts in all insects. And when he makes mention of a partition, which, like a very fine film, separated the young Scorpions, he seems in that place to divide an oviduct: but the author, ingenious as he is, speaks here so perplexedly and obscurely, that it seems as if he intended to propose an enigma for some future *Ædipus*.

I am perfectly satisfied that Scorpions, which I have never known to be referred to any order, ought to be inserted in the first of my plan, with this difference only, that they are brought forth alive; whereas the Louse only lays eggs or nits, from which its young afterwards proceed. The Scorpion is, therefore, like the viviparous Snail, which excludes its eggs in its own body, and afterwards brings forth its young alive, but at different times and intervals; whereas the Scorpion has thirty-eight young ones together at one birth, which afterwards, by degrees, increase and grow bigger.

As the true figure of the Scorpion has not yet been given by any person, that I know of, I shall here represent their natural shape. And that I may the more accurately execute this, I shall divide the Scorpion into the head, breast, and belly. The Scorpion's head seems jointed, as it were, to the breast, as I have found in all the dried Scorpions that I have seen hitherto. In the middle of the breast, or in the head connected to it, are two eyes; and a little further towards the fore parts, there is likewise another pair of eyes, placed as it were in the forepart of the head. Under these are observed two short arms, forceps or pinchers, Tab. III. fig. 1. *a*, which the Scorpion, doubtless, makes the same use of as others animals do of their teeth, and with which it breaks its food, and thrusts it into its mouth. These four short forceps, and the four eyes above them, have never, to the best of my knowledge, been observed or described by any person, but hitherto entirely neglected. The Scorpion can at pleasure put back these forceps or teeth

into its mouth, so that none of them may be seen.

Under the breast are eight articulated legs *bb*, each divided into six joints, the two hindmost of which are each provided with two crooked claws, and the legs have here and there some hairs. At the foremost extremity of the head are two flagella or whips, or crooked arms like pincers *cc*, composed of four joints, the outmost whereof is fortified, as it were, with a thumb, by the contraction of which the forceps is formed. This joint is thick and strong, and contains stout muscles, as we likewise observe in the claws of Lobsters. The belly is divided into seven little rings *d*, from the lowest of which arises a tail composed of six joints, which are bristly and formed like little globes *e*; the last of these joints is armed with an aculeus *f*, or sting.

Dr. Redi says, he saw that the Scorpion discharged a very small drop of water through the sting in its tail; which I should easily believe, since the poison infused by Bees through their sting into a wound, likewise consists of a very clear liquor. And this makes me suspect that the external sting of the Scorpion, in like manner as in Bees, is no more than the sheath, wherein the true aculeus or sting is concealed. I once undertook to examine this matter in a dried Scorpion, but since the lowest ring of the tail, from which the sting hangs, became hard as a horn by drying; I could not accomplish my design according to my wishes. I observed therein, however, two small tubes, which seemed to end in a sacculus or little bag, that carried, I suppose, the poison, and had on the fore part two aculei or stings; but all these things were so confused, that I would not presume to affirm any thing certain concerning them. If I had had the Scorpion alive at that time, and ready at my hand, it would have been very easy to have clearly discovered this matter.

In another kind of Scorpion, fig. 11. I saw that the two foremost crooked arms *aa* differed very much from those which I have before described; for the forceps were, in comparison to the former, very small, and ended in a sharp point. On the fore part of the head were, like these, two forceps or teeth before-mentioned; and above these on either side were three eyes, so that there were six in all. In all other particulars it was like the former Scorpion; unless that in the rest of its limbs there was here and there some very slight difference, as is seen in the figure. This little Scorpion was very delicate, and it may be easily known, from the smallness of the forceps, that this kind have less strength than those of the former; but then the longer they are, the more conveniently they can take hold of their food.

As the larger the animals are, we can attain to the more accurate knowledge of them; I shall now represent again, in a very large Scorpion, all the parts which I have described in



the two former; particularly those two bristly teeth, or foremost forceps, fig. III. *a*, are in this seen very clearly; as also its two foremost eyes *b*, of which there are six on each side of the head, some gradually less than others. In the middle of the head, where it is connected with the breast, are two eyes, which may be distinguished easiest of all, and which have therefore been also observed by all authors; who, notwithstanding, seem to take no notice of the twelve other eyes. The head, breast, belly, tail and sting, together with the legs, forceps, hair and claws, are likewise much more conspicuous in this than in the two former. The six joints of the legs are exactly in this the same as they are in the smaller Scorpions. The crooked arms of this also consist of four joints, and carry forceps of an horrible bigness; but there is a peculiar difference in the tail, since it is divided into six joints in small Scorpions, and in this had only three: I doubt, however, whether this be so by nature, since I think I could perceive that the tail had been broken, and glued on again before it came to me; but all the articulations were not joined together. The colour of this Scorpion is very black, like pitch.

I have another Scorpion almost the same size with the last, having a tail composed of five joints, whereof I have the same suspicion that I had of the former, that is, that it is not natural to it; for I am thoroughly persuaded, that in all kinds of Serpents the tail consists of six joints. The latter was brought me from America, but the former very large one, the figure whereof I have given before, from the East-Indies. The figure of the American Scorpion is like that from the East-Indies. Doctor Padbrugge, governor of the Molucca islands, has this year sent me a drawing of a peculiar Scorpion, which was of a light red, but is now grown of a blue or sky-colour; its tail is com-

posed of six joints, and in other particulars it differs not from the very large one which I have represented, only that it is not half so large.

In Holland there is found a certain species of Scorpions, which are very small, and no bigger than a Bug; they likewise resemble it in the hinder part of the body, which is divided into eleven small rings, and wants a tail. They have six legs, each of which consists of four joints. The breast, which is connected with the legs, is distinct from the head; the forepart of which has a pointed beak covered with hair. They have likewise many eyes, which are distributed over the sides of the head: the crooked arms are placed before the eyes, and spring from the head like the antennæ or horns in Butterflies, being composed of four joints, including the forceps, the structure whereof is the same with that of the Scorpion's before represented in fig. II. All these parts have on them small, bristly hairs, and are of the same colour with the common Scorpions of Germany and Italy. The arms before-mentioned are very long and large, in comparison of the size of this animal; nor can there be a more agreeable sight than the remarkable motions it makes with their assistance, when it changes place, and moves itself like a land Crab. This insect is often found in benches, chests and coffers, that have not been cleaned for a long time, where, in my opinion, it maintains itself on those little animals which there multiply in the dust, and of which there are many kinds; seizing them, I suppose, with its forceps, and swallowing them for food. I have likewise found this insect in scarlet cloth, which had been kept long in a chest. I have nothing farther to say of this animal; I have described it according to the parts that I have found in it, when fixed on a needle and dried.

*The natural history of the covered Snail, illustrated by accurate drawings.*

THE INTRODUCTION.

**T**HOUGH the Snail was reckoned by the Jews among unclean animals, which they were forbid to use as food, they did not scruple the application of it to other purposes. The royal psalmist borrows a moral simile from it, and prays, that the wicked may "consume away like a Snail;" and, however impure and slimy, it must notwithstanding claim the consideration of those, who are desirous of being acquainted with the wonderful works of the creation.

There are many christian nations who place Snails amongst the dainties of the second course, but they are only those of a particular kind. In Holland no Snail is used for this purpose, but the valved kind found in the sea or other waters, the muscles being of a pretty tenacious substance. The way of eating them,

is boiled and well seasoned with salt; and no part of them tastes strong except the liver.

Other nations, as the Italians, Germans and French, eat the garden Snail, especially at the season, that, after a fast of several months, it has cleansed itself of all impurities; for during this period, there grows upon the mouth of the shell a covering, composed of a substance not unlike plaster, which hinders the earth or any kind of dirt from getting into it. In this manner this kind of Snail passes more than seven months, from autumn to spring, without any motion or food.

The shells, blood, and opercula of the Snail kind have likewise their uses in medicine. Amongst the opercula of Snails, that called *Blatta* chiefly deserves our attention; it belongs to the *Murex* or purple Snail, and as it comes

to us from Byzantium, a town in Africa, where the art of dying purple formerly flourished, it has obtained the name of the byzantine Blatta. However, this word Blatta is now made use of, to signify the opercula of all kinds of shell fish without distinction, though there are so many and so great differences in this single part, that an entire treatise might be wrote on it alone; and certainly such a treatise might be very useful, as well as entertaining.

My intention, at present, is to treat of the Snail, known by the name of the vine or covered Snail, and describe its manner of living and propagating its species, which I have made myself acquainted with by a very exact dissection: by means of this, I shall, among other things, prove, that in this creature both the brain and spinal marrow have their proper muscles; and shall likewise shew in what manner this, in appearance, so contemptible a creature is provided, by the greatest of all wonders, with eyes; that may not only be distinctly known for such, but even felt; and how it is at once both male and female in the same body; as also how it proceeds by generation, from an egg, like other animals. Hence will appear the folly of that common opinion, which makes them proceed from slime or mud, a fancy which could only find place in the empty heads of those, who, instead of studying God's wisdom, power, and goodness in his works, spend their lives in reading books which misrepresent them, or at best, only represent them at second hand, stealing from one another.

Hence also it will appear, that this animal is to be ranked in the first species of my four natural orders of mutations, in which insects proceed immediately from an egg, without passing through any intermediate state, as I sufficiently have described in the general history of insects.

I shall here describe that kind of Snail, to which the inhabitants of Brabant and Flanders have given the Spanish name of Caracol. It would be an endless task to treat particularly of every species of Snail, Cockle, Periwinkle, and other creatures of this kind, that are found with or without shells, though all belong to the subject we have in hand; since for this purpose, it would be requisite to call all nature together, and search the seas and rivers, and every part of the earth.

Nevertheless, I shall take notice, in the proper place, of what I have occasionally seen and observed in other kinds of Snails; such as the house Snail, which has a little stone for its sternum; likewise the common Snail, which we meet with in path-ways, without any shell like the first. I shall also say something of the garden Snail, the fresh-water Snail, the Crab, or salt-water Snail, the mother of pearl, and some other kinds of Snails, which I have had opportunities of seeing and examining. Some of these live upon trees, and there are others, but very scarce, which have the spiral line described by thin shells turned the contrary way.

## C H A P. I.

*Of the shell and soft part of the Snail in general, and particularly of the four horns which spring from the upper part of its head, and of the eyes that appear in them, with a description of the construction and motion of those parts.*

**B**EFORE I begin to speak of the body, or soft part of this creature, I shall say something of the shell or hard part: this is preposterously called its house, if we take that word in its proper and common signification, seeing it is the very skin of the Snail, without which it would be as impossible for it to live, as for a Lobster, or a man who had been flayed, or a tortoise drawn out of its covering. This crust therefore ought to be considered as the bone of the Snail, in which all its muscles are inserted, as the muscles of quadrupedes are fixed in theirs. This is very observable in sea Muscles, as I shall in its proper place accurately demonstrate.

To pass now to the soft part of the Snail's body; it is to be observed, that what appears of this part, when it moves forward with its shell, is about three inches and a half long, and almost two inches broad. In the fore part of its head appear four horns, two greater,

Tab. IV. fig. 1. *aa*, and two lesser *bb*, without any spots at their extremities. Under these horns we may perceive its external lips, and its mouth *c*, and between the first and the second horn is the perforation *d*, from which issue the organs of generation, when they swell up for that purpose; at other times this hole is so nicely closed as not to be discernible. Behind, towards the edge of the shell, is a thick border or lip, which on every side, both within and without, adheres firmly to the external edge, and internal surface of the shell; but this part is like the skin, which in naked Snails hangs under the fore part of the body; and under which, as under a veil, they hide their head and horns when they are touched. In this lip or border there are on the right side two openings, one of which *f* serves for the creature to discharge its excrements, and the other *g* to breathe. In the body there evidently appear those flat and broad fringes *bbb*, by the help of

of which, chiefly, the creature moves: they consist of very strong muscles, for which reason I call them the Snail's feet, as resembling in some measure the feet of Bats and Ducks; whose claws are connected to each other by a membrane. This sort is covered underneath with a thin skin, and the upper part is bent, with a number of glandulous spots or warts of different forms, amongst which there run a great many vessels: but I shall hereafter speak more at large of these particulars.

Fig. 11. If after having taken the foregoing survey, we entirely strip off its shell, or rather stony bone *c*, from the tender part of its body, we shall find the fleshy part which heretofore lay hid, is exactly of the same spiral form and shape, fig. 1. *k*, with the shell that covered it, but then it is perfectly tender, without the least sensible hardness.

Here all the intestines, in a manner, appear through the extremely thin and transparent membranes of the body, which are all over spread thick with vessels: for the hard surface being once removed, the least puncture made in the skin that remains, is followed by the effusion of the Snail's blood, like a mucous humour, of a pale purple colour. This can only happen from the body's being all over pervaded by a great number of veins and arteries, so that on dexterously clipping the smallest portion of its foot or border, you may perceive little streams of blood issuing from the wound.

To remove the shell or bone of the Snail, it is best to use a pair of flat pincers, by means of which the shell or bone may be gradually broken and torn away, till we come to the part where the muscles of the body are inserted into it. Tab. VI. fig. 11. *a*. The tendons of these muscles must afterwards be separated by a flat spatula; we must then proceed as we begun, by gradually breaking and tearing away the remains of the shell, till there are but one or two twists left; out of which the little tail in which the body terminates may be then drawn without any difficulty.

All the four horns, Tab. IV. fig. 1. *aa*, *bb*, agree with the upper part of the skin of the body, in being adorned with little glandulous unequal grains, fig. v. *eee*, like so many warts; but those on the horns appear the smallest and most exquisitely divided. The horns themselves, when viewed through a microscope, look as if they consisted of a greenish transparent substance, like veal jelly, through which appear some whitish spots; these I take to be the glands made use of by the creature for the secretion of its slimy or mucous humour. This slimy matter serves to moisten constantly not only the whole body, but the horns; and in my opinion, the constant moistening of the latter is extremely necessary, considering how often and how swiftly the Snail is obliged to stretch them out and pull them back again; an

exercise which, without such a contrivance to keep them slippery, could never be performed.

Though all four horns are very remarkable, the two uppermost and longest deserve our particular consideration, both on account of the power of motion given them by the supreme architect, which is very singular, and exceeds all human art; but more especially because they have evident eyes, appearing like two blackish points, in their extreme ends: they at times stretch these eyes in a manner not to be described, yet by a regular motion, out of the body; and sometimes they hide them by a very swift contraction in the cavity of the abdomen.

I know, indeed, that many who have laboured to investigate the nature of these little creatures from speculation only, have given the name of eyes to these blackish spots visible in the tips of the horns; but their own fancy has afterwards made those very persons change their opinion, when they saw that the Snail struck those horns almost against every object, and that they shewed no signs of quickness of sight. But the knowledge of nature cannot be acquired by reasoning only, for unless we make experience go hand in hand with reasoning, we shall err all our lives\*. I shall therefore lay aside all conjecture, and describe these eyes and their membranes, humours, muscles and nerves; as I have seen them, that the hidden, and for ever to be celebrated miracles of God may be made manifest to all lovers of his works, who have not opportunity to search themselves into these matters.

Those who thirst most after true knowledge, are with reason afraid, lest the poison of fallacies should be offered to them, instead of the food they seek of true knowledge.

To methodize and set all these things in a clearer light, I have subjoined the figures of all these parts immediately after their description. The first thing that deserves notice in the examination of the upper horns, is their extremity, in which three particular little parts are observable. The first of these little parts is placed in the middle, and is a very black spot, Tab. IV. fig. 1. *aa*. This is the real eye of the Snail, fig. v. *a*. The second is the optic nerve of this eye *b*, which, by a certain production like a little globe, swells and appears through the skin. The third, constitutes the extreme end of the muscle of the eye *c*, whereby the external skin, which is equally extended thereon, is first bent in or drawn back, when the Snail endeavours to draw its eyes into its body. This motion always begins about that part or division of the eye *d*, which lies in the middle between the muscle and its nerve. But as the apex or end of this muscle is somewhat more prominent than the eye or its muscle, it therefore first receives all injuries, whenever the creature happens to strike its little horn

\* Perrault, after many observations, expressed his doubts, whether Snails had really any eyes or not; and Dr. Brown has placed his opinion of their having any among vulgar errors; but this author's observations are confirmed by many subsequent examinations; and very lately, Dr. Peterfield has shewn, they are to be seen very distinctly. His account is published in the Edinburgh essays.

against any thing. Thus the eye is defended and kept safe. Moreover, these extreme ends of the horns are stretched smooth, and have a bright surface, somewhat red, and full of prominences or little warts; but the glands *eee* appear to be situated a little lower, between the globular production of the horn, and they are likewise divided on the inside by very small whitish points. The furrows or ridges visible at the bottom between these glands, are the vessels which carry the glutinous humour to all these parts, and again bring it back from them. And that these muscles and nerves may lie convenient, the whole horn is hollow *f* on the inside; so that if it be dissected transversely, the extremities of these parts present themselves on the inside.

To have a more clear idea of this matter, it is necessary to open the Snail, for which purpose you must have a small and sharp-pointed pair of scissors; one of the points of these should have a little ball made of sealing wax fixed on it, to prevent the inward parts from being wounded. Then, after opening the middle of the back, the body must be cut to the verge of the Snail, Tab. IV. fig. 1. *e*; after this direct the scissors forward, and dissect the skin as far as the fore part of the head, between the two upper horns. The dissection being thus made, the first thing to be met with, immediately under the skin, is a certain muscular delicate membrane, which is very thin and fine; it covers all the inward parts, and is provided, here and there, with muscular fibres, which run across from one side of the body to the other, and are inserted into the sides of the shell; you may also then see the stomach, organs of generation, and the like. Afterwards the brain, which lies on the upper part of the stomach and over the gullet, presents itself; and immediately afterwards, the horns themselves drawn back, with their muscles in the abdomen.

Having thus briefly touched upon these matters, I shall proceed to explain and describe by figures, how these four horns, Tab. IV. fig. vi. 1, 2, 3, 4, are circumstanced, when they are drawn into the body, and their inward sides are turned out; for which purpose, each of the horns has its proper muscle. The two upper and largest horns have their particular muscles *aa*, each of which is connected by its proper tendon to the two muscles which move the middle of the body, and these are afterwards with them inserted by their tendons into the spiral part or folding of the shell, Tab. VI. fig. II. *bb, nm, a*.

The two lower horns, not being of such importance as the upper ones, are provided with two smaller muscles *bb*, which arise from the larger *cc*, and draw in the lips of the snail. This is likewise represented in Tab. VI. fig. II. *ll, mm*.

The manner in which the horns are twined and stretched out of the body, is a much more difficult thing to be described; though I think, indeed, that the inward coat, or muscular part

of the horn, performs that office, with the assistance of some other smaller and adjacent muscles, as well as some stronger ones, whereby the fore part of the head, and the skin of the snail is moved towards the outside. The true action, which I think the inward annular muscles have, seems to consist in this, that some of them are successively contracted and stiffened after others, by which means the horn is continually rolling out, and one small portion of it is pushed after the other; to this action, the peristaltick motion of the intestines, as far as the latter is performed by the contraction of the annular muscles, bears some, though perhaps a distant, resemblance.

But the optic nerves deserve more consideration, both on account of their texture and their motion. Before I describe these, I shall take occasion to say something of the brain, from which they arise. The brain *d* consists of two globular little parts, and, by this property, is divided into two portions, as it is in man. The first is placed in the head; but because this, as well as all the other parts of the snail, is, in a wonderful manner, moved sometimes backward and sometimes forward, no fixed or certain place can be assigned to it. I therefore shew both the brain and optic nerves in the situation wherein I have delineated them. The hinder part of the brain, is drawn in Tab. IV. fig. vi. *e*, to the skin of the snail's head, and is situated a little above its shining tooth *f*; for the brain, together with all the parts of the gullet and mouth *g*, and also the stomach and salival vessels *ii* are driven to this depth into the body, by the strength of a muscle appointed for that purpose; but when all the parts are again rolled or turned out, we may then say, the brain is placed at the fore part of the head. Hence it is evident, that the motion of the brain in this creature ought to be observed as a thing worthy of the highest admiration; wherein both the wisdom and infinite power of the almighty are manifest; since he has been pleased to render this part, which in man and other animals he made immovable, by enclosing it in a hard bone, capable of motion in the snail, by the power of its muscles.

The optic nerves of the first pair of horns having spiral originations *kk*, arise on both sides from the brain, which has been so contrived by the omnipotent wisdom of God, that they might conveniently obey, and evolve or turn themselves out, when the horn is, in so stupendous a manner, protruded forth out of the body; and to prevent the least disorder from this egress and regress, the omniscient creator of the universe hath involved and fortified these nerves with ductile membranes *ll* and ligaments, with so much art, that no such disorder is ever to be feared. Nay, lest this nerve should be in any danger, when it is turned up and down inwardly in the cavity of the moveable horn, the wisest of all architects has constructed that part of the muscle which is fixed to the extremity of the horn in such a manner, that

at the same time it performs the office of a sheath or case, wherein *m* the nerve lies in perfect safety, so that it appears to be faintly visible through it; it may, however, be disengaged from this covering, and then its spiral windings appear so admirably constructed *n*, that any person who contemplates this prodigy of nature, must be astonished and struck with amazement.

That muscular, and at the same time membranous, little part which covers the nerves, is so tender in this place, that it may be very easily separated, and divided into parts, with the point of a needle, or with an ivory bodkin; after which the muscle resembles as it were a grey delicate membrane, Tab. IV. fig. VI. *o*. The nerve itself swells by degrees into a globular form *p*, at the end of which is placed an eye *q*; of which I shall presently speak particularly.

The little nerves *r* of the two lower horns, do not arise directly from the brain, but have some parts intervening; but as to the twisted nerves *s*, which are conveyed towards the fore part of the skin, to the root or basis of the horns, they have there the same texture with that of the nerves that belong to the upper horns, though they have no eyes in the ends of them. The same order, in every respect, the same wisdom and providence, are manifested in the construction of these lower, as we have before mentioned in relation to the upper, pair of horns.

The two smaller of these little nerves spring immediately from the basis of the brain, and are dispatched in the same manner as to the larger horns *t*. In fine, all the muscular parts of the palate, mouth, and jaws, which I shall hereafter describe particularly, are furnished with two small nerves *v*, which administer to their motion; these I have represented in Tab. VI. fig. 1. at the letters *bb*, where may be seen the method in which they are bent, when the brain is moved forward.

Fig. VII. *a*. The eye itself is very conspicuous, and in some degree of the form of a round onion; but is a little flatt or smooth on the verge, and swells somewhat into a point where the sight is exerted. But I could not observe that the eye has more than one coat, which covers it on the inside, and which I call the uvea; if this uvea be in the least, ever so lightly, touched, it makes the place it lies on very black, like ink: this I shall shew more clearly hereafter, for I now only describe the eye, as it appeared to me through a microscope. I here likewise shew the grey muscular membrane *bbb*, which covers the eye; and I also exhibit the manner, wherein the circumference of the eye is connected with it: the optic nerve *c* is here represented likewise larger than natural, and its texture and form are shewn; and after what manner the eyes are placed thereon. Here is likewise shewn how the inverted horn *d* is connected

to all these parts, and the cavity *e* it passes through; as also after what manner, and in what place, it is protuberant *f*; on account of the muscle which draws it back into the body of the creature; and which is there fixed in the end of it.

I have observed five distinct and visible parts in the eye of the Snail, as clear as the sun at noon; first, the external coat, which I call the uvea; afterwards on the inside, the aqueous, the chrystalline, and the vitreous, humours, with the arachnoide tunic. But who can credit this? for it seems indeed improbable that on a point not bigger than the nib of a writing pen, such exquisite art, and so many miracles, should be displayed. But what is there that equals the power of God, who is the contriver and creator of all these things? nor can there be any room for chance here, unless in the opinion of those, who destroy and reject the steps of natural knowledge, lest they should ascend in her paths, and be led to the wisest of architects; and, by contemplating even the most minute of his works, be incited to prostrate themselves with a sacred reverence, and most profound humility before him, bidding adieu to their own opinions and former life, which, without the love of God, has been hitherto addicted only to the world.

If the uvea be viewed with a microscope, it has the appearance of a turnip roasted in the fire, until it is very black, and burst in some places; and has some visible small fibres, which connect it with the adjacent parts. But when this eye and its coat are put, with a very fine pencil, into the fourth part of a drop of water, for more water would overflow it, and, after stirring them a little, they are cautiously and slowly touched; the water at length becomes black likewise, and shews the remains of the particles swimming in it: the same thing will happen also if an experiment be made on the uvea of the human eye. But when all the moisture is wiped off clean, and a little wound is made in the eye with two fine and very sharp needles, Tab. IV. fig. VIII. *a*, the aqueous *b* humour will be observed to burst out from thence. If this eye be afterwards press'd more roughly, you will see a more clammy humour issuing from thence *c*; which is properly the vitreous humour. And lastly, after that, the chrystalline humour, which is of a harder consistence, and of a plane round figure *d*; it is limpid, transparent and shining; but it does not run out, until you break the arachnoide coat, which covers it, and which is the fifth part of this eye. From these observations we learn clearly, how "the invisible things of God, from the creation of the world, are clearly seen, being understood from the things that are made, even his eternal power and godhead, so that they are without excuse, because that when they knew God, they glorified him not as God." Rom. i. 20, 21.

The

The use of the eye in the Snail, and the manner wherein it exercises its visual faculty, is a matter of great difficulty to investigate. The grey coat, Tab. IV. fig. VII. *bbb*, which is the expansion of the muscle of the eye, and may be very much dilated and contracted, seems to me to move various ways; nay, that it serves as a cover like our eye-lids: but the bigness or smallness of the pupil or foramen, or aperture of the uvea, and in what manner it is contracted or dilated, as light and objects vary, I have not hitherto been able to observe, nay, I never yet saw the pupil of the eye in a Snail; nor should any wonder at this, if in the human eye, though so big, the foramen or aperture of the pupil is no larger than a Pidgeon's quill; what a small and fine aperture then must the pupil have in this little point, and how few rays can pass into it? however, I don't doubt but the pupil is contractable and dilatable; for I have observed the ciliary duct there, by which, when the pupil is dilated, the eyes of the Snail can receive the humors, and collect external visible objects, which, after passing the humors, are afterwards received in the retina, placed underneath at the bottom of the uvea, by the optic nerve; which is the cause of vision. Hence it may, perhaps, be justly inferred, that the sight of the Snail must of ne-

cessity be very dim; for we ourselves do not see clearly in the day-time, if we go into a house out of the open air; the pupil of our eye is by that contracted in such a manner, that fewer rays of light are collected in our eye. Nay, perhaps the Snail does not receive the rays of light and objects but at a distance, and only sees them through a cloud as it were, and cannot distinctly know them near at hand; as the man born blind is said in the gospel to have seen men like walking trees: I could not at least hitherto observe, that the Snail sees well the things which are near it, notwithstanding all the attempts I made for this purpose. In the eye of the Mole I have likewise seen, even without a microscope, the three humors before-mentioned, but they are there larger, and easier to be distinguished, though it is probable even this creature cannot see distinctly under the earth.

I shall conclude this chapter with admiring the strange and remarkable things which I have shewn in it, from the clearest experiments, and which seem to me the more admirable, the more diligently I meditate upon them: God truly every where shews that he is worthy of the most humble adoration in all his works, which we may and ought diligently to search into, but can never fully comprehend.

## C H A P. II.

*Of the lips, mouth, teeth, tongue, palate, œsophagus or gullet, and certain muscles of the Snail.*

**B**ETWEEN the two lower horns of this creature are seen its lips on the outside, Tab. IV. fig. 1. *c*, and whilst the Snail draws them asunder, the intermediate skin is observed to be set like the edge of a saw, as it were with prominent little teeth. This can never be seen better than while the Snail is eating, or when the mouth, palate, and jaws, together with the outward skin, are taken off and dissected. In this case, Tab. V. fig. 1. the teeth *b* immediately appear behind that skin *a*; and in a boiled Snail they are rendered very visible, Tab. IV. fig. 1v. *r*, because the skin and lips become thus contracted. These teeth are connected by a certain horny concretion, Tab. V. fig. 11. *a*, the teeth themselves being all made of a horny substance; and they are of a light red colour. Since therefore all these teeth are connected one with the other, they ought to be esteemed, in some measure, as one tooth. They are eight *b* in number, and some are larger and more prominent than others, as appears by the microscope. This little part is made in the form of a circle *c*, its convex side lying on the inside upwards, towards the skin, to which it is strongly connected; but its toothed concave side, with which it bites, is directed on the outside. In the middle of the

convex surface of this tooth, there is a small furrow, in which some of the muscles that move the whole are fixed. The tooth afterwards becoming insensibly membranaceous, expands itself like a pretty large pyramid or bodkin, fig. 1. *c*, and in that form constitutes a great part of the palate, which, on each side of this expansion, is beautifully variegated with small ruddy points: these here and there shew little parts that are somewhat hard, and of a horny substance, and serve to prevent the inward part of the body from being wounded or hurt, in case the Snail should at any time swallow any thing too hard or rough. But this cannot be seen, unless the inward parts of the mouth be first dissected, and taken out separately. Then two small, narrow holes or apertures *d* are seen on the upper and under part in the palate, which convey the saliva out of its ducts into the mouth.

In the lower part of the mouth, or where our lower jaw is placed, are, in the Snail on the fore part, two small fleshy substances *e*, which may be called the inward lips, for they contribute greatly to direct the passage of the food; that is, to carry it towards the gullet, and thrust it down. Behind these, a certain very delicate and tender membranous crooked cartilage present

fents itself to view; at the lowest and inward part of which the tongue, Tab. V. fig. III. *a*, and its muscles take root. The tongue itself lies under the concave fold or winding of this cartilage, fig. 1. *f*, and is covered therewith when the Snail swallows its food, just as the epiglottis in us covers the top of the aspera arteria or wind-pipe, when we are eating, lest any thing should slip into the wind-pipe. This texture of the tongue in the Snail approaches yet nearer to that of the tongue of the Serpent kind, which in the same manner shuts itself up in such a cavity. The tongue of the Snail is thus placed in a remarkable cavity, and its basis or root lies in the cavity of the neck towards the belly, where it is observed to swell like a spheroid or oblong globe, fig. III. *b*; but a little on the inside of that part where the tongue appears, there is seen a very delicate muscle, which draws the tongue together with the whole mouth, palate, jaws, and even the brain itself, inwardly into the belly, or at least into the neck. See Tab. IV. fig. VI. and Tab. VI. fig. II, *e*, *f*, *g*.

On the tip of the tongue of the Snail *c*, there is a little horny bone, cut, as it were, into two or three very tender little teeth; with

which, as with a hook, the Snail, when it is about to eat, first lays hold of the small herb, and immediately after suddenly snatches and pulls the piece into its mouth; afterwards it nips them pretty fast with its teeth, so that the noise it makes in biting and eating may be sometimes heard very distinctly. The Snail will sometimes swallow a piece as big as an hemp-seed. These parts of the mouth have three muscles remarkably delicate, by the assistance of which they are, at the creature's pleasure, moved out of the cavity of the body. These muscles are fixed in the lower side of these parts *d*, which are represented invertedly in this figure. As these creatures are most immoderate devourers of vegetables, the keepers of vine-yards in the wine countries anxiously gather them, when the vine puts forth its tender buds and first leaves, and tread them under foot. This I have seen transacted as a work of great consequence in France. We may therefore reckon Snails as a part of the host of God, wherewith he can chastise bad people in the same manner as he did the Ægyptians, with voracious insects of the same nature.

### C H A P. III.

#### *Of the taste, smell, and certain actions of the Snail.*

**I** For a considerable time kept in my chamber, and provided with necessary food, several Snails: these were inclosed in a box, placed in a wooden bowl, and covered with a mat full of holes, through which they could stretch their necks, that I might be able to find out their manner of acting, and sometimes view them with a microscope. I fed them with radishes, lettuces, sorrel, mallows, and other succulent and dried vegetables, which, after keeping them a little in water, I gave them fresh every evening; for they naturally eat in the morning and evening, and they love juicy and fresh herbs much better than old and withered ones. From this I observed, that they had a nice appetite and taste, as well as other creatures, for which purpose they have also gustatory nerves.

They have likewise a very quick smell: this I observed, when I moved a little fresh food towards them, for they immediately perceived it by the scent, and crept out of their little shells and came to it. Thus they were kept alive; but as they were in a dry place in my chamber, I at length observed they did not thrive there for want of dew and rain; nay, that sometimes they lost their appetite, since they would lie contracted within their shells, and were hidden entirely in their horny skin. But I at length found out a method of giving them rain, as it were; which I did, that they might come into the light again, and seek

such food as I laid before them. From this I observed how little we are able to do by our own boasted powers; who, from our very miserable infirmities, cannot, I will not say, make, or even accurately examine, but scarce can with our best diligence give these animals due food or nourishment.

In order to give them water in the manner before mentioned, I made use of a brass tube, to which was annexed, by a worm, a small globe of the same substance, which was pierced with fine small holes, and had been originally made for the purpose of watering some plants, for feeding other insects. This machine forms a very beautiful kind of rain, that falls in little drops. As soon as the Snails feel this little rain, they immediately begin to creep: in the mean time, it is pleasant to see with what velocity they can turn in their little horns, and hide them in the inside of their body, as soon as the little drops fall upon them; so exquisite a sense have they in these tender parts, and indeed the whole body. This creature is very timorous, and retires into its shell, when it finds itself disturbed by the least thing that it is not used to. If it be struck or handled, it not only retires very hastily into its shell, but it immediately covers its whole body with a glutinous moisture.

Whether Snails have the sense of hearing, I could not discover by experiment; indeed, I have not observed any sign of it in them,

though I have made a very loud and harsh noise about them. I find, however, that many creatures, to whom authors have denied this faculty, enjoy it perfectly; for example, the

Camelion. I have likewise observed that Frogs and Fishes have this sense; nay, Fish have a wonderful labyrinth of the ear for that purpose.

## C H A P. IV.

*Of the structure and use of the verge or lip of the Snail, and of its respiration and voice, with other experiments: also of its glands, vessels, and what it has in the place of feet.*

**H**A V I N G described the eyes, mouth, and teeth, and treated of the smell and taste of the Snail; it is proper I should now treat of the aperture, through which the parts of generation occasionally disclose themselves. This I shall consider, when I come to speak of those parts themselves, but previously to that, I shall say something of its lip, or the fleshy verge at the head, and of the apertures in it, as also of the fringed margin of the body, and the little excrescences visible on those parts, and of the vessels that run between them.

Tab. IV. fig. 1. The verge that surrounds the whole body of the Snail is not so broad within as on the outside, and is connected very closely to the extremity of the shell both inwardly and outwardly. As this is provided with a great number of muscles, it accordingly acts with various motions, suitable to the different intentions of the Snail. Hence it is, that its true figure cannot be determined, for it is continually contracting, expanding, and changing its form. Where it is annexed to the upper part of the Snail's body, it exhibits two singular incisions like two little tongues; and underneath the right side of the belly, it has a remarkable aperture, Tab. IV. fig. 1. g, which serves to take in air; besides which, it has another *f*, whereby the fæces or excrements are voided, as if by a small, oblong and curled intestine. The colour of this verge is white, with certain yellow spots, grounded, as it were, on a pale transparent green. On the inside, where it is joined to the shell, it is of a blackish colour, somewhat approaching to blue. It has different uses, as appears both from what has been hitherto said, and from what I shall hereafter observe, when I come to treat at large of the Snail's bone.

On the inside, this verge is arched, as it were, and reaches with its cavities upwards, towards the pointed extremity of the body, to the windings of which, these cavities are adopted. Above, in the inward surface of the border, there are several veins, Tab. V. fig. iv. *a*, which run there naked or uncovered. But below in its cavity, almost underneath, on the left side, and in the declivity of the body, is placed the heart *c*, which may be seen to beat, even through the external skin, before that part is taken off: I have therefore marked its figure from the origin with points, Tab. V. fig. iv. *l*. This

heart and its veins are continually refreshed with the air, which the Snail impels into it through the aperture of its verge, Tab. V. fig. iv. *b*: for as the Snail rolls its body out of the shell, so in proportion it drives the air into the cavity of its verge; and again, according as it draws back its body into the shell, so it likewise expels the air from thence. This may be esteemed something analogous to respiration, as I have shewn in the year 1667, in my treatise on that subject, and exemplified particularly in the case of the garden Snail.

When the Snail has crept out of its shell, and is put into water, the air contained in the cavity of this verge makes it swim on the surface; but when the Snail is within its stony skin, and the cavity of its verge is closed and compressed, it sinks to the bottom, if it be thrown into the water. But if the Snail, as it lies in the water, creeps again out of its shell, the cavity of the verge is immediately filled with the water rushing into it, which then does the business of air, which would have been impelled thither; hence it happens, that by a new kind of respiration, this water is sometimes moved within and sometimes without the shell, according as the Snail rolls its body out, or draws it into it.

The Snail has no voice, nor makes any noise, except that it produces a kind of hissing when touched with a stick, or any thing else, and suddenly draws in its body; for then, as the aperture through which the air is conveyed, is in a manner stopt up, it cannot readily get out; and this causes the hissing sound.

Sometimes it happens that, do what we will, we cannot get the Snail out of its shell, in order to make this experiment, by which we might see that the air is forced into and out of the body, through the aperture of the verge. But if you have a mind to make the experiment, and observe in what a wonderful manner this aperture then shuts and opens itself, you must strike the shell a little on the hinder part with the back of a knife; then immediately the Snail, compelled to it by the pain that it feels, will creep forward, and will plainly shew the opening through which the air passes, together with the manner of its respiration.

The extreme fringed margins of the body are planted as it were with numerous glandular tubercles or excrescences, Tab. IV. fig. 1. *bbb*,  
from



from which the mucus or slimy moisture issues. These tubercles are covered with a great number of vessels, which run between and furnish them with matter for the slimy humour. These glands project beyond the surface of the skin, and are covered as it were with white transparent points, between which, as between ridges, or in furrows, the vessels are seen to creep. This order is contrary to that which the all-wise Creator of the world hath chosen in the leaves of trees; for in the latter, the veins and nerves are usually somewhat prominent, and the succulent part is depressed and placed between them.

The greatest part of the substance of these fringed margins consists of three membranes. The first and uppermost of these is a glandular skin; the middle one is a glandular, but thin, membrane; and the lowest is a somewhat thicker membrane smooth and slippery. Under these the body of the Snail is interwoven with strong muscles, by the help of which, and with a singular kind of motion, resembling, as it were, the waves and billows of the sea, it moves at pleasure its shell and whole body. These fringes therefore perform the office of feet in this little animal, and they may be properly called the general foot of the body. This whole part is tender and spongy; yet, when it is pricked with a needle, it can contract its muscles with so much force, that it draws up and joins itself together, so as to become as hard as leather.

The part of the body which lies under these is very white, and is covered with an even skin, which seems to me more tender than the former; but it is glandular like that, and is fitter for motion, by reason of its fineness. If the Snail be suffered to creep, this motion may be observed very beautifully; for if the glass be inverted, as the Snail is creeping on it, this admirable motion will be perfectly conspicuous: it resembles small waves, which, when agitated with a gentle wind, slowly follow each other; nor can I explain this motion by a more proper example.

As to the motion of the animal spirits being observed, like small globules moving from the head to the tail, and again from the tail to the head, in a naked Snail thrown into the water; it is indeed a mere chimerical notion, invented by those philosophers who make no experiments to guide them, but grow pale over their books only. The reason of the appearance which gave birth to the opinion, is this, that when the Snail is thrown into the water, some air always remains fixed in the mucus of the body, which never shews any regular or determinate motion, although it really has a very strong one; for the little bubbles always retain their order and situation among themselves, though they are contracted and expanded with the body; that is, they are heaped one upon another, and again separated from each other from time to time.

## C H A P. V.

*Of the actions, and of the strength and life of the Snail. How it is to be killed for dissection, with further experiments; and an account of the effect salt has on this creature.*

WHEN Snails are disposed to rest, so as to remain quiet without any motion of their verge or foot, they discharge a great quantity of slimy matter from their bodies, which, when dried, answers the purpose of a couch or hammock, in which they rest. This they do in the day-time, and they will lie in this manner as long as it rains, or the atmosphere continues cool; for nothing distresses them more than drought.

From this we learn also, that their slimy humour, which, at other times is clear and white, is more coloured, or has greater variety of tincts, the less of it they have in their vessels and glands.

These creatures are very fond of company at the time they are increasing their shell, for then hundreds of them gather together in shady places, that they may be at leisure for that business, lying quiet and close to each other, especially for some days before they begin to copulate; as I shall shew in its proper place.

Life is very strong in them, insomuch that they will live six or seven days under water.

Nay, if they are wounded, and even dragged from their skin or shell, they will still live four days, provided they are put into water. They are so strong, that they can very easily creep forward, and move themselves to all quarters, with another Snail sticking to their shell; nay, one will sometimes draw two others. The period of their natural lives cannot be certainly determined, but I am inclined to think they live to a very great age, which may be probably conjectured from the slow increase of their shell: on the surface of their shells are seen a very great number of the same kind of marks, Tab. IV. fig. 11. s, observable in a cow's horn, from which the country people compute the age of that creature.

The dissecting Snails has cost me great labour; for this operation is very difficult, and must be performed whilst they are living. If we sprinkle the Snail with salt, it is not consumed, as is generally thought, but only killed, and then the strong contraction of the muscles draws up all the internal parts to such a degree, that nothing can be seen distinctly. All the

the slimy humour is then discharged out of the body; so that I observed, that the spermatic parts themselves were rendered three times smaller in this species of Snails, which is indeed very worthy of observation. Salt therefore seems to me to be a matter proper for cleansing the Snail, for by this means all its humours are discharged. The insect might otherwise be rubbed over with some purgative medicines, in order to try what effect they would produce; and, indeed, the success of such an experiment would be of some use in the medicinal art. I have often resolved but have not had opportunities to try it. I think that the act of purging in our intestines is performed in the same manner, that this effect is produced on the outside of the Snail; for the acrid, pungent, and provocative stimulus, irritates all the glandular parts of our intestines; and these parts are situated on the skin of the Snail, whereby they throw off and discharge the humours contained in them; and at the same time wash away, as it were, every thing they find offensive. This is manifest in the saliva, which is copiously discharged from our salival ducts, when any acrid and stimulating remedies are held in the mouth. This any person may experience very clearly, if he chews the roots of pellitory of Spain.

I cannot therefore agree that purging is peculiar only to a few particular medicines, which the practice has selected for that purpose; or that particular humours are expelled from the body, by such as are commonly called specific purgatives; as if these knew, from reason and judgment, how to distinguish water from phlegm, and the latter from all other superfluous humours; and to secrete this only, and throw it out of the body. Whereas, it is more agreeable to experience, that, that matter only is discharged, wherewith the body abounds most, and which is more than any other copious in its vessels at that time. If this be so, it will be sufficient to observe, in regard to purgatives, whether they be hot, dry, cold, or moist; nor will there be any further necessity to load the memory with new-invented names and fictitious distinctions.

It is improper to put Snails into spirit of wine, oil of turpentine, or any other such liquors, in order to kill them; and though I have sometimes killed other insects with the vapour of lighted sulphur, that they might remain whole for the dissection; yet I have fancied the fittest and best contrivance for this purpose, is to kill the Snail slowly, or by degrees, by keeping it under the water. This method is attended with this great advantage, that the Snail never contracts its muscular parts; which, on the contrary, are beautifully expanded: for the water penetrating into the orifice, of its glands, mixes with the slimy humour there; and; at the same time, by dilating, surprisngly expands the whole body. Hence I have found that many parts, which otherwise are hidden, or cannot be investigated, but by great labour, become visible with great familiarity, as the aperture of the genital organs with the penis and uterus, the teeth also, and the form of the verge or extremity of the body, the glands and other parts are all rendered conspicuous on account of the water contained in them; the Snails are, therefore, by this means, rendered fit for dissection.

Some curious persons feed this kind of Snail in their gardens, and at their country seats, as I remember to have seen at the Hague and Culenburgh, in the kitchen gardens of the illustrious counts Maurice and Waldeck; and in many other places, particular in grotto's, which are adorned with sea productions. The properest time for removing these Snails is in the winter, for then they lie close in their shells without motion, and are defended therein by a particular kind of operculum, or cover, formed by a hardened quantity of the slimy moisture vented for that purpose, which very exactly closes up the entrance into the shell. If they are to be sent from place to place in summer, the best way is to send them wrapped up in a quantity of fresh herbage; when they are designed to be eat, they should be put into a bag, and chopped straw scattered between them, by the pricking of which they are prevented from creeping out of their shells.

## C H A P. VI.

*Of the internal parts of Snails; and first of the heart, its auricle, the vena cava, and aorta. And also of the blood, and its perpetual circulation. Of the difference of the slimy humour from the blood. Of the cavities of the verge, and also of the sacculus calcarius, or bag of alkaline matter. To which is added, a curious experiment, pertaining to the motion of the muscles.*

AS I have hitherto been taking a survey of many of the external, and of some of the internal, parts of the Snail, I propose to go on now to a description of its shell: but then it will be most proper to discourse of that, after I shall have described those parts, from whence the shell itself derives its nutriment and growth. As I have already gone through

the examination of the principal internal parts, I shall not confine myself rigidly here to the order usually observed by anatomists, who commence their inquiries with the belly or head; they do this to get rid of those parts, which would first taint; but no noxious subject is to be feared in this case, and the animal itself being small, I have chosen rather to treat first thoroughly

thoroughly of those parts, which were first obvious to me. Neither need I be uneasy, if I have delineated one part somewhat larger, and the other somewhat less; the microscope not admitting of greater accuracy: and indeed this avails nothing in our attempts to inculcate a knowledge of the subject, unless some particular points may be more distinctly understood, if on that occasion, the parts are exhibited a little larger than the life.

The best manner of dissecting the Snail is, the shell Tab. IV. fig. 11. *i*, being pulled off, to begin at the verge of the body, fig. 1. *e*; which also should be cut off from the left side, with a fine pair of scissors; in the doing this, taking care not to pierce the apertures *g*, situated on its right *f*, these still remaining unhurt, the verge is to be separated from the body, which visibly adheres to it below; for otherwise, unless these apertures be carefully avoided, the outlet of the intestines, and the passage of the alkaline bag, will be equally injured.

In this management, what first meets the eye, is the skin of the subjacent body, which is concealed by the upper and under part of the verge, or a membranaceous substance, as with a covering, being much more delicate about that place, and of a whitish or palish colour, and composed of oblong muscular fibres. If you have nicely separated this part of the internal skin, you will see the transverse muscles lying under it; which, though not altogether colourless, are in some degree transparent; and on both sides, in the soft or bending part of the belly, there will be observed certain muscles resembling a saw, which stretch their tendons above the peritonæum; but the small muscle, running transversely, is situated above the peritonæum, under which it lies. All these muscles serve to press the body inwards, and to move forwards the contents of the intestines, and of the spermatic vessels.

But if after this the verge, together with its membranaceous parts, be drawn backwards over the bending of the body, and then cut off from the place where it adheres, then immediately appear the veins, Tab. V. fig. 1v. *a*, which run beneath toward the verge *b*, and the heart *c*, with its auricle *d*, and the vena cava just dawning out of it; together with the various cavities, in which the air is moved, and some other small parts beside, such as the alkaline bag *e*, and its duct lying next to the intestine, the intestinum rectum *f* itself, the liver, and certain parts belonging to the spermatic vessels. Some of these I shall now describe in their order, and of the others afterwards in their place. First, of the heart.

The heart is situate in the middle of the Snail's body, near the extremity of the arch of the verge, which surrounds the whole body; and at that place, a little to the left, in the bending of the body, by reason of the thinness of the intestine membranes, which are perfectly transparent, Tab. IV. fig. 1. *l*, it is discerned moving. It is included in an ex-

tremely thin bag or pericardium, in whose cavity there is ample abundance of watery moisture, as clear as the purest chrystal. The pericardium being dissected, immediately appears the beating heart, Tab. V. fig. 1v. *c*, with its auricle *d*; which, being of a membranaceous and exceeding delicate texture, is seen to be interwove within, with divers as well fleshy as membranaceous fibres, in the same manner as is seen in the auricles of the heart of a man, and other animals. The heart itself is of a fleshy substance, and of a pale reddish colour, exhibiting a muscle, which for the space of a day will continue wasting away into water, and yet not be cleared from all its blood. The external superficies of the heart is smooth, and it is shaped like a pear; but the internal parts are uneven, with several fleshy columns, hairs, and fibres, much the same as we observe in the hearts of men and brutes: hence it is that the heart may be easily distinguished by the many sinuses and angles in it, and it is very fibrous. At its entrance, near the auricle, there adhere two little semi-lunar valves *c*, which serve to hinder the blood from returning into the auricle. But as there is only one auricle to the heart, so is it only found in one cavity; and agreeably to this, there are also found two kinds of vessels there, namely, the veins and arteries. The veins, above the auricle *d* of the heart, are conspicuous without much pains, and in particular the vena cava may be obviously seen; out of which others, just springing forth, are interwoven amongst one another after a surprising manner, and form an elegant kind of net-work. The arteries are not discovered without greater difficulty, nor can they ever be seen, but at the first opening of the body. The beginning of the aorta, or great artery, is about that place without the belly, where the heart is united to the calcareous bag *e*; and the great artery derives its origin from the cone, or more acute extremity of the heart, and is a little dilated, at its very beginning, as is common in fishes; immediately from this part it disperses its ramifications every way, both through the internal parts of the body, and outwardly among the membranes, equally backward to the spire, and forward; first, indeed, respecting those parts it borders upon, namely, the calcareous bag *e*, the intestines, the liver, the stomach, and the spermatic vessels; then immediately proceeding to the coat investing the liver, and then to the muscles, nerves, and little glands of the skin. I have delineated *b* some of the more remarkable ramifications, only with their divisions, and have marked the rest of its body, and its spiral shape, with points *iiii*, that the situation of these parts might thence be understood.

The blood contained in the heart, and its arteries, appears of a whitish colour, inclining something to blue; and hence it differs very much from that of men and brutes; for the

blood of all those is of a deep red ; but, as the blood in small animals, excepting those only which live in the bowels of the earth, as many as I have known of them, want that purple colour ; for this reason then authors, who are only wise in their own speculation, have called them *animalcula exsanguia*, or *animalcules* without blood, though even in some human bodies, there has been observed sometimes white blood in the arteries. The blood of the Snail is of a glutinous consistence, clammy, and pituitous or phlegmatic ; if poured into water, it shews itself like a sky-coloured cloud, which gradually expands, and grows more and more tenuous, and at length quite vanishes ; and is indeed a very pleasant sight.

The blood which remains from the nutrition of the membranes, returns through many extremely small veins toward the heart, there to undergo a new concoction. These veins are chiefly scattered about the external parts of the body, and are there very conspicuous ; for those vessels which we see there, are almost all conspicuous, as they may be seen among the pointed little glands of the verge. All these veins converge in one large trunk called the *vena cava* ; which, as we have just said, may very plainly be seen on the internal superficies of that arched membranaceous part of the rim or fringe of the Snail, Tab. V. fig. iv. *b* ; for the veins run off, under and through this verge or fringe, and afterwards discharge their contents into the auricle *d* of the heart ; which then, by its contraction and systole, again protrudes this blood into the heart *c* ; and the heart, with a manifest circulation, again ejects it into the arteries, and those again into the veins ; that the motion may never be interrupted, but the blood maintain its course through the body. Hence the pulsation of the heart is first discerned in its auricle ; but afterwards in the heart itself ; those veins which spring from the *vena cava*, are formed and dispersed with such wonderful artifice, in the aforementioned membrane, that I have determined to set forth an accurate drawing of them ; to the end, that the works of God may be so much the more clearly understood, and more firmly impressed on the memory.

The heart, with its auricle, is never more distinctly seen, than when it is cut open through the *vena cava*, distended with a blast, and then half dried ; but if it be dried too much, it is less forcibly contracted ; and its internal fabric and small valves cannot be so conveniently viewed. But seeing these vessels all contain a whitish or lightly-coloured blood, from which they may be easily taken for nerves ; it is therefore expedient that they be first filled with an injection of some coloured matter ; which operation, by reason of the exceeding smallness and fineness of those parts, is indeed a very curious and difficult task.

For those who delight to engage in such a process, there are colours of that sort which subside ; and those ought to be mixed with so fine a liquor, that it may pass through the pores of the vessels, and fly off into the air. But if any one use a liquor of a simple colour, then they will be all of one tinge, nor can any thing be distinctly exhibited to the eye. I might explain many of the operations and artifices requisite to the perfecting this matter ; but this part of the work, beyond my expectation and design, has grown redundant enough under my hands already.

The difference between the blood and the slimy humour in the Snail is very remarkable, and may be obviously known only by the colour and consistence ; for though the blood is thin and fluid in the veins, it becomes tenacious after it is taken out of those vessels. Nay, although it be immediately thrown into water, it does not mix therewith, unless it be shook a little. On the other hand, the slimy humour secreted by the glands, takes a long time before it is dissolved in water, because it is tenacious and thick ; and this is of a white colour, and may, therefore, by those qualities, be easily distinguished from the blood ; whenever the wounded Snail is thrown into the water, in order to mix the blood and this slimy humour with it.

The blood, being laid upon white paper, leaves no gloss ; whereas the slimy humour covers it, as it were, with a bright varnish, like silver ; it may therefore be mixed with colours, to give them a gloss. Those, who eat Snails, esteem their blood very highly, and call it their liquor, taking particular care that it should not be lost ; and I think they, as well as those who eat oysters, have some reason for so doing.

After what manner the slimy humour distils from the glands of the skin, may be seen in this manner ; the skin must be wiped with spongy blotting paper, until none of the slimy humour is seen, or till the whole is cleared off ; then the skin must be taken between the fingers and pressed gently ; and if this be done under the microscope, the slimy humour will be seen to come out insensibly, from the glandular pores of the skin, like clear and minute points ; these, by continuing the pressure, will become small drops ; and these, in some time gathering together, will form a considerable collection of this matter ; so that the whole skin will be moistened, and become glutinous.

The cavity of the arched verge, in which the air moves, forms a round bow or arch, occasioned by the membrane's expanding itself against the shell ; but this happens only when the Snail lies in its shell ; for when it is taken from thence, the membrane of the verge immediately slips into the parts underneath ; since it is no longer sustained by this support against the shell, being connected to the latter only by the toughness of the mucus,

or slimy humour. If this membrane be again swelled up from its aperture for air, it will be observed to expand itself very beautifully against the shell. This cavity in the right side of the body reaches to the turn of the intestines; but in the left side, where the heart is situated, it goes according to the windings of the liver, and follows the turnings of the latter, unto the third and second convolutions of the intestines in the body.

In this arch of the Snail's verge; near to the heart and its auricle, there is seen, Tab. V. fig. iv. *e*, a certain oblong, triangular little part, to which the heart *c* is fixed and united, there being nothing between them but the pericardium. But on the outside it swells, Tab. IV. fig. i. *n*, through the skin; and is very visible in a boiled Snail, when taken out of its shell, fig. iv. *o*. This latter likewise shews the figure of the body at that time, that is, the convolutions *p* of the liver, and after what manner the verge contracts itself *q*. The colour of this little part is like that of grey ashes mixed with water. On the hinder part it is connected, Tab. V. fig. v. *l*, very strongly with a certain part of the intestines and liver; but that part of it which is seen through the outmost mem-

brane which covers the body, is observed to be interwoven with many vessels. On the other side, its colour is more waterish *m* than where it is of an ashy-grey, and connected to the pericardium *k*.

I first thought that little part was the spleen, but when I viewed it more accurately, I observed that it discharged itself into a pretty large duct, which runs near the intestinum rectum, or straight gut, fig. iv. *f*, and in my opinion opens into it. I therefore now believe this part to be a glandular little body, or a sacculus or bag, whereby the calcareous matter of the blood is drained from the body, and deposited in the intestinum rectum, or straight gut; and accordingly we find that such a matter is there sometimes mixed with the excrements. If this little part be dissected, and put into water, it exhibits a glandular substance; but as it abounds with a grey calcareous humour, it makes the water muddy. On the side opposite to the intestine it appears somewhat bright; and seems to consist of a glassy substance; it has the same aspect in several places; also in the middle, where it seems divided into little grains, which are visible underneath: it tastes like ashes.

## C H A P. VII.

### *Of the liver, bile, stomach, intestines, and salival vessels of the Snail.*

**T**HE liver, which for the most part lies in the hinder portion of the shell, forms a spiral convolution there with the intestines, Tab. V. fig. vi. *a*; as may be seen on the outside, Tab. IV. fig. i. *k*. It is further divided into divers lobes, Tab. V. fig. vi. *bbb*, according to the different course of the intestines, which make as many divisions in it, as they have turnings and windings. Besides these, the liver is very full of greater and smaller vessels, which are dispersed through every part of it, fig. ix. *a*. It has likewise its particular thoracic or chyloferous ducts, fig. viii. *a*, which discharge themselves into the intestines, without any intermediate gall-bladder; in the same manner as in Horses, Pigeons, and other animals, which are said, though without any foundation, to have no bile. I could perceive no remarkable bitterness in the bile of the Snail.

The liver itself seems to consist of small equi-distant little grains, called glands by the great anatomist Mälpighius; to whose judgment we ought to give great credit, since one can scarce find his equal in anatomical knowledge. The liver is of a dark brown colour, a little approaching to green: the hardness and substance of it, are like those of the spleen in a man. It abounds with a juice or humour of a yellowish green colour. In the upper part, where the liver turns round, its outward coat, which is covered with little whitish

points, grows greener. It has very few lobes on the inside. Nothing is more savoury in a boiled Snail than the liver, which, I think, is also very easy of digestion: whereas, on the contrary, all its muscles are hard and tough, except the spermatic vessels, which are likewise very pleasant eating.

The Snail's stomach, fig. vi. *c*, is placed in the cavity of the neck and belly, and consists, as in man, of three coats, notwithstanding its being very tender and thin: it is also provided with veins and arteries. It is of a white transparent colour like parchment; but when distended with food or air, it has the colour of the most transparent membrane: when empty, it appears full of oblong grooves, Tab. V. fig. iv. *n*, which exhibit an agreeable sight; for they are so many contracted muscles, which corrugate the coat in this manner. The stomach grows narrow by degrees, fig. vi. *d*, and forms by that contraction its lower orifice, called the Pylorus. After this follows the small gut *bbb*, between which the liver is principally situated. After these intestines have turned themselves two or three times, then they form the intestinum rectum, or straight gut *e*, which opens, with its foramen, into the Snail's verge *f*. About the spiral convolution of the body is observed *g* a place, where the bile discharges itself into the beginning of the intestines; which appears more evidently, if those biliary ducts are somewhat separated, fig.

fig. VIII. *a*; so that the whole region of the stomach *b*, small *c* and great guts *d*, be parted from the liver. If the intestines and the liver be inverted, some of the parts before-mentioned may be seen more distinctly; that is, the liver itself, fig. VII. *a*, and the small guts in their natural situation *b*; then the intestinum rectum, or straight gut *c*, and the stomach *d*.

And here we must observe, that two very beautiful vessels run, fig. IV. *oo*, along the stomach and the gullet, or œsophagus, which discharge themselves into the upper part of the palate of the mouth, fig. I. *d*. These vessels are of the same structure with that part of the epididymis in man, which lies upon the testicles, and they are of the colour of an agate. On the inside they are hollow and contain a clear liquor, which they discharge by two small apertures which open into the mouth. They are, therefore, plainly the salival ducts of the Snail, such as are likewise observed in man and brutes, and are situated either near the same place, or a little lower.

## C H A P. VIII.

*Of the genitals, penis, uterus, testicles, ovary, and other parts subservient to generation.*

**T**HE spermatic vessels are placed not only in the fore part of the neck, belly, and back of the Snail, but being twisted like vine tendrils, follow the convolutions or windings of the body itself, and extend themselves to the extreme end of the liver; so that they may be justly reckoned amongst the most remarkable parts of the body. Before they can be seen, the skin must be dissected, and some of the membranes and muscles removed; and among the latter there is a very elegant muscle, which, with many fibres, reaches obliquely from one side of the body to the other, and shews itself beautifully upon the stomach, and those parts that serve for generation.

The male and female organs of generation are both in the same Snail, and the penis and uterus, being naturally united, grow firmly together; so that many of the parts are common to both. The small parts, from the structure of which it is known that they belong to the male organs, are the penis, Tab. V. fig. x. *a*, with its sharp, twisted, oblong appendage, which, at the extreme end, is round, in the form of a pear *bb*. To the female parts belong the uterus *ccc* and its ovary *dd*, which opens into the cavity of the uterus; that the little eggs may be increased and covered with moisture therein, as may be seen very beautifully in the Ray-Fish; nay, and in some degree, in the uterus of Hens. But in other animals, as in Tortoises, Lizards, and Camelions, there is found a greater agreement in this respect, with the Snail, than I could observe in fowls.

These two little vessels arise from two small, clear, and snowy parts, fig. IV. *pp*, joined together in the middle, and divided into various little lobes: you would easily believe that they were nothing more than fat. A beautiful little vessel *q* runs through the whole surface, which brings them nourishment and moisture, and, arising out of a very high place under the verge, where the body begins to bend, comes to this part, and gives a great many branches to each of these small parts. These little parts are likewise, by the help of different vessels, which seem to be so many small and tender filaments, laterally connected with the stomach. The salival ducts themselves are, by certain singular vessels or ligaments, also connected with the stomach. I first indeed thought that this small part was the pancreas, but experience has taught me the contrary, and likewise that it is not fat; for it cannot be melted by fire, nor is it inflammable, if put on a bit of glass and applied to a lighted candle.

As to the parts which have a mutual communication among themselves, to these may be referred the testicles: these are, as it were, a congeries or heap of oblong filaments *e*. Then the hidden appendages of the uterus *f*, and a certain common duct between the penis and the uterus, Tab. V. fig. x. *g*. Afterwards there is an oblong vas deferens, which opens at the end by a small tube into the uterus *i*, and has a little ball in the form of a pear at its extremity *k*. Lastly, there is a very beautiful curled vessel *l*, of the same structure with the epididymis in man and quadrupedes, which being twisted in, like a little chain, discharges itself by a small tube *m*, into the beginning of the uterus and end of the ovary.

Having enumerated these things in general, I shall now treat of each part in particular, and assign the reason why I have called some of them common to both organs, and others proper to one or the other. As to the penis *a*, it is nervous and of a muscular texture, consisting, as it were, of three parts; the first is a muscular membrane, then the inward construction, wherein, as in a prepuce, the penis may move up and down; and lastly, the internal porous membranes, which truss up the penis on the inside. Hence it is, that if the penis be cut off in the act of coition, no more than the outward membrane which covered it, and out of which it stretched itself, remains in the body. It is all white, and is firm, and, as it moves up and down very easily on the inside, so it as easily moves through the aperture

ture of the genitals out of the body, and can enlarge and stiffen itself for that end. For this purpose it has not only a muscular texture, but it is likewise provided with a peculiar muscle *o*, by the strength of which it is thrust out.

The act of coition is performed in this manner; first, the outward aperture of the genitals opens itself in the right side of the neck, fig. xvii. *a*; which, when it has more and more insensibly dilated and expanded its orifice, then the two inward orifices, as well of the penis as uterus, fig. xviii. *b*, creep out of the body. Then the penis erecting itself, fig. xix. *c*, and pushing softly out of one of these orifices, comes in sight; but the other aperture, that of the uterus, lies open *d*, to receive the penis of the other Snail at the time of coition. So that the penis *e* of the one Snail is put into the aperture of the neck of the uterus *f* of the other; and again, the penis of the latter *b* is likewise received by the aperture of the uterus *g* of the former. Each of these Snails being therefore excited by a reciprocal stimulating impetus to venery, each impregnates and conceives, fertilizes and is fertilized, and ejects and receives the semen.

After coition all these parts are drawn into the body; for which purpose the penis has a somewhat long and even muscle, Tab. V. fig. x. *p*, which is inserted under the transversal or oblique muscle of the abdomen, where the verge of the Snail's body is: and that this part should not want sense, it has likewise a nerve *q*.

The parts of the uterus have also their nerves and muscles, some of which may be seen in the neck, near the root of the four horns. The matrix itself is a tender, oblong, white and curled *ccc* little tube, which appears most remarkable when it is distended, fig. xvi. *r*, with air or wind; for then it turns itself into very admirable convolutions, being jointed to a ligament, fig. x. *mm*, which connects all its folds, and is of a stronger structure than the membranous and hollow parts of the tube of the uterus. This seems designed for some particular use; for it appears full of glands, so that I first took it for the ovary itself: for indeed all the veins of the uterus, of which there are many, are fastened in this ligament, and pass through it towards the uterus. But, in other respects, neither the uterus nor ovary, fig. x. *dd*, have any thing remarkable in them, as long as the former has no eggs in it. The ovary is not visible, unless it appears like an oblong, white, tender, soft and triangular little part, and contains a substance like the melt of Perch. So small and invisible are the little eggs of the Snail before coition!

Again, the uterus is fastened near the verge of the Snail, and is there connected with the upper part of the abdomen. There are likewise some muscles which serve to contract the uterus, a larger one *s*, and a smaller *t*, which is inserted behind the long muscle *p* of the

penis. The uterus has also its nerve *v* there, as will appear more clearly in the description of the brain; where it will likewise be shewn that these muscles also give some assistance to move the brain on the inner part.

That the penis and uterus in the Snail have many parts in common between them, I am inclined to assert, for this reason; because these parts are forced to move their contents through common passages, as is seen in the sperm from the testicles, and on other occasions. These testicles *e*, as we have before observed, consist of a cluster or heap of oblong filaments; and the same holds in almost all species of this genus of insects: it is even so universal, that it takes place in man and quadrupeds; for their testicles are formed of such filaments. There are sixty-six of these threads in the Snail: they are of a whitish colour, and, in their inward structure, resemble hollow tubes, each being closed up at its extremity. They arise from two trunks, and are divided in a wonderful manner, as it were, into twigs, Tab. V. fig. xi. *x*. The semen is of a snowy colour, and of the same thickness and clamminess as in the males of Bees. I know nothing that bears a greater resemblance to this part, than the pancreas of fish; a description of which I have inserted in a work of Commelinus, which I published; and I have delineated the figures with my own hands.

The hidden appendage, fig. x. *f*, of the uterus is a very beautiful, white, nervous and muscular part, of a firmer substance and texture. If it be dissected, it must be done very cautiously and with an even hand: it is then discovered, that at the root or basis in the hinder part, it has, fig. xii. *y*, a globular and round little part in the form of a pear; from which arises a sharp, hard and crooked style, not unlike a sharp awl. This little bone being taken out and viewed with a microscope, resembles a transparent, glittering, very small, scale of a fish deprived of its skin. At the root, fig. xiii. *a*, on the hinder part, where this little bone is connected to the globular little part, it exhibits some incisions or fissures covered with coats, which penetrate inwardly from the external parts into its cavity. I have counted fourteen of these incisions: it appears, in general, equal and round *b*, and ends somewhat sharp like a needle: then it forms, in its circumference, four margents or prominent borders *c*, between which are seen some remarkable ridges and furrows. This appears very plain when this minute part is dissected, fig. xiv. *e*; for then it is manifest that it is hollow on the inside; so that a hair put into it, almost entirely passes through it. Within the cavity of this little bone, there is contained a limpid or clear humour; but where its root is connected with the globular part, fig. xiii. *b*, it is all hollow and very tender, so that it is easily broke in that part, if it be handled in the least roughly or carelessly. It ferments strongly

strongly with aqua fortis : hence I call it an alkaline little bone.

I could not find out the use of this little part. I thought indeed at first that it was the penis, but experience convinced me of the contrary. It is however certain, that it is of some use in generation ; for after coition, such little parts are commonly found where the Snails have been together. I have observed also the same thing in other kinds of Snails, till at length I made use of it as a sign to discover whether the business of generation had been over. In some Snails which were not given to venery, I found this little part so small, that it was hardly one fourth so big as that already described : it was like a point, slender, short, and tender. In some it was larger, in others smaller, that is, as far as I could judge, the nearer they approached to the time of generation, or the further they were from it. It is sometimes partly yellow, but for the most part it is transparent and very white ; it seems, however, to be subject to accretion, like corals, as I shall demonstrate more clearly in the Snail-stone. I remember to have sometimes seen in a Cuttle-fish, an entire little bag full of such white small parts, which lay there free and disengaged among a glutinous humor, but they consisted of a very soft substance, and were much larger. This fish has gills likewise, and other such wonderful parts ; so that this animal deserves very particular consideration, though much could not be hitherto known or said concerning it.

The common little tube that lies between the penis and uterus, Tab. V. fig. x. *g*, is not very remarkable ; I only observed that it was hollow. But that other, vas deferens *bb*, seems to supply more ample matter for speculation, both because it opens into the uterus *i*, and that it has a little ball or globe *k* in the form of a pear, which contains a fluid of a pale purple colour, somewhat glutinous, and not thin. This little ball lies next to the heart in the body ; so that the great artery is carried round that pipe

with which the ball is connected ; but what use this little part is of, I could never hitherto discover. I once observed, that the little bone before-mentioned, penetrated into this vessel, almost as far as its aperture into the uterus ; but, to the best of my remembrance, I had then irritated the Snail at the time of coition, so that it drew in these parts of generation ; for which reason I afterwards used to distinguish, in a particular manner, those Snails which had exercised coition. Of what use this little globe or ball is, I am ignorant ; I should, however, be inclined to believe, that this is the part wherein the Purple-fish carries that precious dye, wherewith the garments of monarchs, and other great persons, were coloured purple in the times of the Romans. To this the sacred writings allude, when they say, “ that the rich man was clothed in purple.”

I am likewise at a loss to know of what use the curled little vessel *l* is. I observed, however, that it is distributed into various little branches *z*, which, like so many tubes, arise from the oblong, round, and acute little part, placed near the extremity of the spiral liver, and there joined to the liver itself. But if this little part be divided, and opened or unfolded, with the top of an ivory bodkin filed sharp, and somewhat softened by steeping it in water, by which means it does not offer so much violence to the parts as a needle, it appears like a little tree or shrub adorned with leaves, Tab. V. fig. xv. *a* ; with this difference only, that its extreme parts are studded, or embossed and swollen, hollow on the inside, and full of moisture, which is probably conveyed by degrees into that curled small vessel resembling a chain ; but then the matter contained in this little part is more white and compact, and better digested.

Lastly, we must observe that most of the parts hitherto enumerated, are placed behind in the spire of the shell, and are there seen through it in several places.

## C H A P. IX.

*Of the manner in which Snails mutually perform the business of coition.*

**H**A V I N G hitherto, in part, shewn the method whereby Snails generate, I shall now give you a full description thereof ; since it is a matter very worthy of notice that, an hermaphrodite little creature should have need of a companion for the purpose of generation.

The Snails gather together for some days before their coition, and lye quiet near each other, eating very little in the mean time ; but they settle their bodies in such a posture, that the neck and head are placed upright. Thus, whilst the shell of each rests upon the earth, with its double head, the Snails are raised up-

wards, and they support themselves erect, by the extreme ends of the fringes and verge of their bodies, in the same manner as it is said Serpents engender, that is, in an erect situation, and twisted about each other.

At that time the verge, or its aperture, is continually open to take in the air ; but the opening of the genitals in the neck is sometimes observed to be alternately open and contracted. This action is performed in the same manner as the agitation of the outer parts of the vulva in Dogs and Hens, when they desire coition. The Snails being thus animated, softly approach each other, and apply their bodies

one



one to the other, as smoothly as the palms and fingers of both hands can be grasped together: and by this means, not only their bodies, but their necks and heads, are raised up and pressed close to each other. Then are seen the most wonderful motions of their heads and eight horns, which surpass all imagination; like Turtles, they are continually observed to kiss each other, and to join lip to lip. The horns are affected with such various motions, that one can scarce think, how they can possibly have so many and such different muscles. Another circumstance that deserves notice is, that when they touch each other in the least with their horns, they immediately draw them in, or move them up or down again, or sideways; and these motions are often repeated.

These motions sometimes continue for three days, during which time the Snails turn in and out, and join together their genitals, so that the penis and uterus, of each, are sometimes seen to hang entirely out of the body. But since I cannot observe that Snails have organs proper for seeing and discovering things near and at hand, but only for remote objects; hence it is, that for want of this knowledge, I cannot observe their coition but by chance. For though they very often shoot their genitals, like an arrow out of a bow, yet the coition is scarce performed once in three times. This mistake seems to happen the oftener, because every Snail carries its penis in the right side of its neck: it must therefore happen before they have turned their respective heads cross-wise towards each other, that they often attempt a coition unsuccessfully. But they have leisure enough to repeat this business, since they feel for a long time the incentives of their venery, though they have already gone through the business of coition ten or twelve times before. Nay, I have known some of them indulge their venereal desires three weeks afterwards, and that they repeated them again in six weeks after that.

But when they associate in coition, as they should do, each of them stretches its penis, together with the orifice of the uterus, entirely out of the body, which is not done by erection only, as it is in quadrupedes, but principally by turning the inward parts out, as happens in the penis of Drakes. The first thing that opens in the Snail is the aperture, that lies in the neck between the upper and lower horns, Tab. V. fig. xvii. *a*; then the inward parts of generation are observed to come out like two apertures, fig. xviii. *b*; so that by this means the lower horn is pushed out of its place, Tab. V. fig. xviii. *k*: afterwards these parts are very suddenly thrown out of the body; yet so as that the aperture of the uterus appears first, fig. xix. *d*, and immediately after the penis, the thicker part of which turns out first, and afterwards the sharp part *c*. After this begins the coition, and the two lower horns are then so far thrust out of their places, that they touch and press each other *l*.

These parts are afterwards remarkably swelled by the humours that flow towards them, so that they resemble the clammy white of the boiled egg of a Lapwing, which, being mixed as it were with a transparent whiteness, makes a very agreeable sight, resembling an agat. For the appendage of the penis, fig. x. *bb*, is observed to run so far, and by the clearness of those parts, is so evidently seen, that its motion is also obvious to the eye.

After coition the parts before-mentioned may be still perceived for a quarter of an hour hanging out of the body, that is until their swelling has fallen, and then it is surprising to see what wonderful motions the penis has. But if any one should in the mean time handle these parts, the Snail endeavours to draw them in by force, but however much it stretches all its nerves, yet it cannot by any force bring them in, unless they first become flaccid. A certain lymphic moisture then distils from these parts, which soon coagulates, and becomes tenacious and firm in the air. The upper horns being always bent like a circle in the venereal act, are observed not to move much, unless that they are sometimes drawn in, and again stretched out. After all is finished, the little creature, having wantonly consumed the strength of life, becomes dull and heavy; and thence calmly retiring into its shell, rests quietly without much creeping, until the furious lust of generation gathers new strength, and effaces the memory of the uneasiness suffered after the former coition.

In a Snail, dissected a little time after the act of generation, I observed that the penis was smaller, but the uterus a little more expanded and glutinous in its cavity. The ovary was manifestly swelled, and was longer, thicker, and larger, so that it now seemed full of sperm like milk. Afterwards, however, I saw it much larger, and filled with more glutinous moisture. But in five weeks after coition, the ovary became yellow, and like real glue; yet the eggs were very soft like slime, and were scarce visible. When I afterwards viewed the ovary in such a boiled Snail, every thing was callous, and as far as I could discern, an infinite number of little eggs presented themselves in both the Snails, which had copulated with each other. The uterus itself was likewise at that time much more expanded, and became, as it were, glandulous; so that when thrown into the water, it swelled very much. When the eggs were held a little while in the hand, the fingers stuck together. Therefore the ovary, the longer it passed after the time of coition, became more tenacious, compact and yellow; for all the eggs of the Snails are covered with very clammy membranes, and are, at length, perfected in the uterus. They cannot remain in the ovary, since this is placed between the spiral part of the shell, and throws its eggs into the cavity of the uterus. Some Snails lay their eggs up and down on the ground, others tie them all together like a chain. I have seen a  
little

little chain of eggs of this kind, which the vulgar thought dropped down from heaven, and therefore immediately framed a great many superstitious fables concerning it: so far is ignorance the mother of error. The testicles, after coition, are found deprived of their sperm. The blind appendage of the uterus likewise, in the beginning, though not very much, became afterwards contracted, and had thrown off its bone. The common tube between the penis and uterus suffered no change. The vas deferens was more dilated, and in it, as I have said, I found the little bone. Hence it is probable, that this little bone, at the time of coition, carries some of the spermatic humour

through the upper tube of the vas deferens into the uterus; whilst the penis, in the mean time, throws its sperm from the inward part into it. To conclude, the little part in the form of a chain had undergone no change, unless that on the side near the spiral convolution of the liver, the vessels that it distributed there, were here and there very unequally dilated and filled with a calcareous humour; except that some little round whitish membranes, which appear perforated in the middle, and marked with a black spot, were here and there observed fluctuating in its hollow canals, which resemble the leaves of trees.

## C H A P. X.

*Of the brain and nerves, and in what manner those parts have their muscles, whereby they are moved backward and forward in the body; a wonderful particular not hitherto known in any animal.*

**I**T is with very great difficulty that any certain and fixed place can be assigned to the brain of the Snail, as I have observed in the beginning of this account; since, like other parts, it has its muscles, whereby it is sometimes drawn forward, and sometimes backward in the body. This motion of the brain is so wonderful in this little creature, that it deserves the most serious consideration. Since I have never hitherto, nor do I know, that any other has, observed any thing like it in any kind of animal; I shall, for that reason, minutely describe the brain, and represent it by a figure, as I have seen it in a Snail, which I killed slowly under water. The brain is placed upon the stomach itself, which, together with its gullet, always passes through the aperture which the brain forms there. And this is not peculiar to Snails only, it holds likewise in Silkworms, and in all other insects that I have hitherto examined. Hence it is, that when the stomach, with the gullet, and all parts of the mouth, are drawn up on the outside, or down on the inside; the brain being always placed upon the stomach, is transferred hither and thither with it. Since therefore all parts of the mouth may be, according to the dissection of the brain before-mentioned, drawn forward and pushed out; I shall, in the first place, expose to view all the parts of the jaws, mouth, and palate, Tab. VI. fig. 1. *a*. Lest the stomach and its oesophagus should interfere in my giving a full and exact representation of the brain and nerves, as they really are, I cut the stomach about the gullet *b*, by which means the brain is seen immediately. It consists of two parts like little globes, and is therefore divided into two parts: from each of these globes arise a certain part of the spinal marrow, resembling on each side a large nerve *dd*, both which parts are situated in such a manner as to leave a gap or aperture for the passage of the stomach.

These parts, springing from the brain, constitute the true principle or rudiments of the spinal marrow, and they meet again a little lower, and form a considerable knot, Tab. VI. fig. 1. *e*; from which, afterwards, arise all the rest of the nerves that are distributed in the lower part of the body. There we are to observe, that the spinal marrow is double, not only in this creature, but also in man himself, and in quadrupeds; with this difference only, that in the latter it is presently joined together by a certain intervening band, and immediately after inclosed in a common membrane. Nay, all the nerves in the latter, that arise from the marrow, form, each in its course, certain little knots or swellings, which are therefore at least more numerous there. The same is seen in Silkworms, in which the two originations of the spinal marrow are many times tied.

This swelling of the spinal marrow in the Snail has its muscles likewise, by the help of which it is moved up and down in the body. Its first muscle is very small *f*, arising from a coat which covers the swelling or production: from thence, passing under the stomach and brain, is at length inserted by its tendon, in the lower region of the parts of the mouth, a little above the root of the tongue; therefore it can move this little knot and the brain towards the fore parts. The rest of its muscles, which draw it back again to the hinder parts, are common to the inward lips; for the muscles of the latter run on each side over this swelling, and fix some of their tendons therein, though they are otherwise inserted in the horny substance of the Snail. After these muscles have passed over the swelling or production of the spinal marrow, they acquire a little nerve from that part which gives them the power of contraction. To avoid confusion, I have here exhibited only a small part *g* of these muscles, with their little nerve, which is afterwards extended further

further from thence towards the spiral turnings of the Snail's body, being there probably of use to provide for several other parts.

We further observe two nerves *bb* arising from the brain, which are distributed into the several parts of the jaws, mouth and palate, and probably serve for divers uses. But the optic nerves *ii* which have the eyes placed in their extremities, swelled out in form of little globes, are extremely beautiful. Behind these are discovered two other nerves *kk*, which reach, each with three ramifications, to the fore parts of the skin, and to the bases or roots of the upper horns; and afterwards also give two little nerves *ll* to the lower horns, which are of the same structure with the nerves of the upper, and are alike terminated with globular ends. Beyond these a pair of very tender nerves, Tab. VI. fig. 1. *mm*, spring from the brain, each of which being divided into two branches, runs to the muscles of the skin of the head, and is inserted in each side of the Snail's lower horns. Lastly, two larger nerves *nn*, are discovered, which run under the parts of the mouth, jaws and palate, and distribute themselves over those parts, and are designed probably for motion or tasting, or for both.

Again, some of the nerves which spring from the swelling or production of the spinal marrow, are inserted in muscles, situated in each side of the neck *oo*, to which they give motion. Others, on the contrary, are sent away to the spermatic vessels *p*, and to the coat and muscles *q*, which cover and move them. Some nerves also issue *rr* from those swellings, which are distributed in the muscular parts that move the sides of the body. Above, on the right side of this little knot, there arises an oblong little nerve, which is defended by a like muscle, and reaches to the uterus *s*. This muscle may probably also serve to move the spinal nerves on the inside. Behind the for-

mer are two other oblong nerves, one of which bends back under the little nerve of the uterus; but the other, being again divided into two branches, is inserted in the verge of the body *t*; at the upper part of which are still seen some muscular fibres, which issue from the transversal muscle of the abdomen, which is situated within, under the arch of the membrane of the verge. On the other, or left side, a like nerve is observed also *v*, which has the same insertion, and serves for the same use, that is, to give sense and motion to those parts. In the left side we are likewise to observe, what manifold and strong nerves are transmitted to all the middle and lower parts of the body. We will first examine those in the middle. Some nerves are there inserted, Tab. VI. fig. 1. *x*, between the tendons fig. 11. *nn* of that strong muscle, which moves the middle of the body, and those are sent away to the several muscles that run near it. A considerable number of little nerves besides *yyy* are observed, some of which are long, others shorter, and some are divided into two, others into three lateral branches: these descend to the lower verge or foot of the body, in order to give it the power of feeling and moving. I have exhibited none of these nerves in the right side, to prevent confusion *z*.

Here we shall conclude the present chapter. Now, reader, judge whether God has not shewn himself as magnificent and astonishing in the texture of the brain and nerves of the Snail, as in the formation of the similar parts of man; excepting only the mind and principle or seat of the understanding. As those do not appear to the dissecting knife, so they are less proper to come into our analogy or comparison; for those only observe and investigate corporeal and spiritual things, and thence descend to the deepest abyss of the wisdom and secrets of God.

## C H A P. XI.

*Of the muscles of the body and shell, which is the bones of the Snails: in what a wonderful manner this shell is formed on the inside, and how it is increased and nourished. Lastly, how the Snail moves in its egg.*

**T**HOSE who have seen dissections, or have any knowledge of anatomy, know, that the history of the muscles cannot be accurately understood, before the bones in which they are inserted are first known. For the latter are fixed points, towards which every thing in the body, that has a strong motion, is drawn and moved. And though the naked Snails have properly no bones, yet they have a certain extremity, wherein muscles are inserted; as I shall shew in its proper place.

That wise architect, who alone framed and reduced all things into order, has likewise established different rules in the composition of

animals, by the assistance of which he has pursued the same ends and purposes, how greatly soever the ways and means to arrive at those ends differ in various instances. In some animals the bones are found placed in the body, with flesh spread about and affixed to them, as in a man, quadrupedes, and in some birds. In others, we can only find cartilages, wherein muscles are inserted, as in the Ray-fish and some others. The Cuttle-fish has only one bone in its body, except the nose or snout. In some, which are so small that they have no considerable bones, the muscles are inserted in the skin itself, or they meet together in certain

callous or firm points, which are formed for that purpose, and which, in particular places, are as hard as the softer part of a Cow's horn. Though the methods hitherto mentioned, tending to one and the same end, differ greatly among themselves, the wise Creator of the universe has, besides, invented many others much more wonderful: in some animals he has formed bones manifestly on the surface, and put flesh between them with the most exquisite art, as in the Cray-fish, Crab, and many others; and he has likewise followed the same rule in most kinds of Insects, and likewise in this kind of Snails, to which the shell is as a real bone. The immense power and wisdom of God shew themselves greatest and most profound in those little animals, to which he has given both an horny shell, and the harder coat of a Crab; so that the muscles of the softer part are inserted in the shelly substance of their bodies, whilst that very judicious architect has inserted the rest of them in a hard bone, which covers their body, and is continued therewith out of the shell, as may be observed in the Hermit-fish. Though the Tortoise lives in a little house as it were, and carries its bones, like the shell-fish, on the outside, yet God has again established a different order in that creature, since he has given it two sorts of bones, some which grow contiguous with the bone that covers it, and others which are fixed to it by the help of joints; so that by this means the muscles are in this creature strengthened with a double insertion. And as this exhibits a very uncommon object in a living Tortoise, so the sutures of the bones, which constitute the outward shell, are worthy of particular observation; for, in my opinion, they differ from the sutures of the bones of all other creatures whatsoever, as I can demonstrate by a shell that I keep in my collection. But since this animal also lays eggs, that are covered with shells, which I have seen in great numbers in the body; and since those eggs must be emitted through a very small aperture in the bone, on one side of the tail, through which they can by no means naturally pass, it is beyond all manner of doubt, that the sutures of the bones in this creature, must, at the time of the exclusion of the eggs, separate from each other. Anatomists, with all their force, oppose the notion of such a thing happening in human subjects at the time of delivery. I shall not pronounce, for certain, how this matter is, but I believe most firmly, that such a temporary separation happens in Tortoises.

To return to the bones and muscles; we must observe, that the muscles are not simply inserted in the bone, but that a certain part of the bones themselves constitutes one of the extreme ends of the tendons of the muscle, so that the muscles fixed in each side in the bones have two bony extremities. Every muscle therefore consists of three parts; the middle part is flesh, but the two extremities are the white, membraneous, firm, and fibrous

joints of this flesh, which become bony where they are inserted in the bone; or otherwise remain hard and compact, or become softer and more tough, according to the different nature of the parts to which they are joined, and which they are constituted to move. Hence it happens that a muscle is sometimes inserted in a muscle. Nay, which is surprisngly singular and uncommon, Mr. Stenon has demonstrated to me, and to my very esteemed friend Dr. John Oort, in the eyes of birds, after what manner a muscle passes through a muscle by its tendon, as through a pulley, so that the perforated muscle can draw to itself, or let loose the perforator, according as the tendon of the latter, passing through the former, should be brought nearer or removed further; than which structure scarce any thing appears more admirable.

After what manner the muscles are inserted in the shell or bone of the Snail, and united therewith, appears most manifestly when that house of the creature is opened, for it is then observed, that all the principal tendons of the muscles of its body, run, some a little lower, others somewhat higher and deeper, towards the spiral part of the shell, and are fixed, Tab. VI. fig. II. *a*, in the shell itself, or hard or stony bone of the Snail. This may be seen particularly in that winding or sinus of the shell, which is the second from its lower aperture; I mean that through which the Snail throws out its body and verge or foot. There may, after this, be further observed, the insertion of the two longest muscles *bb* of the Snail, which serve principally to move that great and smooth verge or border of the body, by the assistance of which, as with a broad kind of foot, the Snail creeps forward, and moves from place to place; but this must be done with a very slow pace, according to the proverb, "Slower than a Snail." Those muscles in the middle of the body, where they are for the most part inserted, form a strong tendon; between which, towards the hinder parts, is seen here and there some moisture, which is yellowish, pretty thick, and contained in peculiar little cells, of the use whereof I am hitherto entirely ignorant. Backward, under the extreme part of the shell, we see the fibres of these muscles *c* run, which are inserted in the tail of the creature, or lowest extremity of the fringe, which is moved by them. Moreover, there is seen the parts, Tab. VI. fig. II. *d*, wherein all the tendons of the muscles of the verge, that surrounds the upper part of the Snail's body, have their origination. And those, together with the tendinous skin that covers the whole spiral part of the body, afterwards ascend to the last or extreme point of the shell, but are no where further inserted; they are only curled, and there they contract the extreme end of the liver, and move it occasionally, together with the intestines. Above, and near the insertion of these, is seen a small muscle *e*, which draws in the parts of the jaws and mouth, and the cartilage, with which the tongue is covered, together

together with the palate, and some other parts annexed. I describe and represent this in such a manner, that the basis of the tongue *g*, and its fore-pointed extremity *f*, which is armed with a kind of horny teeth, may be clearly distinguished; although they are all necessarily put somewhat out of their natural situation. Afterwards appear those two admirable muscles *bb*, which, by turning in the two upper horns through their cavity, draw the eyes back into the body; the curled foldings *ii* of the optic nerves are found to be transparent through those muscles, and are seen to run towards the eyes. The eyes themselves seem like two black points *kk*, over which a certain part of the horns thus drawn in still appears: under the former, are seen two plain, equal, or smooth muscles *ll*, which draw the lips and some other parts of the mouth into the cavity of the body; at the sides of these appear a pair of muscles *mm*, which are inserted in those of the lips before-mentioned, and serve to draw back the two lower horns into the cavity of the Snail's neck. Between the muscles hitherto described, are found two very wonderful and strong muscles *nn*, which are inserted with two firm and tough tendons in the middle of the body; this is variously and strongly moved by them, and is raised or elevated into the orifice of the shell by their power; between the tendons of those muscles is the proper place of the spinal marrow in the Snail, which from thence distributes its nerves to all the adjacent parts; the latter supplying the nervous fluid or moisture, and giving the power of moving and contracting; as may be seen very distinctly in the body itself. But after what manner the bone of the little habitation or shell of the Snail is formed, and what windings, partitions, cells, divisions, and cavities it has; this truly singular piece of art may be traced very easily in a natural shell, as I have endeavoured to express its structure, according to nature, with all the accuracy of which I was capable. Lastly, the extreme edge of the fringe or foot of the Snail, Tab. IV. fig. II. *qqqqq*, in which I have delineated all the muscles hitherto mentioned, deserves to be carefully regarded. The flesh, and the fibres and tendons are of a spotless white, so that there is not much difference in this respect between the fleshy and the tendinous part, unless for the smallness and solidity of the fibres.

Those parts being, in the first place, thus explained and understood, I shall proceed to describe and to expose to sight the inward parts of the shell. The first part which deserves consideration, is the outward orifice of the shell, fig. III. *a*; which being by little and little contracted and twined round, forms its second division *b*, and thence afterwards ascending further, it forms a third *c*, and at length a fourth *d*, and a fifth, which is the last, and has the extreme end of the liver placed in its cavity.

If any one dissects the shell with a fine saw, made of a small piece of a watch spring, and afterwards breaks open all the inward cells and divisions with a sharp pointed forceps, he will see very beautifully how this turning about or winding on the inside is effected; and how the five separate lodgements in the shell are composed and twisted in a spiral form, as I have represented from the life, in Tab. VI. fig. IV. numbers 1, 2, 3, 4, and 5.

The shell of the Snail makes as beautiful a figure, if it be prepared in the following manner; it is to be cut so that the inward part, or the columella or pillar, about which all the cells and inward divisions are turned, remains alone; in this case, in the upper end of the pillar, where the fifth and last lodgement is opened, there is seen a small aperture, fig. V. *a*, which passes *b* through the whole pillar, from top to bottom, and is always larger and wider at the entrance of the shell, than where the decreasing windings are terminated. These apertures are seen yet plainer, if the lowest part of the pillar be taken off, fig. VI. *c*, and the pillar itself considered apart. In many kinds of these bony habitations, these apertures of the pillar are very plain, from this cause, that all the windings of the shell have each their particular and distinct divisions, which are fastened and joined together in their twistings: we are to except from this account, such shells as have no winding, and are therefore called tubules or tubular shells.

For these reasons, therefore, this kind of shelly covering must be conceived as a certain oblong, hollow, sharp, and flexible tube, which if rolled and turned round a small iron line or wire, and afterwards this thread or line were drawn away from it, would shew such a perforated pillar, which would be the more exact, if all those foldings, together with their inclosures, were applied closely to each other, and fastened and united together. And after this manner are almost all kinds of such little shelly habitations built, in whatever wonderful manner they appear to be turned or constructed. This I myself have found, by strictly examining many different kinds of them which are in my father's museum. This appears however much clearer in some species than in others, in those shells, particularly, which are called tubules, and which are twisted, Tab. VII. fig. V. *b*, only at their extremity. This construction is so plain as to be beyond all manner of doubt. I shall therefore hereafter exhibit other kinds of shells in their proper places, that the difference may be known as far as possible, and by the fewest examples.

From each of these larger habitations may be formed as many smaller as can be desired, provided we first break off the pillar and the internal ridges, and afterwards make them even and smooth with a file. This is indeed contrary to the order of nature, for she always proceeds from the less, Tab. VI. fig. VII. *d*, to  
the

the greater *e*, and so on to the greatest *f*. I have prepared by art in this manner the distinct little shells which I here exhibit as gradually augmented. And that the method whereby this increase is performed by nature may be conceived, I shall now describe and explain how this habitation of the Snail is increased and augmented.

In this species of Snails, I could never discover the rudiment of the shell in the egg itself; but by observing other kinds I have found that the little egg laid by them produced always a very small but perfect Snail; and any person may know, from reason, that it must happen thus, since the Snail's muscles would not be otherwise strengthened by any insertion, which no body in his senses would even have thought; but I follow experience, as the only guide in this case. In other Snails I have often, through the outward shell, seen the little Snail lying in the egg, and moving very distinctly, before it came out, which I have been so happy as to shew to the illustrious Van Beuningen, our ambassador and consul. One remarkable thing is, that as soon as the Snail is come out of the egg, it is perceived to be so large, that it seems wonderful how it could lie and move, so pressed and wrapped up, in that elliptic and narrow cavity of the egg-shell.

Again, since the water Snails themselves likewise move in the egg for some days before they come out of it, hence one is inclined to conjecture, that the young Snail does not leave the shell of its egg before it has arrived at a certain degree of growth; at which, having its little shell sufficiently hardened, it is in a condition to creep out of the egg, and to increase its flesh and bone, or hard covering, with the food it receives. This may likewise be seen in other animals, which bring with them into the world flesh and bones out of the uterus, and only perfect them insensibly, by the use of their succeeding food. By this means, the Snail's shell is nourished, as well as its softer parts; though the former is done in such a manner, as to lead one to think that it differs in some measure from the latter.

It is besides this worthy of notice, that the shell of the Snail has its particular periosteum, by which it is covered and inclosed. And the same may be observed outwardly about the horns of stags, for those are likewise inclosed in a peculiar coat, which they rub off against the trees, and in process of time wear away, that is, after the horns have acquired their full stiffness, and the skin that surrounds them is no more nourished. I have found this membrane so strong and tough in the shells of some Snails, that it would not yield to aqua fortis; but the shell itself, rather than the periosteum, was corroded thereby. This membrane is likewise very considerable in the shells of sea Muscles, for to this the Muscles fasten those filaments by which they hang together, and fix themselves so as to prevent their being carried away with the

tide. The filament I speak of issues from their body, and is very broad in the forepart, almost like a piece of a leather, wherewith some persons draw on their shoes; and by the assistance of this, the Muscles are not only joined to each other, but likewise cling firmly to rocks, wood, stones, sea-weeds, or any thing that is near them. Those filaments in other kinds of Muscles, as in the *Pianna Marina*, are called *Byffus*, and are that matter, of which, as of silk, that kind of very fine linnen used to be made, which, according to *Rondeletius*, was called *Byffus*, and in which the rich man mentioned in scripture was clothed.

In the Snail whereof I here speak, the membrane before-mentioned is pretty strong, and it is visible every where in all the notches of the shell, and their interstices, *Tab. IV. fig. II. s.* In other shells of the same species, I have sometimes found it worn out, by the creatures frequent creeping through stony places; but it is always conspicuous near the aperture out of which the Snail creeps. If those who delight in natural curiosities, or have museums, find a shell stripped of this investing membrane, they conclude that it was rolled in the sea long after the death of the creature originally contained in it.

I have sometimes observed that the Snail, being about to enlarge its habitation, first cleared away this periosteum with its little teeth, nay, that it bit off some small pieces therefrom, and swallowed them; however, I have observed also, at other times, that the Snail cleaned the edge or margin of its shell with its teeth, if it was covered with films, and that the Snail happened to rest for any considerable time. I have likewise often found that the Snail, when it remains quiet for any time, forms films of that kind, and besprinkles them with a calcarious matter, and then those films will ferment with vinegar, as well as the shell itself, when worn or rubbed in the dust. And indeed all these experiments evidently demonstrate that this habitation is the real skin, or rather the hard or stony bone of the Snail, which covers it on the outside.

But if this stony shell be accurately examined, it appears to consist of numerous small, transparent, and as it were membranaceous coats, which have insensibly petrified, or assumed the nature of stone; as may likewise be observed in *Craw-fish* immediately after they have cast their shells, and in the bony skulls of men, which are at first only thin membranes, but are afterwards turned by degrees into bone. These membranes are at first like water, and afterwards grow solid and increase, when many fibrous and angular particles grow by degrees under them, as may be seen most evidently in the heads of abortive children. The same things may be observed in the Snail's shell, if it be lightly calcined, and then put under the microscope.

As to the method, whereby such a shell is increased, the following are the chief particulars, the Snail's whole body is furnished with glands, from the orifices of which flows up a kind of mucus or thick matter, like small and fine rays; which, like so many threads of silk or velvet, are joined together in one common crust or surface, and in process of time are condensed, and acquire the hardness which we observe in the shell. This mucus or thick humour then, is the first matter which grows into a membrane, and afterwards into a stony skin. Its filaments are very conspicuous at the places where the windings of the shell are applied to each other.

The outward scale or enamel of the teeth, in men as well as in beasts, likewise consists of innumerable very small and very fine filaments joined together, which I have found in some teeth hard and polished, like real stone; though the teeth are at first but a kind of mucus or thick humour, and afterwards become membranous, and at length fully hard. I have seen the rudiments of teeth in abortions of five months old, which, together with their filaments, I now keep, and can shew in them this singular construction.

My most respected friend, Mr. Stenon, has likewise discovered such filaments in oyster-shells, and made my father a present, for his museum, of a shell which was buried for a long series of years under ground, in the mountains of Italy, and, by length of time and moisture, insensibly had separated, as it were, into many tender and small shells: from this it is evident, that the shell itself was formed of those, in its growth, in the manner I have explained. In corals I have found nearly the same method of accretion; that is, that they are first thin membranes, which, by an insensible increase of the little grains joined together, petrify; as may be seen in a work published by Mr. Boccone, of corals, in which are two letters of mine treating of the same matter.

If you likewise view the tendons of the Snail's muscles, which are inserted in this part of the shell, you will find that they have grown hard as a stone there; which is indeed easily known, both from the winding of the shell's pillar, which becomes larger by degrees, and from the insertion of those muscles in the shell. In hens likewise, and in peacocks, the tendons of the muscles are ossified, or become by degrees hard as bones. These tendons, especially such as are taken out of the lower parts of the foot, are made use of, by some with us, for toothpicks.

The opercula of the shells, Tab. IV. fig. III. *m*, have almost the same origin, though their substance approaches nearer to chalk or plaster than to a stone; nor is it so hard, but is more spongy than the shell, and therefore is made thicker; but I have observed, that when the operculum or cover is finished, and the creature enters deeper into the shell, it afterwards, under the membrane of the shell's operculum, pro-

duces, sometimes two, sometimes three membranes, of which some are thicker than others, and are more or less calcareous. About the center of this operculum, is likewise seen a membranous filament, which connects all those membranes with the operculum, as if they were fastened with a needle and thread. When the creature frames its operculum or cover, it retires by degrees more and more into the shell, so that the verge equally shuts up its whole cavity, and afterwards presses out the chalky moisture, with the assistance probably of the sacculus calcarius, or calcareous bag which we have described.

The principal part of the body that promotes the increase of the shell, is that verge of the Snail, which the creeping in of the Snail causes to swell so far beyond the extremity of its little habitation, as that creature wants to stretch and enlarge it, thus it presses by degrees a glutinous humour out of the glands of the body, and thereof immediately forms a membrane consisting of filaments, which it afterwards makes thicker and thicker, until it at length attains a due hardness and firmness, by the pressure of the circumambient air. For this membrane is at first so weak and soft, that it breaks through on the slightest touch; and this is the reason why the haliçtations of Snails are found so often uneven with scars, and swellings on their surfaces.

If it should happen that the shell be pressed in by a fall, or by any other means, or be wounded or broken, these Snails know so well how to mend and consolidate it by degrees, by the application of the petrifying humour, that it becomes more firm than it was before in the places which suffered the injury. The outward surface by this becomes very unequal and tuberos, but the inward smooth and polished. Something like this is also observed in the fractured bones of animals, which nature can consolidate again with a callous substance; but even those are then also unequal on the surface after setting. We sometimes meet with ribs of mutton in the same manner, which it is very certain have been formerly fractured. I have seen the same thing in different bones of men and other animals. I have sometimes broke a Snail's shell so that I could put my little finger in the hole that I made, which, notwithstanding, I have found filled up again in four days: so that the same means of accretion and transmutation, to all intents and purposes, are observed in the Snail's shell as in the bones of other animals, with this only difference, that the vessels of the former are not conspicuous; which may probably be owing to their smallness and delicacy, and because the blood contained in them is white: but this makes no difference.

Another thing also very worthy of greater admiration is, that this shell will, even under water, whether it be fresh or salt, petrify or become hard as a stone, however much it has been like a fluid humour in the beginning. This

may be seen in river and sea Snails. But what seems to me a greater paradox is, that some insects frame their shelly coverings, and weave their little nets under water, like Silk-worms, out of small and glutinous filaments; so that these threads, which are spun from a fine and subtle humour, acquire their firmness, tenacity and hardness even in water, as well as the threads of Silk-worms do in the air. I can shew some very rare and uncommon experiments on this head in the water shell-fish which I preserve. Let me add, that I have seen a Snail die the third day after I had taken it out of its shell; though in separating it I had hurted

none of the blood vessels, and had likewise carefully left untouched that part of the shell wherein the muscles were inserted; but that Snail before its death pressed out a certain membrane round the whole surface of its body. This membrane was the same in all respects as that on which I have made the preceding experiments, and was intended by nature to supply a new shell. In the beginning the Snail was very sprightly; but afterwards it insensibly languished more and more, and at length, contracting itself under its verge, it died. Here end my observations on this species of Snails.

## C H A P. XII.

*Of the Hermit fish, and Pinna Marina. Of the inward turnings or convolutions of the turbinated shells. Of the Voluta or Cylinder, the Concha Veneris, and Pencil, and some other shells of the Snail kind.*

**I**F all the things I have advanced in the preceding chapter be attentively weighed and considered, it will appear clear as the light at noon, that the Snail's shell is its real bone, without which it cannot live. Hence it appears what an idle fable that is which is established even amongst those who study shell-fishes, when they shew some of the Crab kind in their museums, adding at the same time that they pass from one shell to another, devour the animals that lived in those shells, and keep them for their own habitations. They dignify them with founding names and additions, as Soldiers, Hermits, and the like; and thus, having no experience, they commit gross errors, and deceive themselves as well as others with their idle imaginations.

Some years since, when I was at the Hague, I employed some fishermen who lived at Scheveling, to bring me all the strange fishes which they should catch. It so happened that among the rest they brought many small Crabs, Tab. XI. fig. 1. *a*; each of which lived in a kind of twisted, round, smooth and polished shell; but when I viewed the animals themselves more accurately, I observed that they resembled Crabs only in their fore part, that is, they had four feet *gg*, and two forceps, of which the right *e* was much stronger and thicker, than the left *f*. I further saw there two tender feelers or horns *dd*, and two prominent eyes *c*; and under the latter there were placed some other small parts. The inward part or body of this Crab was fixed to the pillar of the shell, by the tendons of its muscles, but otherwise it was soft and consolidated, as in Wilks and other Marina or sea Snails.

Aristotle and Ælian tell us, that in some shells there are both a Crab and Snail together; hence the Crab has got the name of Pinnophylax or shell-keeper. These authors likewise harbour another ingenious opinion,

which is, that the Crab provides food for its companion the Snail; so that these two little animals live it seems, and have all necessaries, in common, which is an admirable thing, and which has given some authors occasion to frame several parables, and make various moral reflections. It is beyond doubt that this animal they describe was likewise a species of the Cancellus or Hermit Crab, one part whereof, that which provides necessaries, and creeps out of the shell, is covered with a hard crust; but that which remains within the shell is the soft and tender part of the body; and as the shell serves in this part instead of a skin or covering, there was therefore no need of a testaceous cover or crust, as we have already observed with respect to the Cancellus.

The Pinna is a species of the Ostracodermion, and is at this time called Vinne in the Netherlands, by those who have a curiosity for things of this nature; because, perhaps, the animal living within seeks its prey by violence, and catches and kills less creatures with its forceps. It may possibly also have its name from hence, that its shell is commonly as thin as the fin of a fish, and when stript of its skin, is transparent like the scales of fishes. This shell is contracted into a sharp or pointed end on one part. In my father's museum are many specimens of those shells, which are called by some prickly Muscles.

I shall not deny that small Crabs are frequently found in the shells of sea Snails, when their inhabitants have been killed and taken out of them; nay, and sometimes Star-fish are found in the same manner, for I saw this very thing in the town of Petten, on the sea coast. But this happens only by chance, and these little animals cannot stay long in those habitations; when hunger begins to incite, they go out for food. Thus, when I was looking for insects, I have, in company with



with Mr. Thevenot, and Mr. Stenon, found several small Crabs in the river Seine, in the bones of some ox's skulls which had been thrown into that river.

The shell in which the Hermit abovementioned lies, is on the inside twisted into the like windings as the operculated Wilk; I shall therefore omit its figure in this place. But that the diversity of the windings may be known, in some measure, in other shells, I shall now represent the inward windings of the turbinated kind. The common Turbo is of a very elegant structure; it begins at the basis with broader windings, Tab. VII. fig. 1. *a*, and, rising by degrees obliquely, like a circular stair-case, converges into an acute point *b*, and thus forms various cells and lodgments.

But the figure of the Voluta, or that called the Cylinder Snail, is much more beautiful, because the convolution or winding is more complicate and intricate; its entrance, fig. II. *a*, growing narrower *b* by degrees, forms another round *c*, which afterwards, being still twisted or convoluted *d* round its pillar, produces beautiful and regularly spiral tendrils, which grow narrower by degrees, and at length are lost. This structure truly merits admiration, for all things are there so beautifully divided and separated by inward divisions and cells, that they exhibit a labyrinth of miracles, into the inward cell of which we cannot obtain admittance, unless we first pass round all these windings. Nor can any one discover its wonderful elegance, unless guided by the Ariadnean thread of an unwearied research into the works of God. The Almighty gives knowledge as the price of labour, which the heathens themselves have declared.

No less admirable are the sinuses of the Concha Veneris, with which the women in Hoiland adorn the strings tied to their keys, and polish their whitened linen after bleaching. This shell is constructed with various convolutions, and unusual and amazing windings, like tendrils; and to all those convolutions of the inward part of the shell, the body is fitted and made to agree by its bendings and windings. I have already explained in the Snail before described how this is done. Its entrance, Tab. VII. fig. III. *a*, is beautifully fortified and divided into little teeth like those of a saw; such as are likewise observed to be placed on the inside about each winding, as far as the extremity *b* of the shell, which terminates in a very sharp and small point. But all these remarkable things cannot be exhibited in a single figure.

In the Penicilli Marini, which the French call pencils or plumes, the most wise architect has disposed their windings in a very different manner: they begin in the orifice, fig. IV. *a*, of the Penicillus, and insensibly form

another lodgment or apartment, with their notched or denticulated bendings; then as it were, diminishing by degrees, and rising again with broader convolutions, they form a third lodgment *c*; afterwards they decrease more and more, and make a fourth *d*, fifth *e*, sixth *f*, and seventh *g* compartment. The last is like a little string or tuft of filaments, and is properly the first rudiment from which the Penicillus begins to increase, and whence, by a gradual augmentation, it acquires or raises all the rest of the compartments.

In the cabinets of the curious, there is kept a certain species of Snails, which agrees in its internal construction, well enough with the Cornu Ammonis. This consists of a simple little tube, fig. VII. *a*, rolled into itself, very large before, narrower behind, and ending in a very small point. It differs from most other shells of Snails, because it is divided on the inside into numerous compartments, by delicate partitions; which are transparent even on the outside, 1, 2, 3, 4, 5, &c. In the fore end, the partition which is hollow like a faucer, is naked or plain to the eye, and has a small hole pierced through it there *a*\*. If this hole be accurately viewed, it is found actually to open into the tubular appendage of the partition, which appendage or tube is inserted in the opening of the second partition, and the tube of the second into the aperture of the third, the third into the fourth, and so afterwards to the end of the shell.

All these things appear plainer, if the outward shell of the Snail is picked off; for then the stories or partitions, Tab. VII. fig. VIII. *bb*, situate in the Snail's tube, are seen very plainly, as well as the little tube or siphunculus, that reaches from the first partition to the aperture and tube of the second, and the tube of the second to the third, and so to the extremity of the Snail: all which may be seen about the inward side of the curvature *c* of this creature very distinctly. But since these things cannot be so distinctly exhibited or understood under its natural size, I have thought it advisable to represent, of these, several partitions considerably magnified; in which figures, the acetabulum or partition appears first in its compass, fig. IX. *ddd*, and on the inside its inward fold, hollow like a spoon. On the upper part of this is seen *e* a little aperture formed with the most exquisite art. Behind this aperture is seen the tubular appendage of the acetabulum or partition, which, on the upper and lower side of that partition, is stretched out, like the crooked handle out of a certain spoon, and is received very exactly into the aperture and tubular appendages of the partition, fig. X. *g*, and this again into the aperture and tube of the third *b*.

\* All Nautali are of this structure, as also the Arthoceratila, as well as Cornua Ammonis, which are found petrified, being inhabitants of deep seas; whence they are never got up living, nor the shell seen recent. In the large thick Nautilus, these partitions are forty or more in number, and there runs through them all a pipe; this is called the siphunculus; the animal within is of the Sepia or Cuttle-fish kind. In the Arthoceratila they are more numerous. We see this shell-fossil in the red stones called Swedes paving, and used in court-yards, and for flat walks.

What has been hitherto said, is far from completing the artificial structure of this wonderful Snail: for as this Cornu Ammonis becomes smaller by degrees, so do its partitions, and their tubes *iiii* become less, until at length they become invisible. I observe likewise, that these tubes of the partition are not connected together, but are only contiguous, and are put into each other, in the same manner as the tubes of telescopes, which receive each other in such a manner as to be freely moveable. But on the contrary, the acetabula or partitions themselves increase with the Snail's shell, and are united to it. I preserve some of these acetabula, which shew their very elegant structure, if their tubes are joined together; for which purpose, and that they should not be easily lost, I keep them together bound with a silver thread.

This Snail therefore agrees with all others in regard to its structure, and its shell consists of one crooked tube. It differs, however, from the rest only in that the apartments or cells are placed in a different manner, and have perforated handles: these may be said to form the pillar of this Snail, since they exactly receive each other.

I never saw this shell with its Snail but empty only in my father's cabinet. I should therefore be very glad to know, by what means the body of this little creature, which inhabits that shelly house, is placed there, and whether it extends through all those apertures from cell to cell, and is intersected, as it were, in so many places; or whether it lives only in the extreme apartment, and is inserted with its muscles in the tubes of the shell. But however much I wish to be gratified in this particular, I shall never, probably, accomplish my desire. It would therefore be proper for those who visit foreign countries, for the sake of commerce, to import such things; for though they have never so little curiosity or taste for these studies, they ought to endeavour to make the works of God manifest to posterity, and by due care they might profit more than by any other means whatsoever.

The great Indian Nautilus is nearly of the same structure with the Cornu Ammonis, and therefore I had once thought to give its figure in this place: but since it is found in many of the cabinets of the curious, and of the same structure with this, I shall desist from my intended purpose, and the rather, because the celebrated Aldrovandus has left us a pretty neat and exact figure thereof.

Let it suffice, that I have annexed the figures of the two tubular Snails, or testaceous tubes already described, which afford an example, from which the manner of constructing all the shells of Snails may, in some measure, be understood. All the difference observed between them arises from the variation of their convo-

lutions only: to which, if we further add some outward ornaments of ridges, hollows, windings, plains, tubercles, depressions, extensions, impressions, and colours; and lastly, that the cavity of the pillar sometimes grows together entirely, as I have likewise sometimes observed in the shell of the garden Snail; it is then easy to reduce all the geometrical figures, curves, oblique and right angles, in all kinds of Snails, to one species, that is, to an oblong tube, which is curved, curled, or bent in and out, and grows in this state.

The tubular shell-fish before-mentioned\*, exhibits the most simple articulation of all the kinds, for in their beginning they are stretched out, like a plain tube, Tab. VII. fig. v. *a*, or little intestine, and are turned or bent round mostly near the end *b*. And hence arises that cavity, fig. vi. *c*, whereof I spoke, when I treated of the cavity of the pillar. But these tubular creatures grow together, sometimes ten or twenty, in so perplexed a manner, that nothing certain can be distinguished concerning them, since nothing appears to our view but ends or tops, windings and little apertures.

I shall further add, that almost all kinds of Snails and shell-fish are twisted towards one and the same side; nor can many be found, at least very seldom, the convolutions whereof go, Tab. VII. fig. xi. *a*, in a direction contrary to the others. In some species of oval Turbo's, and some others, this is sometimes found; and such shells, for this reason, that they are less common and more esteemed, are carefully kept in the cabinet of the curious.

#### *The little Turbo.*

I found some years ago a small Snail between the bark and wood of an old willow-tree, the shell whereof resembled a sea Turbo, and from a somewhat broad beginning, terminated Tab. VIII. fig. i. *a*, insensibly in a sharp-pointed top. This Snail is never seen in the day time, except in rainy weather; it then always hides itself under the bark, or in other shady places, and resting there, it fastens that part of its shell by which the body creeps forward, to the wood, the other acute extremity being obliquely directed upwards. The shell of this Snail is likewise curled or convoluted in an inverse manner; and what merits great notice is, that its genital organs are placed in the left side of its neck, in an order contrary to all other Snails. But I have sometimes observed the convolution of the shell to be inverted in the Purple-fish. It is therefore probable that whatever Snails have their shell twisted in an inverted manner, have likewise their genitals in the same situation.

I have very seldom seen this Snail with its shell larger than I have expressed it in the figure; nor have I found that part *b* of its body, which

\* These are called Tubuli Marini by authors: they are simple and plainly hollow. Some are straited, and others smooth on the surface; some perfectly strait, others twisted at the end. They are found loose on the shore, and lodged in solid substances. The animal within is a true Snail.

creeps therefrom, larger than there shewn: for when this part turns out, it carries its little shell like a pyramid obliquely on its body. It has four horns, whereof the two upper ones have their eyes in their extremities. The two lower do not appear so distinctly, being only two obtuse or blunt little swellings. The two upper horns and the eyes are large, in proportion to the bigness of the creature. The aperture of its verge, through which it breathes, is likewise in its left side. Its shell is twisted into seven spiral lines, and is adorned on every side with little ribs or ridges, so that, by this means, very beautiful wrinkles or folds appear in this shell, which has likewise its periostracum to cover it.

The internal parts of this little creature agrees in general with those of the common covered Snail. The parts of the jaws, mouth, and palate, and all the salival vessels and the stomach, are alike in both. The brain lies on the gullet, and may likewise be beautifully distinguished, but in its structure it approaches more to the brain of the common water Snail, which I have represented in Tab. VIII. fig. iv. Its pointed liver fills the extremity of the shell, and, like the latter, it is likewise twisted, but its structure is glandulous. The orifices for the penis and uterus are opened in the left side, so that the penis, erecting itself, springs from a place directly opposite to, that in the common Snail. But it appears from this perfection of the genital parts, that the creature, though so minute, has already attained its full size. The ovary likewise appeared to me pretty distinct. The purple sacculus or bag, was likewise very visible, as well as the little part in the form of a chain.

I preserved this Snail alive some days, by giving it lettuce in a glass vessel, into which I had poured also some drops of water, during which time it moved the whole day. At other times, when the weather is hotter, this species eat chiefly at night. In the month of June I found it under the bark of willows.

If its shell be viewed with a microscope, the aperture, Tab. VIII. fig. ii. *a*, of the inverted twist, through which the body passes, and the opening *b* of the pillar, and the ridges of the surface, or the ribs *ccc*, appear clearly to the eye.

#### *The small flatted Snail.*

Under the bark of willows is likewise found another species of small Snails, the shell, fig. III. *a*, of which is somewhat of a more simple structure, and so thin that it is all over transparent. The Snail contained in this died for drought before I could dissect it. Its shell was all transparent, by reason of its exquisite fineness; so that the dead body of the Snail ap-

peared through it, diversified with some colours and spots.

#### *The oval Snail.*

In the rushy grass of ditches, and on the water-lilly, when its leaves reach to the surface in rivers, there is found a certain species of Snails, which reside there on account of the cool air and moisture, where they may at any time seek out for their food: but they go to feed chiefly late in the evening and early in the morning, and in the heat of the day they remain quiet near each other under the shade. Their shell which they carry on their bodies, is of an oval figure, marked with many hollows or furrows, and adorned, Tab. VIII. fig. iv. *a*, with a periostracum of a pale red colour. The hinder part is so tender, that when roughly handled, it is very easily broke, and this is rolled into a double spiral part *b*. The body of the creature that creeps *c* out from thence is marked with points or black spots, and in the fore part it stretches out two blunt or obtuse *d* horns, under which are seen two others smaller.

In the mouth of this Snail is a pretty strong tooth, which is extended into a horny little bone, and expands itself through the whole inward part of the mouth. The aperture of the verge is on the right side, and the orifices of the genital parts open at the same side in the neck. The stomach is of a pale colour, and is variegated with black points or spots; hence it appears upon the whole gray. The salival vessels which run near the gullet under the brain are very remarkable and large, in proportion to the size of the animal, and are speckled or spotted like the stomach. The liver is the same as in the common Snail. The heart is placed in the left side, and there lies the lime bag also, which is very large, and full of round white globules of various sizes. The brain and nerves are like those of the common covered Snail. The penis appears short, but if the membrane, by which it is erected, be opened, it is found bent on the inside like the tendril of a vine, and is seen to be really very long. The structure of the uterus is the same with that of the common Snail; but on one side of it is a small part that I never saw in that Snail. After this follows the yellow sacculous bag designed for the glutinous moisture; and at length the small part in the form of a chain, which is very black like pitch. The purple pearl-eyed little knot appears half round in this Snail, though it is really somewhat oval. I could not discover more parts in this little creature, though I observed that it had the same muscles as the common Snail; nay, that two of them were designed to pass underneath through the brain, for the purpose of drawing in the parts before mentioned.

## C H A P. XIII.

*Of the garden Snail\*, the house Snail, and that of the fields or path ways.*

ALL the external and internal parts of the garden Snail, which is a handsome little creature, are the same with those of the larger Snail, only that they differ a little here and there in respect of structure and colour. Since therefore the difference is not so great in regard to the rest, I shall here briefly explain the only one that is in the genital parts. The aperture of the genital organs, Tab. VIII. fig. v. *a*, is placed in the neck, somewhat lower than it is in the larger Snail. The uterus *bb* and its ligament *c*, and the bag which holds the glutinous moisture, are like those of the larger Snail *d*. There is, moreover, no difference in the chain-like little part *e*. As I began this inquiry in the month of June, which was indeed far advanced, the little eggs *f* were seen more distinct in the ovary, near the extreme spiral part *g* of the liver; these eggs were, in my opinion, to be carried from thence through the chain-like little part into the uterus, and to be covered all over with the glutinous moisture. The purple little knot *b* was of a colour almost approaching to a pale yellow, and contained a stronger substance than in the larger Snail. The other tube or pipe *i*, which in the larger Snail opens into the uterus, was in this stretched out further, and the alkaline little bone was, in a situation directly contrary, thrust into it. In the larger Snail, likewise, I have found this tube sometimes in the same situation. This little part was moreover formed, where in its beginning it is connected with the uterus *k*, in the same manner as it is in the larger Snail. The imperforated appendage *l* of the uterus has likewise the same structure, but is of a more gray colour: the testicles *m* likewise, were like those of the covered Snail, but consisted of longer filaments, and were divided only into six vessels. The alkaline little bone *n* was of a structure entirely different, and wanted those four little ribs, which I have before exhibited in the magnified bone of the larger Snail, but was very beautifully decorated with little holes, and little prominences that met all together. It was however full as big as the little bone of the other Snail, and may likewise be stretched further out of the body, for it stood on a longer little knot, the neck whereof was much longer, and likewise of a gray colour. The penis *oo* seemed longer and more acute, and I have here delineated its only muscle, Tab. VIII. fig. v. *p*, which draws it in. This was placed in the same manner as in the large Snail. Moreover, the common duct *q* between the

penis and uterus did not differ in respect to its structure. But this Snail twisted about the sharp end of its penis in the dissection, and curled it into various turns *r*, which I never saw so clearly and distinctly in the other Snail.

There is great difference between the manner of coition in the larger Snail and this of the garden; the penis of this latter is rolled out further, and is more erected and much longer; it has at its origination the same glands the skin is provided with. The coition of the garden Snail continues longer than that of the larger Snail. And the whole penis of one Snail is put as far as its extremity into the body of another; hence these two penis's are sometimes seen, fig. vi. *a*, twisted together in a very wonderful manner. But this winding is not seen so beautifully as I have delineated it, unless the Snails are drawn a little asunder; for then is perceived the wonderful manner whereby the penis of one Snail *b* rolls itself round the penis of the other, and enters into the uterus *c*, whilst the penis of the latter is, in its turn, twisted round that of the former *d*, and likewise put into the orifice of that creature's uterus *e*. But if these Snails are pulled away from each other at the time of coition, the whole penis's, long as they are, being drawn from the orifice of both Snails appear in sight, and each creature afterwards turns them in in a wonderful manner, and after a short time draw them back again into the body.

But as each Snail has its genital parts in the right side of the neck, their heads are applied to each other cross-ways at the time of coition, and consequently the body and horns of each Snail have a contrary situation at that time. For in the body of the former Snail *f*, the opening and divisions of the verge whereby it draws the air, are visible; but in the latter Snail nothing is seen of them *g*, for this Snail is placed in a different manner.

These garden Snails are of the most common kind. Their shell is grounded on yellow, and is divided lightly by special small furrows; it is also adorned with tawny or black rings, which surround it nearly in the course of the shell's spiral turns. It is also covered with a very thin membrane or periosteum, which is black or yellow in the same places where the shell itself is painted in that manner, and it likewise preserves its colour when the membrane is taken from it.

Each of these Snails has also four horns, of which the two upper ones only have eyes.

\* The species here meant by the author, is the common small painted Snail, which we find in hedges. We usually call the larger brown kind the garden Snail, because it is more common with us in gardens; but this the author calls the common Snail. This less being more frequent in the gardens of Holland, is the garden Snail of that country.

It was therefore an idle fancy in some persons, to think that the Snail uses its horns, as a blind man does his stick, that is, to find out the way it is to creep through, or to try and distinguish, by its touch, whether objects are hard or soft. The head of these Snails, in that part of it where the lips are situated, resembles, in some measure, the head of a cat; and when well viewed, it appears like it in several respects more evidently.

*The common house Snail.*

The naked house Snail, which is found in moist cellars and about the tops of cisterns, is naked and has no shell, but is covered with its skin only. In this particular it agrees with that part of the covered Snail, which creeps out of the shell. On the outside it is provided with four horns on its head; the two uppermost whereof have eyes at their extremities, Tab. VIII. fig. VII. *aa*, which are situated a little within the margin, on that side which lies towards the eminence placed on the back. The two lower horns *bb* are smaller and have no eyes. There is further seen on its body, that eminence or velabrum *cc* which is fixed to the back, and runs along the rest of the body; and the body is furnished with oblong, acute, and tender glandules, and variegated with black lines and spots. But the horns, head, neck, and whatever reaches beyond the eminence, are adorned with many smaller and more delicate glandules. On the right of the declivity of the neck appears an aperture *d*, through which the genital organs push themselves.

The eminence on its back itself, is of a different colour from the rest of the body, for it is adorned with channelled or crested little grains, and it is moreover very beautifully variegated with black spots. This is not common to all house Snails, for they differ much in colour. Towards the fore part, at the head, the eminence is loose and free, but for the most part, it is kept very close to the body, unless when any one provokes or vexes the Snail in that place; for then it raises and moves it different ways; and I have, for that reason, drawn it as elevated in the figure. On the hinder part, towards the back, the eminence is very strongly joined to the body; but in its right side opens an aperture, Tab. VIII. fig. VII. *e*, whereby the Snail draws air and breathes, and discharges its fœces; for which uses the verge is likewise appointed in the covered Snail, and with this verge the eminence agrees very much, so far as it is placed on the fore part of the body. The hinder part of the body is not very remarkable, only in respect of the different structure of its glandules. Moreover, in both sides of the body is observed a small, black, unequal margin. In fine, there is on the hinder part, above the tail, a prominent substance *f* like a Cock's comb, which is indeed disposed in a different manner in the field Snail. The Snail secretes a glutinous humour from this part.

If any one opens the eminence at the mouth of the air passage with a little pair of scissors, he will see that the inward skin is made on the inside like a net; which structure seems to be produced by the vessels distributed through it, as I have likewise before shewn in the verge of the covered Snail. This little net may be seen very beautifully through the aperture of the eminence on a clear day, when the Snail opens it; for the creature can contract it so closely, that not even a vestige of an aperture appears. In the cavity of this eminence, on the left side of the body are seen the heart, which beats, together with its auricle and pericardium, and likewise other cavities through which the air passes. But when you remove this little net from its place, you will see a small stone underneath, which is called, by authors, Lapis Limacis, the Snail stone, and is said to serve for various uses in medicine. This little stone may properly be called the os thoracis, or breast bone of the creature, for it is placed in the middle of the thorax and back. It is of the figure of a small hollow, and somewhat long shell, fig. VIII. *a*. and being connected in its circumference with various membranes, and on the upper side with the little net, it is thus kept in its place. It is sometimes observed to be altogether membranous, but sometimes it is pretty thick and all stony, and it ferments with an acid; at other times, again, it becomes stony only here and there, and is observed to be interwoven *b*, as it were, with vessels which are filled with stony little grains. Hence one may understand the manner of its production, which is from the coagulation of the stony particles; in like manner as is observed in the membranes which the covered Snail frames, when it lies some time at rest. These shelly stones are found in younger, as well as full-grown house Snails, and I have sometimes found in the largest, very small and membranaceous ones, interwoven with various petrified vessels; and often in smaller ones, I have found them formed of solid stone. Hence I am inclined to think, that the Snails change this their little stone yearly, in the same manner as Craw-fish change those two semi-convex and plain stones, which are likewise placed in their thorax, and are improperly called Crabs eyes.

Near the heart is observed a sacculus calcarius, or lime bag, not much different from that which we have described in the large Snail. Afterwards the stomach, intestines, and genital parts present themselves in the abdomen. The stomach is indeed pretty large and strong, and consists of three distinctly visible coats. The innermost is wrinkled into plaits, and is of a yellow colour; the middle one is muscular; the outermost is somewhat corrugated or rough, with very beautiful partitions, especially when the stomach is empty. Directly before are seen the salival vessels, which, as well as those out of which they spring, are shorter than in the larger Snail, but they are of the same texture. The intestines pass twisting or winding

ing through the liver, which is placed between them, but they are much less rolled and turned in this than in the larger Snail, since they are stretched according to the length of the body, and are not obliged to follow the convolutions of a shell. The liver is divided into many lobes, and consists only of minute glandules.

The genital parts in this Snail are worthy of particular notice, since they fill the whole belly: but I shall treat of these hereafter, when I shall briefly describe the parts of the head, neck and breast. The head presents a tooth, visible in the mouth like that of the larger Snail, and all the parts of the mouth are also formed in the same manner as we have there related. The brain likewise, the spiral marrow, and the nerves, which are placed in the neck, do not differ much, and are easily discovered. The muscles which move the upper horns inward, are much more brown or blackish than in the larger Snail; but the rest, and likewise those which pass through the thorax, have some flesh, as well as their white tendons, and are both inserted in the skin, which is very thick, and where the eminence lies: nor are there any bones in the Snail, in which the muscles should be inserted. A muscle is therefore here inserted in a muscle, and one dilates another, which is a very admirable thing to see in animals.

The organs of generation in this Snail, open by three distinct apertures in the neck, Tab. VIII. fig. ix. *a*, which unite in one passage on the outside. The first opening is peculiar to the penis *bb*, the second to the uterus *ccc*, the third to the purple bag, which is very short in this Snail. The penis is strong and very nervous, and it lies in a little kind of a purse, which may be distended by the breath, that the penis may roll itself out from thence. On the hinder part or side of the penis issues a small filament *e*, which is connected with that of the uterus *fff*. This ligament of the uterus abounds with many granules, which are white, and unequally divided; those, at first sight, I took for the ovary in the larger Snail, thinking that the little eggs were conveyed through certain hidden channels out of it into the uterus: but I now observe, that it has a peculiar kind of tube in this Snail, which opens into the hinder part of the cavity of the penis, and conveys its matter into it. The uterus wraps itself round this ligament, and is greatly strengthened by its connexion therewith, though this connexion is formed in the beginning only by small intervening membranes.

The uterus in the Snail which I dissected, was very much distended and swollen *gg* with little eggs; nay, its texture seemed more strong and firm, than when nothing is found in it. On the hinder part lay the glue-bag *bb*, very much dilated and expanded into lobes, which were again studded in a peculiar manner. When I viewed them with a microscope, I observed, that they were all full of very small spheroidal globules, whereof some were bigger

than others. The chain-like little part *ii* was stretched straight, or upright enough. The ovary was fallen down *k*, and deprived of its eggs, so that nothing was left in it but the membranous inclosures. All the eggs, in my opinion, had descended through the chain-like tube into the uterus, and were to be immediately there covered with moisture, by means of the faculus that secretes that fluid: this I shall explain more at large, when I shall speak of the field Snail. Nor did the eggs, notwithstanding, fluctuate freely in the uterus, but they all lay firmly fixed on one side, which makes me still doubt to advance what I have said of the ovary and eggs as true and certain. But I hope these things will hereafter be made plainer. I shall therefore proceed to the field Snail, the anatomy of which will throw great light on this matter.

#### *Of the field or path-way Snail.*

The common Snail of the path ways and fields differs from the house Snail, chiefly in respect of the structure of its external skin, and in a peculiar kind of verge which surrounds its body; to which may be added, the fissure that is in the extremity of its tail, out of which a certain glutinous humour is secreted: but there is no difference in the internal parts. I have delineated the field Snail, which I here exhibit, in the form it has when contracted. Thus its two largest horns, Tab. IX. fig. 1. *a*, may be seen, except a small part thereof, which is covered by the eminence or velabrum. On the right of this velabrum is seen an aperture *b*, whereby the Snail draws the air and discharges its excrements: the same may be observed likewise in the house Snail. In the cavity of the eminence, the skin is also white and reticulated, as it is in the house Snail. The external texture of this eminence consists of fine glandular granules, or little grains, which are far from being orbicular; they are striated as it were, and rendered unequal by some tubercles, though these striæ or furrows are not as remarkable in this as in the house Snail. The rest of the body is furrowed as with pretty considerable wrinkles; hence it is that many glandular protuberances appear in it, which are of a triangular form, and rise up obliquely, and are divided *cc* by many small glands. The body is, moreover, adorned with a full, or glossy, red verge *dd*, which is beautifully divided and subdivided by black furrows, some of which therefore are more conspicuous than others. This Snail can extend itself to three times the length that I have here represented; and then the divisions of the skin before described acquire as it were another form, by the force of its expansion. The whole body is of a deep brown, mixed with a ruddy colour; but these Snails differ very much with respect to their colour.

As its internal parts are organized, and circumstanced much in the same manner as in the house Snail, I shall now briefly describe only the structure of the genital organs, and add the construction

construction of some of the internal parts, which I have here also delineated. The genital organs are thrust out of the neck, in the same manner as in the house Snail, and are found to be likewise placed behind the parts of the palate and mouth, Tab. IX. fig. II. *a*. On each side the larger horns *bb* may be seen when drawn in; they appear under the divided skin of the head. Behind the proper parts of the mouth, and above the gullet *d*, is placed the brain *e*, which is formed of two small parts like globes, applied close to each other. Immediately after appears the origin *f* of the stomach, together with the salival vessels *gg*, which are here represented as clipt or cut off near the gullet. After these are observed two glandular corpuscles *bb*, from which the salival vessels arise. Then at length is presented to our view the stomach, with its vessels *i*, which are of a pure white, like the colour observed in the intestines *kk*. The windings of the intestines surround the liver *lll*, which consists of small glandules, equally divided and interwoven with very white vessels. It sends forth the gall-bag *m*, which is large, and discharges itself into the small guts that are next to the stomach.

The beginning or rather end of the genital organs is seen in the skin *n* of the neck, and their mouth or opening appears there in the outward skin; which, however, I have not exhibited in this place, that the other parts might be the more distinctly visible. The first thing that presents itself is the penis *o*, which, being twisted like a tendril of a vine, opens with a kind of tube *p* into the cavity of the uterus. Nothing of this kind is observed in the house Snail, but in the covered Snail there is likewise a common duct, and the penis is extended longer. Behind the penis is seen a remarkable pear-shaped bag *q*: this is the purple-bearing bag; it is very large in this Snail, and contains a delicate juice. It opens by a small tube *r* into the cavity of the skin of the penis, by means of which the latter erects itself.

The origination *s* of the uterus is pretty thick and strong, and after it grows smaller *t*, it

twists and bends itself, and goes into the body of the uterus *uuuu*, as it does in many other Snails; But the ligament of the uterus is not seen in this; its place is occupied by several whitish vessels, which are connected *xxx* by a small kind of membrane, that ties the curled windings of the uterus. About the end of the uterus, where the bag of glutinous moisture *yy* is joined to it, is seen a place where the chain-like tube is inserted, or fixed in the uterus: nay, it further appears, how this tube runs through and over the liver, and under the small guts *a*, and is connected with the ovary *β*, which is here empty. This ovary is divided into two parts, as it is in other creatures. The division, however, is not so remarkable in those Snails, which have not exercised venery, as it is in the ovary, which I here exhibit alone, fig. III. *a*. I therefore represent this ovary big and expanded, as I think I saw it some months after coition. For it is then observed, that this little part considerably increases, Tab. IX. fig. III. *a*, and that the eggs *bb* are made visible therein. I have likewise observed this increase in the ovary of the shelly Snail. But the eggs, it seems, are afterwards discharged out of the ovary, and descend through the chain-like little tube *c* into the cavity of the uterus, to the hinder part of which the former is joined, fig. III. *z*. But as the passage of the eggs is so near to the bag of glutinous humour, I therefore think, they are there covered over with a little of it, and that when they grow larger, they get more of it, and, at length, attain their full bigness in the uterus. But I could never hitherto find eggs in the chain-like little part, as I have already mentioned in the description of the house Snail; nor could I see that they are conveyed through it. I shall therefore defer advancing this opinion as an undoubted truth, until I see it myself; though I think, at the same time, the matter may most probably happen so. The heart likewise is seen in its natural situation *γ*, as also the manner in which it is surrounded by the bag *δδ* of calcarious or limy matter:

## C H A P. XIV.

*Of the common water Snail, also, of an uncommon and viviparous kind of water Snail; and of the flatted water Snail, and the muscles of the river Vecht. Also a remarkable observation on the common Snail.*

THE common water Snail, which I find every where at the edges of ditches in Holland, differs much both from the common covered, and from all other Snails. It is distinguishable, not only in regard to the outward skin or shell, but also with respect to its eyes, and the apertures both of the verge and the genital organs, which are all conspicuous on the outside. There is also a still greater difference

in the internal parts; all which I shall now briefly enumerate.

The shell, which is in the form of a spheroid in the large Snail, is in the water Snail rolled in an oblong form like that of the Turbo, Tab. IX. fig. iv. *a*. But there is still a greater difference in its eyes; for as the latter in the common Snail are at the ends of the horns; on the contrary, they are found in this

aquatic or water Snail, to be situated at the bottom or basis *bb* of them, but they are not provided with any visible muscle to move them. Even the horns themselves, which end in sharp points *cc*, are only weakly drawn in occasionally in order to become shorter.

In some of these Snails, I saw with amazement that there were two eyes, placed near each other on the right side of the creature, each of which was provided with its own proper chrystalline humour. This, I think, is very remarkable, and strongly demonstrates the manner wherein the eyes may be multiplied in insects, as I shall hereafter demonstrate, when I shall treat of Bees. The nerves of the eyes in this water Snail are less visible than in the common kinds; nor do they arise immediately, as is said, from the brain, but from a little nerve which lies towards the fore parts of the head. In other respects the eye itself does not differ from that of the covered Snail, only that it is bigger, and in a manner pear-shaped, or like an onion. The chrystalline humour is likewise larger in this, however distinguishably less the little creature may be in itself.

The opening *d* of the verge is very worthy of consideration, and has divers muscles, by which it is dilated and contracted. The Snail sometimes gathers this aperture into an oblong tube, and stretches or protends it above the surface of the water, in order to draw in and expel the air. This may not only be seen but heard also, by the noise which the Snail makes in moving the water. Nay, by the assistance of this aperture, through which the air is conveyed into the inmost surface of the membrane of the verge, and into the cavity of the body itself, the Snail makes a beautiful figure swimming in the water.

This creature can likewise immerse or dive to the bottom of the water, if it compresses the internal air. This is effected in the same manner as when the air is compressed in a glass with water in it; for little perforated glass globules swim at first in the water, by the assistance of the air contained in their cavity: all these little globules subside as soon as the small quantity of air contained in them is condensed; which happens by the common pressure of the air, that is above the water in the glass; but they emerge or rise again to the surface, as soon as the finger or any thing that stops it, is removed from the mouth or orifice of the glass. This is a pleasant experiment, and I have found it very true, according as it has been described by Cornelius Consentinus, in his platonian circum-pulsion.

In the same manner does this Snail sometimes dive under water, and again swim to the surface, by properly managing the quantity of air in its body in such a manner; the latter, being as heavy as the water, it can difficultly be supported on the surface, and is again depressed to the bottom by the least compression of the internal air. But when the Snail expels all the air out of its body, which it will do, if it

be pricked with a sharp-pointed little needle, it will not then be able to swim up to the surface of the water, but by creeping slowly. So that from hence it is probable this creature would die, if any thing like it should happen in dirty or miry ditches; since, in that case, it could not reach the surface of the water, until after some days, and would therefore be suffocated for want of respiration.

There is likewise a great difference, with respect to the external skins or coats of the genital organs; all the parts of generation in the covered Snail issue out of one opening only, whereas in this aquatic or water Snail, all those parts and the entrances or mouths of each are distinct. The penis indeed rolls out and erects itself from the neck through a peculiar aperture. Tab. IX. fig. iv. *e*. But the opening of the vulva is disposed, by the wise Architect, immediately under the tube of the verge *f*. The verge itself likewise differs greatly from that of the common Snail; it is smaller, more hollow, and capable of greater motion; but then it is fitted on the inside to every part of the extremity of the shell *gg*, in the same manner as it is in the common Snail. The tooth *b*, and little tongue which is seen under it, are of the same texture in this as in the common Snail; unless that the tooth is more equal, and not divided into so many considerable notches.

The internal parts likewise differ much both in colour and structure: but the greatest difference is in the stomach, which is membranous in the covered and other Snails, as it is in men and in quadrupeds; but in this water Snail it is of the same structure in all respects with that of the Hen or Cock kind; so that one would think the real stomach of a Hen is here represented, without any difference, but that it is much smaller. Moreover, the colour of the craw or crop is a dark or obscure gray. The gullet of this passes likewise the chink or crevice of the brain, which is a very agreeable sight in this admirable creature. For since the swellings or productions of the spinal marrow, are, by the addition of a certain heterogeneous yellow matter, here distinguished, all these parts are therefore the more distinctly visible. Hence it is, that one may, with greater ease and certainty, establish the anatomy of the water Snail, than that of the covered Snail; for in the former are many coloured parts, by means whereof the muscles, and many other parts, especially those of the palate and mouth, may be easily distinguished.

The salival vessels of this are like those of the common Snail. The liver is likewise composed of visible glandules, and rolled into the like spirals. The heart also, with its pericardium, is placed in the same order. The vessels on the verge, on the contrary, are not so distinctly visible. The lime bag is of a pale orange colour. All the muscles are inserted in the outer part of the shell and its pillar.

The organs of generation likewise differ: the penis in this water Snail is very broad; it is like



like an oblong tongue; and resembles, in some measure the penis of a Drake. The muscles likewise are stronger, and more distinct and numerous than in the common Snail. The uterus is divided into three parts, and opens with two mouths into another, which is under the verge; The first part is of an ashy gray colour, and like the belly or rough tripe aforesaid in beasts that chew the cud; then the uterus becomes more glutinous, and receives some expansion from the chain-like tube; to which likewise adheres the bag of glutinous moisture, and also another little part which may be taken for the ovary. Moreover, the chain-like tube is larger here, but where it is connected with the ovary and liver, it is of the same structure as in the covered Snail, unless that those white studs, which I observed in the covered Snail, are of a yellow colour in the water one. The purple little knot is also here of a full orange colour, and opens into the vulva by a singular kind of tube, as in the naked Snails. I have not seen the egg, but I saw some relaxed, round and transparent little parts in the body, which I thought to be properly glandules. Under the organs of generation, near the stomach, I observed a certain strong plait or fold of vessels, of which a considerable number were detached towards the liver.

The stomach, when opened, very beautifully exhibited its two strong muscles, and in its cavity were found some hard seeds of water plants; by the help of those the Snail probably grinds its food, as Hens and Pigeons do with little stones, bits of lime, and other things which they devour. I have been informed that a Duck or Drake has swallowed a piece of gold, called a pistole, and diminished it by attrition to sixteen grains; and hence arose the story that the Ostrich can digest iron, as Harvey well observes.

The food which these Snails most eat is water plants. I have maintained them for some days with lettuce, with which they were so greatly delighted, that they eat all the larger leaves of it when they had been some days without food. But they were then continually thrusting out their tongues, from which I concluded that they were hungry. I likewise fed the Snails sometimes with ryebread, which they would greedily feed on, if it was first softened with water. At these times may be very distinctly seen the manner of their eating, especially if the bread be cut into fine thin pieces. The next day, after I had laid this bread before them, they prepared for generation; so that I should conclude from thence, that bread yields them the most copious and effectual nourishment. The Teredo or Worm which eats ships bottoms, is also delighted with bread.

On the shell of this kind of Snail, I have sometimes found a great number of eggs, which were laid by another Snail of the same species. They lay inclosed in an uniform, oblong, and pellucid glutinous substance, and they were likewise transparent as chrystal; but after a few

days there appeared in the middle of them a very small gray Snail, which continually rolled or turned about in the same manner, as a bit of wax does in a bottle full of water, when the bottle is gently turned up or inverted. Almost in the same manner did this water Snail turn spontaneously in its shell, and swimming in a limpid humour or moisture, seemed to adhere to no place. The third day after these eggs were laid, the Snail contained in them began to grow yellow, and afterwards they became gray.

This Snail swims with the same body, Tab. IX. fig. iv. *ii*, with which it issues out of its egg. This is done in the manner following: first, the Snail lies upon its back in the water, and turns the whole length or level of its body against the surface of the air that presses on the water, and having afterwards first bent its whole body, it moves it forward in the same manner as the common Snail does; and by this means, swimming in the water, this creature goes forward, though very slow, and affords a very agreeable sight. But lest the heat of the sun should injure it, the little creature secretes a quantity of mucus or glutinous humour out of its body, by the help of which it is defended from the injury of the diurnal rays, and is rendered more fit for swimming; and it can move and turn itself to all parts in the water as occasion requires.

In order to dissect these Snails, it is necessary first to take them out of their shells; then they will die in two days, and are so much swollen with the water which they imbibe, that their organs of generation sometimes come naturally in sight, and their dissection may easily be perfected. But if you wound those parts which most abound with the glutinous humour, nothing can be done to any purpose afterwards.

I have delineated this Snail in the form it is, in when it creeps near the side of the glass in the water, and ascends to the surface; and there, having lengthened the aperture of its verge, Tab. IX. fig. iv. *d*, as into an oblong tube, and stretched it out of the water it breathes.

*The wonderful viviparous chrystalline Snail.*

The miracles which I am now going to advance of this water Snail seem so incredible, that I should not wonder if they should be deemed impossible, or reckoned among the fabulous tales of the poets metamorphoses. For my own part, though I saw them, I was so astonished on this occasion at the inexhausted fund of wisdom manifest in the works of God, and his admirable art and immense power, that I cannot since help thinking on them every moment. I thought I had already so accurately searched into the whole nature of Snails, that I could at length form many remarkable and certain observations, and from thence strike out some general rules. But the further I advance in investigating the wonderful works of  
God,

God, the more and more I find they all as far exceed the bounds of human ingenuity and understanding, as mortal man, who in reality is nothing, is from being able to discover fully the infinite and incomprehensible perfections of God.

The water Snail, which I here exhibit, Tab. IX. fig. v. *a*, naked, without a shelly covering, is found in great quantity in the ditches of Holland, and in large fresh-water rivers; it lies most commonly in the sandy fords or shallows of the latter, or where there are any stones. It creeps in ditches near and among the water plants, and in mud, which it takes as food; and also in white clay, in which I first found it. Hence it becomes dirty, and is often so covered with a crust of filth, that all the beauty of its skin or covering is almost lost. I have therefore broke off the shell from the body of the creature, and only represented the Snail without it. But because the shell has also a singular and remarkable ornament, and exhibits something truly worthy of observation, I shall afterwards delineate it in the manner it was found, whole, and without any imperfection in the uterus, and appeared under the microscope. Though I have found in rivers some of this kind of Snails, which were less than those which I exhibit in the figure, and had little dirt upon them, yet I never was so happy as to see the beauty of their shell wholly free of filth.

The things that demand notice on the outside of this Snail, are the head, Tab. IX. fig. v. *b*, its horns *cc*, the eyes *dd*, the aperture of the uterus, the branchiæ or gills *f*, the verge *g*, the convolution or winding of the body *h*; and lastly, the verge, which serves as a foot *iii*, whereon is placed the operculum or cover of the shell *k*. The head *b* is distinguished from the heads of all other Snails, because it is stretched more out of the body, and is more visible; nor is it at any time drawn back to the inside, but only shortened a little by the wrinkles of the skin. In the fore part is seen a small aperture, which is the mouth; the horns *cc* are sharp at their extremities; and at their root or basis, where they spring on each side of the head out of the body, are fixed the eyes, which are placed somewhat higher than in other water Snails, and therefore agree in some degree with the eyes of shelly or testaceous animals. All these parts are very beautifully variegated with yellow spots on a black ground. On the right side of the uterus or vulva, is seen an extremity or edge, which the Snail sometimes protends out of its shell under the verge. It is of a muscular texture, and may therefore be expanded and contracted at the discretion of the Snail. This is the reason why I first took it for the aperture of the verge. Above the head are seen five appendages under the verge, which, I think, are the branchiæ or gills. The verge very nearly approaches to that of other Snails; but it has not such a strong and remarkable motion, though it is of

a tougher, more firm, and more tenacious texture. The convolution of the body is the same as in other Snails.

The verge, or lowest part of the body, whereby the Snail creeps, is more worthy of notice; for the operculum or cover is annexed to it. This operculum is neither bone nor stone, but approaches rather to the nature of claws or talons; it is therefore in the purple Fish kind, called the unguis or claw, and the unguis adoratus; because when burnt it smells like castor or beaver, and is useful in the suffocation of the womb, or fits of the mother. If the operculum or cover of the Snail whereof we here speak, be burnt, it has no disagreeable smell. Its structure is elegant: it consists, as it were, of many rings, somewhat round, and differing among themselves principally in the brightness or obscurity of their colour. On the inside it is hollow like a shell: the tail of the body, annexed to this cover, is fixed thereto with strong muscles; by the help of which the operculum or cover may be bent, folded, nay, complicated towards the mouth and horns, when the Snail betakes itself to its shell; and by means of this, as it were, little door or entrance, which it carries about it, it securely hides itself in its shell, safe from all common dangers. This the Snail does as soon as it perceives the least unusual motion in the water, for I never knew a more timorous creature than this. It naturally creeps very slowly, and swims in the water with its body opposite to the surface of the air, as I have before related of the common water Snail.

These are the external parts of this Snail; but the internal parts that we have observed in it are indeed so many miracles, so many strange and unheard of things, as probably never, hitherto, came into the mind of any person. I therefore invite and require all atheists, who do not scruple to assign the generation of small animals to accident or chance, to this splendid entertainment, that they may learn to give the praise and glory to God alone.

When one attempts a dissection of this Snail, it immediately draws itself so much back into its shell, and presses its operculum or cover down so closely, that one cannot put the point of a little needle into it. You must therefore break open the shell, which is very firm, with a flat forceps, and take the Snail out with your hands. Then it will be observed that its muscles are strongly inserted in its shell, and principally in the foremost or anterior part of it. Whilst this Snail lives, its dissection can scarcely be performed, since it bends or winds its operculum or cover, Tab. IX. fig. vi. *aa*, against the fore parts of the body in such a manner, that the former is doubly folded; besides, both the mouth and horns *b* are in some measure drawn in.

The dissection ought to begin next to the vulva *c*, and the verge should be opened there with a little pair of scissors; after which four different

different parts come at once in sight; these are a small margin very beautifully folded *d*: the end of the intestinum rectum, or straight gut *e*; then the branchiæ or gills *f*, some of which appear out of the verge in the former figure: and at length the uterus *g*, which I have here delineated as dissected and opened together with the living fœtus contained in it; for the young are brought forth alive by this Snail.

The verge has not a singular or remarkable aperture as in the other land and water Snails, but the whole is almost open on every side: the Snail however knows how to move the muscular parts of the verge, and to swell them out of the shell in such a manner, that by this means it draws the air into its cavity; and this air is afterwards expelled from thence again, when the Snail hides itself in its shell. Thus may this small complicated margin be very easily seen; the doublings or winding plaits or wrinkles of it arise, in my opinion, from the bending and contraction of the body. If this little part *d* be dissected, it appears to be only a congeries or heap of transparent, chrySTALLINE, and equal globules, which are of a stony nature, and make a crashing noise under the dissecting knife. The horns, the upper surface of the mouth, and many other parts of this creature become petrified, and therefore also make a noise like sand, when they are chewed a little in the mouth. I mixed spirit of vitriol with them, and it caused a very strong fermentation.

This first observation is, therefore, very singular, and merits particular consideration. We see how the omnipotent God could frame a little being, which consists, as it were, of small stones, and yet can move, agitate, contract, draw in and extend these its parts; because muscles and their tendons are inserted in and run through them. But who can describe how the veins, arteries, and nerves are there interwoven and disposed? Nobody truly, but He alone who made all these things. That congeries of chrySTALLINE globules, in particular, which is so copious in the horns, that one can hardly find a place wherein the parts aforesaid may not be conceived to be situated; so that even from thence it appears clearer than the light at noon day, what exquisite arts and unheard-of miracles the most sagacious Architect has hidden in the immense volumes of his works.

If the intestinum rectum or straight gut *e* in this Snail be opened, it is usually found to be full of an earthy gray substance, and divided on the inside by many membranous and nervous partitions or inclosures like little valves, and grows larger and larger continually, until at length it passes the liver and small guts, and ends in the stomach, which seems to be like a small tube or pipe. The excrements which this Snail throws out, are a congeries of oval

particles, linked or joined together, such as are found in the intestines themselves.

The parts which I call the branchiæ or gills, Tab. IX. fig. v. and vi. *f*; are likewise very wonderful; they are disposed in a neat order, they are of equal length, and are placed at the sides of the intestinum rectum or straight gut, which they accompany for a great way into the inflexion of the body. If you view them with the assistance of glasses, they resemble a comb with broad teeth, though in softness and delicacy they are like little membranes. At first I thought that these little parts were membranous expansions of the uterus; but from their situation and structure I afterwards found that they agreed more with branchiæ or gills.

The uterus, which, as we have said, is represented, fig. vi. *g*, open here, is situated in this Snail where the straight gut is seen in the common covered Snail. When I opened it gently, I immediately met under its upper coat, which it has in common with the coat of the verge, a congeries of oblong little parts, fig. vii. *a*, which were very numerous, and differed somewhat in their length, figure, and thickness; and when I removed them from their places, I found they were all alive, and were so many living little Worms, as there appeared particles of that sort. On the inside of these Worms was seen an oblong transparent ash-gray coloured furrow or ridge. When I began to dissect one of these Worms, two, nay three, and sometimes four inclosed Worms of the same kind issued forth\*; having almost the same figure, that is, a thick head, fig. viii. *a*, and small tail *b*, like young Frogs or Tadpoles. The former Worms indeed moved somewhat slowly, but the latter being put into water, swam very swiftly, and very strongly twisted about their little tails. I must confess the sight of these astonished me, as I never expected to have met such, and so many miracles in one little creature, or that I should have been so well convinced of my own ignorance and blindness in a single subject.

All these Worms exhibited a roundish little part, transparent through the middle of their body; but at the tail appeared some soft little points almost like hairs. I could not find any excrements in them. The little creature itself, viewed in the sun with a microscope, seemed to consist entirely of small grains of sand. When I had afterwards taken all these parts from their places, a new miracle presented itself to me: I observed that the whole tube of the uterus likewise consisted of chrySTALLINE little stones, which were as numerous and as thick and close together, and disposed in the like order as I have before related they were about the skin, the complicated margin and horns. Hence I really think that this little creature may be properly compared to the coralline crust which surrounds hard coral; for

\* The Eels in paste are in this manner viviparous, and there does not appear to be any distinction of sex in respect of the produce, for all are bearers. The late Mr. Sherwood has given an account of this to the Royal Society, the truth of which I know, having made the experiments with him.

the skin which covers the branches of corals, is almost of the same structure, and may likewise be easily separated from the hard coralline substance underneath. Nay, the ends or tops of coral are also of the same softness; and I have found them still tender after the coral had been out of the water some months: this I have before observed in the letters that I wrote on coral. In the common water Snail I likewise saw here and there some little round chrystalline parts, which I think were likewise globules of sand of the same nature. In the straight gut of that Worm, out of which issues the Gad-fly, I observed something like this, as I shall describe and represent when I come to its history.

When I afterwards opened the uterus, I was more astonished: I found a small Snail in it \*, in every respect perfect, which had already broke out of its membranes, and shewed the same disposition and the same manners with the larger one its parent. Thus I learned that this little creature brought forth young Snails alive, as big as common pease, Tab. IX. fig. IX. *a*, which had their shells and coverings pretty hard; and that they were likewise complete and perfect in all their parts.

This shell, fig. x. *b*, afforded so beautiful an appearance under the microscope, that nothing like it can be imagined. It was twisted into four spiral parts, whereof the innermost diminished its windings by degrees, until it ended in a pretty blunt point, almost resembling a top. Moreover, the coat was covered with a periosteum, and was very elegantly and neatly adorned with seven rows of bristly hairs *c*, &c. Some black spots were here and there likewise seen, which were produced from the transparent body on the inside. It was further divided by many spotted or speckled little lines and other furrows; and also by little ribs that were notched and full of filaments; all which I have not delineated, lest the figure should have grown too big: nor have I leisure enough at this time to enter upon so many things.

These things convince me most clearly, that the shell or stony covering of the body is the Snail's real skin; since it has, even in the uterus, not only its own proper coat, but its hair. We are taught from thence also, beyond contradiction, that all these hard substances are nourished and sustained as well as the Snail's softer parts. For which reason the stony chrystalline little grains before described, are fewer and smaller in the young and tender Snail than in the more grown one.

I find this shell, together with its animalcule, free and disengaged on every side in the uterus, and not involved or rolled in such coats as form the secundines. Hence one might, in some measure doubt whether this part, which I call the uterus, were not rather the œsophagus,

and that therefore this animal had been only devoured by the Snail. But when I dissected another Snail, I found twelve perfect eggs therein, sticking in the uterus; each of which had its little navel-string; Tab. IX. fig. XI. *aa*, and some of them had two *bb*. The strings were somewhat broader near the egg, but where they were connected with the uterus, they were like a small filament. They adhered almost in the middle of the uterus to a small seam or future.

The six first eggs, which are placed in the fore part, each contained a Snail, however small, with its shell and food; the little body of this Snail lay extended out of the shell among the alimentary substance. The first egg had a larger Snail, but the second, third, fourth and fifth a smaller. In the sixth I only saw a small point, the shell whereof was not yet conspicuous.

In the other six little eggs, which were somewhat smaller than these, there was nothing to be seen, because their tenderness made them transparent, and they were of one colour. On opening, them I found that there was a more tenacious liquor contained in them than in the former.

The six foremost eggs were as big as common pease, and were invested with a very tender and fine chorion and amnion, through which one might see the Snail within *ccc* languidly moving itself. Moreover, the whole amnion was filled with the moisture before-mentioned, which is the creature's true nourishment; and the Snail likewise swam in the amnion, as the human fœtus does in the mother's womb. As the Snail grows bigger, this humour is diminished in proportion.

When I had broken the membrane of an egg which contained one of the smallest Snails, I found that the creature taken from thence, Tab. IX. fig. II. *d*, was as big as the head of a common pin; but it did not move out of, nor go into its shell: for its muscles were yet too tender, and some of its parts had been probably broken off.

If this egg was raised or lifted up by its string, the Snail within remained in its situation without motion; but when the egg, which lay out of the uterus for one, two, or three days, was thus kept suspended by its string, then the Snail within fell to the bottom of the membrane *e* which constituted the egg. Hence one may conclude with certainty, that the cluster of vessels was broken on the inside, though it could not be seen, because all things are here limpid, white, and very tender. The humour or fluid itself, that is, the nutritious juice wherein the Snail swims, is limpid, though it still approaches somewhat to the colour of whey, and when put into the water it becomes more thick or muddy; but if it has remained in the water some days, then it ex-

\* Our countryman Dr. Lister has distinguished himself on the subject of this viviparous Snail. His observations in general agree with those of this author, for truth is the same in whatever language it is written.

pands itself like glue, and at length it becomes clearer by the addition of the imbibed water.

When I placed this little Snail under the microscope *d*, I saw its eyes very black like pitch, fig. XII. *aa*, but the rest of its body was colourless, or for the most part white; the horns *b* are somewhat blunt, the mouth *c* is open, all the rest of the body *d* is stretched out of the shell; I found the operculum or cover *e* annexed to the hinder part of its tail, but the shell *f* was adorned with the like elegant apparatus and hair as I have represented in the tenth figure.

From hence, therefore, it is very evident in what manner this Snail, together with its shell or stony cover, is likewise by degrees increased, augmented, and become larger in the uterus. This observation is indeed of such importance, that no body can desire any more worthy of notice. Whoever reads these things must be obliged to confess, that the power of the Almighty cannot be known, by clearer and more convincing proofs, in any part of his works, than in those minute animalcules, wherein that great Architect has inclosed and hidden so many wonderful parts, and shewn such exquisite art, that exceeds all human industry; so that one may employ his whole life in the dissection of the smallest of all animals. For this reason I look upon the whole of my description to be like a delineation of the sun, defaced with coarse materials; and therefore it is no wonder that the wise men of the heathens, when they had seen some miracles concerning the nature of women, cried out, "O! Being of beings, have mercy on me."

I have not accurately investigated the remaining parts of the Snail, because I only dissected two pretty large ones, and a smaller one of this species, and because it happened only by chance, that I began this wonderful dissection, which deserves more than any other to be completely perfected; great numbers of these Snails may be found at any time. I shall for the present briefly relate what more I saw of them.

I have observed that this Snail has no teeth, but instead thereof it has a proboscis, trunk, or little tongue, by the help of which it seems to take its food in as by suction, as is the case in butterflies, and some kind of beetles. This little tongue is so elegantly formed, that it can scarce be exactly described, and as difficultly be represented in a figure; in the forepart it is of a bright or pellucid red colour; surrounded on each side with many small parts, like the branchiæ or gills of fish, or like a comb with a double row of teeth. These little parts grow paler towards the hinder side, and are of a horny substance, such as the little tongue has in its divisions.

The gullet is like a small filament. I have not distinctly seen the stomach, because I had broken some of the parts, but the part I took

for the stomach was like a membranous little intestine.

The ovary is in every respect like that of hens, only that its eggs are not so large: I took these eggs in the beginning for a congeries or heap of chrystalline globules; but when I had dried them upon glass they contracted, which is not a property of the chrystalline granules of this little animal; I found them also soft in handling and biting them. I have nothing to say with certainty of the penis, though I saw something like one.

The liver consists of distinct visible glandules, somewhat like pears, and I confess that the glandules of the liver never appeared plainer to me in any animal. As to the other parts of the abdomen, I have not yet either seen or examined them. The brain and nerves are constructed in a very different manner from those of all other Snails that I have hitherto searched into; neither have I investigated the eyes, since, with respect to these, this little animal agrees in some measure with crustaceous animals, as Crabs and Lobsters: hence I thought I should have found something in it, like the eyes of the Hermit Crab, which I observed to be like those of Bees. The cornea tunica of the eye was in this also divided into little squares.

I have not been able yet to discover how this egg comes out of the ovary into the uterus, for the bottom of the latter seems to be shut up; but whether there be a tube in it there, as in Frogs and Tortoises, I am hitherto ignorant; I am at as great a loss to know what time the egg afterwards remains in the uterus, before the little creature is disclosed from thence as a perfect Snail. If we consider the remarkable size of the shell, we may reasonably conclude that the egg lies there a long time. Hence I should think that such small Snails and eggs may be found in the uterus at any time of the year. As to the Snails themselves, I now know how to get a great number of them, nor will it be difficult to exhibit their foetus.

Who can explain after what manner this egg is fecundated? or how life and motion are communicated to all its parts? so that, like a clock, having been produced with all its wheels or limbs by its parent only, and having life and motion from the male sperm, it continues strong and vigorous, until its little chain be unwound: so we may term the death of all those who have life and breath. These things are known only to that most sagacious Being, who has numbered and measured the chrystalline globules, the hairs of the shell, and all the parts of this little creature's body, nay of all animals, and who has given life and motion to every thing.

On the twelfth of March, in the next year after I began these observations on the viviparous Snail, I collected a great number of this kind, which I put into a large basin full of rain water, and fed for a long time by the help

help of some potters earth dissolved in the water. On the thirteenth of the same month I opened one of these Snails, when I found nine living Snails in its uterus, each inclosed in its proper membrane; though the humour of the amnion was almost consumed, which I looked upon as a certain sign, that their birth was near at hand. The larger of these foetus's were placed foremost in the uterus, and the less next in order. When I had afterwards cut them out of the uterus, and put them into fresh water, I found they lived to the eighteenth of March, moving themselves, and swimming like Snails more grown; nay, their manner of swimming was much more beautiful; but as I then had other matters to attend, I poured them and the water out together, nor have I since observed any thing further in them. The largest of these Snails were somewhat less than those that are represented in Tab. IX. fig. ix. and the rest were still less in proportion.

On the twenty-first of March I opened another Snail of that kind, in which I found forty-four larger, and some very small foetus's, each inclosed in its membrane, and placed in a regular order in the uterus: some days after this I dissected three others, in one of which I reckoned sixty-five Snails, in the second sixty-seven, and in the last seventy-four, the smallest of these young Snails were not bigger than the point of a little needle. When I afterwards viewed them in a dark place by candle light, I observed that they swiftly and very beautifully moved and twisted themselves round in the humour or liquor of the amnion. But I found no eggs in the uterus of these last; hence I learned that these foetus's were arrived to their full perfection, and afterwards only increased, that they might in some months after be in a condition to be brought forth by degrees, and by this means give way to new eggs to be again received into the uterus at that time.

Wherefore at whatever time of the year, you open these Snails, you will always find them pregnant, either with eggs or living Snails, or with both together.

On the twenty third of March I observed

that some of these Snails, which I kept in a larger vessel filled with water, had brought forth several young Snails of equal size or bigness. In some days afterwards I again saw that other young ones were brought forth; so that by this means, and sundry observations, I learned by very certain experiments, that these Snails continually bring forth throughout the whole year. When in the month of June I opened some of those that had brought forth, I found many rudiments of eggs in them, and some eggs of the second degree, which were already so perfect, that the foetus might be discovered in them; nay further, some eggs were still more perfect; they lay in the uterus, and the young of them were to be produced soon.

In the month of June almost all my Snails died, because I neglected to give them fresh water, and therefore in order to preserve them for some time, I put them into spirit of wine among others which had perished some weeks before. I afterwards shewed above sixty young Snails, in the uterus of one of these to Dr. Huygens, who, on his return to Paris, honoured me with a visit; at which sight he was greatly astonished, and highly admired the stupendous and impenetrable secrets of nature.

On the twenty-fourth of July I weighed one of these viviparous living Snails that was fresh taken, and it weighed five drachms; in its uterus I found many eggs, in most of which was to be seen a moveable whitish spot or point, but in the rest of them Snails of a larger size were observed, so that all the larger Snails were then already hatched. Then I began to clear the shell of this Snail of its dirty crust, and I found the periosteum underneath unhurt. Its colour was then yellow mixed with green, and it was variegated with light red furrows and ridges; when the periosteum was pulled off, the shell appeared white, and the ribs or ridges appeared of a purplish red. I have delineated a shell of this kind in its natural bigness, in Tab. IX. fig. XIII, where the structure, windings, fibres, and aperture of the pillar may be clearly and distinctly seen in it.

*Of that species of the Sea Snail, called by the Hollanders Aliekruyk.*

**T**HOUGH many species of shell-fish, of the Snail kind, are found in Holland, I do not know that any of them are eat, except only this sea kind, which is of the genus of the Turbo, and is called Aliekruyk; nor do we eat them at all times of the year, but only between Easter and Pentecost, and a few days after. At this season, hogsheds of these Snails are carried into cities, and, being first boiled with water and salt, are sold out by measure. Seafaring persons in particular, and those who desire to provoke thirst by salt meat, eat these Snails,

taking them out of the shell with a needle or little pin, and then they drink a large draught. For my part I do not like the taste of them; nay, they seem to me to affect the palate with too much saltness, and a kind of rank flavour. The liver is the most savoury of all their parts; in the rest they eat hard and tough, and are therefore used, as I have said, rather for whetting the thirst, than as food. Their entrails also are so full of dirt and sand, that they crash between the teeth.

These

These shell-fish are found very numerous on the shelves or sand banks near the sea, where the muscles are also found, and among the latter they are frequently sold; but they have also peculiar and proper places, in the sea, where they stick together in large heaps. I have sometimes taken them from the piles of timber, on which they are often fixed in the sea, and sometimes I have pulled them from large willow stumps, which were formerly laid on the shore, to break the violence of the waves; between these stumps, and among stones, are sometimes found many other rare water insects, as the Pulmo Marinus, or Sea Lungs, the Urtica Marina, or Sea Nettle, a species of the Echinus, the Stella, or Star-fish, Tubuli, or Sea Worms, Afelli Marini, Sea Wood-lice, and others. The maritime coast of Holland is the only place I know wherein one can make these useful observations, for all other coasts in general are smooth and plain, or covered even with sand.

That this shell fish may be better known, I shall first describe its external, and then its internal parts. Among the external parts I reckon the shell, which is the stony skin of this Snail, as well as of all other insects that inhabit shells, it is on the outside invested with a periosteum, which appears very beautiful in young ones, because no part of the shell has been in them worn out or rubbed off. Underneath, where this Snail, Tab. IX. fig. xiv. *a*, creeps out of the mouth, the door or entrance of its shell, the latter is a little globular *b*, but it loses this figure by degrees, after it is rolled five times, 1, 2, 3, 4, 5, and is terminated in a sharp point. The external surface of this shell is rough and unequal, since from its mouth or entrance to its acute end, it is folded and curled with thirty-one little ribs or furrows; which appear like so many threads above the surface *c*. I have not met with this exact appearance in all of them, as it seems in many to be worn out and obliterated with age; for the older ones have polished shells; and are divided, fig. xv. *d*, only by some rings or wreaths of divers forms and colours; unless these shells may probably belong rather to another particular species, which I think is most probable. As to the colour of the shells, it is a light red in the former species, but in the other it is mixed with green and ash-gray, and sometimes red, purple, blue, or whitish. The internal surface of the shell is all equal and smooth, it is of a dark brown in both species, somewhat inclinable to a bluish purple.

The shells of these Snails are frequently eaten through, by some of the largest Sea Worms\*, as may be seen particularly in the upper or pointed extremity, for it is frequently found gnawed there in considerable holes, in such a manner, that the whole figure of the shell is obliterated in that part; nay, I found from

experience, that those worms sometimes perforate into the inward texture of the shell, and there form various crooked and oblong hollows, Tab. IX. fig. xv. *e*, which sometimes penetrate into the cavity itself, so that the Snail is obliged to draw up the hinder parts of its body.

I have found seven such Worms in one shell, the Snail whereof was still living and unhurt. I here exhibit one of these Worms, fig. xvi. *a*, if this Worm be viewed with a microscope, it is found to consist of many annular incisions, which are adorned, fig. xvii. *c c*, with small hairs on each side; in the middle are seen two veins of a bloody colour, which extend their little branches on either side towards the interfections of the body. In the fore part of its head *a* are also some hairs, which are placed there like antennæ or horns: the like *b* are seen also at the tail. All these Worms had a very thin skin; they were of a tender constitution; and moved but very little. Whether this might have proceeded from my hurting them, by striking them with a hammer, or was natural to them, I cannot say. In the foulness which adheres to Oysters, I saw a species of larger worms, which were not in figure very unlike this smaller kind; and, like the Glow-worm, shined in the dark.

All these shell fish seem to be subject to this Worm as a disease, since few of them are met with, whose shells are entire and found at the end of their convolutions or windings; for the shells are always invested there with a dirty or filthy ash coloured substance, where-with they are more or less infected, and in which these worms seem by degrees to fix themselves, so that at length they seize on the skin of the shell fish, as their proper habitation and food, though the Snail still continues to live in it. This shell has very hard and solid joints, as appears in its spiral pillar, which is likewise very thick; hence it is that the Snail may be easily disengaged from it, since the shell flies in pieces like a flint, if it be struck ever so lightly with a hammer.

The body of the Snail, which creeps out of this shell, but is by its muscles very strongly annexed to the pillar of it; the head and mouth, Tab. IX. fig. xviii. *a*, are nearly like the Snails, and so are the horns *b b*, and eyes *c c*: The colouring of the skin only differs, for it is variegated with black furrows and spots on a white ground: in regard however to the colour of the two species, there is some difference to be observed. Behind, at the verge of the body *dd*, is the Snail's operculum or cover *e*, which it suddenly draws in at pleasure, and by this means shuts up its shell, when it meets with any thing unusual: the creature provides for its safety in the same manner, when any thing is suddenly presented to its eyes; so that I may venture to affirm from hence, that this is the only species of Snails that I know, wherein any

\* This is a common accident to shell fish: not only worms gnaw the shells, but the large shell fish of some kinds have a kind of bony engine, with which they pierce the shells, to get at the creature for their food. When it was doubted, whether fossil shells were real, or exuviae of animals, or representations of them, from the sportings of nature, shells taken out of the earth thus pierced by Pholades, were produced, and the objections ceased.

manifest signs of sight appear; though in the mean time the eyes of this snail do not, in respect to the parts which are common to the eyes of all Snails, differ any thing from those of others. On the inside, at the edge of the shell, is seen the verge, which surrounds the whole body, and is pervious to no air: this I have remarked also in other species of Snails. On the right side of it are two other apertures, one of which serves to evacuate the fœces, through the other the genitals are extended. And these are all the outward parts of this little creature. Moreover, this Snail is of a very strong constitution, for it can live ten or twelve days in the open air out of the water. I have also observed, when I was sometimes in the month of September in the town of Petten, where these Snails are found in great plenty, near the sea piles or sea marks; that they stuck quietly on the dry land, after the tide was out, and on its flowing, were again buried under the water; so that they may, on this account, be considered as real amphibious creatures. The shell *f* wherein I exhibit this Snail, belongs to the second species, and shews its fasciæ or wreaths nearly worn out. The operculum or cover consists of a flexible horny substance, fig. XIX. *g*, which is composed of filaments applied to each other, and rolled like the spiral convolutions of some shells.

I shall give but a brief description of the internal parts, both because I employed only half a day in examining them, and because they do not differ much from the entrails of other Snails. To begin at the mouth, we must observe, that all the parts of the jaws and palate are in this Snail of a bloody or purple colour. In the middle of the mouth is seen the tongue, Tab. IX. fig. xx. *b*, included in a singular kind of cavity, the whole of which it seems may be extended together out of the body; in the respects of colour and structure it does not differ much from the tongue, which I have delineated and described in the Sepia or Cuttlefish; but it differs very much from the latter in this, that it is almost two inches long, and at the same time beautifully convoluted or twisted *z* into spiral bendings, like a serpent closely rolled together, and is thus placed on the inside in the body, so that it passes with the gullet under the brain. The brain is situated behind the several parts of the mouth and palate, over the tongue and gullet, and serves those parts before described as a kind of pulley, through which they are transmitted. The part of the tongue which is in the body is cartilaginous, and so artfully and beautifully formed, that I could not delineate it fully in ten days; for which reason I exhibit it only in its natural size. In the hinder extremity the tongue is of a softer texture, and there includes a white matter in its cavity, which, when exposed to the air, dries away and vanishes, contrary to what happens in the upper part. The use of this tongue will be manifest

to any person who investigates it with more experiments.

On either side, near the tongue, are seen the salival ducts, which arise from whitish and branchy glandules, and reach to the jaws behind, under the proper parts of the mouth and palate; and immediately under the gullet, two glandulous white little parts likewise come in view, the use of which I do not know: under these, on each side, are seen nerves issuing out of the brain, of which the optic nerves are the most considerable. The eyes, for the use of which these are appropriated, have three such humours as I have before described at large in other Snails; the only difference is, that where the eye adheres to the skin, it is surrounded with a kind of white narrow circle, which I have not indeed observed in other Snails.

The stomach likewise is provided in the same manner, as it is in the garden Snail, and when it has decreased into a small intestine, it afterwards proceeds according to the convolutions of the shell, and by its spiral and pyramidal windings, surrounds the liver, which is of a dusky colour, somewhat approaching to that of musk. The liver consists of pretty large visible glandules, which seem to communicate one with another, in form of a shrub; as soon as this intestine has passed through the liver, and the whole circuit of the shell's convolutions, it forms the intestinum rectum, or straight gut, wherein I have observed the excrements divided into quadrangular globules.

The heart with its auricle is situated toward the left side. All the blood vessels are of a whitish colour, and resemble a Spider's threads: this is a very great beauty in the intestines of this little creature. I could not see the sacculus calcarius, or the calcarius bag, nor the chain-like little part. Nay, several of the genital parts could scarcely be distinguished in this subject, for I began this dissection and examination in the first species of these Snails, at the end of the year, that is in September. But the purple-bearing oblong little tube, together with some of the other entrails, were distinctly seen to be of a very elegant structure; all which I must pass over now, and shall resume this dissection at some other convenient time.

#### *Of the small water Turbo.*

Some small Turbines are commonly to be met with, Tab. X. fig. 1. *a*, in the places where the wonderful Snail, last described, is found. These seem to agree entirely in structure and constitution with the viviparous Snail, nor do they obviously differ from it, only that their shells are somewhat longer. I have not yet found them of so large a size as I could wish, and as I have not them now alive, I cannot exhibit the figure of this creature, I therefore hope that the benevolent reader will be satisfied with the figure of its shell only.



*Of the umbilicated marble Snail.*

This little Snail, which is variegated in the manner of marble, inhabits the fresh-water rivers of Holland, and therein adheres to small stones: I have found it in the Vecht, beyond Amsterdam. It is frequently found about pieces of brick-bats and tiles, or pot-sherds, broken pieces whereof have been thrown into the water. In the fore part, where the shell gathers into a spiral form, fig. 11. *a*, it resembles an umbilicus or navel; then it bends or rolls round in an oval winding, and becomes more expanded *b*. It is of a green yellow colour, variegated with a reticulated black ground like marble. The Snail that lives within is very tender, and as it died before I had brought it home and opened it, I cannot say much concerning it, nor exhibit the figure of its body. I saw that it had two oblong and sharp horns, and two black eyes. The structure of its tongue is almost the same with that of the wonderful Snail. It had pretty strong little intestines. Its body, which was contained within the extreme spiral part of its shell, was of an obtuse figure; because, probably, this shell was very thick, firm, and solid. To the lower part of the body adhered a calcarious operculum or cover, which had a kind of swelling or peculiar production where the muscles were inserted into it, so that it resembles the shoulder-blade in the human skeleton. On the outside it was twisted spirally like the shell itself. On the inner part, where this Snail creeps out of its shell, the opening or entrance, which is formed like a crescent, only was open, and over-against it I observed a certain greenish spot, which resembled in substance the shell of mother-of-pearl, and was likewise of the figure of a crescent. To this spot the operculum or cover applies itself, when the Snail creeps out of its shell.

*The flattened Snail.*

Since many species of Snails are found in the rivers of our part of Holland, I shall briefly describe only one kind of the water race, which is to be found there very common, both in salt and fresh water, as also in pasture grounds and near the high-ways. Its body is gray or blackish. On or at the fore part of the head are observed two lips, Tab. X. fig. 111. *aa*, joined together, under which is the Snail's mouth, formed in the same manner as it is in the common water Snail. Under the mouth there is to be observed a part of the body, which I call the verge or foot *bb*, because it serves it to creep with. The Snail frequently expands this verge in such a manner as to cover the lower part of its lips and mouth therewith. A little higher in the head are two black eyes *cc*, situated at the basis *dd* of the horns. These horns are very sharp in the fore part, but broader behind, and the Snail can

contract them in some degree, but it cannot absolutely draw them back into the body.

When its body *e* is pushed forward out of the shell, it is considerably long and slender. Near the shell is observed a part of the verge, which the creature can raise out of the water when it swims; so that by means thereof, it may draw the air into its body; the verge therefore has for this purpose a sufficiently large aperture, Tab. X. fig. 111. *f*, in which is seen the openings *g* designed for the organs of generation.

Its shell or hard skin is twisted or rolled about in a wonderful manner, and on the left side it is smooth or flat *bb*. It is invested with a distinctly visible periosteum, and is divided by very small incisions, ribs and furrows. But if this shell was so soft as that it could be rolled out, an oblong tube might be made of it. On the right side it is concave or diverging as it were from itself, but on the inside it is rolled into itself, fig. iv. *a*, and therefore leaves a small aperture in the middle, which I call the cavity of the pillar.

This Snail is a kind of intermediate species between the common water and viviparous Snail, as will appear from its dissection now to be exhibited. It is very difficult to dissect it, for it cannot be killed without hurting it, and it will not admit of being dissected alive. However, I do not doubt but I may be able to surmount this difficulty, by the invention of some proper apparatus for that purpose, which I the more ardently wish for; because as soon as one begins to break open the shell of this Snail, it immediately discharges a purple fluid or humour, which diffuses itself throughout the inside; even through the viscera. If you kill it in spirit of wine, it likewise expels this purple fluid out of its body; but when it dies naturally in a little water, it shews no purple, because the colour then probably vanishes by the changing the disposition of the parts. When this Snail is drowned in milk, in which however it will live for some time, it is notwithstanding found that the purple humour does not remain in the vessels appropriated to it by nature: and though I saw the heart beating, yet I never found this purple liquid in it or its auricle. Hence I am inclined to think; that this liquor is contained in a kind of sacculus or bag, which I have seen in other Snails, but could not hitherto discover in this.

The shell being gradually and carefully broken off from the body, the dissection should commence from the aperture of the verge. It will then appear, that this Snail agrees greatly with the wonderful species; for the verge is likewise here provided with a similar small margin beautifully folded, and made in the same manner as in the Snail before-mentioned; for in its texture is likewise found a very great number of such chrySTALLINE globules, which crash and make a noise under the instruments. On the other, that is on the right side of the verge, is also observed a congeries of such Worms, as I have in like manner

manner observed in the viviparous Snail ; and if these Worms be dissected, a great many smaller ones, with thick little heads issue from them, which will likewise swim with very great velocity, and they also are stronger in their life and motion, than those which I have described in the account of the viviparous Snail.

These Worms likewise creep with very great swiftness ; first stretching their head forward, and then, with great force, drawing the rest of the body after it. Their greatest strength is in their mouth, which may probably have a kind of feet, as I have seen in other little creatures, and shall hereafter describe and exhibit in figures. These Worms are much smaller in this than in the wonderful Snail. When I was certain of this fact of the Worms, from observation, I kept some thousands of them in the water, wherein I kept these Snails enclosed in a large glass vessel, and I saw that they moved swiftly. The little part of this Snail which contains these Worms in the upper part of its membrane, is on the inside of a bright yellow colour ; and, in my opinion, may probably be accounted analogous to the purple-bearing bag in other creatures of this kind ; but this I shall not affirm certainly.

This Snail agrees with the common water Snails with respect to the external structure of the mouth and teeth. It wants an operculum or cover, but as to most of the viscera it is likewise like them. Its stomach is formed in the same manner as that of the Hen. The brain is situated alike, though there is some difference in the nerves. The heart is placed in the left side of the body. But there is one peculiar thing in this, which is, that the liver consisting of glandules, is not protended to the extreme cavity of the shell : I have found there a small part which was filled or crammed as it were with myriads of the thick-headed little Worms before described. The chain-like little part follows next, behind which is placed another glandulous purple-coloured small part, and after this again is seen another yellowish little

part near the uterus, which is of the like structure with that in the water Snail, and opens with three tubes into the hinder part of the neck. The penis is formed in the same manner as in the common water Snail, nor has it any thing peculiar in it, only that where it is extended out of the body, three small folded parts are seen, the middle whereof is very beautiful, and is, in some measure like a mushroom, supported by a small foot, and divided on one side.

*The small flattened Snail.*

This Snail is in most respects like the former, nor does it differ from it, except that its shell is on each side almost smooth, and is concave, and adorned with a small kind of margin, Tab. X. fig. v. *a*, by the addition of which it happens that the furrows or little ribs in the surface of the shell are bent in a different manner. It is seldom found larger than it is here represented. There is also some slight difference in the external part of the body. The horns are flesh-coloured, though the body itself is blackish. The shell of this Snail put in the sun is almost all transparent, but particularly in its internal windings, which are on every side stained with purple. The punctum saliens, or beating heart, is observed to be deeply tinged with the like colour. But if the body of this Snail, after it has crept out of the skin or shell, be pierced with a small needle, and the needle afterwards extracted, it draws back its body very deep into the shell ; and then it is observed, that a juice of a purple colour insensibly distils out of the wound. This I take to be a certain sign that this little creature has purple blood. Whether this same thing holds in the foregoing Snail, is yet to be discovered as also in a smaller one ; the shell of which is likewise probably so thin as to be transparent. This and the former Snail are found in the ditches in Holland, as well as near the high-ways and in pasture grounds.

*Of fresh-water Muscles, found in the rivers in Holland.*

**I**N the river Vecht above Amsterdam, and in other rivers, is frequently found a species of Muscles, which are indeed buried in the clay and mud next to the banks, but they lie free and disengaged, and stretch out their sharp-pointed part. When the bottoms of the Vecht or neighbouring ditches are cleaned, these muscles are found in great numbers. I discovered three species of them ; a larger sort with thin and broad shells ; a smaller more oblong, and with thicker shells ; and a very large kind, which is of a somewhat different texture.

I only examined the middle species of these, that is, those which are most common. These do not open themselves much, they only make the two wings or lips of their bodies to swell a little out of the shell, and by this means they can

fill themselves with the river water. Besides, they emit out of the shell some small ruddy apiculi, or small points, with sharp extremities ; and, as those are on the hinder part covered with a blackish substance, they resemble so many sharp and black little spines, made like the papillæ that are observed on the surface of a Cow's tongue.

I had intended to complete the whole anatomy of these Muscles ; but when I opened two of them, all the parts that I found in them were so strange, and so much unknown to me, that I desisted from my purpose for that time. For, as I had never before accurately dissected any species of Muscles, I saw that it would have taken up a very long time to have finished this business, and I was then deeply engaged in other matters. I therefore reserve this work for

for a more proper opportunity. But I shall now briefly relate what appeared at first sight to me on the inner and outside of this Muscle, and in its shell, and shall, in particular, explain some things concerning the insertion of its muscles; whereby the history of what I have before said of the Muscles being inserted in the shells of the Snails, will be considerably illustrated.

When the shell of this little Muscle is carefully broke in little pieces with a forceps, and separated in the part where the Muscles are inserted, then offers itself to view in the creature, its lips, and with this the verge; these wind about the whole body, and cover it as it were with two wings or lips. One of these is observed to be, Tab. X. fig. vi. *aa*, bent back to the side of the body. On the lower side of it, and likewise on the other side of the body, are seen papillæ as before mentioned *bb*, tinged with a black colour, which may easily be wiped off with a brush. The papillæ seem to me to be the extremities of so many tubes or trunks, whereby the Muscle draws into its body, small particles of mud and slime, for the gullet seems to communicate with them. On each side of the body are four branchiæ or gills, each consisting of three membranes, the middle whereof is formed like a bull-rush mat, and is composed of longitudinal and transverse filaments, and may be seen through both the external membranes. All these filaments seem to me to be tubes, through which the blood moves as it does in fish. The largest vessels are situated in the lower part of the muscle; and from thence arise, I think, those tubes, which, whoever pursues them so far, will find pretty strongly connected with the papillæ that draw in the food. On each side, the Muscle Tab. X. fig. vi. *cccc* has four such larger branchiæ or gills, and four other smaller ones, *dddd*, placed towards the hinder part.

The body itself consists of two parts, a hard *e* and soft *f*. These I take to be the thorax and abdomen. The harder part is made up of a congeries of many muscles, which run from one side of the body to the other, with strata or layers of long fibres, and being then carried over the soft part towards the branchiæ or gills, and wings or lips, they afterwards give various muscles underneath to the belly. The thorax rises into a point, and is of a colour somewhat approaching to yellow. When opened it exhibits many muscular fibres running transversely from one side to the other, from which the thorax obtains its hardness and strength. Under this is placed the brain covered, with a bright-yellow membrane; but the spinal marrow and nerves are white, and they are divided into branches which are detached in great numbers to the muscles.

I find four different parts in the abdomen, a liver, fat, an ashy-gray substance, and several membranous and muscular expansions. The part which I take to be the liver, is very large; it consists of a congeries of small oblong glan-

dules, which are placed near the hepatic vessels, and resemble so many uvulæ resting on their little supports. Its colour is a blueish red, and where the vessel is thickest, a glutinous matter is contained in it. There is a great quantity of what I call fat in the abdomen; it is divided into small glandulous little knots, and is of a bright white colour, so that one would take them for little eggs, only there is so great a quantity here, that it reaches even to the spinal marrow. Many membranous and muscular expansions are likewise seen in the belly, but whether they are interwoven with vessels and nerves, or with muscular fibres, I cannot exactly determine. To conclude, there is likewise a great quantity of ash-coloured matter, distributed among the fat: we find the same substance deposited round the larger vessels of the branchiæ or gills, and in many other places.

I could not hitherto discover either a heart or a stomach in this creature, but shall reserve both for further inquiries. The principal muscles that arise from the back are here very strong, and divided into many tendinous fibres, and are firmly inserted in the skin or stony shell of the creature, so that by this means various holes and cavities are observed to be formed in the shell, because some of the tendons are fixed in it deeper than in others. Out of the back arises, among others, a very beautiful small muscle, which passes through the shelly part that joins the two valves of the shell together, as through a pulley, and is afterwards inserted in the sharp-pointed extremity of the shell: but the muscles are not so strong about the acute extremity as elsewhere. The same are likewise very short, which is the reason that this Muscle can open the valves of its shell but a little way; so that if you attempt to stretch them further, even with the least force, they immediately break.

On the inside of the shell are observed five particular parts, in which the muscles of this creature are inserted, that is in the fore part of the acute extremity, where the insertion is indeed broad and formed into a circle, Tab. X. fig. vii. *a*, but not very strong. The Muscle is very strong at the thick end of the shell, because the muscles are there very firmly united with the stony bone: but one may there see four little apertures *b* sunk in the shell, wherein the tendons of the muscles are united with the shell, or rather change into a shelly substance. The muscles of the lips are inserted, but not strongly, almost in the whole circumference of the shell next to its extremity *ccc*. We observe that the spiral worm *d* of this shell swells somewhat beyond its arched cavity. There are also two eminences *ee*, by the help of which both valves of the Muscle are very strongly joined together as by ginglymus; which, together with the parts wherein the muscles are inserted, make a very beautiful appearance in some other species of Muscles, and are wonderful in the larger shell-fish of this kind. This shell is on the inside like that of mother-of-pearl. On the

outside it has various convolutions or little ribs, formed like crescents, and is surrounded on every side with a strong yellow-green membrane or periosteum.

I have nothing more to say of this and the other creatures, as I only slightly made these particular experiments, that I might, as far as time would permit, illustrate the history of the covered Snail by the description of some other kinds. I have examined into these things, that the reader, myself, and all mankind may learn to know God by his wonderful works, and adore and love him as the supreme Deity

and the great Creator of nature. Doing this, we safely pursue the steps of Christ, in and by whom every thing we do must be acceptable to God: but if we do not follow or imitate him, we are like those careless servants, who buried in the earth the talents committed to them, which God grant may not be our case; and may all persons, according to their respective abilities, extol and praise him; for which end I have communicated these observations as my mite, and wish they may answer the intended purpose.

*The method of cutting various images and figures in shells.*

**B**EFORE I conclude the history of shell-fish, I shall first subjoin a method, whereby shells may be engraved and adorned with little pictures and figures, which is indeed a business of exquisite art. Take yellow wax, and mix a little Venice turpentine with it, to make it more clammy, then add as much lamp-black with it as will make it very black. With this wax melted in a spoon, we may make any figures we think proper, on the surface of the shell, to be carved; then we cover those parts that are left uncovered with wax, with aqua fortis, which may be conveniently done by the help of a skewer, with a small piece of linen wrapt round it. If this be continued for a short time, all the parts of the shell that are free from the wax will be eaten by the aqua-fortis, and in those places covered with wax will be left an higher surface. And by this

means the shell may be adorned with various figures, and apartments or divisions, which appear to be externally made thereon. But if after the wax is scraped or taken off by melting it, any corners or uneven parts should chance to remain, they must be planed and perfected with the instruments wherewith figures are engraved. Thus three, four, or five eminent figures may be executed one over another, according to the thickness of the shell, and the places which we would have elevated, are first covered with melted wax. But the place which the aqua fortis corrodes with its acrimony, ought to be washed with common rain water. Other corroding liquors are not so proper for this purpose as aqua fortis, because they leave after them a sandy substance like chalk, which produces a roughness that renders the appearance less agreeable.

*The end of the history of SHELL-FISH.*

*A letter from John Swammerdam to the most illustrious Mr. Thevenot, on the anatomy of the Cancellus or Bernard L'Hermite.*

ILLUSTRIOUS SIR,

**W**HEN I had the honour of your company for some days in Yffi-street, it often happened that some miracles of nature excited us to admire the great Creator, who is astonishing in all his works. We have also debated on the same subject often, when you resided in Holland, and I have shewed you various uncommon experiments on bees and other species of insects. But since the secrets of nature have, by the many instruments and contrivances which I have invented, become clearer and more known to me; and since I can in one day investigate what I have before spent a whole week on; I can therefore now add a great deal to the discoveries I formerly made. This you will be convinced of from the description of the internal and external parts of the Hermit Crab, which I first observed some years ago at Scheveling. For, as Dr. John Oort, governor in Nyenrode, sent me a large

vessel of these creatures, which, the better to preserve them for some time, he had taken care to throw into spirit of wine immediately after they were caught: I cannot help giving you a full description of what I observed in them, and what obligations I am under both to my old friend, the governor of Nyenrode, who is greatly delighted with the works of God, and to you, illustrious sir, who keep me continually employed in these matters, and engage and persuade me to search into them. All mankind will admire the stupendous examples of the immense greatness of the wonderful works of God, which that supreme architect exhibits to our contemplation in the variety of the things which he has created, that we may acknowledge his wisdom and infinite power in the works of nature, and be induced to love him most ardently, and above all things.

The

The fishermen who get their living in the sea of Scheveling, take there several strange creatures, as well in common nets as in drag nets, which they either throw again into the sea, or leave on the shore, since they can get no profit by them. This is the reason that it is not yet known, how many and what wonderful creatures there are, to which the eternal power of God has assigned the salt waters as their habitation. I with many more men had such an ardent love for the sciences, as you and the governor of Nyenrode, our friend, for thus the knowledge of natural science, and the hidden causes in physicks would, by degrees, become known; and the incitements to

our duty, by which we are ordered to love our Creator with all our heart, would be doubled. I am greatly obliged to you, because when you were in Holland, you ordered many strange creatures to be brought me from Egmont-street, which we afterwards examined with our common and dear friend Dr. Stenon. But I fear my long preface makes me troublesome to you, by delaying the exposition of what I promised, and the gratification of your eager curiosity. I shall therefore now relate to you in order, what I have observed in the space of two days in the Hermits transmitted to me, and what stupendous things I saw in them.

*The external parts of the Cancellus or Hermit.*

**I**N the open vessel wherein my Cancelli or Hermits were inclosed, I saw some of them had broken out of their shells, and that others still lay in them. The shells of the largest were as big as a chesnut, but those of the smallest were not bigger than a large pea. The creatures themselves who inhabit the inside were large or small, in proportion to the size of their shells. But all these shells were of the same figure, form, and habit, only that there was some small, and, as it is called, accidental difference, in respect to the colour and lines. Some of the Hermits which still lay in their shells, were disengaged from the shell, so that they were affixed, by the strength of their tail only, in the last spiral windings of it; but in others I saw very distinctly that in the middle of their body they were joined in the same manner to the shell itself\*, and this is a property common to Muscles and Snails. Hence, it appeared to me most certain, that the shell was as much the true skin of the Hermit as it is of the Snail.

Hence it seems matter of wonder that the learned Rondeletius should write of the Cancellus or Hermit in this manner: "Bernard L'Hermitte se loge toujours dans les coquilles d'autrui, et qui l'n'en a point de propres;" that is, "the Hermit always inhabits the shells of other creatures, nor has it any of its own." I observe in the covered Snail, that by the help of its muscles it is not only affixed to the shell, but even the tendons of those Muscles increased with the shell, and are actually transformed into it, in the same manner as the tendons of the feet of Cocks and Peacocks are insensibly ossified through age. The same thing is also observed in the Hermit, for the tendons of its muscles, firmly adhering to the spiral pillar of the shell, where the pillar forms its second spiral winding, are observed to be all joined to that rocky substance. But as the tendons do not occupy a great space with their insertions; therefore the body of the dead Her-

mit quits them: and this was probably the reason that the great Rondeletius, following the doctrine of Aristotle, has not observed this matter. As all these shells have one and the same figure and structure, it is manifest even from hence that they are proper to these creatures only, and are increased and augmented with them, as is the case in Snails and all other creatures that inhabit shells. I am therefore certain, that all Hermits which belong to the same species have likewise similar shells; for I am taught by experience, that there are many species of Hermits that are not only very different from one another, but also live in different kinds of shells; this I have seen in my father's collection, and in many other museums.

The shell of the Hermit is moreover surrounded with a very thin periosteum, and hence arises a new argument, which confirms, that the shell is the skin of this creature, which, with its periosteum, covers it on the outside. So that therefore the Hermits, as well as Beetles and crustaceous creatures, have their bones placed on the outside round their flesh, though there is still some difference. This periosteum is very thin, nor can it be better or more perfectly separated, than by steeping the shell some days in lye, and rubbing it lightly with aqua fortis, for thus it parts from the shell. By this method the periosteum may likewise be very easily separated in some other shells. But it is so thick and remarkable in some kinds, that there is no need of this experiment. In other shells, again, which are rolled over rough stones, or that have been drawn through rocky and sandy places with their inhabitants, this periosteum is wholly worn off, and cannot therefore be then discovered in them.

Some of these shells were very smooth and beautifully coloured, Tab. XI. fig. 1. *a*, and glittered like a looking-glass. A species of the Fucus Marinus, rising with small points, covered the largest of them in such a manner, that the whole figure of some were obscured and hid,

\* The solution of these problems remains for future observations. This author asserts, that the body of the Hermit grows to the shell; others affirm, that the creatures will at any time crawl out of the shell, on smoking them with sulphur; if so, the shell is no part of the creature.

nor could the spiral windings of some of them be seen *b*. Moreover some holes appeared behind the points, and also some very singular little grains of sand, some of which were likewise covered with the Fucus. Other holes were observed likewise full of softer purple coloured eminences. In some of the shells a soft sea mud was found, in others a very hard one, the figure whereof was likewise spoiled by winding round the creatures. I likewise saw that a substance adhered to the internal surface of one shell in such a manner, that there was no void space either in the entrance or mouth in the fore part, or a little higher in the shell; only where the tendons of the muscles were separated from the substance of the shell. I observed further, that Worms had pierced the shells in some places, and how some of them had been broken and again joined together. These shells are usually most beautiful when the Hermits are smallest in them, for they are not then covered. In some other young ones of these, the periosteum appears of a very remarkable figure and beauty, where the shells are not yet covered with the accreted matter; as I have observed in some smaller water Snails, in which the whole periosteum was very delicately adorned with bristly hairs. Let what has been hitherto said of the skin of these creatures suffice. I shall now explain the other parts of the Hermit, and that they may be the more easily understood, I shall divide the creature into four parts, the head, thorax, abdomen and tail, and shall afterwards describe every thing remarkable in each.

In the upper part of the head are seen two eyes, Tab. XI. fig. 1. *c*, and on one side of the latter, two horns or antennæ *d d*. Underneath appear some articulated bristly hairs, and also a mouth and teeth. The eyes are oblong, somewhat red, and in their aperture of a dark green colour: they are articulated on both sides with the head, by the assistance of a certain dentated ring, which consists of a like substance with the shell that surrounds the thorax and feet, and the other part of the eye is again articulated with the head. This upper part of the eye is likewise very hard underneath and in the middle, but it is soft above, where the cornea tunica is placed. The horns are composed each of three joints, whereof the largest are those which are joined to the head on each side of the eyes; from these the horns insensibly grow very short, and terminate as it were in small bristly hairs. In this thin and tender part of the horns I reckoned above one hundred and twenty very fine and delicate articulations, each of which was likewise adorned on each side with two pair of fine hairs. In the larger Crabs these articulations are very distinctly conspicuous, and when the Crabs are boiled, the horns may be divided into as many plain and smooth rings as they have articulations of that kind. Between the first and second joint of these horns of the Hermit, there is a smaller

rigid or hard appendage, beautifully adorned with bristly hairs.

Between the horns, under the eyes, appear a beautiful pair of rough hairs, which consists of three joints, whereof the upper one is the broadest. Under these are seen the teeth, which are two little, hollow, white, oblong bones, and are furnished with strong muscles, wherewith they are moved. Between these teeth is placed an external bone, by which the creature takes its meat, for which purpose it has not only two arms or forceps *e, f*, but many articulated rough or bristly hairs, of different structures, which cover the mouth on the lower part. There are two very small, smooth, broad, ruddy, shaggy bristles, or rough hairs of this sort, each of which has one joint only. There is afterwards another pair of larger bristles of the same construction, each of which has two joints. There is also a third pair, not smooth or broad; but with these, on either side, are two pair of such little parts likewise articulated, and every hair of this third part in the same manner consists also of two joints. The fourth pair is somewhat smooth and broad, and these are composed of three joints; to these are also joined another pair, each hair of which has two joints. There is in like manner a fifth pair, that are likewise double, that is, a larger one, composed of four joints; and the other, which is joined to the former, consisting of three. Lastly, there are underneath, near the thorax, a very large pair of bristly hairs, like two legs, each of which consists of six joints, and has also on each side a small part added to it with two articulations. So that computing the whole, there are here twelve pair of small parts beautifully interwoven with bristly hairs, which meet together when the Hermit swallows its meat, as is manifest from their structure and situation.

The thorax underneath is divided in the middle as it were by two testaceous little bones, with which the two arms and the four fore legs, Tab. XI. fig. 1. *gg*, are articulated. And in order to see this distinctly, it is necessary to take the whole Hermit out of the shell, and to lay it on its back. Then four articulated bristly hairs are seen between the eyes. fig. 11. *aa*; but the other bristly hairs before described cannot be seen distinctly, until after these are removed out of their places, because they are covered by them. Near the eyes two horns *bb* come in sight, and afterwards two arms are seen very distinctly, of which the left with its forceps *c*, is always less than the right *d*, though both are composed of five testaceous joints; to the uppermost of which is likewise joined by articulation a small part, which may be called a thumb, and from this the forceps of this creature have their origination.

The four subsequent legs *ee* consist of six joints, which are also like the arms adorned with prominent notches, bristly hairs, ruddy spots and furrows. And further, with the thorax are

are joined two other pair of smaller parts like legs: and in the middle, between each pair of these, are observed some peculiar little bones, whereby these legs are joined to the thorax. The first pair of them, Tab. XI. fig. II. *ff*, has indeed five joints, and, in other respects, it is of the same structure with the arms or forceps, and has, like them, a very small thumb. The other pair likewise consists of five joints, and is very worthy of notice *gg*, because the first pair of these joints, that next to the thorax, or the fifth, if you compute from the extremities, is perforated with two small tubes, issuing from the abdomen, through which the semen or eggs are secreted; which indeed deserves very great consideration. The upper part of the thorax, or back, is furnished with a small shield; behind which is placed such another, but less. On the sides of the thorax the crustaceous covering of the back is thin, and if it be raised up, which may be done without dissecting it, the branchiæ or gills are observed underneath, placed on each side of the thorax.

The abdomen is soft, and has no shelly or crustaceous covering; since the shell itself is its coat, and does the office of that hard skin. The body is in this part bent near the duct of the spiral windings of the shell, with which it is surrounded: But this bending of the body is not so remarkable as in Snails; because the body of the Hermit is not extended through all the turnings of the shell. The abdomen has on the right side three testaceous bristles *bbb*, each of which consists of two joints. Rondeletius, in his Hermit, seems to delineate six such little parts, which are interwoven or planted with little eggs or spawn like beads.

Among many things worthy notice in the belly, what deserves most particular consideration is a certain eminent or prominent point *i*, which is naturally the first thing observed in the thorax, and is as the center, wherein all the tendons of the muscles, and that part of the abdomen meet; and by the help of which, the Hermit is in that part fixed in his shell or stony skin, so that it can never go entirely out of it. Though its thorax, and the hinder part of the abdomen and the tail adhere to nothing, and that there is such large room or space in the shell, as that the Hermit can freely move itself therein; yet the thorax is forced to remain fixed in the shell, like the Tortoise in its house or shell.

The tail of the Hermit is also surrounded with a crust *k*. That this may appear the more plain, I have delineated it larger than it naturally is. This tail consists of two testaceous articulations, Tab. XI. fig. III. *a*, to which are added at the end a verge as in Snails *b*, which forms the third joint, and serves to hide the fundament: for the intestinum rectum *c* terminates there in the second joint. On each side of the tail are three pair of testaceous little

bones *dd*; which, like the arms, are larger on one side than on the other, and beautifully decorated with small hairs. The Hermit makes use of them when it finds an enemy approaching, to hide itself in the shell, or when it desires to rest; for then by their assistance it lies fixed in the hinder parts of the shell, or draws itself back into it. But if the Hermit draws to it, or contracts these little parts, it can then protrude its tail forward into the entrance of the shell, and thus it evacuates its excrements. For this purpose, I think, nature has given it so large a shell; the hinder windings whereof are not all filled with it, as we have before observed. The same is found in Snails that inhabit shells; which, for that reason, discharge their excrements through their neck, and have not a very moveable tail. These little bones of the tail are formed, some larger than others, in proportion to the space in the shell, for this is larger on one side than on the other. In the same artificial manner are built the wheels of french chariots made for ascending.

#### *The internal parts.*

Receive, illustrious sir, this brief description of the external parts of the Hermit Fish, and permit me now to pass to the internal, beginning with the abdomen, because I have begun the dissection there. When the abdomen is opened, the first thing that appears is the outer and inner skins, which are glandulous; and immediately under there is seen a fleshy membrane. After these integuments are dissected or taken off, a great number of whitish filaments present themselves; which are delicately and orderly placed on very numerous and beautifully digested parts, in form resembling intestines, fig. IV. *gg*. As I pursued the course of these white filaments to their origin, I saw they were blood vessels, though of a white colour like a cob-web. What I first took to be the intestines were all appendages\*, sometime plain, and sometimes divided; which were of a tubular structure and whitish colour, and contained a matter separated into dissimilar parts, and condensed into a serum and coagulum. These appendages were so numerous as to cover almost all the abdomen; but they were all connected by the blood vessels, which I was obliged to break open with great attention, in order to discover their origin and beginning: Thus I at length discovered that these were on each side united, Tab. XI. fig. v. *bb*, into two common ducts, which grow near the stomach where the pylorus is placed, and are terminated in many unopened tubes *ii*. What use these appendages are of, and whether they serve instead of a pancreas, which is formed in that manner in many Fish, may be more accurately investigated in the larger Crabs.

\* This is a construction very frequent in the intestines of Fishes.

Among these appendages, at the bottom of the muscles of the abdomen, appeared an intestine; which, without any winding, ran strait from the stomach towards the tail; and whereof I have here delineated, fig. III. *e*, only a small part, somewhat augmented beyond its natural size. It was full of gray excrements, which, when viewed with a microscope, consisted almost entirely of small chrystals, which were regular grains of sand. The stomach also contained partly the same substance, and partly some little fibrous membranes. Its upper part is placed near the back, its inferior in the thorax. It is in structure partly membranous, and partly crustaceous: its bones are very beautiful. Above, below, and on each side, it has many muscles, by which its parts are connected and moved. On the inside, in the cavity of the stomach, I saw three distinct teeth, of a moderate size, each of which was divided into several smaller teeth: the teeth were of a pale lemon colour, but it was changed by degrees into a dark green, in that part where they terminated in little teeth or divisions. Two other teeth-like little parts, which were uneven and notched, adhered also to the cavity of the stomach. This observation is certainly very worthy of notice, that the little creature, living like a Snail in the shell, is furnished with a double apparatus of teeth; for it has two teeth forward in the extremity of the mouth, and five others in its stomach.

Where the intestinum rectum or straight gut begins, I saw the cæcum or blind gut moderately long, and beautifully twisted, Tab. XI. fig. III. *f*, which I first took for the extreme appendage; but as I found it loose and disengaged in all the Hermits I dissected, I therefore believe it is the cæcum. I should not, however, venture to affirm this for certain, because I have not distinctly seen its blind or imperforated extremity; for all its contents were coagulated and separated by the spirit of wine, and the place wherein the intestine itself was seen, appeared so transparent, that I could not observe that particularity. Besides, it was not like the appendages on account of its contents, nor was it inserted in the middle, but somewhat on one side of the intestinum rectum.

In the abdomen, on each side of the appendages, there were two small genital vessels, fig. VI. *aa*, whereof that in the right side was the larger: both were, in many places, beautifully twisted into spiral windings *bb*, and they proceeded thence curled, till they at last terminated in a narrow tube *c*. It appeared likewise how these, in their end, pierce or perforate the last pair of legs, fig. II. *gg*, in the middle of the fifth joint, which resembles a bone or shell with a considerable tube, fig. VI. *d*. This I have delineated larger than it naturally is. This perforation appeared to me very plain, when I squeezed the contents through it, and separated and unbound the tube itself. In it was a substance of a whitish colour, and when examined with a glass, it seemed all to consist of very

small regular little parts, like round globules. I could not discern whether these were the rudiments of eggs, or the globules of a male's semen; since in all the ten that I dissected, the same structure was observable in the genital vessels. The windings of these spermatic ducts were likewise connected by means of blood vessels; and when I opened them, they were ten inches and an half long. These are all the entrails that I saw in the abdomen; only that in the bottom of the belly were placed several muscles, towards which the nerves issued from the spinal marrow. Part of the tendons of these muscles terminated in the point, fig. II. *i*, above described; where the creature is fixed in its skin or shell, so that with their assistance, the Hermit may draw in and hide itself in the shell. Between the appendages I saw many little drops of fat floating, which resembled the oil boiled out of the fat of Whales swimming in water.

If the thorax be opened above in the back, the first part that is there seen is the stomach, with its muscles, which is of a remarkable size in this creature, and is really situated under the back, though I have, for method sake, described it in treating of the abdomen. Behind this stomach, above the place where the intestine arises, is situated the heart, Tab. XI. fig. VIII. *aa*, which resembles an irregular little piece of flesh, and becomes somewhat pointed. It is of a ruddy colour there; but underneath and at the sides it is white. I perceived four vessels *b* issue from it above, and two *c* below; and one of the two lower ones was larger and thinner than the other; which however consisted interchangeably of somewhat thicker sides, and sent off some vascular sprigs *d*. On the outside of the surface of the heart I observed *b* several little holes; but on the inside the heart was fibrous, and furnished with its pillars or columns like the human heart. I discovered only one venticle in this creature, as is the case in the generality of Fish; but I could not see its auricle. Moreover, I observed how the whitish vessels in this heart, were distributed up and down through the body, especially towards the branchiæ or gills, one of which I have represented magnified *e*.

There are here, as I have observed, eleven branchiæ or gills on each side of the body, so that they make twenty-two in all. They are situated at the sides of the thorax, between these long cavities, which there form the articulations of the legs. They are of a pyramidal figure, rising from a broad basis *f*, and ending in a small pointed top *g*. Each of them is, at the upper end, divided into two other parts, each of which consists of a great number of smooth or plain lamellæ *h* or layers, which are applied close to each other like the leaves of a book, and each of them is divided from the others very deeply, which makes indeed a very agreeable sight. The structure of the branchiæ or gills is partly cartilaginous and partly membranous; and their blood-

vessels



vessels are extended near the cartilages. Moreover the beginnings of the appendages are seen very beautifully in the thorax, as has been before observed.

After these little parts, together with the stomach, heart and intestines are removed, the spinal marrow presents itself to view: it is placed entirely at the bottom of the thorax, and is not inclosed in a bone. It extends itself through the lower parts of the abdomen to the tail of the creature, and there terminates in the muscles of that part. In order to describe this matter the more exactly, it must be observed, that the brain, Tab. XI. fig. ix. *aa*, from which this marrow arises, is situated immediately under the articulations of the eyes in the head, which is very short, and joined to the thorax. This brain is seen to be there divided into a right and left part. Above the brain appear the optic nerves *bb*, which are found to decussate over it, and to proceed towards the eyes, as I shall now shew. Underneath, out of the basis of the brain, arise two strong nerves *c*, which properly constitute the origin of the marrow in the thorax: these nerves are placed at a considerable distance from each other, in order to give a passage to the gullet, which is very short, and reaches from the mouth to the stomach. The brain is therefore placed over the gullet, and the gullet again, as well as the stomach and intestine, are lodged upon the marrow in the thorax and abdomen. These two originations of the marrow are again united a little below, and there form a remarkable swelling or knot *d*, out of which many nerves issue, which are distributed over the muscular parts of the thorax as well as the brachia and legs. In men and quadrupeds such clusters are never seen in the body of the marrow, but always in the nerves after they have issued out of that part; but this is indeed the same thing in effect, for as the marrow itself is as it were a bundle of nerves, and is double in all species of animals, it is the same thing whether these clusters are found in the marrow, which is a kind of thick and compound nerve, or in the nerves issuing from thence, which are the separate portions of the marrow. Whoever accurately considers the marrow in man and other animals, will indeed most clearly observe this analogy; though Malpighius himself does not seem to have observed it, when he supposed there was so great a quantity of brains in the marrow of silk worms. After the marrow has formed this cluster in the Hermit, it becomes simple again, though its two parts may, notwithstanding, be palpably distinguished; but these are so nearly applied and contiguous to each other, that they are as if they were but one. Afterwards is discovered another cluster of marrow, and a third, fourth, fifth, nay, a sixth, *eeee*; the nerves of this last are detached to the muscles of the tail. The nerves which arise out of these little clusters, are almost all bestowed on the muscles of the

abdomen; whereas on the contrary, those that issue from, the marrow itself, Tab. XI. fig. ix. *ff*, are likewise distributed to the viscera. It is likewise worthy of notice after what manner the nerves decussate one over another, which I demonstrate in those nerves which issue before the last cluster out of the marrow *g*, and are detached to the muscles of the abdomen.

After the optic nerves have issued from the brain, they are inclosed in the annular *b* crust of the eye, and being again considerably expanded in the latter, they thus proceed to the verge of the cornea tunica, and there terminate like spheres, or in globular forms. No humours appear any where in the whole eye, like those found in the eyes of men, quadrupeds, birds, and terrestrial or water Snails; but it is observed to be of a texture entirely different, which is very worthy of attention. If the cornea *i* be taken from the eye, there is immediately seen under it a kind of limpid matter, fig. x. *k*, which is the colour of jelly, and is divided in a very elegant and regular manner. What part this is, and whether it has its origin from spirit of wine, I cannot exactly determine, as I never saw any thing like it in any insects, whose eyes are of the same structure. I shall therefore at a proper time examine this little body, in the larger Crabs dissected alive.

But before I proceed further, it is to be known, that the cornea tunica is divided like a net, in the same manner as in the eyes of insects, but these reticulated divisions are here much deeper. I find every division to be hexagonal, as well in this Hermit as in insects. Moreover, all these divisions wind themselves above in a spherical figure, which however is not here very remarkable, since the ariolæ or little beds of the divisions, are very small and smooth. On the inside, in the hexagonal cavities of the divisions of the cornea, was fixed the glutinous matter before described, which was there divided in the same manner as the cornea itself. Under the latter appeared a great number of little fibres, fig. ix. *l*, which are placed on the internal surface of the eye, in the same manner as the seeds of the plant turnsol are fixed in their cups. All these fibres, which support the glutinous matter aforesaid, are connected together by the help of a membrane of a black colour on the inside, but above of a transparent green on account of the matter; I therefore call it the uvea tunica.

The structure and situation of these formed as it were an inverted pyramid, with its small point turned downwards; but when I separated these little fibres from each other, they appeared above as black as pitch, Tab. XI. fig. x. *m*, but below only of an obscure or dark brown *n*, and pellucid in the middle *o*: all of them terminated at length in a gray substance, and under this the extremity of the optic nerve came in sight.

When I viewed these fibres with a microscope, I found each of them consisting of other

other fibres, fig. xi. *pp*, all which were composed as it were of regular globules placed near each other. Between these little fibres there appeared also some small membranes, interwoven likewise in several places with globules, between which some vessels appeared creeping in various directions.

The cornea tunica, which is entirely pellucid, is very beautifully situated on this eye, and shews a greenish transparent uvea underneath: where the eyes face each other, the cornea is beautifully divided, fig. ix. *i*, and the crust is there extended further; so that the cornea is placed on the eye like a little cap, lying on the head obliquely.

After what manner sight is performed in the eye of the Hermit, and what effects are produced by the rays of light which pass through the cornea, and the glutinous substance, and are afterwards stopt by the uvea, and thence communicate their motion to the pyramidal inverted fibres; this, illustrious Sir, I leave to your discerning and most correct judgment, not doubting but you will give me the solution of so peculiar a problem.

What I have here briefly related, Sir, is all I have been able, in this short time, to discover in those Hermits, which the governor of Nyenrode sent me in spirit of wine. I offer you these observations in token of, and to preserve, our mutual friendship, and as an example of the divine miracles, which ought to be adored in all animals. Indeed; if we diligently searched into nature, we should for ever find more remarkable and more stupendous miracles, which hitherto lie hidden and wrapped up in the clouds of our ignorance: I hope to be at some time able to go through an accurate examination of the Caterpillar kind; in which, indeed, misery, death, and the grand and splendid resurrection of the body may be so clearly demonstrated, that we shall see them as it were painted before our eyes, and must be obliged to cry out in amazement, that the great God, the parent of all nature, exceeds and surpasses all praise, all eulogies, and all titles of honour, in his miracles, which can never be described according to their dignity.

## The S E C O N D O R D E R.

*Of the natural changes, or of the slow accretions in the limbs and parts of Insects.*

**H**AVING explained the first class of natural transformations in insects, we shall now pass to the second, which, though somewhat more obscure, may yet with due attention be clearly and distinctly understood. But before we proceed to explain this second class, to which innumerable insects are to be referred, it is necessary to observe, that in this order another species of transformation constantly precedes, which is indeed common to the two following, which are the last classes of mutations.

In order to understand accurately the preceding kinds of transmutation in this, as well as in the two last classes, we must call to the attentive reader's mind what has been said in the beginning of this work, where we treated of the first kinds of changes; that is, that some insects issued perfect out of the egg, and others imperfect. As we have referred the insects, which come perfect from the egg, to the first class of transmutation, it is very necessary to know, that this second, and afterwards a third and fourth, or last class of mutations, precedes the completion of the parts in those which issue imperfect in some of their parts out of the egg. Hence it is, that in the first order or class of changes, is perceived only one Nymph as it were, which we have observed is the egg or little creature itself. In the subsequent classes, on the contrary, we shall observe as it were two Nymphs in the course of the changes, and therefore two species of those changes also since another

kind of Nymph precedes the egg, or the oviform Worm of the Nymph.

That all these things may be perceived the clearer, we must briefly observe, that a little Worm always precedes this second and all the succeeding orders of transmutations. After this Worm has been in its egg or first cover in the form of a Nymph, it increases by degrees in its limbs, and in process of time becomes so perfect, that at length it puts on another habit of a real Nymph, and again becomes fluid like water in all its parts, and weak and feeble, or destitute of strength, as it was before, when it was in the form of an egg. Hence it has happened, a matter not hitherto observed, that not only the ancient errors concerning these metamorphoses remain to this day, but even those most diligent searchers into nature, the sagacious Francis Redi and others, declare they have seen the cast skin, under which all the limbs and parts of the insect increased; but never doubted concerning the metamorphoses, at which we greatly wonder.

To speak now in particular of our second class of changes, it will be very proper to observe, that the accretion of the parts undergone in process of time by the Worm, which is commonly found to have six legs, is insensibly and by degrees perfected by the evident external addition of matter; so that after some changes of its skin, we at length observe wings to sprout insensibly out of the body, to swell and become fit to open and bloom, as a tender,  
small

small, soft, delicate hull of a flower does out of a plant. Again, as in the other two changes, under which we shall see the Vermicles or Worms transformed into real Nymphs, the insects are deprived of motion, and as it were of necessity lie unmoved for some time; so on the contrary, the insect, under this change, advances, stands, walks, runs, leaps, and eats, nor is it ever deprived of motion, only that it rests a little at the time it is to cast its skin; and then stupendous changes happen in some of them, as is sufficiently manifest in the Ephemera, or Day-fly. In others, on the contrary, the change is so inconsiderable, that it is with great difficulty observed, only about the protuberant wings, as is the case in the Earwig.

Since therefore the insects which come under our second class of changes, are not at any time deprived of motion, and yet have some of their parts well ordered, and compounded like other Nymphs: for these cogent reasons we are induced to think, that the insect may, at the time it exhibits its limbs and parts in the manner aforesaid, not improperly be called a Nymph-vermicle; for the little creature, whilst it is and remains a real Vermicle or Worm, has notwithstanding some of its parts disposed, and in an admirable manner beautifully composed, just as they are in the Nymph state.

Our second order or class of changes is therefore thus; the Vermicle or Worm having cast off the habit of a Nymph, which it bore, without

food in its egg, increases insensibly by the help of food supplied from without, disclosing many and more visible parts, until it afterwards puts on as it were the form of another Nymph; but this without losing its motion, and it afterwards comes out of that as a winged insect; and having now attained as it were the marriage-state, becomes fit for generation.

This is the species of Nymphs, to which we have given the second place among the natural orders of changes, since the mutation in question is not very intricate, nor is it obscure or difficult to be understood; nay, it may with these rules be comprehended easily, and it approaches very nearly to the first order or class of changes, wherein we saw the creature issue immediately out of its egg or coat; nor does it indeed differ greatly from that order.

As this change is so clear and evident, and as it agrees so much with the budding and blooming of a flower, we have therefore thought proper to compare this, and the other subsequent changes, to this budding of plants. This is the more proper, because, as the increase happens on the outside of the creature, so it is likewise observed to happen in other insects on the inside, and under the skin; which has been sufficiently shewn in the preceding pages, and shall be explained more at large hereafter. To conclude, as this change is very elegant, and very worthy of consideration, it comprehends also a great many insects under it.

*A catalogue of the insects, which are referred to the second order or class of natural changes, called the Nymph Vermicle\*.*

TO this our second order or class of changes we refer first the Dragon-fly, called the Mordella, or Orfodæna, by Junius; by Mouffet, Libella; and by Aldrovandus, Perla. I preserve seventeen species of this genus, nine very large, five of a middle size, and three very small ones, which, because they are tender and delicate, are dignified by some under the particular name of Virgins. One of the smallest species is well described by Goedaert, but as this author neither delineates in its figure, nor takes any notice in its description of those swellings in the back, wherein the wings are inclosed, it is evident he did not know the nature or disposition of this Nymph. Besides, the third figure which he gives us of it, misrepresents nature according to the fancy of an imaginary brain. I never could find that it has hitherto been described by any other author. Among the figures published by Hoefnagel, who has given us the delineations of ten species of the Dragon-fly, there is found none of the Nymphs before mentioned; it is certain, however, that they were in general not unknown to authors. We find that Rondeletius knew the Nymph of the

Dragon-fly, though he very improperly called it the Cicada or water Grafshopper. In like manner we believe that the Mordella is the water Locust of Mouffet. This is most certain, that the Forficula Aquatica of Johnson, or otherwise the Pulex Marinus of Mouffet, is the true Nympha of the Mordella. The Scorpius Aquaticus also of Redi is nothing else but the Nymph of the Perla or Dragon-fly, but belonging to a species which we reckon among the larger Virgins.

I keep in my collection, six kinds of the Nymph Vermicle, from which Dragon-flies have their origin; there are one very large, three of a middle size, and two small. I have likewise a Dragon-fly, which was to have undergone a change immediately, and in which one may observe, in what a wonderful manner the wings are wrinkled and folded in the tubercles on the back, wherein they are enclosed. I preserve besides the ovary of the Dragon-fly, which is perfectly like that of fish, divided into two parts, one whereof is placed in the right, the other in the left side of the abdomen.

\* The famous insect, the Formica Leo, is a Vermicle of one of the Flies of this kind. This creature naturally walks backward. There is another species which moves forward; these are found on land. The more frequent kinds are those of the water, and they are common in our ditches.

The second insect which we reckon in our second class of changes is the Grasshopper. I preserve one and twenty species of them male and female; these are nine larger, six middling, and as many smaller ones, whereof some are conspicuous by their scarlet wings, others are cloathed in purple, others in azure, and others have elegant greenish wings. I preserve also some Nymphs, some Vermicles, and some little eggs, from which proceed the Grasshopper and Locust kinds. Amongst the largest species, I have the great destructive African Locust, which has a cowed or hooded breast, and two very long legs, which, as they have hexagonal thighs, are provided also with a double row of ferrated and long teeth; the internal wings glitter with a deep purple colour. This belongs to those species, which do not shew their colour except when they are flying. I have also the Locust of the Molucca islands, which Dr. Padbrugge sent me. It has a very slender body like the Cavallucus of Redi, and the tail is bent downwards. Its wings are long, and of various beautiful colours like the Peacock. The neck is of uncommon length, and supports a short head. That gentleman sent me also a figure of the Molucca Bruchus, or Grub, the body whereof is as big and as thick as a Hen's egg, and is beautifully interwoven with veins like ribs, but the legs are very short in proportion. I preserve with these the Spanish Locust, which differs from the African only in its size, except that the veins in its wings are disposed in a different manner, and the colour is reddish. I have also the African Locust with short legs, and short thick horns, wherein one may, in a remarkable and distinct manner, see the prominent eyes. Among the middle species I preserve the Mantis or divining Locust, which was likewise brought from the Molucca islands. Of this authors invent many idle stories; one is, that when it is asked the way by travellers, it shews it. "This little creature is reckoned of such a divining nature, says Mouffet, that when a boy asks for the way, it stretches its foot forward and shews it, and is seldom or never mistaken." The other Locusts that I preserve are of the middle size, and mostly french; they are adorned with a wonderful variety of colours, as with so many new-fashioned garments: hence they please the eye greatly with their natural ornaments, but they do not shew their colour except when they fly.

It is remarkable what small difference there is between the Worm or Nymph Vermicle of the Locust, and the Locust itself: this consists only in one thing, that the wings, which in the Locusts are expanded and spread over the body, are on the contrary enclosed in the Nymph, in four little clusters, wherein they are quite folded into each other, in like manner as in the Worm of the Dragon-fly. It was this folding and separating of the wings, that, in my opinion, made Aristotle, Pliny, Hieronymus, Aldrovandus, Mouffet, Johnson, and

other curious searchers into these secrets, call the aforefaid Vermicles of Locusts, featherless or unfledged Locusts and Bruchi. The same creatures they afterwards, when their wings began to swell, called Attelabi; and to these, when by the increase of the bulk of their bodies, especially these of the females, they began to hop slowly, but were not yet able to fly, they gave, not to mention many other names, the appellation of Afelli. The word Attelabus properly signifies the Nymph of the Locust when able to walk. We see seven species great and small of these Nymphs, out of which the Locusts issue. In the figures of the industrious Hoefnagel, which exhibit fifteen species, we likewise see there a delineation of the Nymph Vermicle of the Locust. When I consider all these experiments, I cannot imagine for what reason Goedaert should write, that Locusts had their origin from a Chrysalis; since Aldrovandus and Mouffet, and all other authors make mention of unfledged Locusts, and their opinion is supported by, and agreeable to, experience.

I preserve also a three-fold stomach of a Locust, which is very like the stomachs of animals that chew the cud, and particularly has that part of the stomach called Echinus, very distinctly visible. I do not therefore doubt but Locusts chew the cud, as well as the animals just mentioned: indeed, I perswade myself that I have seen this.

I have likewise in my possession, the oblong eggs of Locusts and their entire ovary, which is interwoven with silver-coloured filaments, which are doubtless ramifications of the aspera arteria, and also with veins and arteries. But the eggs are all as it were horny, and of a brown colour: many of their first rudiments also being white and yellow, and covered with a thin coat or skin. I preserve these in particular cells in my cabinet.

The female Locusts are furnished with sharp tails, which the males have not. According to Aldrovandus, they pierce the ground with these tails, and bury their eggs under it. I can demonstrate this tail to be quadruple, nay, quintuple.

I preserve also the teeth of Locusts, and the coat or skin which the Nymph Vermicle casts, when the wings of the Locusts begin to swell. No man can form any idea, by what means a very thin skin is then separated from the long and small horns of the Locusts; nay, and from the eyes and teeth, and the sharp-pointed claws. In this period the Locusts are so soft and delicate, that their legs may be bent like wax, and formed into any figure, and in that condition may be dried and preserved.

I have also wings of Locusts which I stopped in the act of their exclusion; so that by this means one of their extremities is displayed or rolled out, and the other still folded together and wrinkled. With these wings the Grasshoppers and Locusts, when they have gone through their change, make that crackling noise, as Casserius has very justly observed. We also find that

that the males of Locusts only make this noise, not the females: indeed some species make this noise with their wings only, and others by striking their wings and legs together.

The *Locusta Pulex*, or Flea Locust, follows. This little creature is found hid in that spumous matter, which we sometimes see lying indiscriminately on the surface of all kinds of plants\*. In this spume † it acquires in time four tubercles on its back, wherein the wings are enclosed. I have two species of this insect, and it was likewise known by Mr. Ray, who described the plants growing about Cambridge. It has not teeth like the Locusts, but has only a subtle sharp-pointed proboscis or trunk, like Grasshoppers, on its breast.

We refer also to this second class the *Gryllus Sylvestris*, or wood Cricket; in which insect we also observe that the male only sings, or makes a noise. I remember that I once saw a whole field full of these singing Crickets, each of which had dug itself a hole in the earth, two fingers deep, and then sitting at the entrance thereof, they made a very disagreeable noise with the crashing and tremulous motion of their wings; when they heard any noise they immediately retired, trembling, into their little caverns.

The house Cricket is the next to be reckoned in this second class; since this, like Locusts, has also its wings enclosed in little cases, as long as it remains in the habit of a Nymph.

We likewise rank the common Grasshopper in this class. For although the larger Grasshoppers are not found in our part of the Netherlands; we, notwithstanding, by inference from the less to the greater, refer them to this place; and the rather, because the very diligent Aldrovandus hath left us a delineation of this Worm, with its tubercles on its back, wherein the wings like a flower in its cup are enclosed; as this Worm is called *Tettigometra* by him, it is the real Nymph of the Grasshopper. I preserve a very rare and curious exotic Grasshopper, the head of which is formed like a long and deep episcopal mitre, so that it appeared four fifths of an inch above the eyes, exhibiting us a wonderful work of God in the theatre of nature. We must also observe again, that the male Grasshoppers only can sing, and we can shew their tympanum, and also the little part that modulates or tunes the voice, or impels the air against the tympanum.

The *Gryllo Talpa* or Mole Cricket, or the *Talpa Ferrantis Imperati*, likewise belongs to this class; since, like the insects hitherto described, it has four tubercles on its back, wherein the wings are enclosed. We have the Worm of this insect with and without tubercles, as

also the insects themselves, with their wings displayed. The industrious Goedaert has described the egg of this insect. We can also shew its teeth, and the manner wherein the wings lie complicated in their tubercles.

In this I also reckon a little creature, which is found in the tubercles of the leaves of the black poplar, though I might have described it in the fourth order or class, because it has a more secret method of changing. It is delineated in figure xxiv. of Tab. XLV. To this order I likewise refer another insect, which is likewise represented in fig. vii. of Tab. XLIV. and is found in the tubercles or swellings of willow trees.

The next we exhibit is the Indian insect, sufficiently known by the name of Kakkerlak, which we think likewise belongs to this second class. As we have observed the tubercles before-mentioned in its wings, though not having attained their full bigness their wings did not appear perfect; for the same reasons, we think we should refer to this order that species of Beetles which are commonly found about bakers ovens, and, according to Fabius Columna ‡, in kitchen dirt. They agree altogether with the insects just now mentioned, called Kakkerlak, and are the same that are described by Mouffet under the name of *Blattæ*. We preserve two species of them, together with their Nymphs, wherein the tubercles scarce began to swell.

Next follow the flying or land Bugs, which we find in fields and trees. I preserve twenty-six species of them in my museum, together with a larger Indian one, which are very beautifully adorned by nature with variety of colours; and as with their lustre and gaiety they wonderfully please the eyes, so they are very disagreeable to the smell. Hoefnagel also has figured eleven kinds. Among these which are in our cabinet, we reckon the cruciate, the scarlet, the red marked with black lines, the green, the black, the yellow, the globular, and that which has a sharp-pointed breast.

To this class we likewise refer the flying water Cimices or Bugs, of which we preserve four full-grown ones, and one Nymph. These, like all the rest, carry their weapon in their mouth, and sting vehemently therewith, as I have sometimes experienced myself, though I suffered no injury thereby.

We refer also to this order or class some insects that are very tender and slow-paced, having six slender and admirable legs, and long and acute horns, and a considerable thick body; from the hinder part whereof, about the tail, spring two bristly and sharp-pointed hairs, and they have likewise a sharp sting, as the Cimices

\* This is a species of the Cicada or Cigale. The characters of that genus are very obvious on it: they are, that the beak is under the breast, and is bent downwards; the antennæ or horns very short; the wings four, and placed cross-wise, the back conical, the breast cylindrical, and the legs made for hopping. The Cicada of Italy, which the Roman poets mention, and which their translators render Grasshopper, is of this genus. We have also one on the rose, and others on various bushes.

† This spume is not exfudated, as some suppose, from the plant, but from the mouth of the animal; and if it be well wiped away, without injuring the creature, more will be immediately seen issuing out of its mouth, till there is as large a quantity of it as before.

‡ *Obs. aq. et terr.*

or Bugs, so that they seem likewise to belong to that genus. I could never hitherto observe these little creatures to change: but they are found on various plants, and there become often immoveable. Lastly, I preserve a very slender kind of Fly, which first issues from a Worm which was in the body of that creature, transformed into a Nymph of the third class. But if this Fly creeps out of the body of this insect, after preparing a passage for itself through a small hole which it makes with its teeth, then all the body is hollow, and the dead insect remains in the same situation as if it were still living\*. These little creatures, hitherto not accurately enough examined, are improperly called the Lice of plants. I have some of them, and also the flies that come from them.

We likewise place in this order the water Tipula, of which I preserve many species, and one of the Nymph. These insects are worthy of the greatest attention, on account of the wonderful lightness wherewith they run on the surface of the water. They have an aculeus or sting, like Bugs, in their mouth. I preserve besides another species of this insect, which is of a wonderful delicacy, and of a very singular structure, and very slow-paced.

In like manner we insert in this class the water Scorpion, which has also an aculeus or sting in its mouth. I preserve two species of it, the larger whereof is described by Aldrovandus under the name of the water Tipula, and the less by Mouffet retaining the name of the water Scorpion. I have a Nymph of the smaller species, in which may be seen how the wings bud or disclose themselves by degrees, as is the case in the Nymphs of the Dragon-Fly in this same class.

The common water Flies are likewise of this order. Of those I preserve four species, and we have often spoken of the Nymphs and Worms out of which they issue when small. These, like other water insects, likewise have their sting in their mouth, and they defend themselves therewith, whenever they are attacked or taken. These Flies are called amphibious Bees by Aldrovandus, and are very accurately described by him. They are also called wild Bees by Johnson: nor do I doubt but these are the same with the Marinae or Sea Bee, which has been described by Dr. Piso, and is now in the possession of Vander Linden, doctor of physic; but it appears to be nothing else but a piece of sponge. The learned Mouffet calls these Flies Notonectæ, because they do not swim on their belly, but on their back; and he seems to have likewise delineated the water Bug among the Notonectæ, saying, that it is probable men learned the art of swimming on their backs from them. How far this may be admitted, let others determine.

As all the insects hitherto enumerated have wings, some of them flying in the day-time and others at night, it is easy to conceive that they may be very speedily generated in all standing waters. And therefore in summertime a kind of trembling motion is frequently observed to be excited even in the smallest ditches of water by the motions of insects. But we shall speak of these matters more at large in their proper places.

Lastly, we likewise refer the day Fly, Ephemera, to this order: its eggs and ovary, which is like that of fish, we preserve in our cabinet. We also have in our possession the Worm and Nymph Vermicle, and also the Ephemera itself, both male and female. We can from these objects demonstrate how the wings are rolled and folded in the tubercles of the Nymph Vermicle, for there is an admirable difference between the folds of these wings, and the complication of the wings of the Dragon Fly. We also observe the like difference, with respect to the disposition of the wings in other insects, as will be shewn from our particular observations, to the praise and glory of the most admirable Creator. After this, we shall in its place, from the course of our experiments, assign a reason, why the wings in these insects are disposed in such a particular manner, the knowledge of which will doubtless be acceptable to the reader.

I preserve likewise the one day Flies, fixed in such a position, that it is very easy to perceive the method whereby they cast a very thin skin like a shirt from their whole body, which is wonderful to look upon, and difficult to be expressed in words. At one end of this skin they roll or turn themselves out, as the foot is taken out of the shoe, and at the other end they turn it off in the same manner as a man takes off his glove by turning the inside outwards. All this will become evident, when we describe our particular observations on this stupendous miracle of the Netherlands, and what we have remarked concerning the uncommon, very swift, and as it were horary changes of this little creature; that they may afford perpetual matter of meditation on the incomprehensible wisdom of God, and regular order of nature. In the mean time, we think what Dr. Augerius Clutius hath not scrupled to affirm, very improbable; and that is, that the Ephemera, or day Fly, is produced from a Chrysalis, and he has likewise exhibited the figure of this Chrysalis contrary to all truth. We observe that its figure is subjoined or added also to the track of Goedaert; but these are delineated upon the suggestions of a weak fancy. This will be very evident, when the insects themselves, which the learned Andrew Colvius sent us, are compared with those figures.

\* Since the time of this writer, Reaumur has with great judgment and knowledge written of many of these creatures. They run about the branches of trees and shrubs, while small, and when they have passed part of their lives thus, they remain immoveable for the rest, and their bodies become only a kind of covering for numerous genus. That author calls them gall insects, and pragal insects. The Kermes and Cochineal are of the same kinds.

I have in my possession several species of the Ephemerus collected in France and other places; among which I can shew the least species of the Hemerobius or Ephemerus, called in Dutch Mut; the wonderful changes whereof I have shewn as a matter of the highest speculation, to the most noble Thevenot, the illustrious patron of all our studies, in the road that leads from Amsterdam to Sloten.

Before we conclude this order, we shall refer the Earwig, Forficula, or Auricularia thereto, which creature, with its wings visibly expanded, and its Nymph-Vermicle are also preserved in my collection.

We class or arrange in this order all the insects that we have hitherto described, which are excluded from their eggs under the form of a Worm, and in process of time are augmented or increased into Nymph-Vermicles and so on. Nor can we sufficiently wonder that this order of change has not been hitherto ob-

served or represented to our knowledge by any person. So that upon considering how little the naturalists have taught us concerning these creatures; we are obliged; not without shame, to confess, that they were wholly ignorant of the nature of most insects. For, if we may express the matter as it really is in a few words, the names only of the said insects are mentioned in the books of the naturalists; and if you except these, nothing remains but the false and imaginary inventions of a dreaming and chimerical brain. As I am not afraid to declare this generally, I would always except the industrious Goedaert, who has faithfully delineated, and, in some measure, according to truth described the changes of the Caterpillar kind; as also the most acute Redi, who has, by irrefragable arguments, proved; that no creatures are produced by putrefaction; and lastly, some accomplished Englishmen, the chief of whom are John Ray and Martin Lister.

*An example of the second order or class of natural changes, which I call the Nymph-Vermicle, in the Dragon-Fly.*

N<sup>o</sup>. I. **I** EXHIBIT here, Tab. XII. the Vermicle or Worm of the Dragon-Fly, as yet lying in its first coat, in which, when enclosed, it is called an egg. Many of these eggs, placed near each other in the same manner as they are situated in the divided ovary of the Libella, I here exhibit delineated to the life. This ovary perfectly agrees with that of fish, especially that of the Herring; and consists in like manner of numerous eggs, which are of an oblong figure, as may appear from those dispersed here and there in this figure. The eggs enclosed in this ovary are at length thrown into the water by the parent insect, out of which afterwards issue many small Vermicles with six legs; and these having attained the full period of their growth, cast their skins, and becomes so many Dragon-Flies, like the parent.

II. To shew the method wherein this happens, I have likewise, for the sake of order, delineated to the life the coat of the egg out of which the Worm of the Fly has made its way.

III. I afterwards in the third place, shew the Vermicle or Worm from which the Dragon-Fly is produced, by the power of accretion alone, but I have not delineated it so small as it is when it comes first out of its egg, but somewhat larger, and in the form it has when it has been fed for some time. I shew its eyes, together with two prominent horns in its head: in the breast underneath are observed six shaggy legs, each of which is divided into four joints; and the extreme joint of each is furnished with two claws. The belly is divided into ten rings, the last or lowest of which has some bristly, rigid and prominent little points. It is agreeable to observe in this Worm how its limbs come

imperfect out of the egg, which is likewise a property of the Vermicles of the third and fourth order or class of transmutations, as shall be afterwards shewn in its proper place. And it is for this reason I call the little creature, whilst it remains in this imperfect form in the egg, an oviform Nymph-Vermicle, as I have explained more at large above; and this observation I would have inculcated and understood once for all, in the course of the subsequent orders, as I shall repeat it no more.

IV. I represent this Vermicle somewhat older, so that about the end of the thorax, where that part is connected with the belly, four membranous buds or follicles like flower-cups are observed to spring, swell, and as it were branch out of the body: these four follicles or membranous bags contain the wings, which increase in the same manner as the cups of plants and trees do with their flowers and fruit. But if any one should at this period dissect these bags, he would find nothing in them but a watry humour or ichor, because the wings, too tender yet for sight, have not acquired their strength and perfection, in the same manner as in the cups of flowers and fruits when they are first distinguishable; nothing is found but a moisture or clammy liquor.

V. I afterwards demonstrate this little creature in the state wherein it has attained its full bigness, together with its four bags or follicles, which are conspicuous on its back, and are increased to their due size; at this time I find the wings perfect in them, but folded in each other; nay, we may likewise observe all the colours and varieties of painting of this creature now transparent through the skin:

wherefore, as the insect is and remains yet a Vermicle or Worm, and has some of its parts enclosed in a skin and deprived of motion, like a Nymph of the third order or class, I have called it in this period a Nymph-Vermicle. In what manner this Nymph casts its skin, is shewn in the second figure, Tab. XII. fig. II.

VI. Lastly, I exhibit the same Vermicle as it is when arrived to its last degree of perfection; in which form it is called the Perla, Libella, or Dragon-Fly, and by increasing becomes a perfect creature, because it has acquired its full age and is now fit for generation. As at first it was a creeping and swimming Worm, it is now become a flying Worm or inhabitant of the air. Moreover, its change, or properly the accretion and expansion of its parts, is, with respect to its eyes, wings and tail; extremely admirable, but the legs undergo no change.

I first observed these Worms, out of which the Dragon-Flies are produced in the river Loire at Saumur, behind the house of the very learned Dr. Tanaguil Faber, whose guest I had then been, and who likewise greatly loved to search into such natural miracles. I afterwards found them in many other fresh rivers, small pools, fenny ditches, and other standing waters, and in some places in such great numbers that the whole bottom was as it were planted with them. They can both creep and swim, but they do not move swiftly. They have likewise a sharp sight, and they immediately throw themselves to the bottom, if any one comes to the places wherein they live, or when they perceive the least uncommon object. Their food is soft mud, and a fine earthy substance; wherein they live. They are produced by the Libellæ or Dragon-Flies, for these are likewise usually about waters, and in those places perform in a very wonderful manner the business of generation. Numerous Dragon-Flies are likewise found in the fields and forests, where there are numerous smaller Flies; for, like birds of prey, they hunt after and devour the latter in the air.

If the eggs which the Dragon-Flies throw into the water be examined with a microscope, they appear of an oblong figure, Tab. XII. fig. I. and in the fore part terminate in a point: in this part they are also adorned with a kind of little cups, with protuberant points, somewhat resembling the cups which we have delineated in the Nit or Loufe's egg, and they are blackish in the extreme fore end. At the hinder part the egg terminates in an oval form, and has a glittering surface; besides this it has nothing singular in it.

When the Worms which issue out of these eggs have grown to the form of a Nymph-Vermicle, they then remove out of the water to a dry place, as into the grass, to pieces of wood, or a stone wall, or any thing else they meet with; and therein firmly fixing the acute claws, Tab. XII. fig. II. *aa*, of their legs, they continue immovable a very short time. It is

then observed; that the skin first opens in their head and back; and out of this opening they exhibit to view their real head and eyes *b*, and at length their six legs *cc*; whilst in the mean time the hollow and empty skin or slough of the legs remains firmly fixed in its place; after this the enclosed creature creeps forward by degrees, and by this means draws first its wings and then its body out of the skin, and proceeding a little further, sits at rest for some time longer as if immovable. In this time its wings begin by degrees to expand themselves, and to make smooth and even all their plaits and folds. The body is likewise insensibly extended, until all the limbs have obtained their just size and bigness. As all these things are perfected by the force of blood and circulating humours, and by the assistance of the air impelled by respiration, the creature cannot the first moment fly, and therefore is forced to stay in the same place, until all its limbs are dried by the circumambient air and sun. Thus the Dragon-Fly enters upon a more noble life than that it had hitherto led in the water, for in the latter it was obliged to live in misery, creeping and swimming slowly, but now it wings the air.

It is very seldom that these changes of insects are presented to view by nature, and it happened by mere chance that I observed them for the first time: one of these Vermicles adhered to a stone wall in the river Loire, and it was so softened by the waves dashing against it, that it could only half perfect its change, so that I took it partly free, and partly yet fixed in the skin. I once afterwards saw this change in the large kind of Dragon-Fly, which had crept to land out of a small lake, and cast its skin sitting in the grass. In the smallest Dragon-Flies, which are very numerous in Holland, and of which Goedaert has described the mutation, it is not so difficult to discover this matter, as I have long ago shewn it to many, and amongst the rest to Dr. Matthew Slade.

Another thing worthy of observation in these creatures is, that they must hunt and seek after their food flying in the air, for which purpose nature has given them two large eyes, which make almost the whole head, and are like glittering mother-of-pearl. They have moreover four remarkable membranous silver-coloured wings, with which, as with oars, they can turn themselves like swallows with a prodigious velocity to all parts of the air. But to this the very long tail that they have is also conducive, for with this they steer and govern themselves with great art, and prepare themselves a certain path through the air. Mouffet, who erroneously asserted, that these creatures were produced from rotten bull-rushes, speaks however very rationally of them, when he says: "They form one of the greatest beauties in all nature, being superior by far to all art."

The eyes of the Dragon-Fly are of a reticular structure, and are divided by a double series of interfections, as I have described in another place. Within the mouth are to be seen



seen two teeth, covered with a beautiful lip; with these the creatures bite fiercely when they are taken: and it was probably for this reason that Junius gave them the name of Mordellæ. But whether their bite be venomous, or raises a blister in the skin, I have not hitherto observed.

Since the Dragon-Flies have very large and long wings; and, on the contrary, very short legs in proportion, it is not agreeable to them to walk on the ground, and the more, because when they walk, they do not raise their wings, nor keep them close on their back, like the Butterflies. For which reason they always choose dry branches of trees, on which they pitch when they want to rest or have caught their prey, which they seize with their six legs in the air, convey into their mouth with their two foremost legs, and then break it in pieces with their teeth. In this they do not spare the melliferous Bees; they catch them in the air and destroy them. These Flies cannot be kept alive long in a box, unless they are fed every day with Flies, which they like to eat. They are greatly delighted with the rays of the sun, to which they are indebted both for life and motion; for, when the heavens are cloudy, and the air obscure, they rest and do not eat, having then very little motion.

The thorax, on the inside, where the wings are fixed to the shoulder blades, exhibits a large number of muscular fibres, which serve to move the legs and wings. Through these fibres pass the heart, gullet, and spinal marrow, the greatest part of which are placed in the loins and belly. But as I have not hitherto perfected the exact anatomy of these creatures, I cannot advance any more particulars concerning them. The stomach is shaped like a pear; I have once seen it full of food, and at another time full of air. The pulmonary vessels are likewise numerous here. One may likewise distinctly see the muscular fibres, which I never saw agitated with any remarkable motion.

The male hath its penis placed about the beginning of its belly, the female on the contrary has the orifice of the vulva, in the extremity of her tail; but I have not accurately viewed these parts, since, in order to make the dissections, I should have taken out the entrails of these insects first, that I might preserve the whole form of their bodies. This may be easily done, if one takes out the viscera, and afterwards sprinkles the parts, which are still wet with the inside, with plaister of Paris, or unslacked lime, which imbibes the moisture.

By this means a very elegant specimen of the tail, breast, and eyes, may be preserved; and this contrivance is likewise made use of by painters and engravers. There is upon all these occasions a necessity for a cautious and circum-spect dexterity, which cannot be acquired but by frequent exercise, and is not to be taught by words.

Though the Dragon-fly is, in every respect, a wonderful creature, and has its genital organs placed in a very singular manner in its body; its act of coition in particular exceeds or surpasses all the powers of our imagination. The male, fluctuating and rising up and down in the air, and cutting it with many convolutions, knows how to stretch or hold out its tail with wonderful velocity to the female, Tab. XII. fig. 111. *a*, who places it between the division of her head and eyes, and guides it into her neck, and then, closely embracing it with her legs, receives it very pleasingly *b*; then she immediately bends and turns her body toward the breast of the male *c*, where the masculine organs of generation are placed near the upper part of the belly; and thus continually flying and panting, they perform the business of coition in the air. By this means the extremity of the female's tail is bent back, towards the middle of the male's body, that is toward that part where the penis lies, which is received by the vulva of the female, placed in the top of her tail; but that the female may the more conveniently reach to that part, the male shortens himself as it were, and bends and contracts his tail considerably.

The female being thus impregnated, after some time dips her tail into the water, and throws her eggs into it. These eggs, as I have already observed, are oblong, and while they are small and imperfect, they are somewhat tender and whitish, but afterwards they by degrees grow hard and yellow, having a blackish point at their end. How long such an egg remains in the water before the Worm is produced from it, is as much unknown to me, as how long it is increasing from that time until it changes its skin; but I should think two years are necessary for this purpose, since I have observed that these Worms were at the end of the summer very far from a state of perfection. I have sometimes seen in France so great a number of them in a clayey ditch that had no water plants in it, that they covered the whole bottom.

### *Of the various species of the Nymph-Vermicles of the Dragon-Fly.*

AS I have observed in the general enumeration of these creatures, that I kept six of the Nymphs, one of which I have before delineated, Tab. XII. N<sup>o</sup>. v. I shall now represent and briefly describe four others. The first belongs to one of the largest Dragon-Flies, in the head whereof are observed two equal, but

not reticular eyes, fig. iv. *aa*; before these are placed two horns *bb*, and under the latter may be seen the three divisions of the mouth, whereof the two upper are provided with teeth *c*, which may be most properly called so, only I think them too delicate and tender. Underneath at the breast are situated six legs, which have

two sharp claws *dd* at their extremities, and are variegated with green, yellow and other coloured spots. In the upper part of the back, under the shoulder-blades, may be seen very distinctly four membranous cups, wherein are enclosed *ee* the wings folded into each other; so that it is hard to understand how or by what means such strong, broad, long and remarkable wings as the largest Dragon-Fly has, could be contained within so narrow a compass. But this matter will be easily understood by any person who attentively considers what a large number of leaves lie folded up in the globular cup of the double poppy; for the wings beforementioned agree very well with those leaves in the manner of their lying.

The abdomen is divided at the margin of the belly into various sharp and rough divisions *ff*, the rings whereof are, where they branch out, adorned with many transparent colours. The tail is divided as into five parts, which, whilst the little insect lives, resemble so many pyramidal rough prickles or stings *g*, each of which casts it skin, when the Nymph assumes the form of a Dragon-Fly: these serve principally to close up the fundament, and are likewise an ornament to the hinder part of the body. But in the males they have another use, that is, to keep the creature in coition firmly fixed to the head of the female, and join themselves with the neck of the latter, as I have exemplified in the third figure of the middle Libella, Tab. XII. fig. III. In my last observations I also remarked, that the branches or ramifications of the *Aspera Arteria* likewise shed a coat or skin: and in this respect it agrees with all other species of Nymphs, and with the Worms and Caterpillars of Butterflies and other insects.

The other Nymph Vermicle that I exhibit is likewise of this species, from which the middle Dragon-Flies are produced. It has all those parts I have before shewn in the largest. The lips only and teeth are placed in a different manner, and are observed to be longer, fig. v. *a*, though they may be likewise lengthened or drawn out in the largest Nymph. The legs also are shaggy *b*; the follicles or bags are likewise distinctly seen on the back *c*, as well as the rings of the abdomen, and prickles or stings in the tail *d*. I found the former largest Nymph in a ditch upon some water plants, after it had first crept into the grass and cast its skin. In the Nymph just now described the wings were so perfect, that they might be spread open or displayed in the hand.

The third species I exhibit is not found in Holland, except in the district of Utrecht. I first found this Nymph on the other side of Paris in the river Seine, where many ox skulls had been thrown into it, and these being filled with mud afforded the Nymph habitation and nourishment. I likewise found there many river Hermits, which probably prey upon these and the like insects. This is probably the little

creature that Redi calls the Marine Scorpion; and delineates without follicles or bags of wings, because he had not seen it completely perfect. Of the same nature with this insect is also that which Rondeletius calls the Marteau and river Libella. In the head of this insect are likewise observed two eyes, without divisions; before which are two articulated horns or antennæ, fig. vi. *a*. It has six legs, which are long enough for the bigness of the body *bb*. The four bags or follicles annexed to the shoulder-blades are pressed together close and even; and are beautifully marked, Tab. XII. fig. vi. *cc*, with intercurrent vessels. The body is divided into rings, and is all over bristly *d*. The tail was painted with green and yellow, and divided as into three triangular appendages *e*. This little creature swims faster than the former Nymph; but the Fly again issuing from it, has a slower motion, and prides itself in very beautiful wings, which are variously painted, according as these Nymphs differ among themselves. Whoever attentively views the wings of this Dragon-Fly, will see that their nervous divisions are much closer than in the wings of the largest and middle species; nay, this differs from them in this, that it folds its wings like the diurnal Butterflies, when it lies any where to rest.

I have a Spanish Dragon-Fly, which has sharp pointed wings, and therefore differs from all others; for the wings of ours are for the most part oval, and terminate in a roundish extremity. It has likewise very large hairy horns or antennæ. I have myself delineated to the life another kind of Dragon-Fly sent from Africa, which had spotted wings. I likewise have seen a third species, which had very long and broad wings, and but a small body in proportion: but the wings were conspicuous and remarkable for some paintings on them like dried vine-branches, and exhibited a spectacle of the most exquisite art and admirable elegance. I have therefore delineated this in its natural size, and can shew a preparation of it to this day.

The fourth species of these Nymphs is found every where in the waters in Holland, but especially in the narrow ditches; out of which, with the water plants, such Nymphs may be taken almost every year, not excepting even the winter. They do not differ much from that just now described, as is manifest from the figure, fig. vii. This Nymph, having cast its skin, produces a very small Fly, with silver-coloured wings, and a blue and black body. This kind has also a slow motion, and almost perpetually flies about ditches. This species of Dragon-Fly has the same method of generation with the largest and middle kind, for both perform the business of coition in the air. But I must confess I never saw the manner wherein these Flies that issue out of the Nymphs delineated in fig. vi. propagate their species.

*Of the flying Water Scorpion* \*, which belong to our second class or order.

## THE EXTERNAL PARTS.

OF the water Scorpion which I occasionally mentioned in the general enumeration of insects, I have not seen more than two kinds. These I shall now separately describe with figures, to illustrate the description. The first, which is the smallest and most common of the two, is, like the greatest part of the other more perfect insects, divided into a head, a thorax, and an abdomen. In the head are placed the eyes, and under these is the mouth, which is of a round form, Tab. III. fig. iv. *a*. The head is of a pale red colour, and of a very hard and firm texture. The eyes are hexagonal and reticular: The sting which lies in the mouth, as in a sheath, is hollow, and of a bright red colour. In the upper part of the thorax, which resembles the head both in colour and texture, we find four wings, and in the lower part as many legs, besides two claws placed forward towards the head. The upper wings *bb* are of the same colour with the thorax; and it is remarkable, that the fore parts of these, by which they are joined to the shoulder blades, are of a stronger and firmer texture than the hinder parts, which are in a manner membranaceous, and full of delicate vessels. These upper wings are inserted so close to the lower pair, and cover them all over so exactly, that at first sight no one would imagine the insect had two pair. This disposition of the wings preserves the under pair from getting any wet, though the creature should remain a whole day under water. These under wings are of a pale colour *cc*, and of a membranaceous texture, with little yellow and red vessels or pulmonary tubes most elegantly distributed through them. The upper part of the abdomen, which these wings cover, is of a deep and clear red colour, like vermilion, and is thick set with hair, so as to afford a very agreeable sight. The legs have several joints, and each ends in two claws *dddd*. These are almost of the same shape with those of the land Scorpions *ee*, only they have no forceps or pincers; but the first point is so flexible, and the insect has such a command of it, that it serves the same purpose. The abdomen, whose shape has been already described, is underneath of a pale colour, and terminates in a forked tail, which when opened, is exactly like the figure I have here given of it *f*. The thorax and abdomen of this insect are so unusually flat and thin, that one

would be apt to suspect nothing was contained within them †.

There is nothing more remarkable in this insect, than that it constantly appears covered with a prodigious number of nits of different sorts and sizes, though perhaps we may with more reason consider them as so many little creatures, which live and grow by sucking the Scorpion's blood. These are somewhat of an oblong figure, approaching to round, and have a shining, and as it were bloated surface, without any of the rings observable in most insects. The neck is oblong and shaped like a pear, with the small end sticking in the Scorpion's body. The colour of this insect is a mean between that of vermilion and purple; and when it is pretty well grown, there appears within it an elegant transparent spot or particle, Tab. III. fig. iv. *g*.

This spot or particle induced me to consider with more attention this minute and hitherto unregarded insect, and even to undertake the dissection of it. But who would imagine that on this examination it should prove a perfect and surprising insect? This is however a certain fact: and thus in that infinite variety of works, by means of which God is pleased to make himself known to us, we ever meet with new matter of admiration and astonishment.

This little creature being extracted from the shell that covered it, looks like a young Spider before it has left its egg. On the fore part is the head, fig. v. *a*, and on its head are the eyes *b*: under the eyes are placed its little legs elegantly coiled and folded *cc*; but they appear much more distinctly on turning the insect on its back *dd*; and in this situation also it best appears with what art these legs are laid up in the shell, and all over covered with hair. The colour of this little creature is, as I already observed, a mean between that of vermilion and purple; and this colour shews itself through the coat or shell, which is transparent. I cannot determine to what species of insects this is to be referred; nor can I say to what size it grows, or by what kind of creature it is thus deposited on the water Scorpion in the form of an egg, there to receive life and growth. Nevertheless, I cannot but look on the discovery I have made as very interesting, since it proves that there are in the nature of things eggs which acquire a sensible growth by an

\* The characters of the water Scorpion according to the latter systems are these: the trunk is turned in under the body, the antennæ or horns form a kind of claws like those of crustaceous animals; the wings are four, and they are placed cross-wise; and the legs are four. Linnæus connects the *Cimeæ Aquatilis* with this, and gives to the genus he thus forms the name *Hepa*.

† There is not perhaps in all the animal creation so outrageous or fierce a creature against those weaker than itself as the water Scorpion. It destroys, like the Wolf among Sheep, twenty times as many as its hunger requires. I have seen one of these when put into a basin of water, in which were thirty or forty of the Worms of the middle *Libella*, which are at least as large as itself, destroy them all in a few minutes: he gets on their backs, and pierces his trunk through their body.

entraneous nourishment, unless perhaps some naturalist should choose to consider this as a complete insect, rather than as an egg: nor shall I strenuously oppose this opinion, seeing that in all cases the egg is in reality no other

than the insect itself, which remains in that state till it has acquired strength sufficient to break its prison, and live without such a covering.

### T H E I N T E R N A L P A R T S.

**A**MONG the internal parts of the water Scorpion, the organs of generation seem to be those which best deserve our attention, and which I have accordingly most attentively examined. The contents of the stomach and intestines were of a green colour, but those viscera when emptied appear of a transparent white, with here and there some transparent glandules of the same colour. Behind the pylorus are some varicous or knotty vessels. The abdomen is all over covered also with particles of fat of a most bright white, which look as if they were divided into many appendages of the nature of the intestina cæca.

The number of pulmonary tubes is here very considerable, compared with that which is seen in the generality of other insects. The larger branches of these tubes are of a yellowish colour, and the smaller of a silver white. Their openings lie under the wings on each side of the abdomen. The breast contains two air bladders. The spinal marrow consists of very few joints.

The parts of the male subservient to generation appear of a most delicate and exquisite contrivance, so as to deserve our most special notice; and the dissection of them took me up so much time and attention, that in taking drawings of them I at first overlooked the penis. This is placed backwards near the insect's anus, where there are several other parts worth examining. The root or nervous body of the penis, Tab. III. fig. VI. *a*, which is of a white colour, lies a little higher up in the abdomen, I have represented it here as it appears when taken out of the body. This root of the penis, after having made many serpentine turns, divides into four tubes, two of which constitute the vasa deferentia, whilst the other two perform the office of the vesiculæ feminales in other animals, and open into the cavity of the root of the penis, where they discharge the matter prepared by them. I have given an exact drawing of the vasa deferentia; one of them I have represented as it appears most curiously convoluted in its natural state *b*; the other as it looks when drawn out *c*. These vasa deferentia are considerably wide and spacious, but not equal to the vesiculæ feminales. It is probable these vessels are adapted by nature to secrete a feminal matter different from that prepared by the testicles; for they are largely supplied with glandules to answer that purpose, and consist of a considerably thick and spongy substance. As the vasa deferentia approach the testicles, they grow less and less by degrees, so as to form two slender tubes *dd*,

and this portion of them alone seems to claim the name of vasa deferentia, as they do nothing but convey the seed from the testicles: these testicles consist each of five distinct bodies, separated on all sides, oblong, white and glandulous *ee*, with which are united as many feminal vessels twisted and coiled one over another very elegantly, and in a great variety of directions *ff*. I have represented one of them as it appears when separated from the rest, and extended *g*. The vesiculæ feminales are somewhat shorter *bb*, but they are a little wider than the vasa deferentia. The former contain an aqueous feminal matter, which in the testicular vessels, the glandules of the testicles, and even the vasa deferentia themselves appear of a shining white. From this we may conclude that the mechanism of these genital parts resembles greatly that of the same organs in the Rhinoceros Beetle, which I shall hereafter describe. Indeed in respect to the vasa deferentia, the testicular vessels, and the vesiculæ feminales, they are not unlike those of the human species; and this resemblance is very worthy our notice, in order to discover the general analogy between animals by a careful comparison of their organs, as exhibited to us in accurate dissections.

Among the parts of the female subservient to generation, the most conspicuous is a surprising kind of ovary, divided on each side into five oviducts, one of which I shall here represent, and in part the rest being similar, fig. VII. *aa*. The eggs contained in these oviducts are of so curious a structure, and placed with so much art, wisdom and judgment, that I must own I never met with any thing contrived more nicely, or more elegantly disposed. That this contrivance and disposition may appear the more distinctly, I shall first describe the egg itself, which in shape greatly resembles the seed of the carduus benedictus. This egg is a little oblong, of a yellow colour, with its lower surface somewhat convex, fig. VIII. *a*. The edges of the upper surface are elegantly adorned with seven slender branches, not unlike stiff bristles very red at the points *b*, and white in the middle *e*, so as to afford a very entertaining appearance. That these bristles may be in no danger of creating confusion in the ovary, or of wounding it, or the eggs, or receiving themselves any damage by bending, the bristles of the first egg, or that which is next to the aperture of the ovary, lie flat against the edges of the second egg, so as to form a kind of bed for the lower and convex surface of it *c*. The third *d* and all the other

other eggs are orderly placed in the same manner, so as to afford ample matter for admiring and adoring the all-seeing Architect, who so wisely formed and disposed them.

These water Scorpions live in the water all the day, out of which they rise about the dusk of evening into the air, and so flying from place to place often betake themselves in quest of food to other waters. This is always their course when the ditches in which they inhabit, come to be dried up. This affords us a satisfactory reason for the great number of insects that immediately appear in the smallest collections of water, since they may very well get thither when it is dark; so that the opinion which ascribes to putrefaction the power of forming insects, must by this instance of the water Scorpion's nocturnal transmigrations appear more and more frivolous and unnecessary. I have in fact been told by a person who took great delight in fishing, that he has found the eggs of some kinds of Fish sticking to the wings of Ducks, who by this means he with great reason imagined might serve to replenish the waters on the top of the highest mountains with the insects proper to that element:

The Nymph of the water Scorpion remains in the same place where it was produced, till the wings are full grown, when she immediately falls forth in search of a companion of the other sex, with whom she may carry on the great business of propagation, and multiply the species.

The Water Scorpions of the larger species differ but little from the smaller, which I have hitherto described. The body of the larger kind, Tab. III. fig. 1x. *a*, is much longer and sharper than that of the other; and its limbs are more distinct and conspicuous. It is also of a paler colour, somewhat more gray, but inclining to red. As to the claws in this species there is in them something very remarkable; the joints from which they spring are furnished each with two sharp processes *bb*, in order to receive, and as it were sheath these sharp claws when bent against them. The legs also are much longer, and are made like stiff and slender bristles *cc*; but the membranous extremities and ornaments *d* of the wings differ greatly. I have not examined the internal parts of this species.

*The natural history of the insect called the Hemerobios, Ephemerus, or Diaria; extracted from J. Swammerdam's account of it, formerly printed in Dutch under the title of, The Life of the Ephemerus.*

WE shall leave out in this extract all the pious meditations and religious sentiments with which the original is so liberally furnished, as they would swell this work into too large a bulk, and do not properly belong to the design of it as a natural history. The author published at that time his observations on that surprising insect, to give us wretched mortals a lively image of the shortness of this present life, and thereby to induce us by the help of frequent admonitions to aspire to a better: and we hope we cannot in justice be accused of defeating his well-meant labours by abridging them in this manner, seeing his book, which he himself published, is ready to be had by any one that chuses to read every thing he has said on this subject. It contains also a

great number of Dutch sentences in verse, and in prose, of which it would be almost impossible to give a proper version fit to appear in public; and to interrupt the work with Dutch quotations, would be spoiling the regularity of the work. That the illustrious Thevenot; whom Swammerdam himself first charged with the edition of this work, intended to proceed in the same manner, appears very plainly from a French translation of the natural history of the French Ephemerus, which has fallen into our hands amongst other manuscripts relating to this subject. We shall therefore proceed in this design of giving the reader all that relates to its history, and nothing more, without any further apology.

## C H A P. I.

*The Ephemerus is produced from an egg\*.*

THIS insect, Tab. XIII. fig. xv. has four wings, two little antennæ or horns, six legs, and a very long and hairy tail; it lives at the utmost but five hours. This surprising creature appears every year for three day suc-

cessively fluttering on the surface of the water, at the mouths of the Rhine, the Meuse, the Wael, the Leck and the Ysel, about the feast of St. Olophius and St. John; but this continued appearance is kept up by a succession of

\* The Ephemerus, for so it is the established custom now to write the word, constitutes a distinct genus among the four-winged Flies. The characters are, that there are two large prominences for the eyes on the upper part of the head; that the tail is furnished with some bristly hairs, and the antennæ are short. There are several species of this genus of different sizes.

them, for those which begin to live and flutter towards the noon of the first day, are dead before night, and the same happens the second and third days; which being expired, no more of them are to be seen till the returning year again renews this three days wonderful fight.

At this time the female of the Ephemerus, fig. VIII. after having thrown off her coat or slough, issues from the water and discharges into it both her ovaries, Tab. XV. fig. III. But this is not done till she has for some time fluttered upon the surface of the water in a very curious and surprising manner, beating it with her wings all the time.

It is at this time the female like a fish discharges her eggs, which the male, Tab. XIII. fig. xv. who first quits the water, and afterwards divests himself on the land of a very thin skin, fig. XIII. and XIV. invigorates by ejecting on them his melt or feminal milky substance.

I shall in the succeeding pages describe in a full and accurate manner how this act of generation is performed, how these insects rise from the water, and how they free themselves both in the water and on the land of their old skins.

The first time I observed this surprising insect, was in the year 1661, on a branch of the Rhine running by Culenburg. But Clutius who has likewise written of those insects, says they are to be found at Aarnhem, Zutphen, on the canal called Vaart near Utrecht, at Rotterdam, and in many other places. Doctor de Mey, a most reverend and learned divine, has likewise given us an express treatise on this subject, as appears by the appendix to Goedaert's historical observations. Nor has the observation of these insects been confined to our times, some of the greatest naturalists of antiquity have

made mention of them, as appears by Pliny; Aristotle, Ælian, and others who have written on these subjects. We find this little creature described in their works by the name of the Hemerobion, Ephemerus, and Diaria, as appears by many passages in their works, as likewise by Augerius Clutius's work, published in the year 1634, of which I just now made mention.

The eggs of the female Ephemerus dropt into the water, and there impregnated by an effusion of the male's sperm, in the manner we have described, gradually sink to the bottom. But this is effected in such a manner, that the eggs are scattered over the muddy bottoms of rivers by the motion of the waters. The figure of the eggs themselves does not a little contribute thereto, as they are of a plain convex shape, Tab. XV. fig. 1. and are thereby the apter to disperse in their descent. This appears by placing a few of them on the point of a knife, and then letting them fall gently into water, for they immediately separate of themselves in a very curious manner.

It is hard to say, and God only, who gives these insects life and motion, knows how long their eggs lie at the bottom of the waters where they are deposited, and how long it is before the contained insects break through the skin that surrounds them, and perform as it may be called their first moulting. It is not improbable that these things might be experimentally ascertained by dredging for them at different seasons, or keeping their eggs in a vessel full of water with a sufficient quantity of mud at the bottom. For the present we must be satisfied to observe that the eggs of the Ephemerus produce, after an unknown time, a little Worm with six legs. This is the creature fishermen call the bank-bait.

## C H A P. II.

*The egg of the Ephemerus produces a little Worm with six legs, called the bank-bait by fishermen.*

ON searching the bottoms of waters frequented by the Ephemerus, some time after it has laid its eggs, we find a multitude of little Worms with six legs, which differ in nothing but size from those that are more grown. But this is not to be found till a long time after the parent insects have made their appearance, for the growth of this little insect is so slow, that in the beginning of June in the year following, about which time the bait turns to an Ephemerus, they are scarce three quarters of a Dutch inch long, Tab. XIII. fig. 1. which is but about the third part of the length of the full grown Worms, fig. III. that have complete wings, and are just upon the point of making use of them.

Besides two kinds of Worms remarkably differing in bigness, a third is observed to be

produced at the same time from the mud, fig. II. which is bigger than the lesser kind by almost two thirds, and is a third part less than the largest kind. Nor is this difference between these Worms in respect to their various age, all we observe, for those of the same age differ greatly both in length and thickness. When the largest kind of these Worms is about three thumbs breadth long, in the beginning of June, when they are about to begin to fly; the middle kind is not completely two long; and the smallest is scarce a thumb's breadth in length.

There is another remarkable difference between these Worms of the Ephemerus, which is, that the smallest kind, fig. 1. not only is without wings, or those prominences which cover the wings, but it does not even shew the

least

least signs or vestiges of any such part: whereas, on the contrary, in the other kinds of these Worms, the little sheaths of the wings, fig. II. begin at that time to appear, and in the largest

kind are as conspicuous as possible, fig. III. resembling a little flower, that increases by degrees, and is ready to break out of its cup.

### C H A P. III.

*Of the life of the Vermicle or Worm of the Ephemerus, when out of the egg; and of its food.*

IT is very worthy of notice, that these Vermicles or Worms never, or but very rarely, are observed to swim at the bottom of the river, or even in the middle of the water. They can indeed swim very swiftly, and move and throw themselves easily into serpentine windings in the water, whilst their head is bent sometimes up and sometimes down; the rest of the body advancing with the like twisting convolution and serpentine motions. But, notwithstanding they have this in their power, they are always found near the banks of rivers, and they live there in the most quiet parts. The more mud there is in the bottom, out of which they first rise, the greater number of these Worms is usually found. But you can very rarely catch them lying on the mud or adhering to it, but they live within the mud or clay itself in hollows made oblong and smooth. These are bored, not obliquely or downwards, but always parallel to the horizon: therefore, Vander Kracht says right in Clutius, that these insects live in separate little cells.

As the Bees, therefore with wonderful and perhaps inimitable art form their habitations with wax; in like manner do the Worms of the Ephemerus make these hollow tubes, Tab. XIII. fig. v. *a*, or long holes for their residence, and bore them in the mud, in proportion to the bulk of their bodies. Hence, when these Worms are expelled out of their holes, so that they must creep on the plain or smooth bottom, which does not support every part of their bodies, they immediately lose their ability to go forward, though they are even surrounded with water, and are able to sustain or bear themselves up by swimming. This I have experienced, when I had drawn a great number of these Worms out of their holes, in order to dissect them; they always fell on their backs, and, as if they were in a swoon, could not turn themselves again: whereas, on the contrary, when they are in their little holes or burrows, they can creep very quickly backwards and forwards, and move themselves every way as they have occasion. I observe that it is common to all kinds of Worms which live in these kind of cells or holes to be able to move very quickly into their retreats, and when they are taken out of them, to faint as it were away. This I have observed in the Worms which live in hollow trees, and also in those which are found

in fruit, in the tubercles of the leaves, and in the galls or warts of plants. It is very worthy of observation, that the Cossus or Worm of the great Beetle, whenever it is taken out of its house, covers its whole body with a web, by the help of which it forms a new hole for itself in the wood; for it could by no means pierce or make a hole, unless it were provided with some kind of stay or support to lean against by pressing its body in that part, and finding a due resistance:

The bait or Worm of the Ephemerus is so weak when out of its hole or little tube, that if at any time it ceases to move, when swimming in the water, it immediately sinks to the bottom in confusion, and there lies on its back.

We are to remark further, that as soon as the Worms of the Ephemerus have issued out of their eggs, they prepare to build their cells or houses, which we have observed are long and horizontal hollow tubes or caverns made in the clay or mud. But they make these tubes by degrees larger and larger, according to the size of the body, so that by this means the full grown Worms are always found in larger, Tab. XIII. fig. v. *aa*, the young ones in smaller tubes, *bb*.

The all-wise Creator has given them parts appropriated to this purpose; their two fore legs are formed, in some measure, as they are in the Moles and Mole Crickets. These Worms have jaws likewise, which are provided with two teeth somewhat like the forceps or claws of crabs, and these serve very well to assist in making those holes in the mud.

Hence you will immediately see them piercing or boring, when they are thrown into a little mud mixed with water. If you do not give them a sufficient quantity of the mud, they will nevertheless continue to undermine what they have, at one time hiding their head, and at another their body, and afterwards their tail, attempting to prepare new cells.

The fishermen say, they are certain from experience that these Worms, when the water sinks from the brink or edge of the river, always bore holes through the mud into a lower and deeper part, and that they likewise go to higher places, when the water rises. This, I think, they are under a necessity of doing, since they have several air-pipes in their tracheæ, by the help of which they frequently draw new air, which is necessary to their life. This they could

not do, if they were confined at too great a depth when the water rose higher.

I have often observed that when they were drawn out of their cells and put on the wet sand, they have chose rather to creep out of the water, than go to the bottom under the sand. This might possibly be owing to the want of mud, and the warmth of the water, which is probably injurious to them.

As to the food of these creatures, it is very difficultly discovered, unless by the dissection of them, which taught me that they live on clay or mud only. Whenever you open them, you will always find mud both in the stomach and in the small and great guts. These Worms are therefore in this respect like the Moth, which feeds on the same substance of which it makes its habitation.

## C H A P. IV.

*How long the Vermicle or Worm of the Ephemerus is winged; why it is called the esca or bait; and how long it lives.*

**H**AVING considered the egg, the Worm, and the food of the Ephemerus, the next thing is to see for what space of time this Worm is fed or nourished: and though it seems a thing impracticable to determine how long any creature which lives in the earth under water is in feeding, yet this problem may be solved by considering the different bigness of those Worms which I have beforementioned. Since the smallest kinds of them, when fed for one year, in which time the largest kind prepares to fly, is three quarters of a thumb's breadth in length, and the middle species is then only one half; it follows, that every Worm is feeding three years before it becomes fit to undergo its change, because the largest kind of Worms which begin this change, are two thumbs and a half long.

The largest day Worms when fully nourished or fed, regularly go out of their cells into the water, and thence afterwards rise into the air, as I shall explain hereafter. As every creature has its enemy, these have many; the fish persecute them immediately after they go into the water, in order to undergo their change; and when this is accomplished and they rise out of the water into the air, the birds immediately hunt after and prey on them. This has been observed by the sailors, fishermen, and others, who live near the Rhine, so that they learned from hence to use those little creatures as a bait to catch fish. And hence it is that these Worms are called by the name of bait or bank-bait, near the village of Duerstede, Culenburg, and in other places. This has likewise been the reason that these creatures, when they afterwards began to fly, have been called by the name of the flying bait. But this creature is called *Haft* at Rotterdam, Schoonhoven, and Dordrecht, the most ancient city in Holland, as soon as it becomes capable of flying. Hence has arisen the common proverb among the Dutch, "*Het isser zoo dicht als haft*," to indicate a very numerous multitude, because these little creatures at the times of their change, fly so thick together in swarms, that they can no more be counted than the falling flakes of snow.

These Worms afford a very good bait for fishing at any time of the year, if the weather be favourable for that purpose; for since they live three years in the mud before they are changed in so wonderful a manner, like Silkworms, into flying creatures, they may be easily taken out of the banks at any time of the year for the sportman's purpose. But this cannot be conveniently done when the waters have risen high, for it is then necessary one should go naked into the water, which I have sometimes got done, that I might have an opportunity of investigating the nature and disposition of these insects, and be able to examine anatomically the internal parts. When the fishermen use this Worm, they fix the hook in the head, which is its hardest and most firm part. And as it is very long-lived, by the perpetual motion it makes in the water, it becomes a very proper bait to allure the fish to swallow the insidious hook.

How very durable the lives of these Worms are I could thus form a judgment: I have sometimes pierced one of them with a little needle, in order to dry and preserve it when dead, but it has been still living the day after, though it had been a whole night in a little vessel of urine, into which I had thrown it in order to kill it. But however tenacious they are of life, when they are taken out of their cells, and put into water mixed with clay they cannot live more than two days. Therefore, whoever desires to keep these Worms alive ought to put them in nothing else but moist sand or wet clay. By this means I have known the largest live four days, and the smaller eight. But when they are all covered with water, they cannot by any means continue alive, for they must have air.

If any one desires to send these Worms abroad, the best method is to tie together some tubes made of the largest bull-rushes, and to put the Worms into them; for otherwise they can scarce be sent well, because by running up and down at random, they hurt each other. By this method they may be likewise easily carried to other rivers, as fish are carried from one place to another.



## C H A P. V.

*Describes the external parts of the Esca or bait, its colour, and the difference in its manners and disposition.*

**H**A V I N G accurately examined the Worm of the Ephemerus, I observe that it is divided into fourteen annular divisions; the first constitutes the head; the three subsequent the thorax; and the other ten the belly, with the tail annexed.

In the head, Tab. XIII. fig. iv. *a*, the eyes are very conspicuous, being invested with a uniform and smooth coat, and covered on either side with bristly hairs. When the Worm is on the point of changing its old skin, we observe this smooth coat to part or separate by degrees from its eyes, and the eyes when the little creature begins to fly, appear reticular as they are in Flies. A little lower under the eyes are seen two tender horns *bb*, terminating in sharp points, and articulated or divided into joints. Under these are seen a pair of dentated forceps or jaws *c*, constituting the creature's mouth. About the origin of these jaws, underneath, several more hairy and membranous little parts appear, which are somewhat like these that we observe in Crabs and Shrimps.

To the first ring of the thorax are fixed the two fore legs *d*, the structure whereof, and the joints of which they consist, merit great notice. The structure is in some measure like that observed in creatures that borrow under the earth. Hence the strongest motion which these legs have is outward, by which they can the more conveniently pierce and remove the earth, like Moles in making their cells.

Every leg is composed of four joints, and terminated by a single claw. The first joint is affixed to the breast; the next to this is somewhat crooked, as is likewise the third, which consists of a matter somewhat more bony and horny than the others, and is armed with prominent brown red little points like teeth, and surrounded laterally with numerous hairs. The fourth joint is very small, and is armed with a small claw. The muscles likewise, and their insertions may be seen very distinctly here, by the help of which the bony joints are beautifully moved.

To the second division of the thorax, which is the third ring of the body, and properly constitutes the loins, and is covered both above and below with a shield of a horny little bone, is annexed a second pair of legs, Tab. XIII. fig. iv. *d*, which consists of five joints and one claw; and are here and there furnished also with hairs. Somewhat behind these, the follicles or little sheaths *e*, wherein the first pair of wings are concealed, are seen on each side. These sheaths are here and there interwoven with air vessels, which appear on their external surface, like

common little veins or nerves. When the Worm is just going to cast its skin, the internal or under wings are folded in a wonderful and elegant manner, and appear through their external coats or follicles.

There appears on the third ring of the thorax, which is the fourth of the body, the insertion of a second pair of wings, which are much less than the first pair, and are wholly covered by them. This first pair likewise partly covers the hindermost or last pair of legs, which consist like the others of five joints and one claw, and are adorned with numerous hairs.

The first ring of the abdomen, or the fifth annular incision of the body, is all even and smooth, nor is it joined to the legs, the wings, or any other part. To the six following rings are affixed very beautiful branchiæ or gills *ff*, perpetually fluttering, and beating up and down with a tremulous motion. By the help of these Clutius erroneously thinks the Worm swims; but these parts are undoubtedly the branchiæ or gills of the creature. In Lobsters, Crabs, and Cuttle-fish, which approach in many respects to the structure of insects, we constantly find these little parts framed and situated in the same manner, with this difference only, that in Crabs and Lobsters they are enclosed in a hard shield, wherewith the back is covered, but in these as well as in the Cuttle-fish, they are situated higher on the body than in the Ephemerus. In the figure of this Worm given by Crachtius, twelve gills are expressed on each side. This error seems to have arisen from a wrong view, since there are only six on each side, the whole only make twelve.

The eighth and ninth divisions of the belly, which constitute the twelfth and thirteenth rings of the body, are all even and smooth. These are succeeded by the tenth or last, that is, the fourteenth division of the body. This is adorned with three hairy and bristly tails, Tab. XIII. fig. iv. *g*, to which are also added two crooked appendages, which are not so remarkable in the females; but in the males they are likewise accompanied with some other little appendages underneath.

As to the colour of these Worms, the smallest appear of a pale blue with a tinge of green. This, however, cannot be properly said to belong to the creature itself, but is rather owing to the viscera which are seen through. The eyes of all these Worms are of a blackish brown colour, and the back is speckled with pale brown spots, which increase by degrees with its age. The mouth is palish, and is furnished with redish brown teeth; of this colour are also

the

the forceps or jaws which are beneath them, having two teeth and constituting part of the mouth. The horny parts and the claws of the legs are likewise of a reddish brown.

The exuberant wings insensibly change their pale colour into a yellowish one, which, in process of time becomes a bright blue, and at length a brown black. The whole body of the creature is by little and little stained with a pale yellow colour, and the blackish spots in the back, where it constitutes the upper part of the belly, are changed by degrees into a deeper colour.

The difference between these creatures with respect to their sex is another point very worthy of notice. For the eyes, Tab. XIII. fig. iv. *a*, of the male, are twice as large as those of the female, fig. III. but the body of the male is commonly much less than that of the female, which is the case in insects in general, as far as I have observed; and it seems to be ordered very prudently so by nature, or more properly, by the very wise Creator, in order to give the due room to a large number of eggs. The male in this species has the tail very long,

and besides he has three or four other appendages, placed partly on the sides, partly under them, which can scarce be distinguished in the females. The male that I exhibit in fig. iv. of Tab. XIII. is the largest of all I have seen, though much larger females may be found.

As to the disposition and manner of this insect, I can say little from my own observation: but one thing I may venture to affirm, that among all the species of insects, I never saw any one more mild, gentle, or innocent. For in whatever manner it is treated, it is always calm and peaceful, and when left to itself, it immediately goes to work, and begins to dig a cell for its habitation. I have observed indeed in the smallest species, that when rudely handled, it bends its head towards its breast, and makes itself somewhat stiffer. Of all the actions of this creature none is more admirable than the agitation of the branchiæ or gills, Tab. XIII. fig. iv. which adhere to either side of its body, for these are so orderly, distinctly, and continually shook and vibrated, that the mind, when intent on these incomprehensible movements, is filled with astonishment.

## C H A P. VI.

### *The anatomy of the internal parts of the Ephemerus.*

**H**AVING briefly described the egg, Worm, food, age, external parts and disposition, so far as I observed, of our little insect, what should naturally come next into consideration would be to explain its change. But as this is performed so hastily, that it consists almost only in the casting of two coats or skins, and the displaying or unfolding of some limbs and parts before covered, in order to understand the difference between the swimming Worm and this flying insect the more distinctly, I think it better to describe its internal parts first; and the rather, because all these parts under both forms of this creature may be in this account taken notice of.

Though in describing the internal parts of the Esca or Worm of the Ephemerus, I shall enter upon them in a method not yet observed by any person that I know of; yet, according to the example of Clutius, I shall not complain of the scarcity of books, treating of this subject, nature herself being the best interpreter of all her works: books are to be admitted no further than as they express the truth of what she represents to our senses. I am therefore in pain for those, who, relying on the experiments related by others, frame innumerable fictions, and thereby deceive their readers with themselves. It cannot be possible that any person relying on his own understanding and judgment, should, in such a variety of experiments, follow the straight path of truth, and with an unprejudiced and candid judgment pass a just sentence on the observations of others, especially since we ob-

serve that the most certain experiments are obstinately rejected by many, unless they correspond with their own opinions or prejudices. I shall build only on what I have seen, though I may in this perhaps be blamed; for that not having had a sufficient number of the Worms, I have not been able to bring their dissection to the utmost perfection, so that in this respect I cannot every where satisfy my own inquiries. But I have long since learned, that the works of God are as inexhaustible and incomprehensible as his own perfect nature; so that these things ought not to be contemplated by us for any other purpose, than that we should be humbled by a due consciousness of our ignorance, and be obliged to adore their Creator, and love him truly.

In order to make the observations I have to offer as clear as possible, I shall at the same time declare the method, which I made use of in the year 1670, to determine the true dissection of the several parts; for it is by no means my intention to deceive either myself or others. Before I proceed to the description of the internal parts, I shall, in order to assist the memory, briefly enumerate what parts are observable outwardly in the Worm of the Ephemerus, as also what inward parts I found in the male, and what in the female.

The external parts of the Worm are the head, skull, horns, eyes, teeth, mouth and tongue, together with their hairy membranes, which are like those in the Crab kind. The breast, legs, claws, wings, belly, and what ap-

pertains

pertains to it; the twelve upper branchiæ or gills, the ten lower oars that serve the creature for swimming, the tails with their appendages, and lastly, the apertures of the pulmonary tubes under the breast.

The inward parts of the male are, besides the blood and membranes, muscles and fat, the stomach and intestines, the pulmonary tubes, the heart, the spinal marrow, and the spermatic vessels.

In the female I find all the parts just recited, with only this difference, that instead of spermatic vessels an ovary is here seen, surrounded with small membranes, which are interwoven with very many pulmonary tubes.

As I have not yet accurately examined the internal parts of the head and eyes, for want of a sufficient number of Worms and Flies, I shall not say much concerning them, nor of the parts of the thorax, the latter being for the most part filled with the muscles of the legs and wings.

If the male Worm of the Ephemerus, which it is easy to distinguish from the bigness of its eyes, be first laid on its back on a small piece of a fir board, and then fastened with the smallest needles that can be had on black paper or a small piece of linen, we immediately see a thin and watry humour distilling out of the wounds in the skin, which is the real blood of this insect. And yet it is not red, as is the case in Earth-worms, the blood of which, as well as that of quadrupedes, is tinged with that colour. I don't know a more proper instrument to open the skin than a fine and small pair of scissors, for little lancets, though never so sharp, are not fit for this purpose, because they always pull and tear the parts asunder, and especially if the membranes be not equally hard.

When the skin is after this gently and deliberately separated with a fine sharp-pointed pen-knife from the parts underneath, an interior very thin and membranous skin immediately appears. If this be afterwards cautiously removed, the muscles of the belly present themselves to view, as well those which extend from one division to another, with straight fibres of the body, as those which are pro-tended obliquely and across: other muscles are also seen, which serve to move the branchiæ or gills. The coat or other skin is likewise fibrous, and seems to be joined to the muscles before described.

After the muscles appears a very fine and delicate membrane affixed to them, which I take to be the peritonæum. About and under this appears a quantity of fat, consisting of small, fine, and white vesicles, which contain a real fat in the form of fluid oyl. Whoever views these vesicles without a microscope, may naturally take them for the fat itself, whereas they are only thin and very tender bags containing it, as is the case in man and other animals. This will be very plain, if these pingueferous bags, which are of equal bigness, be

viewed with a microscope. The younger the creatures are, the more conspicuously they exhibit this fat, since it then lies here and there dispersed on the membranes, nor is it heaped together so thick as in the older ones.

After observing these, we come to the stomach, Tab. XV. fig. v. and to the intestines which are continued from it. Here is presented to view the œsophagus, or otherwise the tube of the upper orifice of the stomach, which descends like a fine filament from the mouth or jaws through the back and thorax, and enters and is connected with the upper part of the stomach. Where this little tube is connected with the stomach, it becomes narrower and cloffer *a*, as may be seen about the lower part of the stomach, or towards its lower orifice *b*.

Though the stomach *c* consists of divers parts, yet it seems throughout to be formed of a thin and tender membrane, corrugated on the inside, and full of reticulated or net-like folds or plaits. On the outside it exhibits a smooth surface, and is expanded regularly, especially when it is swollen or filled with food, or if it be artificially distended with air, by the help of a small glass tube. No veins or arteries are seen in it, for the blood of these insects is of a watry colour, and therefore does not distinguish the vessels containing it from the other parts; this is the reason that these creatures were called exanguious or without blood.

It is however observed, that the stomach *c* is provided with many tubes which resemble blood-vessels. But if they be well examined with a microscope, it appears they are branches of the pulmonary pipes, Tab. XIV. fig. 1. *aa*, for they give little air canals, not only to the stomach but to all the external as well as internal parts of the body. Hence, even the legs and their claws have air tubes. The intestines, Tab. XV. fig. v. joined to the under part of the stomach, appear to be threefold in regard to their form and structure: there appear, 1st, the crooked or small gut *dd*; then 2d, the colon *e*; and last, the rectum *f*. Within the small gut, somewhat further towards the hinder parts, are observed some lunated wrinkles, not unlike those little vales of the small guts in the human species, which the anatomists call annulares. A little below where the colon *e*, rises out of the former, are seen several oblong furrows, which are very fine in the living creature, and resemble so many long muscular villi or hairy parts extended in the cavity of the intestine, corresponding in some measure with the echinus, which is a natural part of the stomach of quadrupedes: then the rectum follows this, and is folded very elegantly, until it terminates at the external parts of the body with a pretty large orifice, through which the fœces are discharged.

The stomach *c* is situated between the fourth and fifth annular divisions of the body, and there, together with the small gut, takes up the whole foremost region of the belly, that is, the 6, 7, 8, 9, 10, and 11th incisions. But

the other three divisions, namely, the 12, 13, and 14th, contains the *intestinum rectum et crassum*, or the thick and straight gut. As the stomach has a great number of small air-tubes, so the intestines have also the same, but most especially the rectum, which has vast numbers of them, where its two muscles, Tab. XV. fig. 1. *ii*, which force out the excrements are situated.

As the food of this Worm is mud or clay, the stomach and intestines are usually found filled with it. This mud is found almost always to shew itself both through the stomach and intestines, and indeed through the whole body, but more particularly so in the back. And hence, as the body is so transparent, it follows, that the Worm does not appear to have always the same colour, since the mud is sometimes paler, sometimes greener, and sometimes more flesh-coloured, as it is more or less digested or changed in the stomach and bowels.

As the time approaches when the Worm is to undergo its final change, and put on the form of a flying insect, no more mud is found in its intestines. The same likewise happens in the Cossi or Worms of Beetles, and in Bee-Worms and Silk-Worms, as also in other insects, for they all at that time become clear as crystal. Some insects are all their life-time transparent, so that their vessels, the viscera, and their motions may be at all times seen and distinguished in the body.

Of the inward parts of the Ephemerus, the most worthy of notice are the pulmonary tube, and the *aspera arteria tracheæ* or wind-pipe, Tab. XIV. fig. 1. *aa*, as it is called in birds and quadrupedes, and in the human species. This tracheæ does not proceed in the present insect from a simple trunk, as in man or other animals, but consists of two principal trunks, which are placed on each side of the body running in a serpentine manner, nor are they distributed in the breast only as in us, but throughout the head, belly, legs and wings, so that by their means the stomach and intestines, together with the muscles and nerves, are all supplied with air. As this appears to us a very wonderful thing, because we do not understand the reason of it, it most evidently teaches us how devoutly and religiously we ought to adore God in all his prodigious works, which are equally inexhaustible and impenetrable.

The pulmonary tubes \* in this insect, as well as in the others that I have examined, consist of innumerable little rigid and curled parts, which are artificially joined together like twisted or spiral rings, and are so closely linked to each other by the help of their tender and delicate investing membranes, that they can easily retain the air, and convey it to all parts of the body.

When the Worm changes its skin, I should imagine that these pulmonary pipes likewise cast their covering, though I have never hitherto been able to see it; for at the time when I began these experiments no such thing appeared to me.<sup>a</sup> The change or casting of the skin of these pipes is so remarkable in Silk-Worms, that it amazes the understanding; for in the very short space of time wherein that creature casts its skin, some hundreds of these pulmonary pipes in the inside of its body, cast also their tender little skins, which are all compounded of such twisted rings.

The colour of these pulmonary tubes or pipes is like that of mother-of-pearl, but somewhat inclining to gray; but the more frequently the skin is changed, it becomes by degrees of a clearer and more transparent whiteness. They are therefore much whiter in the flying creatures than in the Worms which precede them. They are distributed through the whole body, in order to convey the air, which they carry as well to the internal as external parts of the insect. Hence these two most considerable and remarkable tracheæ, Tab. XIV. fig. 1. *aa*, which are placed in the Worm on each side of the body, distribute their ramifications and branching air-pipes all over it; that is, in the head towards the nerves and brain *bb*; in the thorax *cc* to the muscles of the legs and wings; in the abdomen *ddd* to the obliquely ascending and straight muscles, as also to the spinal marrow *eee*; and to the small guts or seminal vesicles *fff* of the male; to the hairy branchiæ or gills *gg*; to the stomach, Tab. XV. fig. v. *c*, and the intestines, Tab. XIV. fig. 1. *b*; to the skin *iii*; to the coat of the wings *kk*; to the ovary, Tab. XV. fig. 1. *ll*; in the female also to the coat that invests the ovary *mm*; to the eggs themselves. fig. VII. *n*, as is seen when they are taken out of the body, and even to the heart itself. Fig. IV. *oo*. *tt*.

I have found it a difficult matter to discover the external aperture of these pulmonary pipes, since they do not open into the mouth or throat, as in other creatures. For which reason the nearer they approach the head, the smaller they become, when it would be natural to suppose they would become larger and more capacious. At length, after repeated investigations, I persuaded myself that I observed that the little apertures or entrances of these pipes opened underneath in the side of the breast; almost in the same manner as I afterwards discovered them also in Locusts, in which last mentioned insect these apertures may be easily seen. But as the Ephemerus lives in water and mud, therefore its tracheæ must be opened by narrower orifices, on which account it is more difficult to discover them.

From these experiments it appears most evident, why the Worms of the Ephemerus or Day-Fly, when the water of the river increases,

\* The doctrine of these pulmonary tubes in insects has been confirmed by all succeeding observations: the latter authors only have changed the names of these vessels, and their openings on the surface of the body. They call the tubes tracheæ, and the apertures on the surface of the body, which this author terms *puncta respiratoria*, they call *stigmata*. This last term, though more modern, is exceptionable; for *stigmata* is used in botany to express the heads of the styles in flowers, and pure philosophy condemns this equivocal use of terms.

rise likewise higher, and go to other cells, for they very frequently want fresh air to breathe. And for the same reason, when the water is lower, they must be likewise found to descend deeper; for they would then become too dry, and their cells or habitations would be dried and shut up.

The pulmonary pipes hitherto described cannot, in any insect, be examined better than in the Worms, when they have been dead some days, as their viscera are then growing black; for then they exhibit a very beautiful appearance to the eyes, because they are of the colour of mother of pearl, or silver when cleaned by boiling; also, as they consist of a somewhat hard and firm substance, so that they do not soon putrefy: hence they also retain at that time their form and roundness.

If the breast and belly of these worms be viewed with a microscope, the whole abdomen is seen to be interwoven with white silver-coloured vessels. In order to discover whether there be really any air in these vessels, they must be put into a little drop of water, and pressed with the point of a needle, for thus the enclosed air will immediately shew itself. When these insects are dissected under water, and some of the pulmonary pipes are cut off with a fine pair of scissors, they immediately rise to the surface of the water; the same thing may be seen about their broken ramifications, the extremities of which are then carried upwards. In a Worm that has been dried, having been divided in the middle, these air-pipes are most easily discovered, because they always in that case remain open from the force of their curled rings, though all the other parts grow perfectly hardened.

Amongst the many things which may be observed concerning these pulmonary tubes, it is particularly worthy of notice that so great a number of them are distributed towards the branchiæ, Tab. XIV. fig. 1, or gills, so that three principal branches *ppp* of the air-vessels may be seen in those which I have represented as cut off: the middle one of these branches is always blackish *qq*, except in the centre of it, which is whitish and transparent; the other two run on either side of the middle black one, and distribute a large number of silver-coloured vessels *ggg* through the branchiæ or gills. These vessels are not well distinguished by their colour, because the six branchiæ or gills, Tab. XIII. fig. 1v. *ff*, through which they are conveyed from each side of the body, are white and very transparent. Under these, on each side, are observed five rowing fins, Tab. XIV. fig. 1. *rrrr*, of a yellow colour, by the help of which the Worm swims.

I made during my dissections some further observations on those branchiæ and their vessels, but as I do not know where the papers are, the observations have also entirely slipped out of my memory. Hence I am ignorant what use that feathered little part *ss* is of, which is seen under the first as yet entire pair, and whether

it be likewise found about the other branchiæ or gills. Neither do I know the proper communication between these branchiæ and the air-pipes, Tab. XV. fig. 1v. *oo*, between the latter and the heart *tt*. I cannot therefore say any thing more with certainty concerning them than what may be gathered from the figure. I omitted, to prevent confusion, delineating in this all the air-pipes which are about the heart, having exhibited some of them only entire, and others cut off or broken *vv*.

Indeed, in my figures I have not always observed the proportional magnitude of the parts, since I looked upon that as a work of great labour and little use, and therefore I have not scrupled sometimes to delineate one part larger than another. Besides, I never intended to publish these experiments, without being first revised; and this I have afterwards thought the more necessary, because from that time I acquired a greater knowledge of the parts of these insects, and became more capable of ascertaining their anatomy. I hope the benevolent reader will kindly pardon the imperfections of this work, which I must confess are innumerable; for what man is able to describe, even with the uninterrupted labour of many years, all the miracles that are to be met with in this little insect.

The heart, Tab. XV. fig. 1v. *tt*, is found to be placed in the upper part of the body in the back, as it is in Silk Worms, Bee Worms, Cossi, or Worms of Beetles, Caterpillars, and other insects of that nature. It is somewhat protuberant *xxxx* in several places, and it is so in Silk Worms also, as has been observed by the diligent Malpighius. But this author does not seem to me, as far as I can learn from my own experiments, to have fairly from this drawn his conclusion that this insect has more hearts than one. I have discovered the motion of the heart but very inaccurately in the Ephemerus, and only in that part of it which I here represent in the figure; but I have entirely forgot, against which of the annular sections it was placed in the back.

The spinal marrow, Tab. XIV. fig. 1. *yyy*, is wonderful and very worthy of notice in this, as it is in all other insects that I have dissected; it consists as of eleven knotty tubercles, somewhat long and oval. The first of these knotty little parts serves instead of a brain, out of which\* \* the optic nerves may be very distinctly seen to arise and spread themselves. In the same manner I have observed, that the rest of the nerves issue from the ten subsequent little knots; but these that arise from the lower knots, are not so numerous as those from the upper. The spinal marrow is moreover found to be here and there beautifully strengthened with ligaments *zz*, which are composed partly of a strong horny substance, and partly of tendinous wreaths or fasciæ. This is the case in the breast in particular, for there the spinal marrow sends out a great many nerves to the muscles, *aa*, *bb*, which move the legs and wings: the same

same thing happens about the muscles of the branchiæ, Tab. XIV. fig. 1. *cc*, and rowing fins.

From each little knot, Tab. XIV. fig. 1. *ee*, of the spinal marrow, there constantly issue two stronger nerves, which unite and become more swollen when they approach the subsequent nerve; for which reason the spinal marrow appears every where divided and open. But while it is in its state of nature contained within the body, that gaping does not appear; because the nerves are there only simply contiguous to each other, and do not therefore appear to be far distant from each other; as I have shewn in the sixth figure, Tab. XV. in which the spinal marrow, as it is naturally contained in the body, and the fourteen annular incisions of the creature wherein the marrow lies are delineated.

If any one has a mind to view the spinal marrow, without hurting or injuring the creature, let him fill the body with air blown in through the hinder part: for thus the marrow will be by the force of the swollen intestines so strongly pressed against the transparent skin, that one may conveniently view its natural situation and form, even with the naked eye, as well as with a microscope. But this contrivance can be used in the males only.

The spinal marrow, as well as the other parts of the creature, has its air-pipes, and indeed a great number of them; so that the brain and nerves are continually as it were ventilated with injected air. I do not doubt but the marrow has veins and arteries, though I never saw them; for in Silk-worms I have clearly seen various small vessels spring from, and approaching to the heart, which I have even filled with a coloured liquid. But whether they were veins or arteries, I cannot yet affirm.

The spermatic vessels, Tab. XIV. fig. 1. or genital organs, are as conspicuous in the male of these Worms, the day before it changes its skin, as in the male Ephemerus, or the Fly thence produced after changing its coat. These spermatic vessels are found to be placed on each side of the stomach and intestines, and appear like the small guts in Fish. There are, however, some bendings and windings in them, like the seminal vesicles in the human species and they are found in manner of tubes: therefore, in this respect, they are also analogous to the spermatic vessels of some quadrupedes, as Moles, Hedge-hogs, and the like. They are in these Worms of an oblong figure *ffff*, and are extended all over the belly, as is evident from the annexed figure, wherein I exhibit one of them taken out of the body, and the other somewhat larger than nature in it. They contain in their cavities a very white humour like milk, which is the sperm. The seminal vessels themselves are likewise perfectly white, and they are of a thin and membranous texture, and have many air-tubes all over them both within and without.

In the lower rings of the abdomen appear two other little parts *dd*, which likewise in my opinion belong to the spermatic vessels; for they seem to have a common passage with them and with the intestines, Tab. XIV. fig. 1. *d*; which however I could not at that time so accurately discover, being engaged in other parts of this dissection. And indeed we must dissect a great number of these insects, if we would endeavour to discover the whole fabrick, searching in another what we could not examine to our wishes in the former; and even with this caution we cannot always execute our design perfectly.

The ovary is double in the females, Tab. XV. fig. III. and it is placed in the same manner as the ovary in Fishes. But if the skin of the abdomen be opened a little way with a fine and sharp-pointed pair of scissors, that congeries or heap of eggs, fig. 1. *ll*, situated on each side of the soft part of the belly, comes in sight. Between these, in the middle, the stomach and intestines *ff* are somewhat obscurely seen through the other parts, and the latter are themselves strongly connected with the membranes *mm* of the ovary. The stomach and little intestines appear the more plainly, the more they are filled with mud, which is the food of the Ephemerus; and for this very reason the eggs may be seen also more beautifully; for their whiteness, shewing itself brighter on account of the diversity of colours, makes them the more discernable.

The double ovary of the Ephemerus has innumerable air-pipes, which are tied to a small membrane that surrounds the ovary; and by means of the latter they are conveyed to the little eggs hidden on the inside. But if this membrane be removed with the point of a fine needle, and some part thereof put together with the eggs into a spoonful of water, the eggs immediately separate from each other, and there remains a fine, delicate and tender bundle of minute vessels, fig. VII. *g*, which I take to be mostly air-pipes, being like fine filaments, and conspicuous by their colour like mother of pearl.

The eggs are likewise so extremely small, fig. II, that they can scarce be seen. It is therefore necessary to view them with a good microscope, and to put them on black or blue paper, which contributes to their being the better distinguished.

The eggs are of a plain round and oblong figure, and are surrounded with a tolerable firm membrane, which appears cloudy under the microscope, and they are of a white colour, like the inner skin of an egg-shell. Since therefore the eggs of the Ephemerus are so small and delicate, the reason is evident, why the Worms issuing from them must be increasing three years before they come to perfection, and are able to commence their change.

## C H A P. VII.

*The signs by which to discover, whether the Ephemerus is to fly in a short time; as also what may prevent it, and to what class or order of natural changes it belongs.*

THE general preceding signs of the approaching change of the Worms of the Ephemeris into flies, are, in regard to the weather, a warm and dry spring; a mild winter, without much rain or snow; and a gently running water. The peculiar signs whereby to know that these Worms will change into Flies in a short time, consists in a protuberance of the wings on the back; for about that time the smooth and depressed form of the upper part of the body is changed into a more swollen and rounder shape; that is, that glutinous fluid which is at other times found in the coats that surround and defend the wings, becomes thicker and more clammy: hence it is, that the wings are at that time in some degree visible through their external skin, Tab. XIII. fig. VII. *aa*.

These signs are more certain when the colour of the wings within is observed to change from a yellowish and palish to a grayish hue. There is also a still greater certainty, if, after the external coat of the wings is taken off from the insect's body, the wings can be expanded without hurting them: as appears in Tab. XIV. fig. 1. under the letters *εεε*; where I exhibit the magnified wing, and as it is artfully folded by nature.

Another sign likewise presents itself in the dissection of these insects: that is, when we find the genital parts and eggs have acquired their full bigness, their due hardness, and true figure. We may then take the whole creature out of its skin, by art, and by this contrivance change it into the form of a flying Ephemerus ourselves, not waiting the moment of nature.

All the viscera of this insect are then cleared from their contents, which were a kind of dirt; nor is there any thing in the stomach and intestines but transparent and depurated humours, which appear the more dusky, foul, and coloured, the further the time of the change is distant; so that they are sometimes

yellowish, and sometimes dusky and red. At other times a little mud is found in the extremity of the thick and straight gut and colon; but, on the contrary, these insects are all over clear and transparent, when the time of their change is just at hand.

The following accidents keep back the changes of the Ephemerus, destroy its life, or prevent its growth; infomuch that so great numbers of these insects are not produced as might be expected; nor do they come to such maturity. An inclement, boisterous, tempestuous, long, rainy and snowy winter, destroys numbers. By this the cells inhabited by the Worms are destroyed, being worn out, or shut up and covered with sand. Too much drought or dry weather afterwards occasions the same destruction; for they are then compelled to quit their little cells, and make themselves new ones from the decrease of the water; and many are lost in this operation. From what has been said, we may easily see what favours and what injures the Ephemerus; what lessens it troubles and misfortunes, and what increases and multiplies them.

What I have a little before advanced concerning the maturity of the wings, shews to which of the orders of the four natural transmutations this insect belongs; that is, to the second class or order. For all the insects of this order are changed in the same manner as the Ephemerus.

Indeed, Clutius feigns that the Worm of the Ephemerus is changed into a Nymph of the third order, and on this loses all its motion, like the Nymphs of Silk-worms; he even exhibits a figure of that Nymph, though there is no such thing in all nature. Hence it is evident how much they are deceived who neglect the truth of experiments, and give credit to their own reasonings, or to the false relations of others.

## C H A P. VIII.

*How and in what a wonderful manner the Worm is transformed into an Ephemerus.*

WHEN the time of the change of the Worm of the Ephemerus is approaching, and the wings, Tab. XIII. fig. VII. *aa*, hidden in the cases or husks, have acquired

their due strength and form, and that it is no longer in the power of the Worm to delay its change; those which have their parts thus disposed and prepared, march out of their habitations

tations into the water. This usually happens in the evening between six of the clock and half an hour after. This I observed on the thirteenth of the month of June, in the year 1671, pursuing the change of the Worms of the Ephemerus.

The other Worms, which are not as yet come to this state of growth, remain in their cells. Those which have crept into the water move forward, and make all the haste they can from the bottom to the surface; which, when some more swiftly and others more slowly are arrived at, each of them, fig. VII. is changed into a winged insect, fig. VI. and VIII. But this change or casting of the skin is so suddenly performed, that even the most attentive person cannot otherwise judge, than that the Worm breaks or bursts its way and swiftly flies out of the middle of the water.

Every insect that I have hitherto observed has a certain and determined time appointed for it by the omnipotent God, to expand its wings and dry them, that they may become smooth and polished, before they are able to prepare themselves for flight. But the Ephemerus, on the contrary, is almost at one and the same point of time a reptile and a flying creature. Wherever one sees at this time a little water bubble up, if we cast our eyes on the surface, there is immediately a winged insect observed to issue out of the middle of the water. Argus would want eyes, if he should attempt to trace these miracles of the adorable Creator of the universe.

If any one goes into a boat and fixes in a situation directly against the descending stream of a river, then he may very well see these insects emerging or rising up, and casting their skin. For, though you should as soon as possible catch the Worm still floating on the water, yet you can scarce look at it before it is winged and flying. This may however be prevented, and the Worm taken out of the river before the change is performed, if it be struck a little, or bruised on the breast; which is necessary to be done, if one would view the creature at this period not yet changed, but covered with its skin.

It is difficult to say what is the reason that these wings are so swiftly expanded, and yet have neither muscles nor joints in them, but only artificially plaited and folded; nay, they must again change their skin the moment after. This difficulty surely is very worthy to be solved. I indeed thought it necessary that these wings should be provided with muscles and joints in the substance of them, as we have observed in many other insects; for the latter can by the help of such joints and muscles very artificially contract their wings into a narrow compass, and again quickly unfold or display them. This holds, amongst the rest, in Ear-wigs, which hide or put up very long wings in a small sheath, which folds and covers them so neatly, that they seem to be quite destitute of wings. But though the Ear-wigs

can by the power of muscles and joints, which they have in the middle of their wings, closely fold these wings in the same manner as in the Ephemerus, which has not yet gone through its change, and again quickly expand them; and though I thought the Ephemerus was in need of the like assistance, yet the supreme Architect has not been pleased to make use of the same structure; and it appears that even this structure was not necessary.

If the trials that I have hitherto made can throw any light on this instantaneous expansion of the wings, it must consist in this; that I think the water, which is warmer on the surface than in the bottom of the river, flowing all over and penetrating into the wings, contributes very much to their expansion. For by the assistance of the water, the blood which is then driven out of the heart into the wings, in order to promote this needful expansion, may be impelled with greater force, in the same manner as we see the blood is, by the help of hot water, drawn more plentifully into the feet, and those parts are more distended when any one is blooded in the foot. Thus, because the blood and all the humours in this insect, when it gets into the water swims about and is employed in changing its skin, are violently moved; hence the surrounding water may be of great service to impel the humours contained in the wings, so that they may be more expanded. Wherefore we likewise observe that in the wings of insects, if wounded at that time, there follows a mortal hemorrhage, or if the creature survives, the wings are never afterwards displayed. To the more ready expansion of these wings, the impelled air likewise probably contributes very much, because it is conveyed thither through the numerous pulmonary tubes, and may serve for giving strength and firmness to the pulmonary pipes, and for expelling the humour from thence. If you cut off the wings of the Worm of the Ephemerus when it is very near its change, and throw them into a basin of water, you will immediately see them expanding by force of the water flowing round them, and at length extending themselves into their natural, smooth, and even surface, so that they would serve the creature to fly, if they were dry and strong enough. I have often made this experiment on the wings of this insect, and by that means have in some measure learned how they are expanded. When I have put them in the water, in the manner beforementioned, I have observed that their larger folds were first opened, Tab. XIV. fig. 1.  $\epsilon\epsilon\epsilon$ , and then, by degrees, the wings were stretched out in length, Tab. XIII. fig. IX. Afterwards the longitudinal plaits of the wings were expanded, fig. X. until at length the whole wings, fig. XI. were entirely shewn open. This may be seen in the insect itself, fig. VIII. which I have delineated from the life; but the figures of the wings beforementioned are drawn with the help of a microscope. So long as the wings con-



continue in their plaits and folds, they are of a dark gray colour; but this by degrees becomes more faint when they are expanded.

When the Ephemerus has, fig. VI. and VIII. taken its first flight, it seeks out with all speed for some place where it may quietly rest; and having found such a one, it casts off, fig. XII. and XIII. a very thin and tender skin from its whole body, that is, from its head, breast, belly and wings. But before I treat of this other change of the skin, I must observe that it is always made on dry land, whereas the former is constantly performed in the water. And the first change is likewise much more admirable and worthy of observation than the second. When the Ephemerus first cast its skin or outward coat on the surface of the water, it at that time entirely loses its former shape; but this is not the case in the second change.

Therefore under the first of these changes, in which the skin of the Worm opening on the head and back, suddenly is separated from the body, until the Fly speedily and quickly makes its way from thence, some very considerable parts are lost, that is, fig. IV. *ff*, all the branchiæ or gills on each side, together with the ten rowing fins under them. Nay, when these branchiæ are separated, they do not leave even their hairs upon the body, but all vanish away so entirely, that only some small vestiges or points remain of them, which form a little margin or border on the sides of the belly. The Ephemerus loses also its teeth or forceps *c*, and the former shape *dd* of its legs, and the cases of its wings *e*, and tails *g*, and other parts. Hence the Ephemerus having gone through this change of its skin, is become as it were another creature. fig. VI. and VIII.

But as it is very difficult, perhaps impossible to observe all these things in the very short space of time in which the skin is casting, any person may do this at his leisure, if he gently and dextrously strips the Worm, that is to change immediately, of its skin. For then the parting branchiæ or gills, which adhere to the exuvia or cast skin of the Worm, are seen very plainly: there likewise appear those prominent apiculi or points they leave on the body of the Ephemerus itself; nay, you may likewise see those little holes which received the apiculi or points just mentioned. The pulmonary tubes may be likewise seen. Why should I say any thing of the muscles, tendons, vessels, and nerves which are separated from their membranes, like ripe fruit falling from a tree? for neither reason, observation, nor experience can discover any thing of them, since they are all directed by the omnipotent wisdom and providence, and conducted in such a wonderful manner that they are altogether incomprehensible.

Again, though many parts of the Worm of the Ephemerus are extended and become longer under the first change of its skin, yet the horns which project from the fore part of the

Worm's head only cast their skin, and when it is off they become more slender and short in the flying Ephemerus than they were in the Worm itself. The change that happens about the eyes merits yet greater attention, for their cornea tunica which was of a smooth and equal surface in the Worm, seems in the Ephemerus, after casting its skin, to consist of a congeries of many eyes, which form a little net equally divided. The legs likewise, together with two of the tails, become as long again by the change: but the third or middle tail is entirely taken off, having served no purpose but to the Worm.

When I say the two eyes of this creature are composed of a congeries of lesser eyes, six, nay seven thousand of which I have observed thus clustered together in some insects, whereas in others, as Spiders and Scorpions, they are dispersed all over the body; I would not have any one conclude from thence, that these eyes are formed as they are in the human species and other known animals. They are by no means such, for they want the humours; but every globular division of them emits an hexagonal filament like a needle, which terminates in the net-like tunic or coat of the eyes, and this coat itself ends at the nerve and brain: so that these creatures see in a different manner from us. We see by the assistance of rays collected on the inside of our eyes, but these perform vision by a collection of nervous filaments, which, when they see, are lightly and gently affected and moved in their prominent extremities by visible objects, and by the rays of light or colours and other appearances, as I have described at large, and expressed in figures in my treatise on Bees.

As to the succeeding change of the skin of the Ephemerus, which immediately and without interruption follows the first, we are to observe therein, that the Ephemerus having once cast its skin, chooses no particular place to rest or settle in, in order to undergo the other.

It fixes upon any place it can find in its flight, and it does not regard whether it be wood, stone, earth, a tree, a boat, a ship, a beast, or a man. It seems to be a most innocent little creature indifferent to every thing, so that it can rest any where, in order to cast off this second skin, which is done in the manner following.

The Fly firmly and strongly fastens its legs, which are armed with sharp claws for that purpose; then it appears as if seized with a shuddering and trembling motion, and immediately its skin opens on the middle of its back in the small shield that is placed there: this opening becomes by degrees so large towards the fore parts, that the creature can thrust its head out of it. After this it draws its legs also out of the skin, Tab. XIII. fig. XII, XIII. whilst the claws, adhering to the cast skin, are in the mean time still firmly fixed in their places; and this indeed contributes much to remove the skin from the rest of the body.

Moreover,

Moreover, it must be well observed, that the head and legs are stript of their skin in the same manner as we draw our feet out of our shoes, or our head out of a narrow cap. But as to the other parts, namely, the first and second pair of wings, the skin is drawn off from them in such a manner, as that the inside is turned out and the outside in, as we invert a limber pair of gloves, the inward surface or inside of the fingers being pulled out. At the time when half the skin is drawn off the wings, these insects are as helpless captives, and fixed in that condition, fig. XII. they even lie for some time without any sensible or remarkable motion. The rest of the body is likewise by this second change extended and becomes much longer, and the tails become a third part longer than they were after the first change. So that the tail and legs which were made, under the first change, a third part longer, are now again as much more lengthened; but this holds more perfectly in the tails than the legs. For, as the tail consists of hollow rings which are capable of being drawn out from each other, hence its extension is much more conspicuous than that of the legs, because the latter only lay folded in the skin, but are now extended fully to their length, and nothing more. It is moreover to be observed in regard to the tail, that its hairs, which were planted very thick in the Worm of the Ephemerus, are placed more remote from one another when it flies, and they also become much finer and thinner, since they likewise cast their skin twice, and appear issuing out of their hairs as out of little sheaths.

The Ephemerus having thus partly shaken and partly drawn off its skin, by inverting or turning it inside out, being now perfect, seeks again the water, on the surface of which it flies and beats up and down gently and quickly, and, as it seems, wantonly sports and plays, and then rests again, leaning on its tails, and striking its wings against each other. Whilst the Fly is thus in motion on the surface of the water, and loosely playing with its wings, its tail, which is hollow and full of hairs, very easily supports the body; for, as it contains air in it, it is therefore carried lightly upon the surface of the water, and does not sink under it. Something like this is observed in several other insects, which will continue in the same manner, suspended on the surface of the water by the help of hairs, within and between which the air is detained, as is the case in the Worms out of which Gnats and Gad-Flies are produced. The air, however, does not always continue in the tails of the Ephemerus, but sometimes comes out of it, and may at any time be let out if they are pricked with a needle, in order to dry and preserve them; for then they generally become corrugated or wrin-

kled, and sink or fall together. There is also another reason why the Ephemerus flies thus lightly on the surface of the water, and that is, because it carries a small bladder full of air in its body; unless we should rather incline to think that it is the stomach of the Ephemerus, which is then inflated or blown up with air. But I shall affirm nothing certain concerning this matter, since it is not sufficiently clear to myself.

The male, fig. VI. as appears to me, changes its skin twice, but the female, fig. VIII. only once. I do not, however, advance this as undoubted truth, since I have not yet confirmed it by a sufficient number of experiments. For this reason, if it be thus, we observe that the tails of the female are a third part shorter than the tails of the male. Besides, another more remarkable difference is, that the eyes in the male are twice as large as in the female. A third difference is, that the yellow colour of the body in the male approaches more to red than in the female. The male likewise has, besides his two larger tails, four appendages, like crooked little tongues, which cannot be so distinctly seen in the female. These are the great differences of the two sexes.

The Ephemerus does not engender either in the body of the water, or on land, nor in the air, but the female throws out her eggs on the surface of the water, and the male afterwards casteth his sperm upon them\*, and he has probably, for this purpose larger eyes given him by the all-seeing Creator, that by means of this advantage he may easily find out the eggs of the female wherever she has dropped them. As therefore a great many species of fish without coition throw out their eggs into the bottom of the water, to be afterwards impregnated by the male, so the Ephemerus throws its sperm into the water. These eggs, when cast out, are not collected and concreted together in the form of a perfect ovary, like that which the Ephemerus carries in its body, but are separated and dispersed from each other as they are in fish. That the Ephemerus while a Worm does not perform the business of coition in the water, is manifest from hence, that it does not come out of its cells only at the time it is to cast its skin. Nay, if it should go out of them, as it sometimes does through necessity, or to breathe fresh air, yet it is by no means able to do any act to propagate its species in the water, for it cannot remain suspended in the water but while swimming, and it sinks immediately to the bottom when it has a mind to rest in it: but at the bottom it has no fixed residence till it has made a new cell or habitation for itself. To these we may add another, the strongest argument of all, that is, that no insect ever enter upon the business of

\* This, though common with fish, is strange among the insect kind; but in the whole compass of natural history nothing is more variously performed than the impregnation of the eggs, nor any thing so little understood; it seems, they may not only be impregnated by a male sperm cast upon them when laid by the female, but even by the same fluid cast at random while they are yet in the body of the female. Monsieur Demours is particular in his observation of the water Newt, the male of which has no penis, but discharges his sperm in the water near the female, whose eggs, though none of the sperm absolutely enters her body, are so impregnated.

generation, until they have cast their last skin. At least, I have been taught so by all the experience I have had in their examination.

Neither do the Ephemeri breed or engender in the air; this may be easily observed when they fly. Besides, they could not possibly breed in the air, because the legs of the males are so vastly lengthened after the last change of the skin, that Clutius took them for horns. Those who would favour such an opinion, must consider what an apparatus is necessary for such coition in the air; as may be seen in those Flies which do it, and particularly in the Libellæ, which perform their venereal embraces in a wonderful manner, flying and wandering all the time in the air, visibly coupled a long while together.

I therefore conclude from all my observa-

tions, that the Ephemeri never engender together, either in the air or water, but that the female only throws her eggs on the water, and the male afterwards pours its sperm, which it carries about it flying, as the female does its eggs, upon them; so that this operation is performed without any communication of the two sexes. All these things are hastily transacted in the short period of a most transitory life, so that a more accurate inquiry into them cannot possibly be made.

These little creatures do not eat in the whole course of their lives, while perfect flying creatures, as is also the case with many other insects. I have likewise found by experience, that Frogs, Lizards, Serpents and Cameleons, are capable of living without eating many weeks; nay months.

## C H A P. IX.

### *How long the Ephemerus lives, and what hastens its death.*

THE Ephemerus thus flying about and wandering over the surface of the water, and moving sometimes up and sometimes down through the air, never lives more than four or at most five hours, that is from six of the clock in the evening, or half an hour after, until eleven at night. This I say from experience, because I have carried some of them enclosed in a box into my chamber, and there accurately observed the length of their lives. All die in this very short space of time, nor do any of them, which is a matter very worthy of observation, die a natural death on land. All of them invariably go to the water again, after they have gone through the second change of their skin. God therefore, the supreme artist, has been pleased to assign this insect a short life that surpasses all adoration.

Who has so great a genius, or is so conversant in the art of writing, as to be able to describe, with a due sense, the trouble, and misfortunes this creature is subject to, during the short continuance of its flying life. For my part, I confess I am by no means able to execute this task. Nor do I know whether nature ever produced a more innocent and simple little creature, which is, notwithstanding, destined to undergo so many miseries and horrible dangers.

Besides, that the life of the Ephemerus is short, nay, amazingly and incomprehensibly so, an infinite number of them are always destroyed in the birth, being devoured by fish. Nor does Clutius acquit any species of fish of this barbarity except the Perch and Pike. Though the rest of the Ephemeri have escaped this cruel danger, yet on land, when they are engaged in the great work of changing their skin, they are barbarously devoured by Swallows and other birds. Nay, if they escape this danger, when they afterwards approach again to the surface of the water, and carelessly sport and play there

with their wings and tails, they a second time become a prey to the fish, which drag them away to the dark bottom of the water and devour them. If they fly higher into the air, another kind of torment attends them, for then they are persecuted with a different barbarity by other kinds of birds, which tear their limbs asunder and devour them. Though these insects then are the most innocent, perhaps, of all others, they are more cruelly treated or used than the most mischievous of wild beasts.

As the Ephemerus abounds with useful lessons and moral precepts, so it affords sufficient matter for various speculations. It is ingenerated, grows to its bigness, and then generates, lays eggs, casts its sperm, grows old, and dies in the space of five hours. This short time comprehends the morning, noon and evening of its life.

When the Ephemerus is flying, and particularly a little before the end of that time, the Trout, which eats it as its food, comes to its perfection: its flesh and flavour being finer than at any other time. This I have been assured of by Nicholas Tulpius, formerly consul at Amsterdam, for he fairly made trial of the matter.

One may ask further this question, why, exclusive of all those dangers and misfortunes, the life of the Ephemerus should be so short? In answer to this let it be observed, that the eggs of the Ephemerus, whilst it still swims as a Worm, are arrived to their perfection, so that as soon as the insect is increased and perfected by changing and extending its limbs, those eggs are instantly fit for production or birth: to which may be added, that the Ephemerus has not the nourishing of its offspring; wherefore God has made this creature likewise, more than others, void of reason, as the Ostrich among birds, that He, from whom springs all reason

and knowledge, might take upon himself the care of nourishing its progeny.

Since therefore this creature assumes its winged form only to propagate its species, it follows, that when this is done, its death is naturally near at hand, and for this purpose it seems to

remain three years hidden in the water and mud, and to undergo after that time its change, and get wings in that form living, till this business of generation is performed, and then it dies.

## C H A P. X.

*That the Ephemerus kind flies three days and sometimes four : certain other species thereof are also described.*

**T**HAT the Ephemeris are changing and flying during three days continually, is known to all who live near the rivers, famous for this annual miracle ; I have observed them flying the fourth ; nay, even the fifth day, but then very few in number. These were a succession of the insects hatched one after another, and hence I think these had been Worms of the same year, the wings whereof had acquired their maturity somewhat slower than some others ; and that these latter were sick, or prevented by some other impediment, which hindered their change in the appointed time. As, on the other hand, it is certain that the transformation of the Worms of this species, which are changed before their time, happens on account of their wings and other parts being perfected earlier than natural. As this may and certainly does happen in all the insect kinds, I see no reason why the Ephemerus should not sometimes be produced in its winged form, some days sooner or later than the strict time, since it is certain from experience that the general change of them may happen fourteen days sooner or later, as the season of the year favours it more or less.

If we attentively consider the things that have been here related of the Ephemerus, it is evident that Mouffet speaks truth, when he says, " The Ephemeron, or Diaria is a wonderful Fly, whether we consider its make or the shortness of its life." But some of the other particulars related of this insect by this author, as well as by Aldrovandus, Johnson, Clutius, and others, who are cited by all the latter writers, do not much correspond with the truth. Far be it from me to reprehend or animadvert on others in these matters ; since it is possible that these gentlemen might have described a different Ephemerus from mine, as there are various species. Besides, nature, or her author God, is perfectly inexhaustible in the make, properties and disposition of these creatures. I shall only recommend it to any who shall be desirous of knowing the truth, to consult the insects themselves ; for nature far surpasses all the writings and treaties that can be compiled, and in this and all other cases will teach more in one instant of time than any one can learn in a long series of years out of the best library.

It astonished me to see in a book written by Augerius Clutius, that Dortmannus there exhibited a figure of the Ephemerus, devised upon a weak and erring memory, or feigned from mere imagination. Goedaert having observed this, and being furnished with many more observations of that kind, undertook to amend it of his own pleasure, but without success ; since he changed nothing but what appeared to his fancy to be improper, and left the whole figure of the insect, which was delineated from memory only, altogether incorrect. As he attempted to correct these errors from his own imagination, it should seem to follow that he multiplied them, although he rendered them more seemingly like the truth. Indeed Goedaert himself owns he never saw this insect.

While I was engaged in investigating the nature of this insect, I met with various species of it at different times, but I never had the good fortune to see the Ephemerus of Hoefnagel, which Clutius delineates ; and which is found also among the figures of Hoefnagel. But I once found its Nymph troden upon in the road that goes by the lake of Deimermeer. I at that time thought it had its origin from a kind of blackish and toothed water Worm, which has a closely corrugated or wrinkled skin ; since the latter having attained its full bigness, leaves the water, and betaking itself to land, is there changed into a Nymph, which in process of time, perhaps, acquires the form of the Ephemerus delineated by Hoefnagel. This Ephemerus afterwards throws its eggs into the water, which is the case with many other insects, and with several other species of the Ephemerus which I can shew. I saw and took some of those species in the river Loire at Saumeur in France. These do not differ in their general form from the Ephemerus of our country, but they are less, and of a somewhat different structure. I have seen great swarms of these flying, when I chanced to walk in the evening on the bridge that is over the river at Saumeur. Some of these carried about them their second skin still sticking to their tails, as they flew up and down above the bridge. I have nothing farther to say of this kind, or of all other species which I preserve, only that some of them are as short lived as our Ephemerus, which I have been hitherto describing,

describing; but I have observed that others of them live longer than these. I therefore apprehend that the various species are distinguishable from each other by several further peculiarities; and, for this reason, I do not pronounce those authors reproachable, who relate any thing of these or of the like insects, because what they say does not exactly agree with the species of one particular country. Far be it from me to be guilty of such temerity; since God is infinite in all his works, and the species may be numerous.

About the end of June 1670, when I resided in the village of Slooten near Amsterdam, I went sometimes in the evenings into the fields, where so great a number of minute insects which were somewhat larger than Gnats, at times pitched on my cloaths, that I was all over covered with them. Each of these cast a small skin on my cloaths; after which, I observed that all of them returned to the water, and there, like the larger Ephemerus, sported and beat up and down. These insects are produced nearly in the same manner as the Ephemerus before described; for they live in ditches and water-trenches, and when they are to suffer a change into the Fly state, they likewise, at regular times, cast two skins, one in the water and another on the land. The Worms of the smaller Ephemerus differ from the lar-

ger, in that they do not hide themselves in mud, or form cells or long holes, but mostly inhabit stony and sandy bottoms: therefore nature has formed them of a rougher and more robust constitution than the larger Ephemerus. Their skin also is more like the crustaceous integument of Crabs and Shrimps. They have likewise branchiæ or gills, and rowing fins, on the sides of their bodies. When in the middle of summer any one takes up stones from the Rhine or Leck, or other collections of waters in our own country, for carrying to the land, he will most commonly see some Worms of that kind sticking to them; which is likewise the case in other countries and other rivers, as I myself have learned from experience in the Loire, the Seine, and other rivers of France. Hence it is evident that there are many distinct species of the Ephemerus, and that the authors who describe an Ephemerus, however different from that of our country, do not merit certain censure. I can for the most part exhibit to the naked eye the Worms before mentioned, and every thing that I have hitherto advanced concerning the Ephemerus, according as they are in nature; since I have preserved them to this day, that they may serve the better to illustrate and confirm what is said in this treatise.

*The end of the wonderful history of the EPHEMERUS.*

## The THIRD ORDER.

*Of natural changes, or slow accretions of the parts of insects.*

HAVING explained in the preceding chapters the two first orders or classes of natural changes, we now advance to the third; which, we must observe, is always preceded by another change, as we have before described at large.

As this change is more obscure and intricate than the first, and more difficult to be understood than the second, in order to give a distinct and plain description thereof, we shall compare it with the first and second; for by this means it will be easier to comprehend what they all three have in common, and in what they differ from each other. As the first order of transmutations consist in this, that the creature increases in its parent from almost invisible, but really existing rudiments, and lies enclosed in a membrane until it has acquired sufficient strength therein to be able to creep out of it; so on the other hand, the other order is much more imperfect; for in this the insect increases likewise as in the first order, but it comes out of its egg imperfect; and therefore because in some parts, but chiefly in regard to the wings, it is still defective; it must, in order to acquire its due perfection, take in food from abroad; by the help of

which, the rest of its parts, which we from time to time observe to increase and expand, like a flower from its cup, are at length perfected.

The order of nature is quite contrary in those insects which undergo the change of our third order: for though they increase in the same manner as those in the first order, and come forth imperfect, as those in the second order, nay, much more so, out of their egg, many of them not having even legs; yet all these imperfect parts are increased and augmented in a very obscure manner under the skin. Hence, as the creature issues complete in all its parts out of the egg in the first order, and in the second the accretion or expanding of its several parts is performed externally and openly; but in this our third order, on the contrary, this germination or sprouting is all transacted within the covering of a skin, and can with very great difficulty be observed, unless by the change of the skin.

As therefore those insects which undergo the first order of transmutation, constituted under the form of a Nymph, creep only simply out of their egg or skin: and as those which belong to the second order of changes, likewise

likewise expand afterwards as it were into a second Nymph; though in the mean time they do not cease to move and eat, nor do they ever at any period of their lives lose their motion; so on the contrary the matter is quite otherwise in those which are subject to our third order of transmutation; for as soon as these which first issued imperfect out of their egg or former Nymph, and increased in their parts as they have grown under the skin, like a flower in a tender flower cup, and afterwards cast this skin by the force of the protuberant parts; under this other transformation they entirely lose all their motion, except that of the tail only; for this is not swollen with moisture in a great many, and only changes its skin.

The insects which undergo this third order of change, are produced imperfect out of their egg, and want at that time a great many of their parts: but they by degrees acquire them under the cover of their skin, where they are gradually perfected and enlarged. The legs, wing, horns, and the rest of their parts are by this means increased to their due size with the body: this is performed insensibly by absolute growth or addition of parts. Finally when the limbs are come to the full period of their increase, they raise the skin with a visible swelling and render it somewhat prominent in different parts; and under these protuberances of the skin, we can plainly discern the several limbs and other parts which lie disposed in a wonderful manner under that covering, like a flower growing slowly in its cup; until, after the skin is at length cast, all these parts very clearly and distinctly present themselves to our view: at that time the veil, if I may be allowed the expression, is at length removed, and all the impediments which till then obstructed the sight, and which have produced so many errors amongst all the naturalists without exception, is removed, and all is made plain and easy. Hence it is, that we can very easily exhibit to the eye all the parts which before lay under the skin; as I have actually done in the presence of Thevenot and Magallotti, who accompanied me in these experiments, and whose testimony is sufficient to put the matter beyond doubt.

We call this change with Aristotle, Pliny, and others, the Nymph; because we see issuing out of it a perfect insect, fit for propagating its species, and adorned in all the splendour and beauty of its kind, as a virgin in a very rich nuptial garment: the creature having thus passed the infantine years of a Worm or Caterpillar, comes forth without delay to meet its fellow of the other sex in the spacious and beautiful tapestry of the fields, spread for its use by nature.

On these principles our third order of natural transmutations consists; the Worm, after it has cast off the form of a Nymph, in which it lay without food in its egg, is afterwards increased by degrees, and acquires more parts

by the help of the food it is supplied with, until at length it casts its skin, and attains the form of a second Nymph, which clearly and distinctly exhibits all the limbs perfect in all their parts, and is once again deprived of all motion as it was before in the egg: this motion is again restored afterwards in a few days by the evaporation of the superfluous moisture.

These insects are therefore twice held in the state of a Nymph; that is, first in the egg, which is their first Nymph; then in the last change or second Nymph. But there is this considerable difference in the two, that when they are in their first Nymph or in the egg, their limbs cannot only be less distinctly seen, than in the second, the reason of which we shall assign hereafter; but also that before they are changed into the first Nymph or egg, they have no remarkable motion preceding, nor are they increased in their limbs in any manner different from other insects, or from the seeds of plants. On the other hand, before they are changed by accretion into the second Nymph, they do not only evidently move themselves from place to place, but also increase in the same manner as other insects during their growth, which have the power of moving or going where they please, and take their food in at their mouths. This being well understood, the difference between the first change which is called an egg, and the second which we call a Nymph, is very evident; though each of them is only an accretion continued in the limbs though in different manners. We beg the reader will attentively regard what has been hitherto said, because it is of the highest use, and eradicates entirely the false notion of a metamorphosis or change of one creature into another, that universal chimera of erring opinions, and totally destroys and subverts the monstrous opinion of a fortuitous generation of creatures.

As the parts of the future insect are seen much more plainly and distinctly in some of these Nymphs than in others, as Aristotle, though not perfectly right in this matter, has likewise observed; we shall therefore divide them into two kinds, in order to make the understanding of them more distinct: that is, we shall call one of these a Nymph simply; and the other the Nymph Chrysalis. Nor shall we regard that the word Nymph Chrysalis does not perfectly or exactly express the thing itself; and that all the Nymphs, which we call Chrysalides, are not of that gold colour, whence the name: for we have not judged it proper to depart from the received appellations, or to make professed innovations in the terms: so far are we from this intent, that our great industry and study are employed to find out truth, and, when found, to explain her simply and in her natural ornaments. Hence we have resolved to persuade no body to believe more than what may be shewn plainly to the eye, and with due attention observed by every one, as well as by us, in nature herself.

*A catalogue of the insects which belong to the third order or class of natural changes, which I call the Nymph.*

**A**MONG these insects which are changed according to the first method or species of the third order, and, by the power of the increasing and expanding limbs, which breaking open the skin, obtain the form of a Nymph, wherein all the parts appear to be finely and beautifully expressed, I first reckon Bees. I preserve in my collection their queen, as she is called; and also several of the drones, which are properly males; and also the working Bees, which are of neither masculine nor feminine sex; since the proper organs neither of male nor female are to be found in them: whereas those organs are very distinctly conspicuous in the queen and in the drones. This queen has been improperly called the king. I discovered the egg-bag of the female, or king, as it used to be called, in the presence of the incomparable anatomist D. John Van Horne, professor of anatomy and surgery; being assisted therein by the singular favour of Dr. W. V. Hoorn, a physician of Slooten, who readily gave us admittance to his bee-hives.

I likewise preserve the Nymph of the drones, of the queen, and of the working Bees. I can likewise exhibit their webs, which are like those of Silk-worms, and also the honey-combs; between which are the cells or houses of the drones and queen, and working Bees, besides many other things very worthy of observation concerning these little cells; for I have prepared them different ways, that the most artificial order wherewith they are constructed might be made evident. I likewise keep in my cabinet the sting of that usually called the king, and its bag of poison; as also the bag and the sting of the working Bees, which I have found to be divided into three parts. In fine, I preserve also in this collection the testicles and penis of the drones.

It is worthy observation in Bees, as well as other insects, that the lungs are found most distinctly conspicuous in them, consisting of two white bladders. But in insects which have blood, and are by that distinguished from these, the lungs, when cleaned from their humours, are only composed of bladders, as the celebrated Marcellus Malpighius has most accurately shewn: nay, I shall scarce scruple to assert the same thing of the other viscera; excepting only that the skin and the other membranes are interwoven with small and scarce perceptible closed arteries, veins, and the like. These vessels I have also observed are sometimes again opened by the inexplicable power of nature.

The elegant and amazing structure of the rest of the viscera in Bees merits the highest admiration. But as we shall hereafter describe them severally and at large, we shall now say

nothing more on them, for as we here treat only in general of these insects: we can only treat of them in general terms before their particular history to be hereafter exhibited.

Considering however that wonderful republic of Bees, which is founded upon affection only, and excludes all kind of superiority, we cannot but exclaim that nature has concealed in the history and manners of these creatures, treasures of inestimable miracles, which are notwithstanding freely opened to us, provided we diligently investigate the disposition of those creatures. An unwearied scrutiny is the only key to nature; nor is there any other than this, which can open the way into her mysteries.

After the hive Bee, we are to name the Bees that live at large in gardens, fields, and forests, and hence are called wild Bees. I preserve six species of these, among which there is one with very long horns; another has an extremely rough hairy body; and a third is extremely like a Wasp: I have exhibited some of these in their natural size, in fig. IV. V. VI. VII. VIII. Tab. XXVI.

I likewise reckon in this third order the wood Bees of Aldrovandus, or that called the solitary Wasp by Mouffet. Their Nymphs, the web of the Worm, and the Bee itself are in my cabinet. I can likewise shew the little nests which these creatures make of small stones, grains of sand, and dirt. In these nests we sometimes find a very remarkable Wasp, together with a Beetle, and the Worm out of which the Beetle is produced: nay, that Vermicle or Worm was once in my possession changed in the exact space of one year into such a Beetle, having had no other food in the mean time but little stones and dirt. These observations create some doubt which of the three beforementioned insects builds the nests just now mentioned; but to me it appears very certain, that the wood Bee is their architect; for she carries the little stones, and the nest itself is found to be appropriated only to her. Such nests are found in great numbers in the ruins of walls in France.

We might likewise mention the Apes *Manuetae* of Mouffet here, but because they belong to our fourth order, and are not Bees but real Flies, we shall therefore describe them hereafter in their proper place.

Next follow the Wasps; of these I preserve seven kinds, together with the combs, in which some of their Nymphs still lie enclosed and sealed up as it were. I have shewn the proboscis of the common kind of Wasps, in Tab. XVII. fig. VII. the poison bladder in Tab. XVIII. fig. IV. and lastly the ovary, in Tab. XIX. fig. IV. In Tab. XXVI. fig. X.

I exhibit one of the largest kinds of Wasps, and another uncommon kind in fig. II. *ibid.* to these I have finally added, fig. XIV. XV. some Wasps of the smallest kind. I have more than once observed, that the Wasps carry the matter whereof they make their nests upon their legs.

In this order I rank also the Pseudophecæ, which we usually see produced out of a Chrysalis, which is understood to be corrupted or rotten: I preserve twenty kinds of these in my collection. Hoefnagel has given us delineations of twenty-four; Goedaert likewise described a few. We may properly insert this kind of Fly in our fourth order, as will appear when we come to that part.

Among the Pseudophecæ which we keep, is the *Musca Trifeta*, or Three-Hair-Tailed-Fly of Mouffet, whereof I preserve four kinds. I have represented one of them in Tab. XXVI. fig. XIII. and some smaller ones, in Tab. XLIV. and XLV. I preserve also, amongst the said Pseudophecæ, the *Musca Unifeta*, or Single-Hair-Fly of Mouffet, indeed two species thereof, together with the Worm and Nymph; the Chrysalis, which afforded these, is likewise in my museum, from which, when rotten, this Fly has its origin. I preserve also several other exotic and more uncommon kinds of Pseudophecæ, of which I shall have an opportunity to speak in my particular observations.

To this third order, we likewise refer the insect, called by Goedaert, Devorator, or the Devourer. This is that species of Pseudophecæ, which kills Spiders, and may therefore be properly called the *Ichneumon Wasp*. This Wasp seems to be somewhat of the like disposition with the *Musca Lupus*, or Wolf-Fly; for as the former grinds or breaks her food with her teeth, this latter pierces it with her aculeus.

I likewise keep in my museum the Flies called *Panopes*, which are destructive of grapes, and may properly enough be referred to the genus of Pseudophecæ. I have found from observation, that these Flies are not invariably disposed to one kind of food, but will, when they cannot meet with grapes, satiate themselves with any other food they can find.

Next follow the Hornets: I preserve two species of these, together with the web, which their Worms form; I can also exhibit their Nymphs, and the cases wherein they enclose those Nymphs. These creatures are so voracious, that if they are cut through the middle they will not quit their food, and if that be fluid, I have seen them eat while it ran out of the wound; this I have often experienced with a little honey. We exhibit the largest species of Hornets in Tab. XXVI. fig. IX. and one of their cells in Tab. XXIII. fig. XV.

The humble Bee also belongs to this order, whereof there are eight species, among which I preserve the exotic one with purple wings.

In the figures of Hoefnagel there are likewise found eight species. Goedaert has also described the Worm of the humble Bee kind. I have represented the nest of one of them in Tab. XXVI. fig. I. and afterwards one of the Bees of the middle size in fig. XII.

Further, I ascribe the Gnat to this order; this creature is produced in the water, as will be shewn in its particular history; this it might be proper to subjoin immediately to the treatise of Bees; but as the Nymph of the Rhinoceros Beetle, on account of its remarkable bigness and peculiar structure, throws great light on the system of this order, we shall first give a description thereof.

The *Musca Chrysopeis*, or Golden Eye, I preserve also in my collection, and have two distinct species thereof. Goedaert has likewise described two species of this elegant insect.

I likewise have the *Musca Florilega*, or Flower Fly, which is black, and a great enemy to young flowers; whole armies of this kind sometimes instantaneously possess fields and gardens. They are said to come out of the water, which I should the more easily allow, because I know a great many kinds of insects, which, after having been in the water some time, fly out of it at once; thus myriads of the *Libellæ*, or Dragon-Flies, fly together, at one and the same time, out of the water, as do likewise Gnats, *Ephemeris*, and many other species. On observing this, many have erroneously persuaded themselves that these insects are produced in the air itself. But it is particularly worthy of observation, that the *Ephemeris* always dies a little after its birth; whereas, on the contrary, other insects remain a long time on the earth alive: the reasons of which difference we have assigned in our observations on the history of the *Ephemeris*.

I likewise preserve the Fly that is like the Butterfly kind, and the Scorpion-Fly, male and female; as also the Wolf-Fly, of which I have five species. The carnivorous Fly, called the *Cæsar*, is also to be found in my museum. I can likewise exhibit fourteen species of the common Flies, and twenty-four species of the more uncommon kind; some of these have wings adorned as it were with the figures of serpents, some distinguished with fasciæ or wreaths, some with spots, and others with grooves or furrows, some of them also have the belly and breast variously painted with red, green, yellow and gold. We see delineated in the figures of Hoefnagel, twenty-five species of the common, and thirty species of very rare, Flies; and the industrious Goedaert has left us the figures of forty-eight species of Flies. Hence, when I consider the great diligence of that naturalist, I cannot sufficiently admire, that he has been always so much a stranger to the true knowledge of these things; but I must add that it happened unfortunately, that his thoughts were committed to writing by others; who, mixing their own chimerical notions



notions with his, involved the true knowledge of these matters in greater darkness.

To this order are likewise to be referred some very small and uncommon Flies of peculiar origin, some of which are produced from the tubercles or warts of willows, Tab. XLIV. fig. v; others spring from the axæ or bosoms of the leaves of the willow tree, Tab. XLIV. fig. xv; others issue from the rose willows, Tab. XLIV. fig. xvii; others from downy matter or flocks of the catkins, Tab. XLV. fig. viii; others from the stinging nettle, Tab. XLV. fig. v; others from the sponge of the dog-rose, eglantine, or sweet brier, Tab. XLV. fig. ii; others from the excrescences of oak, Tab. XLV. fig. xix; and lastly, others are produced from a kind of Worms that walk with their sheath or case, Tab. XLV. fig. xxxiii. and xxxiv. I have described all these little Flies in the fourth order, because they perform their change in the manner peculiar to that distinction.

The Ant likewise belongs to this class, but as we shall treat of this insect hereafter in our particular observations, it may suffice to say here, that I preserve both the winged male Ant, and the female, the body of which is somewhat thicker; and the labouring Ant, which has no wings, nor does it seem to be either of the male or female sex. It is worthy of observation, that this little creature is obliged to carry its young wherever they can have nourishment at hand; whereas others, in general, carry the food to their young; other insects, in a manner different from either of the two former, expose their issue, as if they were orphans, and oblige them at first to find nourishment for themselves. The first species is indeed very industrious; the second gentle and good-natured; but the third, unmerciful, and resembles a cruel stepmother. However, the great Creator of them, who does not despise the cries even of the Raven, Job. xxxix. preserves them all.

I moreover keep, a thing very wonderful, five hundred and forty-five Flies of one and the same species, which have been likewise produced from four Chrysalides of one species of the diurnal Butterfly; so that the life and motion of these four creatures seems to have transmigrated into those of the five hundred and forty-five others. I can shew also one hundred and eighty-seven little Flies, which burst out of only one Chrysalis that had been wounded. I have likewise one hundred and forty-five, seventy-seven, thirty-nine, and eighteen little Flies of different sizes, which have been changed into Nymphs, in the bowels of diurnal Butterflies, which belong to so many different species; but I shall treat of these more accurately in the fourth order.

The *Tipula Terrestris*, or Long-legs of the land, belongs also to this order, which Aldrovandus describes under the name of the largest Gnat, but Mouffet calls it *Tipula*. There are five species of this in my museum, but Hoef-

nagel delineates no less than sixteen. This insect is produced from a Vermicle or Worm which commonly lies under the grass, and is called by the fishermen, in our language, *Im* or *Imme*. I preserve two Nymphs thereof, wherein the parts of the insect are represented tho' somewhat obscurely; so that they may be likewise referred to the Chrysalides: the difference is not very considerable. I likewise have a very obscure delineation of one of these Nymphs by Goedaert.

Next in this order follow the Beetles, whereof I preserve nine of the largest kinds, twenty-one of the middling, thirty-seven of a smaller, and one hundred and thirty-six of the least kind. Among these there are twenty-five exoticks, brought from the East and West Indies, Ægypt, Brasil, France, and other parts. Hoefnagel has likewise delineated thirty-five species of the common Beetles, and seven more rare and uncommon. We find nineteen species of the small Beetles described in Goedaert, to which are added five of their Nymphs, indeed very beautifully delineated. I preserve likewise seven Nymphs of Beetles, and among these the *Scarabæus Nasicornis*, or *Rhinoceros Beetle*.

What deserves very particular notice in the Beetle, as Fabricius ab Aquapendente has justly observed, is, that the bones, which in larger creatures which have blood are placed in the inside, are situated on the outside in the Beetle. And, on the contrary, the flesh, which lies on the outside in sanguiferous animals, is here hedged on the inside within the bones, or horny substance of these insects. Another thing which merits the greatest attention is, that in the very muscles of these little creatures is discovered the same structure, that the great anatomist Nicholas Steno observed in those of the larger animals. This is particularly remarkable in the structure of the muscles of the Locust's legs, by the help of which that creature can leap up and down so nimbly, that it raises itself into the air two hundred times the height of its body.

As nature shews herself wonderful in the similar structure of the muscles given to these two kinds of creatures, so indeed does that great immense difference, which is between the bones of the larger or sanguiferous animals, and the horn-like texture of the little bones in insects. Among these insect tribes, nothing is more various, or can be more worthy of notice, than that exceeding great, and at the same time beautiful diversity of structure, which is to be met with in the horns of the Beetle kind. I really think that according to this diversity alone the distinctions of the Beetles into species may be determined.

I preserve seven species of the *Scarabæi Nasicornes*, or nose horned Beetles, among which there is one; whereof the horn is bent like a bow, or arch-like, towards the back or shoulders. I can shew the curious this creature, together with the lice wherewith it is infested. But I have

have observed, that it is produced from the largest species of *Coffi* or Hexapode Worms \*, which are in the exact space of two, and some of three, years changed into Nymphs. Besides this horn upon the nose, it has two horns which arise near the eyes, and terminate as it were in knotty extremities. I shall give its whole peculiar history in its proper place. I preserve besides this two other nose horned Beetles, which are very small, and have the horns divided in a manner into two parts. I can likewise shew another species of the unicorn Beetle, which has the horn likewise bent like a bow or arch towards the breast, and serrated on the inner part with four teeth: whilst in the mean time the bony coverings of the shoulder, loins, and breast, are stretched vastly forward, and terminated in this horn, which is planted in the concave part of its arch with bristly hairs, of a gold colour, and soft like velvet. I have likewise two other nose horned Beetles, which have the horns undivided in their originations, but afterwards terminate in split points. In these Beetles the breast bone is likewise black, horny and divided, and terminates in one of their horns, which is as it were serrated at one end; but at the other divides itself into two obtuse horns. The last named species of the Beetle is also adorned with very singular and knotty horns placed near the eyes. I exhibit also five species of these exotic *Nasicornes*, or nose horned Beetles, of their natural size, in Tab. XXX. fig. 2, 3, 4, 5, and 6. The largest Beetle that I have in my collection, is, together with its horn, six inches long, and its body half an inch broad: if its wings be expanded, they measure seven inches.

I preserve with these in my cabinet, the Beetle called the flying Stag, or flying Bull; the *Lucanus*, or Stag-horned Beetle, the male whereof is horned, but the female, as is commonly asserted, has no horns. It is very remarkable in this as well as in the other insects of this kind, that their wings are hidden and folded as it were within little sheaths, from whence they have obtained the name of *vaginipennæ*, or sheath-winged. We likewise observe when these insects fly, that these little sheaths, or cases, wherewith the wings are at other times covered, are only elevated, and are not agitated by the motion in flying. There is nothing in this flying Stag more worthy of notice, than the proboscis or trunk wherewith it swallows its food: this food is a juice like honey, oozing out of the oak. This trunk is delineated among the figures of *Hoefnagel*, which are indeed the best and most accurate of all the figures I have hitherto seen. I can exhibit the method whereby the wings lie folded under the outer pair beforementioned; we are not to say they are in reality plaited, for they are rather contracted by the assistance of joints. I have observed that these joints are placed almost in the extremities

of the wings, and are moved by the help of peculiar muscles; hence a fluid likewise drops from them when they are wounded, which is not the case when wings are merely membranous. When I offered a little honey on the point of a knife to one of these Beetles, it followed me like a dog, and sucked the honey very greedily with its trunk.

Besides these, I can likewise shew twenty-one species of the *Capricorn* Beetles. These creatures have all wonderfully long horns. Some of these which I preserve are furnished with branching and prickly horns with knotty and short joints; and the horns of others are divided into very long, equal, and as it were knotless joints, some of them are somewhat situated in the middle, and are knotty again where they are joined to each other. The body of the largest *Capricorn* Beetle I have is above four inches and an half long, and the horns are as long as the body. I have likewise another above two inches long, which is covered with prominent party-coloured hairs like a Turkish carpeting, and makes a wonderfully beautiful figure: its fore legs are much longer than the rest. Moreover, I have a species of these flying *Capricorn* Beetles, which has very tender legs and horns; which, however, are considerably thick about the bending of the joints, and where the muscles are inserted. I have likewise a Wasp with this kind of knotty joints.

With these I preserve seventeen of the flying *Capricorns* with much shorter horns. Among these there is a kind of Beetle, that vibrates its wings with so much velocity, that it is with very great difficulty to be taken, and hence we have called it the flying Beetle. A thing extremely wonderful in this Beetle is, that its teeth are on the inside full of ramifications, by which structure it is indeed distinguished from all others. This Beetle flies in the day-time, and is the same with the fourth and uncommon species of the Stag Beetle of *Mouffet*.

I have moreover nine species of the said flying *Capricorns*, having still shorter and smaller horns.

I likewise insert the *Cicindula* or Glow-Worm, which is of the Beetle kind, in this order. It indeed resembles a flying diamond or little star; it glitters with as much light, when it is yet a Worm with six legs, as when it is changed into a perfect Beetle: in that state it must first elevate the sheaths or cases of its wings, or at least stretch out its tail or the extremity of its abdomen, in order to disclose its light.

Lastly, among my Beetles are thirty-two species, furnished with horns that have knobs at the tops of them. These globules of the horns are indeed constructed in a most wonderful manner, for some of them resemble bunches of grapes, others are like the leaves of an open

\* As all Butterflies are produced from Caterpillars, all Beetles are produced from Hexapode Worms. Some of these live on land, some in water; but they are in general all longer lived creatures than Caterpillars.

book, and others again are of various different structures. One may by the help of these horns very easily distinguish the male from the female. This is likewise the case in the nocturnal or night Butterflies, for their males may by this sign be very easily distinguished from their females, while they are still in the Nymph state. Of these species of Beetles some are oblong, others round, others short, others indented, serrated, party coloured, or variegated and sprinkled over as it were with dust or meal, rough with small tubercles, squares or cheques, or conspicuous by their spots and various other ornaments. Among these I can likewise shew a Beetle found in the nests of wild Bees, and delineated in Tab. XXVI. fig. III. Almost all these Beetles fly at night.

I refer also to this order the common dung Beetle, which has its horns terminated by knobs. I have two species of this, which, like the blue black Beetles, emit a bright and glowing light; one of them is conspicuous by a purplish gloss, like that of copper, on its breast and belly: the other glitters like green molten brass or copper delicately gilt, and indeed makes a very beautiful figure.

I have moreover four species of the Buprestes, or green, gold, and yellow Beetles, which are of an offensive smell; the horns of these are formed like those of the Capricorn Beetles, and the males are smaller than the females. I have likewise another species which smells like a rose.

I keep also four species of the Cantharides, to which I think the former in respect to their qualities and virtue are nearly related. I have likewise the eggs of the common golden yellow Beetle, which are like mother-of-pearl. Some of these insects have knotty horns, and others have them formed like those of the Capricorn Beetle. Among these I can shew a very beautiful Beetle, the body of which is adorned with little apertures and impressed furrows. This was given me by the very celebrated Dr. William Piso, formerly principal physician to his highness prince Maurice of Nassau.

I can likewise shew the Indian Beetle, the sheaths or cases of whose wings are of a shining black like ebony, and have many little indentings, wherein are seen little oblong feathers adorned with all kinds of colours, bright as any kind of gems whatsoever.

I likewise reckon the Curculio or Weevil in this order; which, from a Worm destructive to corn, is changed into a Beetle, and of which a magnified delineation may be seen in Redi. Aldrovandus describes a Weevil which is changed into a Butterfly, and indeed belongs to the same order, but to the third species of it.

I preserve also six species of Beetles with long necks and Hogs noses, which I therefore call flying Hogs, or Hog Beetles.

Next follows the Proscarabæus, Vermiculus, Majalis, or May-Worm, which, as well as others we likewise think referable to this order. We have three species thereof, two of which have

horns like those of the Capricorn Beetles; but those of the third are knotty. Goedaert has likewise described a Vermicle as belonging to the last, but he has very preposterously joined them together.

To these I add the Staphilinus, which, seeming of a middle nature between the Beetle and Scolopendra, can very quickly kill Earthworms with its teeth, and afterwards suck them. Goedaert has committed three errors concerning this insect, which we shall hereafter explain and set right. This insect and the Worm from which it is produced are likewise described by Mouffet. I preserve five species of it, together with the Worm and Nymph, which exhibits the parts of the future insects but somewhat obscurely. These insects have horns like those of Capricorn Beetles, but their wings are complicated in a very uncommon manner.

I preserve beside these four species of Beetles, which, whether they lie on their back or belly, can contract and press their head and breast close to the ground, and jump into the air: wherefore we think that the name of Grafshopper or Locust Beetle is a proper one for them.

I have likewise the small Beetle, which, having firmly and strongly fixed its foremost legs, and bent and put its head through the space between them, makes a continual noise in old pieces of wood, walls and ceilings, which is sometimes so loud, that, upon hearing it, people have been persuaded that nocturnal hobgoblins, ghosts, or fairies wandered about them. I think that this may be properly called Sonicephalus, or the noisy-headed Beetle. Other species of Beetles make a strange noise by rubbing their head against their breast, and others press their tail or belly close to the sheaths or cases of their wings, and by that means make also an uncommon creaking.

I have also four species of the Scarabæi Testudinati, or Tortoise Beetles, and some of their Worms and Nymphs. Goedaert has likewise described two species of these.

I also have the Scarabæus Aculeatus or stinging Beetle, with its tail formed like an aculeus or sting, which is not met with in any other of the Beetle kind.

Moreover, I can shew a very small Beetle with its Nymph, which is produced out of a Worm without legs, and is found hid within the outer skin of the leaf of the fallow tree. This Worm has its food there ready and sufficient for it, until it is at length changed into a perfect Nymph in all its parts. I have described the whole change of this Beetle, which is carried on very obscurely, in the fourth order, and have exhibited its figures in Tab. XLIV. fig. XII. XIII, &c.

I have moreover a detestable Beetle, produced from a Worm that eats the roots of ginseng, and is changed into a Nymph within that precious drug. The same is likewise found in old logs of wood.

I like-

I likewise keep those Beetles, with their Nymphs, which are produced from Worms that gnaw dried flesh. By the assistance of these Worms a skeleton may be easily cleared of the flesh that sticks to it.

I am also to add that I have a Beetle, the Worms of which eat the bag of the musk; I have, on account of the obscure manner of its changing, described it under the fourth order, and given its figure in Tab. XLV. fig. xxxii.

Lastly, I rank in this order the largest, the middling, and the smallest Hydrocanthari, or

Water Beetles, concerning which I have occasionally inserted various observations of the greatest importance to the naturalist. I preserve five species of these; the smallest is called the common water Flea, and water Fæmella. When this dives under the water, it has the art to enclose a little bubble of air very dexterously in its tail. I have represented the parts of generation of the Hydrocantharus, in Tab. XXII. fig. v. and the Worm called Vermis Sicarius, out of which it is probably produced, is exhibited in Tab. XXIX. fig. iv. and v.

*The third order or class of natural changes, according to the first species or method, which we have called simply the Nymph, exemplified in the Ant.*

## TAB. XVI.

## FIG. II.

No. I. **T**HE Ant's egg delineated in its natural size, or the Worm of the Ant in its first skin or coat, wherein it is called the egg. The first of these figures exhibits it magnified.

II. Is the skin beforementioned after it is cast. This is a kind of thin membrane, which the Vermicle or Worm of the Ant, quitting the form of an egg, throws off loosely, and rolls up as into an imperceptible point.

III. The Ant's Vermicle or Worm, imperfect in many of its parts, without legs, come out of its egg or skin, and here represented in the form wherein it is commonly found in the earth at that period; that is, having its head bent towards its breast. Figure II. exhibits a microscopic view of it.

IV. The Ant's Vermicle or Worm having attained its full bigness; that is, when all the limbs and parts proper to the Ant are already increased under the skin, but still lie hidden. Figure III. gives it as seen under the microscope.

V. The former Vermicle or Worm, having cast its skin and exposing to view all its parts, which were before hidden; It should therefore be now called a real Nymph, whose limbs are swollen with a fluid matter, as will be made more evident in the explanation of the fourth, fifth, and sixth figures, which exhibit the same state of the creature magnified, together with its several parts.

VI. The same Worm now come into the state of the Formica or Ant, as will be more accurately and largely described in the subsequent explanations of the figures.

## TAB. XVI. FIG. I.

The Ant's egg magnified, perfectly smooth and equal, distended, glittering, and without any annular divisions. This is naturally so small that when placed on a black ground it is scarce visible to the naked eye. This must be well observed in order to distinguish the true or real egg of the Ant.

The Vermicle or Worm of the Ant delineated larger, and presenting its head and mouth, together with the twelve annular divisions of its body. The head is bent towards the breast; and if the Worm be touched or moved in the least, it always contracts itself in that manner. Though this be a real Vermicle, yet it is commonly called the egg of the Ant. But this appellation proceeds from the grossest ignorance, since it palpably is a real creature, having life and motion, though it is yet without legs: it does not bear the least resemblance to an egg, nay it is sometimes larger than the Ant itself. But such is the ignorance of those persons who seek for these Vermicles and expose them to sale in the market: they are bought there in order to be given as food to various kinds of birds, and they are very greedily eaten by them.

## FIG. III.

I here exhibit the method whereby the Vermicle or Worm beforementioned leisurely and quietly undergoes its natural change; the blood and other humours insensibly swelling about the breast and near the head, and by that means the creature itself becoming thicker, larger, and more swollen: by this means at length loses all its motion, that is when it has cast its skin, and brought to light its limbs, that were before hidden.

## FIG. IV.

The same Vermicle or Worm, having cast its first skin, and presenting to view all its limbs and parts, which were before hidden under the skin; hence it is in this state called a Nymph, which I represent magnified, and reclining on its side.

## FIG. V.

The same Vermicle, lying on its back, is in this figure expressed magnified.

FIG. VI.

The same Vermicle or Worm is here again exhibited, and all its members are distinguished by letters annexed: hence it is indeed very evident that the Nymph is the real insect, but still destitute of motion in its limbs. This it enjoys, when it acquires the perfect form of the insect which it now represents.

*a a*, The two eyes in the head.

*b*, The teeth.

*c c*, The horns, which are folded near the legs upon the breast.

*d d*, The first pair of legs folded under the horns.

*e e*, The second pair, conspicuous under the first.

*f f*, The third pair, which are laid on the belly.

It is likewise seen in what manner, all the strong joints of these six legs are laid on the breast between the horns.

*g*, The annuli or rings of the abdomen, together with the margin or border on each side. But this is more manifest in the fourth figure, wherein that margin or verge, as well as the little swellings of the loins, are more distinctly exhibited, and at the same time it is seen how the body is all folded up and bent.

The creature in this form is, as I have observed before, the real Nymph of the third order, according to the first species or method of transformation, which clearly and distinctly exhibits all its parts and limbs without exception, so that all those parts may be seen in it, which are afterwards found in the common labouring Ant, whose Nymph it now properly is. This Nymph is therefore the Ant, and the Ant is a Nymph, but the Ant hitherto lies as it were hid under a peculiar disposition of its limbs; and this is the principal difference.

When this Vermicle or little creature cast its skin for the last time, then all its limbs and parts are very white like curdled milk, and are fluid as water; so that under this form it ought to be considered as if it lay yet in its egg, since it is there disposed in the very same manner, and is as properly a Nymph. The only difference is, that in the egg its limbs, though certainly existent, are not visible; though on the contrary they manifestly appear, when it is a second time reduced to this condition, so like that of an egg. Hence this little creature is twice, as it were, a foetus, twice in its egg-state, and twice hatched or born. But the life it leads is not in all its circumstances the same; it differs indeed very much, for it appears in the first state like a poor and miserable Worm; but the second time, which is in some measure its renewal and regeneration, it is formed into a perfect creature. This process is formed in so remarkable a manner in Butterflies, that we see therein the resurrection painted before our eyes, and exemplified so as to be examin-

ed by our hands; hence the Italian poet said most truly,

Non v'accorgete voi, che noi siam vermi,  
Nati a formar l'angelica Farfalla.

That is,

Dost thou not know we Worms are born,  
Angelic Butterflies to form?

We must further observe, that the writers of natural history ancient and modern, Aristotle, Mouffet, Harvey and others, who have called this change in the Aurelia an egg, have not wandered entirely out of the path of reason, provided their words be taken in the sense now mentioned. I would however have it observed, that they must be said to have really deviated from the truth, in that they have not annexed the signification mentioned in this place to their Aurelian egg, but have proposed it as a real and simple egg, without any respect to the essential parts. This cannot totally be overlooked by those, who labour cautiously to investigate the natural changes in the insect tribe.

The head, the breast, the belly, and the rest of the parts of this insect are invested with a thin kind of membrane, and are so very closely surrounded by it on every side, that even the extremity of the eyes, horns, teeth, and legs, are enclosed in it, together with the rest. However these lie in a loose manner over each other, nor are they united or connected to one another by an uniform cutaneous crust, as is the case in a particular manner in Butterflies. The membrane, which encloses the parts of the Nymph of the Ant is not every where of equal thickness, indeed least of all where the limbs are close or applied to the body near the breast; but where they are not so closely laid together, as in the extremities of the legs and horns, there the investing membrane is equally thick in all its parts. This is very seldom observed in the Aurelia, nor have I ever seen more than one example thereof in the Chrysalis of the swift Butterfly, the trunk of which is in part distant from the body; for there the investing membrane is observed to be every where equally thick, as may be seen among the figures of the Rhinoceros Beetles, in Tab. XXIX. But this is uncommon in Chrysalides, though it is constantly the case in Nymphs.

Passing these considerations over, it is manifestly evident from hence, that between the limbs, which are seen and represented in the Ant's Nymph, and those which appear in the Ant itself, there is no other difference, than that the appearance of the parts is somewhat more evident and plain in the Ant, but in the Nymph somewhat obscure. We must observe that the same thing holds equally in the Ant's Vermicle or Worm, which hides the limbs and parts under the skin that is not yet cast off. For in reality the egg, Worm, Nymph

Nymph, and Ant, are all but one and the same creature variously cloathed, and lying under different yet accidental forms. Therefore the Ant, that I may express the business with sufficient accuracy, is covered or surrounded in the beginning, when it is an egg, with an oval or spheroidal skin; and afterwards, when it appears under the form of a Vermicle or Worm, is covered with an annular and hairy skin; and thirdly, when it is a Nymph, and is found wrapped up in a divided and articulated veil; until, fourthly, it at length casts this skin, and afterwards retains this its last form, wherein it is a perfect insect, stript of all its integuments; is still the same Ant, in this variety of appearances: so that having thus, at certain distances and stated times, cast off all these coverings, the creature is perfect, and is never changed more. This must be in the same manner understood of all other Vermicles or Worms which have no legs; nay, of those also which have legs, that is, of such as so long and so often change their skin, until at length they no longer change their form, but become perfect insects, afterwards procreating their species in the same order.

When this Nymph casts its last skin, many remarkable changes are observed; the eyes are altered in the head by a slow accretion, and change colour from white to black; the horns, the legs, and the rest of the body; are more and more discoloured; a superfluous moisture is exhaled from all the parts, the limbs, which were till now without strength and motion, begin to move, and at last the investing skin is disengaged from all those parts; and then, and not before, this Nymph is called an Ant.

FIG. VII.

In this figure the Ant is represented under that form in which it shews itself when it has cast the last skin. All the obstacles which impeded the sight in examining its parts, are now removed. Hence we may see the Ant no longer covered or veiled but in its real form; nor is it after this last operation, during its whole life, further augmented or changed; as it has attained its full maturity and the greatest strength of life. The same thing likewise is found in the same manner in all other insects subject to these changes, for none of them are ever increased or changed, after having cast the last skin. Hence, doubtless, the reason may be assigned, why we see these insects never become larger in other countries than in our own, unless they are of a different species; or are such as eat somewhat more plentifully, while they are in the form of Worms and Caterpillars; for by this means their bodies may become something, though not much, larger than usual, as we have shewn elsewhere.

By the power of insensible perspiration, the Ant's skin after all these changes is grown very hard, and becomes as it were horny, though it was some weeks before the last transformation,

tender and fluid like water, so that the creature could not stir one of its parts with even the least motion. In the more conspicuous, that is, in the larger Nymphs belonging to larger insects, this change is still more considerable than in the Ant's Nymph: for their skin which was in the beginning of the change likewise very soft and tender, becomes in a few days horny and as it were bony, as shall be hereafter explained in its proper place in the Nymph of the nose-horn Beetle, which likewise belongs to this order.

It will be now proper that we exhibit in figures the limbs and parts of the Ant, in the same manner in the Ant itself, as we have before shewed them in its Nymph. To this purpose I have allotted this seventh figure, wherein I represent the common labouring Ant, such as is usually found in the gardens and pastures all over Holland and elsewhere. I here delineate the Ant magnified in such a manner, as it very cautiously carries the Worm or Vermicle in its mouth, or between its two teeth, without the least danger of hurting it, Tab. XVI. fig. VII. *a*. These teeth of which the Ant has only two, are more properly jaws, an upper and a lower, which hang crooked or bent on the outside of the mouth, and have seven ferrated incisions or divisions, serving as so many particular teeth. This may be clearly seen in Tab. XVI. fig. XI. at the letter *a*. Moreover, the divisions of the head, breast and belly may be distinguished in this state much more accurately than in the Nymph. The eyes are very black, Tab. XVI. fig. VII. *bb*, the antennæ or horns under the eyes are of a faint red colour *cc*, and are composed of twelve horny joints; the first of which, that immediately under the eyes, is very long: but all these joints are covered or surrounded by bristly hairs. It is likewise shewn very distinctly here what form and structure the head and thorax are of, and that they are invested with a horny, striated or furrowed, crooked, and indented skin. This skin resembles the fibrous joints of the wild pines, when they are cleaved or cut, where it is knotty. The construction of this furrowed skin is seen yet plainer in the Ant exhibited in fig. XI. The incisions of the thorax, fig. VII. *d*, are divided into six sharp-pointed prominences, which become more conspicuous backwards towards the loins. The loins themselves consist of three knotty vertebræ or joints *e*, and are every where set thick with bristly hairs. Underneath at the thorax are seen strong hairy legs *ff*, each composed of four joints; the last of which, or that properly called the foot, is divided again into smaller joints, and the last of these is armed with two claws.

The abdomen or belly, the colour whereof is somewhat more red than the rest of the body; this being of a light red, shines like a looking-glass, and is surrounded with bristly hairs *g*. I call this creature I have been describing the working Ant; nor do I think it is pro-

provided with either male or female organs, as I shall demonstrate to be the case in the Bees; since it seems to be designed by the most wise Creator for labour only, and to carry, remove, preserve and nourish the young of the others.

FIG. VIII.

To make this history of the Ant as complete as in my power, I have here likewise delineated the male Ant in its natural size.

FIG. IX.

I delineate the same magnified in this figure, both because the limbs of this creature may be the more conveniently described, and that the differences as well as agreements between one Ant and another may be the clearer or more evidently explained.

It appears then that the teeth *a* and antennæ or horns *cc*, are in this, in every respect, like those of the working Ant; only that the teeth in the males are somewhat less than in the working kind: and this is likewise observed in the female Ant. Something like this is also seen in the teeth of male Bees. The eyes in the male Ant are much larger *bb*, and surpass those of the working and female Ant; and this holds likewise in the males of Bees, Ephemeri, and other insects.

Besides these, three points or dots like mother of pearl are in this seen in the head; which I have likewise observed in Bees and Flies. They are indeed remarkable eyes of a distinct kind from the others, and make a peculiar difference between this male and the working Ant: but there is still a greater difference in respect to the breast, for besides that it is in this disposed and painted in a quite different manner, there are also four wings *dd* very conspicuous on it, whereof the two first are nearly twice as large and strong as the two hinder ones. The structure of the loins *e* and belly *f* is likewise very different from that of the working Ants: and the whole body of the male is larger, and of a darker colour; as is likewise the case in the males of Bees.

These males of the Ants, which differ in respect to their Nymphs from the two other kinds, the latter having their wings regularly disposed and folded, are not to be found at all times of the year among the swarms: hence it is probable that the working Ants kill them, when the business of generation is performed. The Bees we know act in this manner by their males, which are called drones. And this is probably the reason why the males are so frequently ill treated by the working Ants, as I have often seen.

These males of the Ants regard nothing but generation, and therefore are admitted into that republic only for this single purpose, to propagate their species. The same thing exactly happens among Bees, with whom the Ants

have indeed many things in common; there is no superiority or pre-eminence among either Bees or Ants; love and unanimity, more powerful than punishment or death itself, preside there, and all live together in the same manner as the primitive christians anciently did, who were connected by fraternal love, and had all things in common.

FIG. X.

I here exhibit the female Ant in its natural size.

FIG. XI.

The female Ant is here again represented magnified. She is naturally not only longer than the working Ants and males, but also much more bulky and corpulent: it is easy to discover by dissection very small, white, oval eggs in her. She has likewise teeth *a*, eyes *bb*, and horns *cc* like the former; and in the hinder part of the head towards the neck, she is furnished also with three small eyes, like mother of pearl; so that in this respect, the female remarkably differs from the working Ant, and is partaker of the privileges and benefits of the male. The female Ant is likewise distinguished from the two former kinds, in respect to the structure and form of the thorax *d*; this part in her being somewhat browner than that of the working Ant, and somewhat redder than that of the male. There is scarce any difference in the legs *ee*, or in the feet *f*, nor about the belly *g*, only that this is larger because of the eggs that are to be lodged therein: all this is evident in the figures. Whether all the species of Ants are so constituted as to have in each community a great many working ones, some males and some females, I cannot of a certainty affirm. I am however positive, from my own observations, that this is the case in the most common species of Ants, which are found in the fields and vineyards in Holland and about Amsterdam; for I have there frequently taken them out of the ground, and from among the roots of the grass, and brought them to my chamber and kept them alive by proper food to complete my observations.

To do this I used the following method: I provided a large deep earthen vessel, and about six inches from the brim or verge of it, I put a bank or artificial rim of wax, and then on the outside of the circumference of this I poured water, in order to prevent the Ants confined in this enclosure from getting out. I afterwards filled the cavity of this dish with earth, and therein placed my little republic of Ants. It happened that in a few days the Ants laid their eggs in this vessel: from which were produced those Vermicles or Worms, erroneously called by the vulgar, eggs, which I have before described. It cannot indeed be expressed in words, with what industry and solicitude these working

Ants take care of the young ones, and with what love they feed them: they carry them with amazing fondness between their jaws from place to place, nor do they omit any thing necessary for their support or nourishment.

When the earth wherein they lived grew dry, I observed that they carried their young ones to a lower part and deeper under the surface; but when I poured a little water thereon, so that the mould became moist, it was then wonderful to see how they all, stimulated with love, endeavoured as much as they could to take away their young and carry them to a dry place. Nay, I observed that after I had poured in a greater quantity of water, they with all their might carried them to the highest part of all. If I only moistened the dry earth, then they likewise carried their young out of the damp part. Thus I had opportunities to see very distinctly, that the young ones moved and sucked nourishment out of the fine and small particles of the earth.

I often endeavoured to nourish these young Worms, without the assistance of the working Ants, but I never succeeded. Nay, I could not exclude even the Nymph of those Vermicles,

which the Ants likewise carry daily from place to place, without the assistance of the working Ants. I gave them sugar, raisins, apples, pears, and the fruit of other trees and plants. I never found that they built those artificial nests mentioned by some authors, and therefore I apprehend that is to be understood of some other species. Even in those places which they spontaneously inhabited, I never discovered any work of art performed by the Ants of this species; only broad passages and crooked ways, designed for carrying their young from one place to another. I have observed likewise that they follow the sun's motion, and convey their young according to the course that luminary pursues: this I have observed in the fields where they inhabit little hillocks of earth; for they there carried their young constantly to those parts where the ground was warmed with the sun's rays. I never observed that Ants provide themselves any food for the winter, although this has been so strongly asserted: and therefore I think they eat nothing whilst the winter is severe; as is common with many insects, and in particular with some species of Bees, which in the midst of winter abstain from all kinds of food\*.

*Of certain other kinds of Ants, some of which spin like the Silk-worms.*

**B**ESIDES the species of Ants hitherto described, I have seen five other kinds, some of which I preserve in my collection. The first species is very large, and was brought from the Cape of Good Hope. I have delineated it in Tab. XVI. fig. xvi. of its natural size. Its head, eyes, horns, teeth, breast, legs and belly are seen there as they naturally are. It is of a bright red colour: but whether this was the working Ant or the female of that species, I could not discern: as it had no wings I am certain it was not a male. I am likewise ignorant of the disposition and nature of this species of Ants.

The other species of Ants, which I have seen in Holland, is flesh coloured, and of such size and form as is expressed in fig. xiv; but I cannot now determine whether this was a working Ant or a female. I met with this species at Honteslard; where I examined in a wooden bole its eggs, Vermicles, Nymphs, working Ants, females and males, in great numbers mixed together in some mould, where they were set in order to serve some birds for food. The males exceeded somewhat in bigness the Ant I expressed in the figure, and had four membranaceous wings. But what de-

served particular notice in this species was, that the Nymphs were all enclosed in a sheath or case, which, when the working Ants carefully preserved, carried here and there between their jaws, made a very agreeable figure; for those Ants carried on this occasion a bag bigger than themselves. I experienced then for the first time that the Vermicles of Ants, as well as the Silk-worms, form a bag or follicle, and that those that are enclosed in it are changed into Nymphs. This web was of an oblong oval figure, and wrought with delicate and fine threads about the body, being of a rusty iron-colour, and when I opened it, I found a Nymph in the inside. I likewise carried some of these enclosed Nymphs with me to Amsterdam, which after some days gnawed their way out of their webs, and produced some male Ants: this happened on the eighteenth of July. I gave the figure of such a sheath or case entire, and in its natural size in figure xii. and a section thereof in fig. xiii.

The third species of Ants that I observed, was somewhat less than the common Holland Ant: this does not spin. I have given the history thereof at large. Its body was much blacker and brighter than any of the other

\* Our author is not single in his opinion that Ants do not eat in winter; Leewenhoeck appears to be of the same mind, and imagines that they spend that season, like Dormice and many other sorts of animals, in a state of sleep; and this seems to be reasonable, as Ants are observed to move more slowly as the cold weather advances. Mr. Gould also agrees with Swammerdam that the Ants do not make any provision for winter. But though our author here did not observe any such provision to be made by those he examined, yet probably some other species may, and other naturalists tells us very wonderful things on this subject; and further, this opinion of their providing for winter seems to be countenanced by the royal and inspired naturalist, Prov. vi. 6, 7, 8. However, if it be true that they remain in a state of rest during the winter, the provision they make may be for their young, for whom their affection is wonderfully remarkable.



species. I found these Ants running on some willow-trees, and they seemed to live only there. But I have not been hitherto able to see their males.

The fourth species was again less, but of a thicker and more reddish body; nor have I ever found its males. The fifth species was of a more slender, and at the same time somewhat longer body than the fourth: I saw the males of this with four wings. The sixth species that I observed was wonderfully small; it was of a bright red colour, had two eyes, two horns, two jaws, and six legs; and it was, like the rest, divided regularly into a head, thorax, and belly. I have not yet seen the males of this species; and therefore I only represent the working Ant belonging to it in its natural size in figure xv. These little Ants are seen only about the middle of the month of July; but then some hundreds appeared, and they yearly at stated times infested the cheese-loft and pantry, notwithstanding all our endeavours to drive them away. After October not one of them was to be seen until the next year. It seemed to us that they came out of a wine-cellar, and crept through the small clefts between the beams and timber planks to the place where they could find food. This, which was first conjecture, we afterwards found to be true; for when the cellar had been kept full of water for some months, we never afterwards perceived any Ants.

What merits particular regard in this history is, that these Ants remained so long as to the middle of July in the earth and sand, and then first came in sight; but after October all of them betook themselves again to their little cells. Whether they lived in the mean time without food, or whether, as is common with many insects, the old ones died, and young ones were produced out of the remaining eggs

and Nymphs, I cannot determine: but from the analogy of other insects I can easily judge that the manner of these creatures living was very singular and uncommon. Besides, it is probable that the males of these Ants were destitute of wings, since I have for some years made my observations on them, but could never find any whatsoever that had wings. I would not, however, aver this for truth; because nature is wonderfully consistent with herself in all her works. Dr. Padbrugge has informed me that he also observed many species of Ants in the East-Indies; and particularly that there were white Ants there, less than the common Dutch ones; and that they were very destructive of food and some kinds of merchandise. I have this year received from the same gentleman a very beautiful figure of the black spotted red Ant, which he sent me from the island of Ternate: it is somewhat less than the Ant of the second species which I have described above. The largest Ants this gentleman has observed he assures me were as long as the first joint of the thumb; and their nests were six feet long in circumference and were divided into various particular cells: these places of reception were sometimes all found under the earth, and sometimes mostly prominent above the surface; but they were always framed with an amazing art. I cannot determine how this matter is, for Ants make no nests here: it is enough for me to give a faithful relation of what I have been informed, and particularly to recommend the authority of this curious gentleman. He likewise sent me the figure of a Frog with that of the red Ant; its hinder legs are cloven, which is very uncommon, and probable the case only in Frogs that live on dry land. This will be rendered more certain by accurate researches.

*The very curious history of the Nasicornis, or Rhinoceros, or horned Beetle, illustrated with accurate figures.*

#### I N T R O D U C T I O N.

“WE admire the shoulders of Elephants  
“ that carry towers; the necks of  
“ Bulls, and the furious tosses from their horns;  
“ the ravages of Tigers, and the manes of  
“ Lions: but we should know that nature is  
“ no where more complete and perfect than  
“ in the smallest objects.” This is a very just  
sentence pronounced by Pliny in his far distant  
age, though the wonderful works of nature  
were at that time but obscurely known. We  
should therefore, surely, endeavour to search  
into nature near at hand, and where she is  
conspicuous in the most minute things, or her  
miracles will never be discovered. Then will  
it be made clearer than the sun at noon, that  
as many natural mysteries are hidden in the

narrow compass of the most vile and contemptible of animals, as in the vast viscera of the largest. In order to elucidate the incomprehensible power of nature, it must be investigated in the smallest creatures. Nor let the extreme minuteness observed in these, deter any from the inquiry; it should rather encourage us to be more diligent: for the less the work of nature is, the greater and more magnificent it afterwards shews itself in those at first invisible parts, and exhibits to our sight and touch all those things which before eluded our senses, and our most acute intellectual faculties. The greatness and majesty of God are conspicuous only in the works framed by his infinite power. But as our eyes are not  
sufficiently

sufficiently acute to view these things perfectly, it is necessary to invent and find out all kinds of assistances and artificial contrivances proper for assisting the sight, by the help of which these things may be distinctly seen. By this means, and no other, we can attain to know with what order, measure, rule and wisdom God's creatures are all formed, and how they depreciate all the work of human art and industry, the latter not being able to bear too near an inspection. The best of them only express the external ornaments, wherewith the surface as it were of God's works are covered; and they are therefore destitute of that true food of the mind, wherewith the works of God abound. The more accurately these are examined, and the more perfectly they are explained, the more wonderful, lovely, and adorable they always proclaim their Creator. Though many works of art, which derive their powers from nature and the effects of regular motions, perform wonderful things; yet when they are more intimately examined and investigated, they immediately betray the imperfect condition of the artificer. Therefore all the masterly touches of Apelles, compared to the very refined lines of nature, are only rude, unpolished and coarse; and all the splendor of tapestry finished by human art vanishes, when only one of nature's works contained in a single pulmonary tube of an insect is produced: who can delineate even this, the least of these wonders, with adequate dignity? what genius is able to describe, or what industry can investigate it? our eyes and fingers, and all the powers of our understanding are deficient in this respect, as will be evident from what I shall presently shew

concerning the lungs of the Rhinoceros or nose-horned Beetle; and thus it will be at the same time most strongly demonstrated, that the works of God are most wonderful in the smallest objects. Thus I conclude this introduction, crying out with the royal prophet: "I praise thee, because in beholding thy works I am transported with admiration: I celebrate thy wonderful works when my mind is most enlightened."

Though I shall attempt in the following pages to describe to the praise and glory of the supreme being, the whole change, or, if I may so call it, the transfection of the nose-horned Beetle, consecrated of old to Mercury, and expose to public view its origin, life and propagation; yet I would not have any one think, that I intend to give its accurate and perfect history. As I happened to be dissecting one of these Beetles in July last year, in the presence of the very learned and experienced physician Dr. Matthew Slade, I discovered the wonderful construction of its general parts. I was thence led to examine into its origin, and made a dissection of the Worm out of which it is produced. This having been the occasion of the history that I shall here exhibit, it will contain no more than an accurate narrative of those things, which I then and afterwards remarked in regard both to the internal and external parts of this insect. But if God gives me health and leisure, I shall probably at some other time prosecute this subject much further, though what I now advance is sufficient to satisfy the most curious adorers of divine miracles, being of the greatest importance and most wonderful dignity.

## C H A P. I.

*Of the places wherein these Beetles live: of their generation, eggs, Worms and food; how long they are feeding; with various other uncommon incidents.*

**A**S to the places wherein the Rhinoceros or nose-horned Beetles commonly live, they are most usually our docks and yards, where they lie among the chips and saw-dust, and in the ashes of reeds which are burned in tarring of ships, and among the rubbish of kitchen gardens; in the remains of the sumach wherewith leather has been tanned; as also about old trees, and in rotten wood.

These Beetles generate in the months of June and July; the male, Tab. XVII. fig. 1. alone has that remarkable horn on his nose, whence the species is named nose-horned; the female is somewhat larger, fig. II. the male gets upon the female, and with the horny or bony part of its penis, as with two crooked claws, fixes himself upon the horny or bony part, which constitutes the vulva of the female; by this means the female cannot escape, and the male in this manner injects his sperm,

which it has in great quantity, and so impregnates the female. In the same manner the male Butterfly of the Silkworms holds its female fast by the assistance of two crooked and horny claws, fixing himself on the horny or bony ring, in the hinder part of the female's body, and by this means engenders with her, as not being then able to get away from him. The males are so very violent on this occasion, that they will fix themselves to the females after they are dead; and they are hooked so strongly together, that you may tear them to pieces easier than separate them.

After coition the female Beetles in this species penetrate deeper into the wood or other matter; they inhabit and lay their eggs there, not in heaps but scatteredly and at distances. The annexed figure III. exhibits the magnitude of these eggs, though some of them *a* are often observed to be greater than others *b*, as  
one

one female is larger than another. The egg is of an oblong round figure, and of a white colour, and has a thin, tender, membranaceous, flexible and soft coat or shell; it contracts very easily with air, and corrugates or wrinkles up when the moisture evaporates; the same thing happens in Hens eggs when they have not the hard or outer shell. It is difficult to say in what space of time these eggs ought to be hatched by the mere force of the sun and heat; but about the end of August we always find the young Worms or Vermicles, fig. iv. which have come from these eggs. If one of these little eggs be dexterously opened with a small pair of scissors, a tenaceous and whitish moisture flows from it. The first, and indeed a very rare, change that I observed in these eggs, exhibited two perspicuous ruddy points, which were transparent through the coat of the egg, and were likewise surrounded on each side; with some other spots of the same kind. I observed indeed afterwards, that the two former were the teeth of the Worm yet enclosed in the egg; and that the lateral points were the apertures of the pulmonary pipes. It is extremely worthy of regard how hard the teeth of this Worm are, even in the egg; so that this insect, whose teeth attain their perfection before all the other parts, is able as soon as it comes to the light to feed itself, and by gnawing and devouring the wood wherein it is placed to nourish itself. The manner in which this Worm is disposed within the shell of the egg, likewise deserves great consideration; it lies there folded up, so that its fundament is between its teeth, and the latter rest on the former. The body being thus folded up, the legs are very curiously disposed on each side at the verge of the belly, and one may see that their claws insensibly acquire a colour, and become stronger through the coat of the egg. The Worm itself, in due time, breaks open the shell of its egg in the same manner as a chicken, and creeps therefrom to the next piece of wood or other substance. The Worm\*, when thus fresh excluded, fig. iv. is very white; it has six legs, and a corrugated or wrinkled body covered on all parts with hair; but its head is then bigger than its whole body, which is a very wonderful thing, and indeed holds likewise in other creatures in some degree, not excepting even the human species. As the head of this Worm is horny or bony and extremely hard, the all wise-Creator therefore forms it first, lest the other softer and more humid parts, which therefore increase faster than the bone, should precede it in growth; and thus has contrived that all the parts should attain their determinate size and due form at the same time; and therefore the most wise providence of God here again becomes obvious to our senses. The

colour of the head becomes by degrees yellowish, and after this somewhat red, until it is at length changed into a brownish red. This Vermicle or Worm has two teeth or jaws, the tops of which are likewise cut and divided into smaller teeth. These teeth deserve particular consideration, because they are so large and strong, that one may certainly very properly call them jaws. They may however be much more distinctly seen in the Vermicle or Worm, whilst it is still white and lies in its egg, than when it has been for some time out of the shell and is grown bigger.

If one views these eggs from time to time with great care, whilst the Worm still lies in them, the heart beating on the back presents itself to view. If the same eggs be then opened, they exhibit, besides the outmost coat or shell, on the inner part, some other fibrous and membranaceous little parts, and two very singular ones on each side, situated where the legs are placed, towards which are detached a great many white little fibres. These little parts are like those umbilici or marks at which Pease and Beans are fixed to the pods. But this similarity does not hold in respect to the office of nutrition, since there is no such thing in eggs, for they carry their nourishment enclosed within them.

Among all the eggs of insects, of which I have various species in my collection, I know none worthy of greater attention than those of Earth-Worms, for these insects have a red blood in their vessels, which, whilst the Worm still lies in its egg, may be observed to move, and is wonderfully carried about in the heart itself. This is the reason why I take the present occasion to mention this singular phenomenon; though the egg of the Earth-Worm is not larger than that of the Rhinoceros-Beetle, yet the former creeps out of it in form of a Serpent, and is many times as long as it appeared to be in the egg. I saw two species of these eggs, of different sizes, and of an oblong roundish figure, uniting on each side in a prominent point, and therefore one would be inclined to say that this microcosm or little world had two poles, and that one may hope to discover a great many wonders therein. They are of a pale yellow colour, and have a tinge of green. In the spring these eggs are found dispersed here and there in the earth. In order to hatch them properly, I put them into a dish, and covered them with white paper which I always kept wet. If any person does this carefully in his chamber every day, he may very easily discover these wonders. In the same manner I have also hatched the eggs of Snails. I have likewise two eggs as big as those of the nose-horned Beetle, but covered with a perfectly hard shell like a Hen's egg, which is indeed very rare.

\* To the Beetle kind we are to look for that destructive insect mentioned in the scripture by the name of Kankerworm, and coupled with the Locust for its devouring nature. The common mealy Beetle which flies in the evenings about hedges, and which children play with, calling it the Miller Cockchaffer or Dor, is common to the East as well as Europe, and is probably in its Worm state the creature meant in those passages. The Worm hatched from the egg of this Beetle lives under the surface of the earth, and feeds upon the roots of corn. A few years since it almost created a famine in some parts of England.

Whoever would preserve these and such kind of eggs must pierce them with a very fine needle, press out the contained humours, and having afterwards blown them up with a small glass tube, he must fill them with a little rosin dissolved in oil of spike. I have now some eggs taken out of the ovary of the human species and kept in this manner. These I discovered in the year 1666, and from hence I began to suspect that I should have found eggs in all other animals; nor was my reasoning in this point without its foundation.

Let us proceed in the history of this insect. As soon as the Vermicle or Worm of the nose-horned Beetle has crept out of its egg, it immediately finds its food ready prepared for it; that is an old tree growing rotten, or the remains of the sumach, for in those the egg is deposited by the mother Beetle. Nor does she afterwards take any further care of her egg or of the Vermicle; this creature therefore, though much less in bulk, resembles the tall Ostrich, whereof the inspired writer says, Job xxxix. 14, 15, 16, 17; "Which leaveth her eggs in the earth, and warmeth them in the dust, and forgetteth that the foot may crush them, or that the wild beasts may break them. She is hardened against her young ones, as though they were not hers, her labour is in vain without fear: because God hath deprived her of wisdom, neither hath he imparted to her understanding." Many are also of this disposition, though some of them take great pains to deposit their young among proper nourishment. However negligent and careless this Rhinoceros-Beetle may be in providing for her issue, yet we observe in others a much more admirable innate sense or instinct, by which they maintain and bring up their young after they are out of the egg. Do not the laborious Ants and careful Bees teach this lesson? the latter daily nourishing their offspring with banquets of the purest honey.

Other insects enclose their young or eggs in rotten trees, as the celebrated Redi well ob-

served. Some again hide their future progeny in the shoots of fruits and plants, which for this purpose they first pierce with sharp instruments, given them by God for that purpose: lastly, others leave or place their issue in the bodies of living animals, or in other inaccessible places, in order to find natural nourishment ready as soon as they are out of the egg, for it is not allowed them by nature to take any further concern about their progeny.

To this place might be likewise properly referred those particular observations which I have made on the excrescences of oaks and other trees and plants. But since we shall professedly treat of these hereafter in their proper place, we shall remit the reader thither, and now rather prosecute the history of the Rhinoceros-Beetle.

How long the Vermicle of this Beetle is in nourishing, until it acquires a strength proper for undergoing its change, I cannot easily determine: for some years before I knew that this singular creature was produced from those Worms, I kept them above a year in the remains of sumach and earth in a glass bottle, and during all that time observed no change in them. I have likewise, not long since, kept such a Worm a whole year in the same sumach wherein I found it, without wetting it; however much this moisture may be requisite and necessary to sustain the life of these Worms, this I mention only to shew the strength of their life\*. And hence I also conclude, that if this Worm can live for a whole year, after being come to its full growth, surely the younger Vermicles or Worms that are not yet grown to perfection, must take some years to their increase, before they attain this state: and it is certainly an admirable thing, that even the Worm out of which the Ephemerus before described is produced, should require three years before it attains its change, though its appearance under this last form does not continue above five hours: this may be seen at large in the preceding history of the Ephemerus.

## C H A P. II.

*The name of the Worm out of which the Rhinoceros-Beetle is produced; also its external parts, disposition and motions. That it loves heat, and that it casts a skin; with other incidents tending to illustrate this subject.*

**T**HE Worm I have been hitherto speaking of, is described by Mouffet and other authors, under the name of *Cossus*, and is, when it is arrived to its full growth, half an inch thick and two inches long, and of a white colour; its body is very deeply wrinkled, Tab. XXVII. fig. v. *a*, and is divided in a beautiful

manner into folds or plaits. The whole body is composed of annular incisions common to insects, and to which authors give the name of annuli or rings; this denomination, however, does not seem so proper, when these annuli or rings are not composed of a horny or bony matter, as is the case in many beside these. On

\* We have an account of the strength of the principle of life in the beetle recorded in the Philosophical Transactions, which is altogether surprising. Mr. Baker, a person of undoubted credit, kept one of these alive under a glass, without any food, two years and a half, and it then escaped by accident. He had first attempted to destroy it by drowning it in spirit of wine, but it revived after repeated trials of this kind, though in one of them it was kept in the spirit a whole night.

each side of this Worm are seen nine reddish points or spots *b*, not exactly round, but somewhat compressed like the seed of the kidney-bean. These are the orifices of the pulmonary tubes, and hence I call them puncta respiratoria, or points of respiration. The first annular incision, which constitutes the head, has no point or mark of that kind: the second exhibits the first aperture of the pulmonary tubes, over which there is likewise a coloured spot *c* in each side of the body. The third and fourth rings again have no such spots or points, because, as shall be afterwards explained, the sheaths or cases of the wings, and the wings themselves, which the Beetle to be produced out of this Worm hides under these sheaths, increase in process of time in that part, and cannot be perforated. On account of those sheaths these insects are called vaginipennia, or sheath-winged. The fifth therefore and sixth incisions, and the rest that follow in order behind these, to the number of twelve inclusive, have each their points of respiration. The head, which is of a bright red colour, and somewhat rough, has several distinct parts, eyes, horns *d*, and teeth *e e*, but the lip is split in two parts, and is visible among the teeth: above these are placed the antennæ or certain prickly and articulated hairs, which lie as it were under the skin; these are very useful when the Worm is feeding. In Locusts likewise the same bristly hairs are observed, but more conspicuous, and they are of great use at the time the Locust changes its skin, and casts it off from the claws, teeth and eyes. It is not difficult to keep the Locusts alive, if raisins are given them to eat; for if these are put on a thread one after another, and hung up in a wicker basket, the Locusts will eat them even to the skin. The Cossus has six small legs *g*, three on each side of its body, of a yellowish red, furnished with claws and hair, divided into five joints, and placed at the second, third, and fourth annular incisions of the body, or the nearest to the head. The other or hinder rings of the Worms shine like a looking-glass, the skin being there extended and very smooth. Hence the surface is there of a transparent blue, and under it are seen some of the air-pipes, Tab. XXVII. fig. v. *b*, of a silver colour, making a wonderfully elegant and beautiful appearance. The rest of the skin terminated at the anus *i* is covered with fine and tender bristly hairs *k k k*. The motions of this Worm are sluggish, and all its actions heavy. Its greatest strength is in the head, breast and legs, for by the help of these, it immediately forms for itself another hole in the earth or other matter, whenever it is taken out of it. And when this happens, it bends its back very much, and gathers its belly as it were into a semicircular cavity, nearly in the same manner wherein I have delineated it.

It frequently happens, that the sumach or wood wherein these Worms live, grows by a natural fermentation warm in the same manner as moist hay, and at length becomes very

hot. The Cossi do not regard that, for the warmer their habitation is, the better they live in it; they have at these times much better health, and are more brisk and lively than usual, and if they are roughly touched, they are more quick and violent in defending themselves by biting; though these Worms are not otherwise of a mischievous disposition, but on the contrary they are very gentle and mild.

Whilst the Cossus becomes insensibly bigger, it sometimes changes its skin like the Silk-worm: but I have not yet learned from observation how often that happens. Before the Worm casts its skin, it first, like Silk-worms, also discharges itself of all its excrements, and then bending its body, it makes a new hole in the earth, that it may be able to cast its skin the more conveniently in a separate habitation. Nothing in all nature is, in my opinion, a more wonderful sight, than the change of skin in these and other the like Worms. This matter therefore deserves the greatest consideration, and is worthy to be called a specimen of nature's miracles; for it is not the external skin only that these Worms cast, like Serpents, but the throat and apart of the stomach, and even the inward surface of the great gut, change their skin at the same time. But this is not the whole of these wonders, for at the same time some hundreds of pulmonary pipes within the body of the Worm, cast also each its delicate and tender skin. These several skins are afterwards collected into eighteen thicker, and as it were compounded ropes, Tab. XXVII. fig. vi. *a a a a a a a a a a*, nine on each side of the body, which, when the skin is cast, slip gently and by degrees from within the body, through the eighteen apertures or orifices of the pulmonary tubes before described, having their tops or ends directed upwards towards the head. Two other branches also of the pulmonary pipes that are smaller, and have no points of respiration, cast a skin likewise, *b b*. Moreover, each of the eighteen points or apertures of respiration are likewise observed to open and dilate their orifices at the same time. If any one separates the cast little ropes or congeries of the pulmonary pipes with a fine needle, he will very distinctly see the branches and ramifications *c c c c* of these several pipes, and also their annular composition. The skull is then likewise divided into three parts 1, 2, 3. Its middle part shews the teeth *d d*, which are renewed and the old ones thrust out: in the middle of these is seen a lip *e*, and on each side there are prominent horns *f f*. Behind the lip may be seen the skull, terminating like a triangle in an acute point, on each side of which are seen the two other portions *g g* of the bone divided into three parts. The sharp-pointed or prickly antennæ are likewise changed, and from the eyes themselves is taken a transparent membrane. This happens likewise in Serpents when they cast their skin. The exuvia or cast skin exhibits six apertures, wherein the legs *b* were fixed: and the divisions or wrinkles, and little depressions

depressions of the skin are still plainly conspicuous. Nay, on the hinder part *z*, where the skin is twisted and complicated, whoever accurately examines the skin itself, may still observe the coat that was cast by the intestinum rectum. It is likewise remarkable, that the skull remains fixed to this cast skin of the Cossus; whereas the contrary happens in Silk-worms, whose skull always separates from the cast skin, except under the last change, when the Silk-worm is changed into an Aurelia or Chrysalis. The head and teeth of the Cossus, having lately cast their skin, grow white and become flexible and tender, though they are

otherwise hard as horn, nay, as bone; inso-much that when the Worm is provoked, it attempts to bite even iron. But what effect this change of the skin in the pulmonary pipes at length has in the Worm, will afterwards appear, when I shall at the same time shew more clearly, that there are more than eighteen principal branches of pulmonary pipes in the Cossus, as is likewise the case in Silk-worms. This may be likewise exemplified in the Worm of the Hornet, which has twenty points of respiration. But I shall now proceed to the anatomy of the Cossus.

### C H A P. III.

*The anatomy of the Cossus. The manner in which it is to be killed. Its blood, heart, fat, pulmonary tubes, throat, stomach, spinal marrow, and the nervus recurrens. Whether the Cossus is eatable. How it may be seasoned or preserved, with some uncommon observations.*

**I** H A V E various contrivances to execute the dissection of the Cossus, according to the different ends I proposed to myself in each dissection; but that which I use most frequently for this purpose, is to kill the Worm in spirit of wine, or to suffocate it in rain water somewhat more than lukewarm: after some hours I take it out again, and thus it not only loses all its motions, but its muscular fibres are never afterwards contracted, which would otherwise very much incommode the dissection.

When the skin is opened along the back, where the heart is placed, which is extended through the whole back, in form of an oblong canal, and appears about the lowest rings in the manner of lymphatic vessels; immediately after the blood, which is a watry humour or ichor, issues out at the wound, the moving fibres of the annuli or rings, Tab. XVII. fig. VII. come then in sight. These are indeed very wonderful to observe, and can scarce be well described, for they shoot over each other, from one ring to another, in a straight, transverse, oblique or decussated direction, and often join one another as by inoculation. Some of them are longer, some thicker, and some smaller than others, as I have endeavoured to represent in some degree in the figure just now cited. But the muscles are not so beautiful in any of the insect kind as in Snails, as may be seen in their history, and the figures illustrating it.

All along the course of the heart in the Cossus, similar moving fibres are likewise placed, which are inserted into the heart itself; and they, like so many different little ropes, expand and contract it. The external surface of the heart resembles a membranous oblong tube, fig. VIII. *a*, which is very narrow *b* about the top, and is likewise contracted like a knot about the middle of the body, and widens again *c*,

and at last is joined *d* very closely in the hinder part under the thirteenth ring. On each side of the heart are seen some blackish uneven points or spots, which render the heart, though transparent enough of itself, the more distinctly conspicuous.

If the incision be afterwards made somewhat wider, the fat appears, consisting of innumerable, very small, and as it were sandy, fig. IX. globules, which, when viewed with a microscope, seem to be again composed of innumerable and yet smaller particles, all which are supported by very thin and transparent membranes or coats, fig. X. *aa*, which are variously distributed through the body of the Worm, and with their number and diversity very much obstruct the sight of the internal parts. If this fat be viewed with a microscope, the pulmonary pipes *bb* appear to run up and down through it, and the fat itself is exhibited in form of minute, oily, globular particles *cc*, swimming between white, spherical, and membranaceous parts. But when the fat of the Cossus is received into a small glass, and placed on a burning coal, still covered with its ashes, then in roasting there issues out of it an oily white substance in great abundance, which being put on paper has the same effect that oil has, and when thrown into the fire it burns very bright; and therefore from all these signs, I conclude it is of the true nature of fat. This fat is not of a regular but various figure in its disposition, like certain pneumatic vesicles, which I shall hereafter delineate in the sheaths or cases of the wings. This, however, is to be understood only in respect to the division of these transparent coats, whereby, as a foundation, the fat is supported, for the figure of the particles of the fat itself is commonly spherical. In the Silk-worms, whose fat is yellow, it appears of  
a very

a very irregular form. When this fat of the *Coffus* is further examined, with the help of a powerful microscope, it appears of an unspotted whiteness, and is covered or surrounded with transparent little bubbles, almost like bladders: it is contained or enclosed in little membranes, and is a real oil or fluid fat; and hence therefore if these membranes be wounded a little with the point of a very fine needle, it easily flows out, and a drop of it then falling into water, swims on the surface like other fat. Whilst this fluid fat, discharged in this manner, and the white membranous particles are breaking, the object in general is thereby darkened, and the water becomes muddy, as if there was starch, lime, or chalk mixed with it; because the fat then divides itself into many little particles: but it is more beautiful to see this in the Nymph than in the Worm. The fat of larger animals, viewed with a microscope, is likewise observed to consist of very minute particles; which, because they are white, one would say are like grains of sand; however, they are not so transparent, and all of them seem to be almost of the same size, which is not the case with respect to sand. Therefore the globule composed of fat ought not to be considered otherwise than as a mass of little grains of sand fastened together, though every particle of fat is contained in its distinct membrane, all which break in pieces and fall to the bottom, when the fat is melted. In the first rudiments of calves and sheep, in the wombs of their parent, these small particles of fat appear even to the naked eye, without a microscope; for as there are not a great quantity of them there, they may be the more distinctly observed.

To proceed: as therefore the fat hinders much the view of the internal parts, this impediment is increased by the addition of the pulmonary tubes or pipes, for they are distributed through the Worm, in eighteen principal branches, in so different and beautiful a manner as cannot be expressed by words. These branches proceeding from the points of respiration, are afterwards divided into innumerable little sprouts and shoots; so that there is no part in the Worm, to which some of these air-pipes or their ramifications are not extended. They are conveyed even to the muscles, to the brain, to the nerves, whose most minute divisions are likewise provided with their air-pipes. Wherefore this Worm, as well as the other species of insects, seem indeed to be sustained much more by the power of a subtile air, than the larger animals and those which most abound with blood: unless one should be inclined to think that the air is mixed with the blood, by means of the circulation, and with this is carried through the arteries to all parts of the body, which opinion is indeed not very improbable. All the pulmonary pipes in the Worm are straight, and have on bladders, for only the perfect Beetle has them.

We shall now leave the considerations of these pipes, and explain more accurately the other parts. The first of them that offers in

our dissection is the stomach; which is indeed seen most distinctly, when the Worm's skin is entirely opened, Tab. XXVII. fig. XI. and XII. *aaaa*. It then appears that almost the whole body of the Worm is possessed by this part. It consists of several coats, and has moving circular fibres, whereby its contents are agitated. It is always, except when it casts its skin, found distended and full of chewed wood, or the like substances, amongst which the creature lives; and this is the reason that it appears bluish, or sometimes reddish, its contents being easily seen through its coats. This stomach is very narrow at its origin, at the mouth, whence it forms the gullet *b*; but it is a little after expanded until it makes its upper orifice called the œsophagus. In that part the stomach *c* is on the inside in front armed with about seventy little tooth-like parts *dd*, whereof some are longer than others. These are divided into six orders, whereof the two upper ones, 1, 2, look forward with their points, but the other four, 3, 4, 5, 6, which are conspicuous toward the lower parts of the stomach, have their ends directed partly to the fore *e* and partly to the hinder *f* parts. All these open into the stomach, in the same manner as the appendages in fishes open into the intestine next to the stomach. But I shall not take upon me to affirm that one of these tubes is inserted into another; as is the case in the Whiting. I only would say, that each tube separately opens in the same manner as may be seen in the Salmon, in which the pancreas opens into an ecphysis with above sixty peculiar and distinct tubes. A little lower the stomach is rendered conspicuous by twenty-two whitish glandular tubes, Tab. XXVII. fig. XI. XII. *g*, whose ends are turned towards the hinder parts. Finally, about the lower part *b* of the stomach, a little above the beginning of the pylorus, are likewise observed thirty such tubes *ii*, which are also uneven, and some shorter than others; these are there situated obliquely and run inward; these also open into the stomach there, and their ends point forward. If the middle series of the tubes before described are broken off from, or taken out of, the stomach, they resemble the crown of a trepan. On the other side, where the stomach lies in the belly of the Worm, and the tubes are directed towards the hinder parts, a future like the ridge of the peritonæum divides it *f*. There are infinite pulmonary fibres also inserted in the stomach: on each side of the stomach are likewise placed some small vessels *kkkk*, disposed in a very regular and beautiful manner, which I call the *vascula varicosa & crocea*, the swollen and yellow vessels, after the example of the celebrated Malpighius, who in his excellent treatise on the Silkworms, has given that name to the like vessels in that insect. Where the stomach terminates about the pylorus, is seen a narrow and short intestine *l*, which is soon dilated *m* into a large, thick, and very capacious, though short, gut, and may be properly called the colon; for it is of the same structure with the colon in the human species. This intestine

is commonly found very full of excrements, which are like the dung of Dormice. It is by reason of the thickness of this intestine, which is naturally so vastly distended, that the least or lowest annuli or rings are smooth and transparent. Another reason is, that, as the Worm has no fat about these parts, the silver-coloured pulmonary pipes, distributed all over this intestine, appear very beautifully through the transparent skin; and indeed the elegance of this sight is the more remarkable, because the intestine is of a purplish or bluish colour. The pulmonary pipes just now mentioned reach on each side *nn*, from the points of respiration to this intestine, and are distributed thereon, as well as on the extremity of the stomach and straight gut. I have omitted representing here the other pulmonary pipes, that I might be able to exhibit the other eight orifices *oooo* thereof in their natural situation, and as they shew themselves when the fat and all other impediments are removed. This intestine bends itself by degrees towards the stomach, and there ends in a narrower canal, which is directly under it *p*, and which I call the straight gut; because it agrees with that intestine in figure, insertion and use.

I at first supposed the spinal marrow, Tab. XXVIII. fig. 1. to be in this, as it is in other insects. But afterwards, by opening two Worms which I had kept since the last year, I observed that the marrow in this creature differed very much, not only from that of other insects, but also from that of the Silkworms, to which in many things else the Worm has great resemblance. As the marrow in the Silkworm consists of many globules, which the celebrated Malpighius has been pleased to call so many brains, this, being formed in a quite different manner, scarce extends to the third or fourth annular division of the body; but whatever part of it afterwards reaches to the other rings of the Worms, or whether what we see there are no more than nerves shooting from this principal body of the marrow; which, like sun-beams, beautifully and wonderfully distribute themselves through the body of the creature, and thus give sense and motion to the circumjacent muscular parts, none yet can say. Though there is a distribution like this in the Silkworm, yet the spinal marrow itself in that insect is extended through the whole body. Hence the marrow in the Coccus is very short, but the nerves are longer. I have again, since the first experiments, examined this marrow in a smaller Worm, which I had raised from the egg; but because the body of the Worm is very short and compact, the marrow is therefore situated somewhat deeper, and thence appears very distinct and beautiful. The *a* brain of the Coccus is placed in the head, and consists of two hemispheres, which together form one body. In the fore part are seen four little nerves issuing out of the substance of the brain; also, out of each side of the brain there issue two remarkable

nerves *b*, which first leave a large opening between them, and afterwards again meet together a little lower, and there constitute the body of the marrow *c*. This marrow, it appears, may be divided into fourteen globules, as it were distinct, whereof the three last together form one more globular division: moreover, the nerves very elegantly branch as they spring out of this marrow.

We must here observe that the gullet passes through the opening of the marrow which we have just named, in its course towards the external mouth of the Worm. And indeed there was a necessity for this structure, for as the stomach and gullet are situated in the neck and belly, and the brain lies above in the head, the marrow must necessarily have been situated only on one side, unless there had been a hole in it for the gullet to pass through; hence it is contrived that the marrow possesses the middle of the body. The most wise Architect of the universe has taken care, by means of this opening, that the marrow should not be forced to twist or turn itself round about the gullet, which could scarce have been any other way avoided. In the same manner the gullet passes through an opening of the marrow in Silkworms: this the famous Malpighius has neither described nor delineated. This author has likewise delineated fewer globules of marrow than are really in the Silkworm, and he has entirely omitted the brain. But it is easy to add to what has been discovered before. As this marrow is divided only once, and that at the beginning of its course in this Worm, it opens many times in the Silkworms, as Malpighius has very just remarked. It is also further remarkable that two considerable branches of the pulmonary tubes, which are silver coloured, and glitter like mother of pearl, are observed to pass over the marrow of the Coccus in many serpentine windings. These branches with their ramifications accompany the nerves issuing out of the spinal marrow, unto their finest or most delicate divisions, which is also the case in Silkworms. However great, therefore, the difference may be between the marrow of the Coccus and Silkworm, the brain and branching nerves meet again in both. The *nervus recurrens*, Tab. XXVIII. fig. 11, deserves most consideration of any; because, as in larger animals, and in man, this provides nerves for the beginning of the stomach, and other parts adjacent: it performs the same office equally in the Coccus and Silkworm. But in order to understand how this is managed, I must repeat what I have before observed, that the gullet passes from the external mouth of the creature, through the opening of the marrow towards the stomach, and that therefore the marrow seems to be divided into two parts, purposely that it might transmit the gullet. A further advantage that arises from this is, that the brain is there lodged gently on the gullet, and is joined to it by means



means of the emitted nerves and connecting pulmonary pipes ; so that the brain lies above on the gullet, and again the gullet and stomach are placed upon the spinal marrow ; which part having no bone, is thus defended by them. The brain then being situated in the manner thus mentioned in the *Coffus* and in Silk-worms, emits underneath from its basis two tender little nerves, which I represent, fig. II. *aa*, as they appear when cut out of the *Coffus*. These nerves, called *recurrentes*, are directly from thence carried *bb* upwards towards the mouth, and being then very beautifully bent they run back *cc*, and uniting *d* a little above the brain, form a knot there. Out of this knot there springs another nerve *e*, which being conveyed under the brain, and descending along the gullet by degrees towards the lower parts, reaches to the beginning of the stomach, and there, before it inserts its branches in the stomach, making another knot less than the former, at last terminates in numerous very small nerves *g* : but these I could not trace further in the present experiments ; though I am confident I could do a great many more things in these matters by the help of some peculiar methods of dissection, if I had not been then stinted in time.

As these *nervi recurrentes* are extremely remarkable and worthy of consideration, I have therefore represented them separately, and somewhat beyond their natural size. In the next place I have added a very exact figure, wherein the brain, fig. III. *a*, the spinal marrow *bbb*, &c. the *nervus recurrens*, and the rest of the branching nerves are shewn as they appear in Silk-worms. But there are two of these nerves very remarkable *pp*, which I would have the reader seriously and repeatedly consider : they are perforated *ss* in a wonderful manner by the *vassa deferentia* of the testicles in the Silk-worm Butterfly *rr*. But whether this conduces to pleasure in this species of insects, or to any other use, I leave others to

determine. I have in the same manner delineated with the others the genitals of the Silk-worm Butterfly, and expressed them in the same figure with these nerves. A short explanation of this, as well as of all the other figures, will be found at the end of this work.

I have found out an excellent and uncommon method of preserving all these parts of the brain and marrow, by the help of which I can form them into a body, and keep them in their natural colour and size ; whereas otherwise they are utterly destroyed by keeping. I shall communicate it when I publish my peculiar anatomical observations. I have, as a specimen of the use of this method, preserved in this manner a great many such minute parts, which though they cannot be investigated and examined without infinite industry and tedious labour, in the creatures themselves, yet when they are thus preserved, present themselves more familiarly to view than in their natural bodies.

I cannot in the course of this history avoid relating, how much the Peacocks and Peahens are delighted with eating these Worms ; and hence I am inclined to believe what *Mouffet* alledges from *Pliny* and *Hieronimus*, that the ancients used to eat them as a very delicate kind of food in *Pontus* and *Phrygia*. But probably this was the species of *Coffi*, out of which the larger Beetles are produced. If any person would eat the *Coffi* of our country, they must be first kept fasting until all their excrements are consumed. When I have a mind to keep the Worm itself for future observations, I make a small incision in the hinder part of its body, and having afterwards pressed out the entrails through the wound, I fill the cavity with injected wax. Another method is this : all the fat of the *Coffus* must be first consumed with oil of turpentine, and then it may be preserved according to art. This different and much more uncommon method of preserving, I shall likewise explain in due time\*.

## C H A P. IV.

*The manner wherein the Worm is changed : how its inward parts are transformed in their increase and growth, and the wonderful metamorphosis of the Worm into a Nymph. Also the method whereby the points of respiration, or breathing holes, are transposed : to which are added many uncommon observations.*

WHEN the time of this Worm's change approaches, which in the year 1673 happened on the sixteenth of August, in those I observed the *Coffi* penetrate deeper into the ground, or into whatsoever substance they in-

habit, and seek for places that are more firm or compact, wherein with the pressure of their hinder part, they form a very artificial oval cavity, *Tab. XXVIII. fig. iv.* every where smooth and polished. They lie a little while

\* The Beetles are a genus of insects scarce less numerous than the Butterflies. We owe the first rational attempt towards arranging them, and disposing them in method, to our countryman *Dr. Martin Lister* : he divided them first into the land and water kinds : the first comprehend all those called by this author *Scarabæi* ; the latter *Hydrocanthari*, or water Beetles. These last are of two kinds, according to their place of living, some delighting in fresh, others in salt waters. There are vast differences in their horns or antennæ, of which we shall speak presently ; but these do not so happily distinguish them as the two great divisions of the Butterflies.

immoveable in this cavity; and immediately after they become, by degrees, by voiding the excrements and by the evaporation of their humidity, more slender, shorter, and uneven in the body, with more furrows or wrinkles than before; these, however, are also disposed on the skin in a very beautiful manner: and hence both the distention and clearness of the skin disappears so perfectly, that one would think the creatures were starved by degrees, and their substance consumed with hunger. It is remarkable that at this time the internal parts of these Worms do not appear protuberant through the skin, as is the case in Silk-worms, and in the Worms of Bees and other insects; though one may see even these already under the skin, and also distinguish by what degrees they increase.

Before I prosecute this matter further, it is necessary to know, that if the *Coffus* be dissected about this time, its division into the head, thorax, and belly, may be distinguished very clearly. The gullet, fig. v. *a*, keeps its original form: but the stomach *bb* is changed and greatly contracted: the same likewise happens about its appendages, *ccc*, for these almost totally vanish. The *vasa crocea* or *varicosa dd*, the yellow or knotted vessels before-mentioned become more loose and free; though in the mean time they do not yet separate from the stomach. On the hinder part of the stomach, about the pylorus *e*, is seen the insertion of these vessels; for they arise there in four distinct tubes, so that properly they ought to be called *intestina caeca*, close or blind guts. The same may be likewise seen in dissecting the Bee-worm, in the figures of which I have likewise delineated these vessels. The intestine colon *f* to this time nearly keeps its bigness, nay, it now presents *g* its little cells to view more distinctly than ever. Towards the hinder parts, under this, or towards the *intestinum rectum h*, are seen curious vessels twisted in a wonderful and very beautiful manner, on each side of that intestine *ii*. We may likewise at this time easily divide the substance of the stomach into its three coats, and distinguish its moving fibres.

It is admirable beyond all comprehension, how the Worm of the Hornet that is to put on the form of a Nymph, discharges at the same time all its excrements, together with the inward coat of the intestine, or rather of the stomach, which embraces or contains them; so that by this means this entire membrane and all the collected *fœces* are thrown out of the body together. The same thing happens in this case as does with respect to infants whilst enclosed in the mother's womb: for they likewise retain together in their intestines until the time of birth all the excrements which are formed in the space of nine months. I have also observed the same thing exactly in the Calves from the Cow's belly: nay, what is very singular is, I have found in these excrements hairs in every respect like those that

cover the surface of the body, and particularly those about their mouth. From this observation I really think it is most clearly proved that animals often lick their body in the uterus with their tongue, and thus swallow their own hairs with their food; and that those hairs are afterwards mixed with excrements as I have found them. Therefore it is most strongly demonstrated, that the humours wherein the animals swim in the uterus, and which are likewise found in their stomachs, serve them as food. Their excrements are whitish in the upper part of the intestines, and yellow a little lower; a little deeper they are of a yellow green and blue; and at length, in the end, they are of a brown and blackish colour. The excrements that are found in the Worms of Hornets are in all respects of the same form, figure, and substance: hence it is clearly evident, that all the Worms of Hornets feed upon one kind of food, and this is principally a small species of *Cantharides*. In these Flies the little parts over the eyes, the legs, and the cases which cover the wings, are observed to glitter like gold, and these are found in their *fœces*. The Hornets therefore bring up their young like birds of prey.

After we have observed the manner wherein the external and internal parts are changed by a slow accretion in the *Coffus*, it gives us pleasure to observe that such of its parts as are not to be changed at all, and others which have lately increased by degrees under the skin, are gently distended by the force of the blood and impelled humours: hence it happens, that the body in general contracting itself more and more, and all the blood being propelled towards the fore parts, the skull at length opens very artificially into three parts; which likewise happens, as we have before observed, in the change of the skin, which the Worm undergoes. The skin then likewise opening in the middle of the back, is, by means of an undulating motion, which is observed along the annular incisions of the back and the rest of the body, carried down insensibly by degrees: and hence the eyes and horns, the lip, and the sharp-pointed antennæ, cast their *exuviae* or skins at one and the same time, and are extended, and inflated with blood, humours, and air: they thus acquire by degrees the situation which they before had in the *Coffus*. Whilst all these things are doing, a watery and thin moisture is diffused between the new and old separating skin, which renders the parting of the two the easier.

The first part of the Nymph that appears after this change of the skin, is the horn on the nose, fig. vi. vii. and viii. *a*, which before lay under the skull in the *Coffus* state. Under this are afterwards seen some very low prominences on the basis of the horn *b*. At each side of it also two spherical tubercles appear *cc*, issuing from the teeth of the *Coffus*, which are much shorter here in the Nymph

as also in the future Beetle, than they were in the Cossus or Worm. Near these tubercles on each side are likewise seen two other pair of sphericle simlar tubercles *ee*, which sprung from the horns *ff* of the Cossus, and which are to be afterwards changed into the horns of the Beetle. Two such little parts also, but more oval in their shape, are observed *gg* to be placed on each of the inward parts of the sides of the former tubercles. These little parts have their origin from the jointed *bb* bristly hairs of the Cossus; and are likewise, though in another form, found afterwards in the Beetle. Three beautiful short tubercles present themselves also in the middle *i*, which upon changing the skin have likewise arisen from those particles, which may be seen in the head of the Worm under the letter *k*. A little under these there appears also a larger sphericle division *l*, which is horny or bony in the future Beetle, and forms the neck which is beset on each side with hairs. Above this, near the horn, is seen on each side the breast bone *m*. A little lower on the breast is seen the first pair of legs 1, 1, with their joints: and under these another pair 2, 2. Then follow the *nn* sheaths or cases of the wings on each side, under which a part of the covered wings *oo* is likewise prominent. These wings appear at this time beautifully expanded by the force of the blood and air that are by degrees impelled inwardly, though they were before complicated, and appeared as if grown together under the skin of the Cossus. Below these is placed the last pair of legs 3, 3, which are in some measure covered with the wings and their cases. All these legs and their joints are stretched out stiff, and distended with the fluids of the body and air, and thus remain without any motion fixed in the same posture, until the Nymph is changed into a Beetle. Finally, under the last pair of legs may be seen the rings of the abdomen *pp*, divested of their skin; and the extremity of the fundament *q*, out of which the intestinum rectum has cast its exuvia or skin, as the gullet did with the upper parts. These little parts are like two small shields. As to the eyes they are very conspicuous in the Nymph, but they cannot be represented by the same figure, because they are situated a little deeper behind the horns. The whole motion of the external parts of the Worm is now totally lost, in the same manner as it was before when the Worm was in its egg: hence the creature is twice as it were in a uterus, and twice in the state of a fœtus. Some small motion remains in the tail or fundament of the Nymph, because the extremity of the abdomen undergoes the least change of all. Thus the Nymph, by moving the hinder rings of its body or tail,

can move itself and change its situation in its little cell: this is likewise performed by the Chrysalis of the Silk-worm when it lies in its web.

In this most wonderful change of the skin, and transposition of limbs and parts of this insect, nothing demands greater attention, than what we may observe about the points of respiration: for though each of those nine points which are situated on each side of the body casts a skin, yet this can be distinctly affirmed only of the five foremost ones, for the four lowest or last points on each side change their skin as the rest, but they lose all their pristine form at the same time; three of them on each side become shorter, and the fourth is entirely closed up. At the very same time that the Worm, under this prodigious change of its skin, is transformed into a Nymph, a vast number of distinct tubules or pipes is likewise thrown out from all those respiratory points, and these tubes, being each obliged to pass through that narrow orifice, appear like so many small and simple filaments, though, in reality, each of these eighteen little fibres, as they seem, is composed of many pulmonary pipes, that are laid close together.

In order to understand these things the better, I shall add a figure to the description of them, and in Tab. XXVIII. fig. ix. a Nymph of the Cossus laid on its belly, and shall exhibit all the annular divisions and points of respiration in its back. These points shall be afterwards severally represented in their situation, as they appear after the Nymph is changed into a Beetle. The first thing then seen here is the horn of the nose 1, fixed on the head, which constitutes as it were the first ring of the creature: then follows the second annular incision 2, wherein the first point of respiration is placed, so situated laterally under the first pair of legs in the breast, that it does not appear but when the Nymph is killed. The third and fourth rings, 3, 4, are seen both without points of respiration, because the wings and cases thereof are placed there\*. Besides these, two annular incisions in the Nymph are concreted into one ring, and then form the lower part of the thorax or back. In the mean time, when these parts are casting their skin, on each side between the rings of the thorax, two little ropes as it were of pulmonary tubes are cast out of the body, as has been before represented in the figure, where we have described the change of the skin which the Worm itself undergoes. But these apertures are afterwards closed up in the Nymph, until having cast its skin, it at length becomes a perfect Beetle, wherein these orifices are at length totally abolished. The fifth ring 5, contains the second point of respiration, which

\* In the outer cases of the wings in Beetles there is a vast distinction, not only in colouring and ornament, but in shape; some cover the whole body, and are a defence to the inner wings, with little foldings of those more delicate parts: but in others these outer wings or cases of wings are short, and only fall over the shoulders. This is the case in that common and distasteful black Beetle which crawls about damp hedges, with its body naked and annular; the under wings are beautifully folded up under their small cases.

cannot be seen distinctly, being situated partly under the wings of the Nymph. But a particular, very worthy of notice here, is, that this other point of respiration is in the Nymph removed to a greater distance from the first, than it had been at first in the Cossus itself, and as I have figured it in that state; so that by this means it is considerably drawn back towards the hinder parts. The sixth ring 6, next to the former, contains the third point of respiration, which is very distinctly seen externally in the Nymph, at the extremity of the abdomen. In like manner the seventh ring 7, shews the fourth point of respiration, and the eighth 8, shews the fifth. But the sixth and seventh points of respiration, conspicuous in the ninth and tenth 9, 10, rings are again closer. The eleventh, twelfth and thirteenth rings 11, 12, 13, constitute as it were one connected joint together; and the eighth and ninth points of respiration, which are situated at or near these rings in the Worm, likewise become not only closer and more compact, but the last of them is in this state almost invisible. As to the fourteenth ring 14, it is not visible when the Nymph is in this manner placed on its belly, but on the other side it is seen beautifully, resembling two oblong oval little shields. O wonderful changes! whereby the creature comes into the world as it were new formed, and yet is most certainly the same that it was in the Worm.

The Worm being in this manner disengaged from its skin, transformed by accretion, and having its limbs and parts changed into the state of a Nymph, closely twists and compresses the cast skin by the motion of its fundament, and the skin is afterwards thrown towards the hinder parts under the belly. The Nymph is at that time very white, only that on the fifth, sixth, eighth, ninth and tenth rings of the back, there appear some delicate or horny hardish corpuscles, which approach to a bright red colour; in the little shields also of the last ring, and here and there in its body and legs the like substances are at this time also seen. The Worm or rather the Nymph is at this time very delicate, tender and flexible, and as it becomes remarkably shorter, on the other hand it is expanded considerably in breadth and thickness; for the blood and air have very conspicuously inflated the wings and the rest of the parts, in the part towards the head, and distended them so that they are become rigid. If we view this Nymph nearer, we observe that the transparent productions of the wind-pipe appear not only in the legs, but in the wings themselves, and in their sheaths and cases; nay, they are seen also in the substance of the horny or bony part that strengthens the thorax.

About this time the Worm or Nymph resembles a tender young infant very lately brought into the world, and which is rolled up in its first swaddling cloaths, and cannot yet bear much handling. We may more properly indeed compare this Nymph to an Embryo, which,

being lately conceived in the uterus, may, by force of the injuries offered it by the mother's imagination, be injured in various manners: for the impressions which the Nymph receives at this tender age, are not abolished even when it is grown up or is become a Beetle. Hence, if the horn, legs, or other parts are bent in the Nymph, or disturbed in any manner, they always afterwards remain thus deformed in the Beetle; and the Beetle carries with it through life the vestiges or remains of all the injuries inflicted on this feeble and tender little creature; this is agreeable to the sentiment of the poet:

*Quo semel est imbuta recens, servabit odorem  
testa diu. —*

That is,

“A new vessel will long preserve the scent  
of the first liquor poured into it.”

This change therefore merits the greatest admiration and the most attentive regard, by means of which the creature for some days exhibits the future parts of the Beetle so finely and beautifully disposed, and formed in such a manner, as that they will one day serve the creature in a more perfect state of life, to walk, fly, and take its nourishment. I therefore really think, that the Cossus of this species constituted in the form of a Nymph, affords an appearance so singular, that among all the strange and astonishing appearances of insects, it cannot be equalled. I should be very glad to see hereafter the Nymph of the stag-horned Beetle, for I should think it would make a much more splendid figure when it prepares itself like a bride, in all its decorations, for a new and more noble state of life.

The Chrysalis of the swift Butterfly described by J. Banhinus in the year 1590, among the Mouches ou Papillons non vulgaires, or the uncommon Flies or Butterflies, is very rare and admirable. Aldrovandus, Lib. II. Cap. de Chryf. Tab. VII. fig. 1. exhibits a kind of figure thereof. Mouffet also, pag. 105, describes the least species of the said Butterflies, and properly calls it the swiftest of all, for indeed the swallows do not fly with greater velocity than these little creatures.

One thing very singular in these Butterflies is, that they fly and eat at the same time, though this also is the case with swallows, and among insects with the Libella or Dragon-Fly. On the other hand some Flies, after they have seized on their prey, rest in some convenient place to devour it, as in particular the Wolf-Fly. But as Swallows eat and fly at the same time, so these, at other times nimble Butterflies, flutter when they feed in so slow, regular, and orderly a manner about the flowers where the food proper for them is deposited, that you would imagine they had lost all motion, and hung suspended in the air; but they are hard at work all the time, for they then thrust out a very slender proboscis or trunk about two inches long, with two perforations in it, through  
which

which they suck the honey of the flower; and this being exhausted, they so quickly draw back this surprising organ, and so artfully coil it up between the little forked parts which are placed under their eyes, that it entirely disappears, so that to find it out, one must be well accustomed to the study of these creatures. This insect being scarce, I have given the figures of it, as it appears in the respective stages of its existence as Worm, Tab. XXIX. fig. 1. Chrysalis, fig. II. and Butterfly, fig. III.

As the manner of feeding of this Butterfly is very singular, I shall add another observation of the same kind, in regard to the manner of feeding of a certain aquatic insect that always lives under water. This insect is, properly speaking, no other than a peculiar kind of water Worm, consisting of thirteen rings, the head and tail included. The head is very large in proportion to the creature's size. It has six hairy legs, fig. iv. *aa*, besides two spots or small parts covered with hair likewise *b*, which terminate the tail, and are used by the creature when it swims as a rudder to govern its motions. The insect by means of this tail, can also at pleasure suspend itself on or near the surface of the water; when it erects its tail above the surface, the water flows from it on every side, and thus is this suspension formed. This insect has besides in its head two very remarkable teeth, or more properly jaws *cc*, which are large, sharp, crooked, and very strong, and it is perhaps able to contain the muscles such teeth or jaws require, that nature has made the head so large. This Worm has six eyes *dd* on each side of the head. I have here represented eight of them. There are besides six articulated bristles belonging to it, of which four *eee* lie underneath and between the teeth, and the two others under the head *ff*; but some may imagine that these last should be called horns.

This is a crustaceous creature like a Shrimp. On each side of the body are six holes for respiration *g* in the rings of the abdomen, with two more for the same purpose under the body near the fore legs. This Worm is represented in the most curious figures of Hoefnagel, that were engraved after his minute and most accurate designs, part first, page 1. Mouffet also describes it in the 37th chapter of his theatre of insects, and gives in some sort a drawing of it. This insect lives entirely on other little creatures that inhabit the same element, in particular on the Scrophula and small fresh water shell fish. When about to eat, he seizes with the two teeth we have mentioned the little creatures that come in his way, and pierces their body with its sharp and crooked points, which being perforated from the point to the root, he in a surprising manner sucks through them into his mouth the blood of the unfortunate captive. This may be easily seen, especially when the blood of his prey is of a red colour, as the teeth are transparent. I threw to this Worm a bit of a Cossus, at the same time carefully observing with a microscope how he devoured

it: together with the blood, there ascended some air in small bubbles through the cavities in his teeth. The sight of this creature in the water is very acute, for which purpose nature has supplied it, as I already mentioned, with twelve black eyes, which are placed at some distance from one another, but these eyes, like the eyes of other insects, have no motion, and therefore are placed in a different manner from those of Crabs, Crawfish and Shrimps, which are moveable. When therefore this Worm perceives any thing that it likes, it immediately darts at the object through the water, seizes it, and pierces it with its sharp pointed teeth. In this manner we may procure ourselves a very entertaining and surprising sight, by throwing to it a small Earthworm; for let this last move, twine, and otherwise bestir itself ever so much, the other keeps his hold, and very calmly sucks the blood of his prisoner. The intestines of this Worm differ extremely from those of land insects; its windpipe has fewer ramifications, though these at the same are more large and spacious. They are likewise more membranaceous, of a less firm texture, and not of quite so deep a colour. The heart is situated near the back, and the spinal marrow in the lower part of the body. This last consists of globules as in the Silkworm, but these lie so close to each other that they form a connected body of marrow, more like that of the Cossus than a Silkworm. In the part where the nerves unite with these globules, the spinal marrow itself looks like a bracelet composed of coral beads strung upon two threads. The remaining parts are the stomach and the intestines, which are partly of a white and partly of a bluish gray colour, the same with their contents, from which indeed they receive it. The Vasa Crocea, or yellow vessels, as they are usually called from their colour, are in this insect purple, or otherwise, they are thick set with purple spots, but they look whitish at bottom, which affords a very agreeable sight.

On examining with a microscope the teeth of this Worm, they appear very sharp pointed, Tab. XXIX. fig. v. *a*, and a little bent towards the point. There was likewise a kind of future *b* in that part where I cut out one of them, formed by a sharp protuberance in the middle of the upper segment, with a suitable cavity in the middle of the lower to receive it, the edges about both being smooth and even *c*. The aperture by which this insect sucks the blood of its prey, lies on the surface of the tooth near the point *d*, and resembles an oblong slit, with black edges covered with very fine hairs. It is extremely probable that some peculiar species of the Water Beetle proceeds from this Worm, when having remained in the water a sufficient time, it betakes itself to the land to undergo its mutation; but this is mere conjecture. The horse Fly has another method of feeding itself, being furnished, as I have elsewhere remarked, with a sting as well as a trunk or proboscis. As to the

the Gad Fly and its Worm, I shall hereafter treat of it by itself, under the fourth order or class to which it belongs; but I cannot help remarking in this place, that the Worm from which it comes breathes by its anus, and carries its legs in its mouth near the jaws; thus serving to prove that the Almighty can form vessels of

every kind like the potter, some for more, and others for less honourable purposes, but all to his own glory; so that there is not a creature, however contemptible in appearance, which does not clearly point out the existence, and loudly sing forth and extol the adorable perfections of a supreme Being.

## C H A P. V.

*In what manner the Nymph is filled with a superfluous moisture, which afterwards evaporates. The anatomy of the Nymph. How, on casting off its skin, it becomes a Beetle, with some wonderful discoveries in natural history.*

**H**AVING shewn in the foregoing chapter what the Nymph is, and by what means the Worm puts on this elegant form, to prepare itself as a bride for its ensuing nuptials, and for the act of generation; I shall now treat of those changes, by means of which the Nymph attains this present state, and at the same time give a dissection of some of its internal parts; for thus the reader will more easily understand how this Nymph grows at last to a Beetle, and being arrived, as such, to a state of maturity and perfection, propagates its species.

The first thing to be considered on this occasion, is that peculiar motion of the blood and humours, which expand the parts of the Nymph, and make it weigh at first, a little after its change, a great deal more than it does even afterwards in the Beetle state. This singularity is likewise remarkable in the Nymphs of Bees and Hornets. The Nymph of the Hornet in particular weighs ten times as much as the Hornet itself. This makes me consider the Nymph under these circumstances as a dropsical person, who, by having his limbs swelled with superabundant humours, loses the power of those muscles by which they were to be put in motion, and thus remains inactive till the superfluous moisture is some way or another dissipated. Nor is it the limbs alone that are thus swelled in the Nymph; all the muscles themselves partake of the change, and even the very bone into which they are inserted. This, which was before of a horny substance, loses its solidity, and by becoming membranaceous and soft, and in a manner fluid like water, is no longer capable of being acted upon by them, and continues in this condition, till the superfluous humours are evaporated in a certain space of time, which is absolutely necessary for that purpose. We may perceive by a continued observation, that the external skin of the Nymph is at first extremely delicate, that it hardens, as it dries, by degrees, and that its colour grows more and more yellow, till it changes at length to a deep red, after that to a deep brown, and at last to a light red. But all these appearances are owing to the growth

of the internal parts, in order to form the future Beetles, as they shew themselves through a transparent skin that covers them.

When this Nymph has passed some days in sweating off the superfluous moisture, with which it is loaded, a little articulated whitish line appears like a slender thread through the transparent skin, with which the legs are covered, which is no other than the first rudiment of that horny or bony substance, which begins to harden, and is in time to constitute the legs of the creature. On stripping off this skin, and attentively examining the solid or horny part it contains, the latter appears to float in a limpid fluid, which surrounds it on every side, and is at this time so very tender that it is easily injured, and will fall off on the slightest motion. But what seems chiefly to claim our wonder is, that the Worm which grows from the nose of the male Beetle of this species, should be so very hard at its perfect growth, as, according to Mouffet, page 153, to bear being sharpened on a grinding-stone; whereas the same organ, while the insect is in a Nymph state, is altogether soft, and more like a fluid than a solid substance.

On dissecting some of these Nymphs after they had been in that state a little time, I found the horn of the nose filled with a kind of jelly, and this matter broke out at the wound made to examine it, every time the creature breathed, in the same manner as the blood of a man's body does when the side of the thorax is wounded. The eyes were now somewhat firmer, but nevertheless they were still loaded with superfluous humours. I found between the folds of the wings and the cases that covered them, some insects of the Louse kind, which I have likewise often observed sticking to the body of the Cossus and to the Beetle itself; for there is perhaps no species of animals which is not troubled with this kind of vermin, though those of one animal differ in shape from those of another. Such part of the wings as had no case to cover them, had, to make up for that deficiency, a much thicker skin to defend them, than the parts which were thus sheathed. On pulling the legs from  
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the thorax, the skin came off from those of the future Beetle in the form of a stiff sheath, just as a boot comes off a man's leg. It is also very remarkable, that the extremities of the pulmonary tubes were inserted into this external skin of the insect. But I shall hereafter speak of this matter more at large. The intestines which lay in the abdomen were formed in quite a different manner from those of the Worm, of which I have before given a figure, and in particular they had more sinus's. The stomach itself ended in a kind of very small gut, and indeed all these alterations seemed requisite to prepare the parts to the great change in the body itself, which was grown at this time considerably shorter than before. But as the stomach was greatly abridged, and therefore its muscular parts had without doubt suffered considerable changes, both that and the intestines were now softened into a kind of slimy humour to facilitate so surprising a change. The pulmonary vessels retained their former situation and figure. The whole abdomen was filled with a kind of calcareous substance resembling starch, and of so bright a white as to dazzle the eyes of all who saw it. On a nearer examination of this substance, I found it to be nothing more than a collection of those little bags in which the fat is deposited, and which little by little lose their form and office, and are at last so entirely wasted away, together with their contents, that not the least vestige of either is to be found in the succeeding Beetle. About this time some spots are observable in this most extraordinary substance, of a brighter white than the rest of it, and many of the pulmonary tubes seem to take their direction towards these particular parts. This induces me to think they may be the rudiments of the pneumatic bladders with which the Beetle is furnished in a vast abundance, unless we are rather to consider such pneumatic bladders as consisting of the pulmonary tubes dilated occasionally to answer that purpose. For my own part I cannot take upon me to decide this point. I observed the same things in the Nymphs of Bees, after I had finished the history of those insects: but be this as it will, these spots are so brittle and tender in the Nymph that they are destroyed by the slightest touch: by their dazzling whiteness also they hinder us from distinguishing properly the adjacent parts: for this reason, to proceed well in our examination, we must be constantly washing with fair water the intestines of the insect. Were it not for this obstacle, we might doubtless here distinguish many more things worth of notice. In the thorax, some parts were a little more solid. The muscular fibres of the legs and wings were somewhat more firm or tough than the white of an egg just beginning to harden. All the other parts were as soft and tender as possible. On separating the external skin of the body from the internal, the space between them was found to contain a great quantity of moisture, but in many places this separation was absolutely impossible.

As the several parts in the Nymph grow by degrees stronger and stronger, the insect may be seen to make a proportionable use of them. We see the legs move within the skin that covers them, and even the claws that terminate the legs begin to brandish themselves up and down. The same is visible, and in the same manner, in the *Aureliæ* of Silkworms during the last days before their transmutation: if during this period you strip the legs of their external skin, you will find very little moisture under it. Even the horny or bony substance which constitutes the joints of the legs appears hard, perfectly formed, and covered with hair.

I cannot say how long the scene of this insect's mutation continues, having forgot to take notice of it, though at the same time I was witness to the change of above fifty of these Nymphs into Beetles. Sometimes these insects remain in a Nymph state during the whole winter, especially when the Worms throw off their skins towards autumn, and a sudden cold succeeding checks their further operations. Hence it happens that they remain without food for some months, nor could they take it to any purpose, their parts being too soft and tender to allow them to make use of it.

When the proper season of the Nymph's final change approaches, all its muscular parts are observed to grow stronger and stronger, to be the better able to shake off their last integuments, and this is performed in the same manner exactly as in the already described change of the Worm to a Nymph; so that in this last skin, which is very delicate, the traces of the pulmonary tubes that have been pulled off and turned out become again visible; nor is their number limited to eighteen, there appear absolutely twenty of them, as has been already sufficiently observed.

It is now proper to see how all the parts of the insect, but especially the wings and their cases, are at this time swelled and extended by a flow of air, blood and humours, driven into them through the arteries and pulmonary tubes. About this time the wings are as soft and flexible as a piece of wet paper, so that blood issues from them at the least wound. But when they have acquired their due hardness, which in the sheath or cases is very considerable, the vessels that before yielded blood so freely, are so firmly closed, that neither they nor the wings can by any cutting or tearing be brought to yield the least fluid. This induces me to advance as a thing not to be doubted, that whereas these wings and their cases are so full of vessels and pulmonary tubes, they ought to be considered as consisting entirely of such vessels and tubes. It is also probable, for the same reason, that the membranes and skin of the other creatures are no more than a complication of vessels, as nerves, arteries, veins, lymphatic ducts and the like, for so long as the embryo's of the human species and of quadrupeds remain in the womb, their skin appears composed of nothing else. The same may be said even of the bones themselves;

and this observation alone would be sufficient to recommend to our attention the history of the insect now under consideration. It would take too much compass in this place to describe the surprising alterations which happen in the membranaceous wings of butterflies, and how evidently nature manifests herself, and exhibits her wonderful powers in these minute creatures: certainly the great and wise sovereign of the universe made every thing for our use, and to his own glory. All his creatures, the least as well as the greatest, furnish us with proofs of his gracious intentions, his stupendous majesty, and the immensity of his power.

We therefore, on observing the mutations and transpositions of the growing parts of man and other animals, may well cry out with the royal prophet: " My substance was not hid from thee, when I was made in secret and curiously wrought in the lowest parts of the earth. Thine eyes did see my substance, yet being unperfect; and in thy book all my members were written, which in continuance were fashioned, when as yet there was none of them. How precious also are thy thoughts unto me, O God! how great is the sum of them!"

Hence we may justly declare, that insects, even under this miserable state of mortal life, acquire as it were a heavenly existence; for

those which in the former part of their life inhabited the earth, lived in mud, and under thorns and briers, and fed on coarse provisions, in their more perfect state, raise themselves into the purer air, and flying towards the skies, maintain themselves with honey and oozing liquors of flowers: some of them can even abstain from food during many months. Are not all these conditions much better than those to which they were subject under the troubles and anxieties of a former more vile earthly life? but I shall illustrate these subjects more fully, when I have leisure, in order thence to demonstrate the glorious resurrection of the dead, by the most evident and palpable proofs drawn from nature; for I can produce such manifest examples and such powerful arguments for the purification and succeeding glorification of bodies, from the history of insects, that I do not doubt but such unheard-of miracles will strike all mankind with the highest amazement. Natural truths are perfectly convincing and wholly divine; since what is true proceeds from God, who is truth itself. And what is more true, than that the books of nature are those visible things, by the assistance of which, as by sacred steps, we ascend by various advances, to divine and eternal truths? for it is God himself who is the author of Nature.

## C H A P. VI.

*The difference between the male and female Rhinoceros Beetle, after the Nymph casts its skin, and is changed into either of them. Of the points of respiration, the eyes, the brain, the optic nerves, the pulmonary tubes and pneumatick bladders. Of the heart, and of the genital organs of the male and female, with a moral conclusion.*

THE Nymph of this curious Beetle being disengaged from its skin, in the manner explained in the preceding chapter, assumes a quite different form, in which it is dignified with the name of the Beetle, whose internal parts, with the difference between the male and female, I am now about to describe. Before I begin this explanation, I must observe that the Nymphs, which have their horn prominent in the fore part, always become male Beetles in this species; but such as have no horn always females: and there are very certain external signs for distinguishing the sex of these insects. Besides, the males, which have smaller bodies than the females, have also two larger and more beautiful horns\*, whose tops have knobs thereon made like combs; and,

when the creature is flying, they are expanded in the manner of the leaves of an open book: this is a very wonderful sight in some of the Beetle kind. But as some remarkable things occur, which are common to both male and female, I shall first describe them, and afterwards proceed to the peculiar points which mark the difference of sex.

The parts common to both are, first, the points of respiration situated outwardly; secondly, the eyes and the brain; thirdly, the pulmonary tubes and pneumatic bladders; and lastly, the heart. The things peculiar to each are the horn and genital parts in the male, and the ovary in the female. I shall proceed to describe these in order and with brevity: as to the particular description of the other

\* The antennæ of Beetles are of two kinds; those which are pointed at the end, and those which have that part shaped in the manner of a comb.

There is also a difference of a very particular kind in their insertion, the greater part have them fixed upon the substance of the head; but in some they are carried upon a kind of trunk: the Beetles which have them in this strange situation, are those the antients called Gurguliones.

Upon these forms and insertions of the antennæ may be established an exact classical distribution of them, a thing yet wanted in natural history.



external and internal parts, the disposition and manners, the use they make of their wings, and their food, and the length and shortness of their lives, as also how far they are hurtful, and how far innocent, with other like researches; these I shall at present pass untouched, partly because I have not yet sufficiently searched into them, and partly that I am fatigued beyond my strength, with investigating, delineating, and describing those amazing things. I must have a long space of time to perfect all these inquiries; nor can any person execute such things perfectly, but he who can spend his whole life upon them.

Of those things, which are outwardly conspicuous in this Beetle, the points of respiration deserve our greatest attention; these I shall now describe and represent by a figure, as they are naturally disposed on one side of the perfect insect; for they have the same situation and structure also as the other. They vary considerably from those which are seen in the Worm, for here they are disposed in a different order near each other, and are placed in a somewhat oblique and declining situation; by this means one of them occupies an higher place in the body than another; they are likewise more oval, not round, and are much deeper, or more hollow than before, and appear as it were like little trenches and furrows in the Beetle much more than in the Cossus: the cavities also of the canals which they distribute internally in the body, are much wider and more open than they are observed in the Worm; for as the Worms live in dust and under the earth, and creep up and down there, it was necessary that their pulmonary tubes should have orifices more close and even, lest the dust should slip into them.

The first of these points is placed inwardly, Tab. XXIX. fig. vi. *a*, in the cavity of the second ring of the body, or in the os pectoris, or breast bone; nor is it visible there till after that bony substance has been separated from the body. The second *b* is somewhat further distant from the first, and being turned more toward the lower parts, is directed thence obliquely towards the other. This point, which is conspicuous immediately under the wings, is placed on the side of the fifth ring of the body. The third *c* again is situated somewhat higher, along the course of the curvature of the abdomen, and this lying upon the sixth ring of the body, is not far distant from the second. The fourth *d* again is placed somewhat lower and nearer the former, and is situated upon the seventh ring of the body. The fifth *e* stands somewhat lower and is placed on the eighth ring. These five points of respiration, whereof the Beetle has as many on the other side, and which makes ten in all, are indeed the principal places through which it draws its breath; for the other eight, which were visible in the Cossus, are in this perfect state of the creature partly pressed together, and some totally closed up; because the body

is become so much shorter than it was in the Worm. All these five points are covered in each side of the body with the cases or sheaths of the wings, except when the creature is flying; for at that time the sheaths of the wings are lifted up, and remain elevated without motion; hence these points are likewise at that time discovered: and this seems continued that the Beetle might the more freely draw its breath on this occasion, fill its pneumatic bladders with air, and thus make itself lighter for flying.

Moreover on the ninth ring of the body there is observed a sixth point *f*, on the tenth, a seventh *g*; and on the eleventh, an eighth *h*; all which are very considerably contracted and depressed, and run along each side of the body. But as the abdomen terminates by converging into a sort of a point, and the twelfth, thirteenth, and fourteenth rings are wonderfully contracted and diminished in their diameter, hence the ninth point *i* of respiration is totally obliterated in each side of the body, as I have before with sufficient clearness described and figured in the Nymph. But I now only represent the natural situation of these points.

The eyes are also extremely remarkable in the perfect Beetle, and they differ very much from those in the Worm, as well in bigness and number as in figure. Each side of the head has one, which consists of a congeries of many smaller globules or little eyes, forming by their union as it were one common net or reticulated body. This is properly made of the tunica cornea, for the eyes of all the insects that I know, have the exterior tunica or coat constructed or formed of a horny or bony matter, and divided like a honey comb into hexagonal parts, all which are on the upper part spherical or projected like little globes: But these globular divisions are not in this Beetle so remarkably protuberant as in Flies and Bees; they are much smoother, more depressed, and smaller, and they have no hairs. These horny divisions penetrate from the outmost surface to the inmost, and seem to be formed within by a kind of net of hexagonal pulmonary tubes running through each other: Within this net the uvea tunica, or a part analogous to it, is seen on the inside under the cornea. This is of a blackish colour, and is regularly received into the inward cavity or hollows we have named in the cornea, so that by this means it is to be found only in the uppermost surface, and not in the bottom of the eye. In the eyes of men and quadrupedes the uvea sinks to the bottom, and is also perforated in the anterior part; but neither of these is the case in the eye of the Beetle, and for this reason no rays of light can be collected in this case inwardly in the eye; but they only pass through the spherical divisions of the cornea, and are then immediately stopped upon the uvea. I would not presume to affirm that the rays are by any means collected

lected, when they pass through the cornea, though this is not improbable. If one removes the uvea, by means of water and a fine pencil, from out of the inward cavity of the cornea; this latter becomes then all bright and clearly transparent.

After the uvea follows a matter or substance like glue; it is somewhat viscid, but thin, and divides itself into very fine filaments, Tab. XXIX. fig. VII. *a*: these may be taken for inverted pyramidal fibres. When the cornea tunica is removed from these filaments, blackish spots are seen on the eye, which are the remains of the uvea still sticking there; for the pyramidal fibres are by means of the uvea connected with or joined to the spherical apertures of the cornea. All these fibres terminate in a thick, fibrous, and inexpressibly white tunic or coat, Tab. XXIX. fig. VII. *b*; the substance of this, however, is of a darker colour *d*, where it is united to the optic nerve which is here separated *c*. Many pulmonary tubes likewise run up and down here, which strongly connect that coat with the optic nerve, which it receives: these air-pipes pass also through that white fibrous coat we have described, and are conveyed *e* along the inverted pyramidal fibres, reaching to the cornea itself in form of very delicate ramifications; and in my opinion form the hexagonal divisions of the eye. Here at length may be conceived, in what manner the eye, whilst the exuvia or skin is casting, acquires its extension, form, and roundness by the help of the internally impelled air and blood. The roots of these pulmonary tubes are found to be situated under the optic nerve, where they first provide for the coat, wherewith that delicate nerve is invested; and thus, with a considerable ramification adhering underneath, is also surrounded with or accompanied by such air-tubes.

But we must here take particular notice that these eyes are, in each side of the head, divided as it were into two parts, fig. VIII. *ff*, as I have represented in a particular figure, wherein is likewise exhibited *g* the horn of the head. This division is produced by means of two horny or bony prominences of the skull, which extend themselves from each side of the eye unto the outmost surface thereof; hence it happens that the eye is in the same manner divided in its internal part, fig. VII. *b*; since the inward structure is analagous to the outward. The optic nerve has no incision or division, but the pyramidal fibres are wanting where this incision is, because they evidently could be of no use there.

In order to discover these things accurately it is first necessary to lay the brain bare; for this purpose nothing more is requisite than to cut off the horn, if it be a male, with a sharp knife, and then to raise and separate the cranium or skull from the brain. After this, the brain *i* comes in view. This, as I have before observed, when I treated of the spinal marrow,

consists of two globes united, and is by this means divided into a right and left part, as is likewise the case in men and in quadrupedes. It is indeed very remarkable that the brain is in this Beetle furnished with many pulmonary tubes, Tab. XXIX. fig. VII. *k*, which make a very beautiful appearance in the living animal. Optic nerves are observed to issue out of it on each side, which are much larger in the Beetle than they were before in the Worm. Moreover, a common kind of membrane is observed there, which invests both these nerves and the brain itself, and is sufficiently thick and strong: this may be properly called the dura mater. Numerous air-pipes run through this membrane, and interweave it as it were with one another, so that you would say this dura matter, when separated from the brain, is like an admirably beautiful net. The optic nerves are very slender where they issue from the brain *ll*; but they are considerably dilated *mm* a little after, and then again they grow small *nn*, until at length they are swollen again where they approach to the inward compartments or reticulations of the eye *o*. In that part these nerves are enclosed and surrounded by the interior parts of the eye, and when greatly magnified resemble the head of a Dutch sailor covered with a shaggy cap, such as sea-faring persons use to wear: I compare to these shaggy hairs, those pyramidal fibres which terminate in the convexity of the white fibrous coat.

It may not be improper to observe here that this Beetle is very short sighted, or pore-blind. I therefore would have the reader consider the construction and difference of the Bee's eye, which sees more acutely in the day time; for he will find that the optic nerve in the Bee does not come so very near to the eye, nor is in itself so remarkable and conspicuous as in this Beetle. Others may reason from these facts as they think best; it is sufficient for me to have proposed the truth. I have not yet examined the eyes of the water Beetles, which I know can see both in water and air. I have seen the pyramidal fibres of the eyes in Crabs and Lobsters. All water Snails, as well as the human species, have three humours in their eyes, as I have described before at large. On this occasion it may also be observed that their eyes are sometimes multiplied. I proceed now to the pulmonary tubes, which are simple in the Worm, but are enlarged by the addition of bladders in the Beetle state.

These pulmonary tubes which in the Worm resembled the branches of trees without leaves, represent here in the Beetle a tree expanding its verdant and leafy branches: and here the autumn and winter of the miserable life which this Worm leads, is now in the perfect Beetle state changed into a pleasant and lovely spring and summer; with this only difference, that as the leaves of the trees have a plain and smooth surface, so these bladder in the Beetle

are

are hollow, somewhat swollen, and expanded to an elliptical figure, and are somewhat swelled or blown up, Tab. XXIX. fig. ix. *aa*, by force of the air impelled into them. There is likewise this considerable difference, that out of the ends of these vesicles, where they rest upon their hollow pulmonary tubes, other pipes and ramifications *bb* again break out laterally, which, after they have been again dilated into vesicles, form air branches, vesicles and pipes: so that this division and process continues, until at length they terminate in very delicate, and as it were invisible pulmonary passages, which always remain round with open cavities. Hence the structure that occurs here may not be improperly compared to the third species of the Sea Wrack of Dodonæus. Nay, it is likewise observed that many tubes of this kind sometimes issue *cc* out of the same vesicle, which I have represented magnified above its natural bigness. Whenever the air gets out of these vesicles or bladders, they fall and become flat, and by the mutual contact of their sides, form a plain substance like the smooth leaf of a tree; whilst in the mean time the tubes affixed to them always remain open. The reason of this is, because these little branches rising from the principal air vessels consist of contorted and spiral parts, which, like the rings, made of silver thread or wire, and twisted round a small cylinder, always preserve their roundness. In the same manner this silvery web of pulmonary tubes appear to me to be compounded of a horny or bony pellucid matter, white as mother of pearl, and wound into spirals. These tubes are likewise lined on their inside with very delicate membranes, which keep their spiral form with all its windings in their situation. But where they are dilated into pneumatic vessels, they are entirely membranaceous, and besides, when viewed with a powerful microscope, are observed to be planted or set there with small studs or bosses like little grains. This is indeed a very agreeable object. Moreover, these vesicles are of a palish or white colour, and having no polish are nearly of the aspect of a Spider-web, or any thing of a like kind, covered with dust. The tubes on the other hand, are bright and splendid, and of a silver or of a pearly colour. See the explanation of these in Tab. XXIX. fig. x.

The reason of this difference between the pulmonary tubes of this creature, while it is in the Worm, and when it arrives at the Beetle state, seems to lie in the repeated change of their skin, whereof I have made mention before. The same thing is in some measure observed in the pulmonary pipes of the Silkworm Butterfly, for in this the tubes of the lungs, because they many times cast these internal skins, are every where very much dilated; though they have no distinct vesicles. However the matter be, since these white little parts, which are seen in the fat of the Nymph, ought to come principally into consideration

here, I think this difficulty may be at length solved, if there were some more dissections made for that purpose. But I must reserve the doing of this to another time, and shall, till then, leave this matter uncertain. One may conveniently inflate or blow up the pulmonary tubes of the Beetle before described with a flexible leaden pipe, or the quill of the wing of some small bird: what in Holland we call the Cheese-bird has feathers admirably suited for this purpose; for the quills of this bird's wings are very perfectly hollowed throughout, especially if they be first strengthened by a small glass tube; and these parts thus distended afford a very beautiful sight.

Any one may see the pneumatic vessels, together with their tubes, without any dissection, provided he removes or takes the external wings, called the cases of the wings, from the body, and views them when turned to the light with a microscope. They even appear through the abdomen of the Beetle, and they may be likewise seen in the horny or bony and membranous part which covers the lower part of the body: but they are presented in the most beautiful manner between the plates of the external wings; for there they form innumerable and most singular figures. Three considerable branches of the wind-pipe commonly appear between these cases, that is, two on each side, and a third shorter in the middle; and out of these one may afterwards see the respiratory vesicles beautifully issuing and placed between them, in the same manner as I exhibit them here in a minute portion of that part; wherein two larger branches of the trachea, Tab. XXX. fig. 1. *aa*, are represented on each side, and between them the pulmonary pipes issuing therefrom, together with their vesicles *bbbb*, out of which other pulmonary pipes arise, which are again dilated into vesicles *cccc*; and these are again attenuated into pulmonary pipes, until at length they end in most minute and invisible filaments. In the inner part of the outer wings there may be also observed some other small points, projecting beyond the surface of the case or sheath, out of the middle of which issue oblong dispersed hairs. These I am confident are placed here to prevent the subjacent wing from being too much pressed, and at the same time to give it the means to fold and hide itself the more easily under the sheath. We have before shewn the use of these numerous tubes and pulmonary bladders; which is, that by their help the outer wings or cases of the wings may be expanded. I would likewise have it observed, that all these vesicles or bladders appear somewhat smooth, which may probably be owing to the contraction of the sheath or cases, which happens when the humours are exhaled, and the blood-vessels are closed or shut up.

The heart is much shorter in the Rhinoceros Beetle which I am describing, than it was in the Worm or Cossus; it is likewise

more knotty; it is in some places dilated, fig. VII. *aa*, and elsewhere is again contracted *bb*, as I have shewn in a small part of it: but I have not had opportunity to search into it fully. I shall therefore now pass to those parts peculiar to

the male and those to the female; such as the horn, the penis, testicles, and seminal vessels in the male; and the ovary, uterus, and vulva in the female; and after these are explained I shall conclude this history.

*The parts peculiar to the male.*

THE horns of the male Rhinoceros Beetle is formed of a tolerably solid horny bone, which makes it so firm, that one may bore or pierce even hard wood with it. It is crooked and bent backwards towards the bone of the thorax. It is of a black red colour, and so smooth and polished on the surface that it shines like a looking-glass: and so likewise do the covering of the thorax; and the cases or sheaths of the wings, called also the outer wings: these are likewise parti-coloured, but approach more to red. The horn is ornamented with several small holes impressed thereon. It is first membranaceous in the Nymph, and as it were full of a fluid; it afterwards becomes more firm, and at length acquires the full hardness we have named. And though this horn is flexible at the time of the creature's casting its skin, yet in the space of two or three days after this change, it becomes so wonderfully hard, that it is not only as firm as a cartilage, but even approaches to the nature of a bone. It is not, distinctly speaking, situated on the nose of the creature, but on the head, and may therefore be most properly called a production of the cranium or skull only, for it springs out of the substance of the skull where it lies over the brain. The male only has such an horn by way of ornament. It is on the inside hollow, as that of an Ox appears when separated from the head, but its cavity is filled with no other matter than the dilated air-bladders; which, together with a multitude of tubes that adhere to them, are enclosed in it, and insinuate themselves even into its bony substance; hence the horn becomes much lighter, so that it may be carried the easier by the Beetle when it walks or flies. This insect is therefore properly an Unicorn, for he has only one horn. It will not be improper to mention here, that if a Stag be gell while young, his horns will never grow. This I have been informed by a curious and creditable gentleman. Wherefore these animals become in this respect like the female of this our Beetle, when their masculine vigour is taken away.

With regard to the penis of this Beetle we are first to observe the nervous and the horny or bony part, Tab. XXX. fig. VIII. and IX. *a*; this last is as it were the prepuce, or rather a kind of sheath for the penis: it is erected principally by its assistance, and is again drawn back into it when the occasion is over. On the foremost side of this case are situated two little horny bones resembling claws or hoofs *b*, which, forming a chink or crevice in the mid-

dle between them, are capable of being separated from each other by the help of proper muscles, in order to make a way, or afford a passage for the penis when it is erected. The muscles for this service are situated in the bony substance of the beforementioned sheath, and are likewise articulated therewith. By the help of these two little bony claws the male in the time of coition fixes himself in the horny part of the female's vulva. Behind this sheath is placed a nervous, soft, and very thick part of the penis *c*; wherein is placed such a horny little bone as I have observed also in the root of the Bee's penis. Next follows the body or root of the penis *d*, which is nothing more than a small tube, but it has a considerable nerve in the place where the vasa deferentia and seminal vesicles meet. I have observed this nerve also in the water Beetle, and very conspicuously in Bees. The vasa deferentia *ee* are next seen on each side, and they contain a very white spermatic humour: they are indeed somewhat slender where they are connected with the root of the penis; but they become again dilated towards the middle, and thence become more slender where the principal testicular vessel is united with them on each side. The testicles which discharge their sperm through these vasa deferentia, are of a very singular structure in this Beetle. They consist on each side of a simple vas testiculare, which is about two feet two inches long. On one side I exhibit here entirely rolled out and unfolded *f*, whereby it appears at the same time, that the end of it is somewhat thicker, and, like the close gut or intestinum cæcum, has no orifice, Tab. XXX. fig. VIII. and IX. *g*. But on the other side I exhibit this testicle *b* in its natural condition; so that only the extreme end of this vas testiculare appears removed from the mass *i*. The vasa deferentia and vas testiculare have in this creature innumerable pipes and pulmonary vesicles: and by the assistance of these, the convolutions of the testicular vessels are firmly kept tied together; so that they cannot be disengaged from each other, unless these pulmonary tubes are first removed, which cannot be done without continued labour and great patience. Between the vasa deferentia are seen the seminal vessels *kk*, which contain a spermatic matter of a duskier colour than that of the testicles or dilated vasa deferentia. And this seminal matter is doubtless generated and secreted in the vesicles themselves, as is likewise the case in the human species and quadrupedes; in some of which the vesicles may be found distended

with

with several ounces of sperm. Each of these vesicles is terminated by a small curled filament *ll*, which is indeed divided on each side into six small tubes; on the tops of which are deposited so many very beautiful little glands *mm*. These being united to these twelve tubes, by their means send the seminal matter at the time of coition through the vesicles to the penis. I exhibit some of these glands also as they appear *n* when they are more swollen in the middle than in the circumference, and are there filled with a pellucid matter, resembling that substance in a Hen's egg, which Harvey calls the *colliquaneantum*. But the substance which surrounds the middle part, is filled with matter like the white of an egg when beginning to concrete. Hence it is easy to conclude, that the dusky fluid which is found in the vesicles is generated therein, unless one should rather incline to think that it is thus changed in the vesicles, which should have been first proved. The middle part of these glandules is like a globe cut somewhat smooth on the top; but if the glandule be inverted *o*, this part appears entirely globular below, and the little branch of the vessel united to the vesicles is there fixed in its center. This I exhibit somewhat larger than the natural size *p*, representing in the same figure the substance *q*

that surrounds it, which contains a seminal matter much resembling the white of an egg. All round these glandules and seminal vesicles are inserted numerous branches of the *aspera arteria*: one would almost think that one saw the ciliary ducts in the human eye. The vesicles have no communication with the *vasa deferentia*, which is likewise the case in Bulls and many other animals, and even in other insects, and as particularly in Bees. All these genital parts are perfectly white, except the vesicles, which appear gray on account of the dusky seminal matter they are swollen with, which is in some measure seen through them. These little parts are situated in the lower region of the belly, and are there found folded or wrapped one with another, in such a manner that at the beginning of the dissection one would think they could not be disengaged by any industry. But patience overcomes all such difficulties. I observe further, that insects differ very much with respect to their genital parts, as is plain in the organs of Bees, the water Beetle, and others which I have occasionally delineated. These parts are likewise very beautiful in the Hornet, though I have not yet sufficiently examined into their structure. I shall now pass to the ovary of the female.

*The genital parts of the female Rhinoceros-Beetle.*

THE female, which is distinguished in this species by having no horn, Tab. XXX. fig. x. *a*, on its head, shews on dissection, its ovary situated in the lowest region of the abdomen; but it is found to be situated higher when it is distended with eggs. In order to exhibit this the more clearly, I represent it, together with the head and gullet, and the stomach *b*, which is very slender, and the intestines *c*, together with the orifice *d* of the latter, which opens below and near the orifice of the ovary, as they are all naturally fixed among one another. The ovary *ee* consists of twelve oviducts, six whereof are situated on each side, but these afterwards meet in certain common passages, which immediately afterwards form one single trunk, which may be called the uterus or rather the vagina of the creature. This trunk reaches to the extremity of the abdomen, out of which the female discharges her eggs through the horny ring, which is formed like a crescent, and is shaggy *f* in the lower part. In one of these common ducts is here exhibited a perfect egg, and above are seen four other rudiments or imperfect eggs, adhering in three particular oviducts: the other three oviducts of this side are empty or without eggs. On the other side may be seen three more perfect eggs in the oviducts, which otherwise appear very closely contracted in those parts, where I have delineated no eggs in them. I dissected this female the 17th of August, at which time

these Beetles have done laying eggs, and even the young Worms are by that time found. But if the extremity of the vagina which is shaggy, be examined in the inner part, eight horny and bright red little parts, together with the passages that then lead both to the vagina and to the intestinum rectum or straight gut, are obviously seen. Under the vagina, not far from its external aperture, is seen an oblong or pear-shaped bag, Tab. XXX. fig. x. *g*, which opens by a small tube into the vagina. When this bag is cut, a yellowish matter is always found therein, which, after it is concreted, runs into small crumbles, if touched ever so lightly: its yellow colour is seen through the bag. What use this substance is of I am yet ignorant. Above this bag are found two other tubes, which have close extremities, and unite in one short and narrow tube, which is likewise inserted in the vagina. One of these little parts *h* in the Beetle I dissected was pellucid, like a lymphatic vessel, but the other was very white *i*, nervous and hard. The use of these little parts likewise is altogether unknown to me. One may also see here, in what manner all these parts are furnished with numerous pulmonary tubes, out of which issue many pneumatic vesicles or bladders, which likewise emit other tubes *k k*, &c. These pipes connect the oviducts, stomach, intestines, and all the rest of the parts here delineated firmly together, so that they cannot be disengaged but by repeated efforts. There is  
a kind

a kind of entire trunk *l* of these pulmonary pipes, seen near one side of the common duct of the ovary; and other smaller branches *m* are seen about the stomach and intestines. Whilst I was engaged in drawing these pulmonary tubes, I purposely omitted to delineate the knotty vessels or *vafa varicosa*, which are much narrower and closer in the Beetle than in the Worm, for I could scarce have avoided confusion, if I had undertaken to exhibit to the life so many different minute little parts. It is also remarkable both in the male and female, that these little insects are now filled as much with pulmonary tubes as their Worms were before with bladders of fat.

Before I conclude this account, I shall exhibit, because it is pertinent to the subject in hand, five different exotic Rhinoceros Beetles, each of a peculiar structure. The first has a breast-bone, fig. II. *a*, which extends into an oblong tube, somewhat crooked about the anterior part, and at length split or divided in the extremity. The horn of its nose has also a sharp rising from the middle of it. In the second, Tab. XXX. fig. III. *a*, the breast is divided into two acute points, in the manner of a fork; and the horn, which like a proboscis, projects from the skull, turns itself in a peculiar manner, and is elegantly bent back between the teeth of the fork. This Beetle was brought from Japan. The breast-bone of the third, fig. IV. *b*, terminates in a short horn somewhat divided; from each side of which two other shorter crooked points project out of, or from the breast-bone: the horn on the nose in this is likewise very short, and terminates in two arched and sharp-pointed branches. This Beetle was brought from Brasil. I only exhibit the thorax or breast-bone of the fourth, fig. V. *c*, because it is in the body like the first, second, and fifth. This bone is pretty large at its origin, but it terminates in two short, crooked, obtuse points, and is adorned also on the lower part with some ridges projecting beyond the surface. The horn on the nose in this species is split as in the first species; The breast-bone of the fifth, fig. VI. *d*, is divided in various manners, it first emits a somewhat prominent obtuse point, afterwards it grows small, and then expands again into an eminence somewhat divided, and at length it terminates in two acute points or ends near the eye, one of which is considerably larger than the other. The margins or extremities of this

bone have two ornaments like those which I mentioned in the fourth species. The other side of the breast-bone is divided and extended in like manner as that which I have here figured. The horn that rises from the nose is bent back like a segment of a circle against the prominence of the breast-bone \*, and is obtuse at its extremity. A more accurate explanation of the parts of these several species will be given at the end of the work.

Now that I am near concluding this subject, I shall beg my readers to consider, whether the parts of these little creatures changed in so wonderful a manner, and formed with an art not inferior to the construction of the human body itself, can be formed by the assistance of heat and moisture, or be produced by chance from putrefaction? Or whether the infinite wisdom of God, and that most powerful hand, whose fingers made the heavens, and framed all nature, must be considered as the only instrument of their existence? I should indeed believe no one would presume to deny this. I shall therefore conclude this history, by observing that the Beetle is only a Nymph disengaged from its skin, and changed by accretion; as the the Nymph likewise is only a Worm that has changed its skin, and is altered or transformed in the same manner: hence these several states exhibit only one insect under three different appearances, which, after its miseries and mortifications, is advanced by degrees to a glorious and happy resurrection. The Worm leads a miserable life under the earth. The Nymph, deprived of motion, remains long as it were dead; but the Beetle, living at pleasure above and under ground, as also in the air, enjoys a superior degree of dignity, which however it has attained by afflictions and death, for without passing through these difficulties, it could never have come to that perfection. Here calm and serene weather succeeds a storm, and death opens the gates to life. Hence the apostle speaks most justly in respect to us: "I think that the sufferings of our temporary state are not worthy the future glory which shall be revealed in us." We therefore, treading in the foot-steps of our Lord Jesus Christ, and having suffered all the miseries and punishments of this life, expect the reward. My spirit, in the mean time, raising itself with fervent zeal to God, cries out: "My soul magnifies the Lord, because he discloses great things unto me: he is powerful, and his name is holy."

*The end of the wonderful history of the RHINOCEROS-BEETLE.*

\* We have in England two species of Beetles which are able to leap in a very surprising manner. In other insects this motion is performed by means of the legs, which are made of various lengths and forms adapted to that purpose: but these creatures do it by means of their thorax, which is also formed in the under part in a peculiar manner rising and elastick for that purpose: one of these is of a chestnut brown, the other of a greenish black. They both have flattened bodies and slender legs.

*A particular treatise on the Culex or Gnat, which likewise belongs to the first method of the third order of natural changes called the Nymph.*

AS Ants, Bees, and Beetles are generated from a visible egg, in such a manner that an intermediate Worm first issues out of this egg; in the same manner a Worm or Vermicle, out of which the Gnat has its origin, is produced from the egg of a winged parent. As the several parts of the Worms out of which the just mentioned three insects arise and increase by degrees under the skin, and the creature having cast it, at length appear to our sight, all these incidents have place in the Worm and Nymph of the Gnat. But there is, notwithstanding, in this insect a considerable difference, which is, that whilst the Nymph of the Ant, Bee or Beetle, is without motion, and cannot change its place, this Nymph of the Gnat, on the contrary, has the power of loco-motion, and swims in the water; for this reason, it appears at first sight to approach in a great degree to the Nymphs of the second order.

On a just examination of the subject, this difficulty will be found, however, of small moment: for the Nymph of the Gnat, in reality, has no more motion in its legs than the other Nymphs of this third order; for it is never observed that it moves in the least its head, breast, horns, wings or legs; the contrary whereof is observed in Nymphs of the second order. For this reason, though the Nymph of the Gnat has so strong a power of moving from place to place, yet that is no obstacle to prevent our referring it properly and justly to the third, and not to the second order.

The true reason of the difference consists in this, the change which the tail of the Nymph of the Gnat undergoes, is not so remarkable, as that the Nymph should thereby lose the faculty of moving briskly. The tail is the only part, by the help whereof this Nymph changes place. The limbs and other parts in this Nymph, are in reality as immovable as they are in the Nymphs of Ants, Bees and Beetles. And even these Nymphs are not wholly deprived of the power of moving their tail, as is evident in the Nymph of the Rhinoceros-Beetle just described; for this can, by the motion of its tail turn itself a little in its terrestrial habitation. But in the Nymphs of Ants and Bees this is not observed, until they have passed the greater part of the Nymph state, and are very near changing their skin. Having therefore removed this difficulty, which might appear more considerable than it is to those less acquainted with these changes. I shall proceed to give the particular history of the Gnat and

and its Nymph; from the particulars of which all those things which have been said in the preface will be better explained and easier understood.

The Gnat is produced out of a very small egg, which is exposed or cast into the water by the parent Gnat, when she is engaged in laying her eggs, and in a few days this produces a very small Vermicle or Worm\*. I was first informed that the Gnats sprung out of the water by the curious and learned Mr. Duiffen, a very vigilant protestant minister at Saumur in France, who had observed it in his kitchen garden, where there was a stone basin with water in it, out of which he saw plainly that Gnats arose at a certain season.

Afterwards, on my return to Holland, I found the Worm of the Gnat swimming in water, and immediately took its figure. Hence it happened, that when I saw it in the admirable figures of Dr. Hook's micrography, I immediately knew it, since that very learned English gentleman has delineated it with the greatest accuracy. But this celebrated writer does not seem to me to have examined the tail of that Worm with sufficient attention. I shall observe further, that the Nymph of the Gnat has been somewhat improperly exhibited by him, unless he had some other species of this insect. This is the more probable to me, as I find there are various Nymphs of Gnats, as well as many kinds of the Flies themselves.

In Tab. XXXI. fig. iv. I exhibit in its natural size the Worm out of which the Gnat is produced. The same is likewise represented in fig. v. magnified by a microscope, and thus it presents to the eye very obviously the construction of its breast and body. It may be likewise observed here, in what manner it raises itself to the surface of the water by the help of its tail, and also the construction whereby it is divided into the head, breast, body and tail.

In the head, which lies sunk under the water, I have shewn in this figure various particulars particularly the eyes, the horns, and the lower part of the mouth. The eyes are black *aa*, and have a smooth and polished surface; nor are they divided like a cluster of grapes, or by an hexagonal network, as in many insects, but are of a figure somewhat lunated or like a crescent. The horns are shaped not unlike the collar-bones, Tab. XXXI. fig. v. *bb*, in the human species, and are furnished with hairs towards their ends. The opening of the mouth

\* There is not in all the insect world a creature more happily suited to shew the several operations of life than this. A moderate microscope discovers to us very clearly what passes within its transparent body. The creature is at first greenish and somewhat dusky, but as it grows towards the change, it becomes pale and greenish. At that time the beating of the heart, and the motion of the stomach and intestines are perfectly seen, and the two principal pulmonary tubes may be traced along their course very clearly.

is likewise shewn here *c*, appearing like a blackish triangular spot. We may likewise distinguish by the microscope seven other little parts of the mouth, whereof I exhibit three, as well above the mouth as at its sides; but the seventh, which is somewhat brown, is observed to have its two bases placed near the thorax, and reaching to the eyes. This little part is somewhat whiter in the middle, and grows browner a little lower near the mouth, but in the anterior or fore part, it appears to be formed like the nails of our fingers, or the scales of fish. Where this little part terminates with its brown curvature or winding, almost in the middle or lower region of the head, I exhibit the first of the three pair of little parts already named. This pair is of a triangular figure, on account of the hairs wherewith their inner side is surrounded. About the end of this follows another pair of the like little parts, the beginning of which are horny or bony, but the extremities are hairy. Below these again are seen a third pair of little parts which are somewhat thicker and more shaggy, and extend to the hairs of the horns. These three pair of little parts are, properly speaking, articulated bristly hairs, which the Worm of the Gnat makes use of to direct the food to its mouth. I have before observed something like this in the hermit Crab, in which I have described many little parts of a somewhat like kind. The mouth of this Worm is in the fore part beset thickly with hairs, which are all of equal length, and are placed equally distant from one another: this is shewn at the letter *c*.

In the thorax are certain regular divisions *dd*, which are produced by the growing and extuberant joints of the legs and wings of the Gnat within. Hence I can shew even in this Worm all the limbs and parts of the future Nymph, and of the perfect Gnat lying under the skin, as I shall do on a succeeding occasion in the Worms of Bees, and shall thus exhibit an example applicable to all other insects belonging to this first species, or method of the third order of natural transformations. Afterwards, when I come to the second method of the third order, I shall present to the eye a kind of similar instance on the diurnal Butterfly. We may likewise further observe how the thorax of this Worm is distinguished with furrowed lines, and beset on each side with bristly hairs, many issuing together as it were out of one center.

The belly is divided into eight annular sections, Tab. XXXI. fig. v. *ee*; to which, if you add the shaggy extremity *f* of the tail, and that part of it which is likewise strengthened *g* with the bristly hairs, and is extended by the Worm above the surface of the water, ten rings must be reckoned in the whole. In that part of the tail which is seen *b* above the surface of the water, there appear certain black spots, and some depressions or holes, as also many bristly hairs. But here we must take particular notice, that whenever the Worm, swimming in the middle of the water pulls

down the part of the tail just mentioned under the water, that part never becomes wet. Therefore, when the Worm wants to rest, or cease moving, it immediately goes up to the surface, and there, by means of its tail, suspends itself almost in the same manner as we see a little glass figure of a man hang pendulous in a glassy bubble in water. This is done the easier by this Worm, because its tail always remains dry: hence it is also observed that as soon as this appendage of the tail has again emerged to the surface, the water immediately flows away from it on every side. And one may distinctly see that a kind of basin or hole is by that means impressed on the water, when the body of the Worm gravitates downwards; the water not being able to penetrate into the dry tail and its depressions, is stopt in its circumference: and therefore the Worm, in regard to the extremity of its tail, very beautifully swims in the water in the manner of an empty hollow glass. The like effect may be likewise produced by art, if a needle be drawn through a cork and put into the water; for the cork will then swim on the water, and in like manner make a considerable depression in the surface.

Near the extremity of this tail I exhibit some bubbles in the water *i*; these are frequently seen, and they arise from the air which the Worm can at pleasure emit there out of its body. I have seen that the Worm, in order to draw in the air, has raised its head out of the water. When it has happened that the tail had lost its dryness, and the Worm by this means can no longer suspend itself on the surface of the water, which is the case when it is bruised or handled too roughly; I have on these occasions observed, that it put its tail in its mouth, and afterwards drew it back together with its hairs. In this method of proceeding the insect resembles water fowls, which, by drawing their quills through their beak, prepare them in such a manner that they can resist the water. They secrete this fat matter by means of a double gland which they have in their rump, in which this oil, which strengthens the wings against the water, is generated and excreted, and they thence take it into their beaks. I have sometimes covered anatomical instruments of steel with this matter, in order to keep them from rusting, and have found that the steel continued perfectly defended from rust by means of it; and I think it would have greater effect, if one had a great quantity of it boiled and properly managed.

As this whole insect is pellucid, I have here exhibited the two transparent pulmonary tubes which appear in the middle of the tail where it floats in the water. These arise from the body near the thorax, and contain, Tab. XXXI. fig. v. *kk*, in them the quantity of air whereby the bubbles are produced. This insect therefore breathes at its tail, in the same manner as the Worm of the Gad Fly. But this tail is not so absolutely necessary for the Worm of the Gnat, that it cannot live without it. It only  
ferves



erves for its conveniency, and by its powers enables the Worm to rest or hold itself suspended on the surface of the water. Hence it is, that the tail is entirely destroyed and thrown off when the Worm casts its skin and is changed into a Nymph.

As to the other part of the belly or tail; whose extremity is likewise shaggy, with bristly hairs, I exhibit about it some small lumps *l* of an earthy matter, which fall into the water and there melt away by degrees *m*. These are the excrements voided from the intestines. We may likewise observe here the intestines themselves, which contain these fœces, and are seen through the transparent belly, situated between the pulmonary tubes *k k*, and at length terminating in this other extremity of the belly which is the real tail. It is very singular, that in this Worm, not only the motion of the intestines, but also the propulsion of the excrements in them *n* may be seen through the integuments of the body. This motion of the intestines, the never-enough celebrated Dr. Hook first discovered. I observe likewise that these pellucid intestines appear sometimes white, sometimes black, and are sometimes divided into little knots. This variety arises from the contents and excrements being more or less changed in them. Lastly, I likewise shew small hairs in the eight rings of the abdomen, three in some, and in others four, and also the squamous or scaly windings and constructions thereof.

When this Worm is arrived at its full growth, and its limbs having attained their due perfection, are swollen or filled with blood and humours, it throws or casts off its old skin, and exposes to open view all its hitherto hidden limbs and parts; this is when it is changed into a Nymph, which is delineated in its natural size or bigness in Tab. XXXI. fig. VI. and in fig. VII. as it appears magnified with a microscope. In the latter design, the head, breast and belly may be more distinctly seen than in the Worm; nay, and the eyes also, and the horns, the trunk, the legs and the wings. All these parts are however fluid like water, and must in due time evaporate this moisture in the water, to such a degree as to acquire due firmness.

Lest the delineation of these parts should be obscured by annexing letters to them, I shall shew them all in a less finished figure, which I have added for that purpose. Before I begin, it must be particularly observed, that the head, which before in the Worm hung downwards towards the bottom of the water, is always raised upwards in the Nymph, and is likewise, by means of two tubes, suspended on the surface of the water, in the same manner as the tail of the Worm was before. Hence, as the Worm then drew the air through the tail, being changed into a Nymph, it now breathes the air with its head through the tubes just now mentioned. Hence it is also observed, that the tail which in the Worm was protended up-

wards, lies in the Nymph sunk under the water; and this is indeed a remarkable change in the insect with respect to its manner of living.

One might take these tubes in the head for the horns which the Worm had before, and which are now, after casting the skin, dilated and adapted to another use; but those horns were situated nearer to the foremost parts of the head. The tail is likewise upon the change of its skin considerably altered; it has acquired in this state a beautiful feather, to serve as a rudder, by the help of which this Nymph moves freely from place to place; and swims in a quite another manner than it used to do when it was in the state of a Worm. Dr. Hooke has also observed this change of the Nymph, in respect to the manner of its moving and swimming, as appears from his Micrography. In many insects, nay, particularly in these which belong to the second mode of the third order; it is observed that when they are changed into the Chrysalis they have a motion in their tail; though all the rest of their body become wholly immoveable, as is also the case in this Nymph. We have fully treated of this in the beginning of this chapter.

On one side of the head in this design is seen an eye, Tab. XXXI. fig. VIII. *a*, covered a little on the upper part with a membrane; which invests the proboscis or trunk, and this eye, is now divided into hexagonal and globular divisions. Above this appears to be situated one of the antennæ *b*, divided into several black knots which are so many joints. The trunk *c* which is the Gnat's sting, and which partly covers the eye, is placed with its sharp point between the legs and wings. The legs *d d d d* are in a wonderful manner twisted and bent, but especially in the hinder part; and they are hidden between the wings, and appear plainly through the transparent substance of the latter. This I here exhibit delineated, that both the wing of this side may be seen, and also the membrane that invests it *e e*, and which is placed above the legs. The body is divided into eight rings, on which some of the hairs, that have changed their outer covering *f f*, are observed to rest. Through the middle of the whole length of the body appears a beautiful border or rising verge *g g*, which I could scarce discover in the Worm of the Gnat, nor have I afterwards found it considerable in the perfect Gnat itself. The tail, which hangs down, has, as I observed, a moving jointed fin *h*, by the help of which the Nymph removes from place to place. In the upper parts of the head are seen the tubulated horns *i i* before described, by means of which the creature, while in this state, hangs and breathes on the surface of the water; but by the help of this construction the Nymph is now better prepared to be changed into a Gnat after casting its skin. This insect, while in the Nymph state, has no certain colour; for, upon its change, it grows white, and afterwards becomes somewhat green, and at last it approaches to black.

After

After this Nymph has lived some days, moving itself backwards and forwards in the water, and its tender limbs are strengthened, it bursts and casts its skin in the middle between those two horns or tubes, by the help of which it was before suspended on the surface of the water; and after this, on account of the lightness of its body only, it remains on the surface, until its wings are expanded and dried with air; then the Nymph having assumed the form of a Gnat flies away, leaving its cast skin swimming in the the water, where it insensibly decays.

The Gnats of this species \*, which are best of all known in Holland on account of their mischievous trunk or sting, are easily distinguished into males and females. I exhibit the male in Tab. XXXII. fig. I. and also a microscopic view of it in fig. II. Between this Gnat and its Nymph there is no other difference, except that the limbs are disposed and placed in a different manner in the Nymph from what they are in the perfect Gnat. Hence, as the head, breast, belly, &c. may be seen and unfolded in the Nymph, we may distinguish all these things in the Gnat itself, but much more accurately, for the external skin of the Nymph, which prevented the more distinct view of all these parts, has been now, upon the last change, thrown off.

In the head of the male Gnat, I particularly exhibit, in the enlarged figure, the eyes, horns, and trunk; as also two other parts placed near the trunk or sting, between or under which the latter is properly placed: the eyes *aa* constitute the greatest part of the head, as is the case in many other species of insects. They are of a greenish colour, and they form as it were an hexagonal piece of network, the divisions whereof rise in a globular figure. Near the eyes I represent the horns *bb*, which arise as it were out of two yellowish flesh-coloured little globes, and are beautifully divided into twelve black knot-like joints, which are surrounded with hairs like tender flaxen threads. Toward the extremity of each of these antennæ is seen a circle, consisting of six hairs placed in a circle; above which appear the extreme ends of the horns surrounded or covered with yet smaller hairs. As to the other two long and crooked parts, between which the trunk or aculeus is observed to be situated *cc*, I find them divided into three joints, beset with hairs toward their extremities, and moreover covered every where with a kind of brownish feathers, which resemble, as the feathers of Butterflies do, the little scales of fishes.

The trunk is of the same colour, and is adorned *d* with the like scaly little feathers, but it is not divided into joints, being immovable in the middle; though there are plainly some divisions toward the end of it; and it is there

likewise near the end regularly surrounded by five hairs on each side of it. On full consideration of the whole, the part before described, and which we usually call the trunk *e*, the aculeus or sting of the Gnat, is nothing more than a sheath or case of the real sting *e*, which is represented in this figure only projecting, or as if thrust, out of it. This sting is provided with so sharp a point, that I could never observe the least breadth therein, with the best microscopes that I used in the year 1688. If you put the edges of the sharpest razors, or the points of the finest needles and lancets before the microscope, you will easily see that they have visible breadth, and appear blunt, ragged, and dull. I do not find this sheath in all Gnats; and this is the case in that species described by Goedaert, the sting of which I should incline to think is very short, and lies rather in the mouth than in any sheath or case; so that the same thing seems to obtain here as in the Louse kind, the sheath and trunk of which are also discovered with difficulty, though these little creatures prick or sting vehemently, and give us great trouble by sucking our blood.

Thus I observe, with respect to other insects, that there is great difference as to their stings and trunks; some of them have their proboscides eight times longer than others, besides that the construction differs greatly in both. But I have elsewhere said enough on this subject, when I treated of the swift Butterfly, which is represented in the history of the Rhinoceros Beetle, Tab. XXIX. But when I come to the Gad Fly I shall, from the observations I have made on the sting and trunk, offer some reasons why many insects that feed on blood, still preserve life, through deprived for a long time of the blood wherewith they naturally nourish themselves. This question may certainly arise with respect to Bugs, Fleas, and several such insects, and also in regard to the Gnat kind. I now return to the subject and shall give a more full explanation of the trunk of the Gnat.

The case or sheath of the sting, as I have already observed, is immovable in the middle, but where it is united to the head it appears to be jointed. If one dissects it under the microscope, and very quickly breaks it off at a little distance from the head, or cuts it, Tab. XXXII. fig. III. *a*, in its circumference, but in such a manner, as at the same time to draw this broken case of the sting from the sting itself, which is placed on the inside; this way at length the aculeus is plainly seen naked and disengaged from all impediments, in which state it could not be viewed before. When I first made this experiment, I thought I had discovered the whole aculeus in this manner: for I observed an acute pellucid little part of a bright red colour *b*, which consisted of a horny

\* We have in England three very distinct kinds of Gnats: the largest of these has brown eyes, and a black and white body; the middle kind is altogether brown: this has the most mischievous bite of any. The third or smaller kind has a red breast; this also bites severely. The Worms of all these are alike in form, and, what is very remarkable, they differ little in size. We have beside these a multitude of distinct species very small, which are, in the fen countries, very troublesome.

or bony matter, and was moderately strong and yet flexible. But upon examining this little part afterwards with a larger magnifying glass, I observed that there was a considerable aperture just below its sharp point; and I also observed two little drops of a real liquor, at some distance from each other, lying in the middle of this little part, as in a little hollow tube. As I was attempting to express or get out this liquid under the microscope, it happened, contrary to my expectations, that I broke that little part. This accident had great advantage, for on the inside of this little part I then discovered five distinct aculei or stings, and consequently thus found the whole construction of the aculeus.

I observed that two of these aculei which were hidden within the tubulated little canal of the general thing were, much more slender, Tab. XXXII. fig. III. *cc*, than the three others, which appeared thicker and stronger, *ddd*. I likewise observed that they were somewhat broader where they were articulated with the head, but that they afterwards became small, and that they were finally considerably extended, before they terminate in their delicate and fine points. All these aculei were of a delicate smooth surface, but in the middle they were somewhat thicker and more distended, so that in that part they appeared of a browner colour, exhibiting to the eye within a pellucid bright redness: but they consisted of a flexible horny or bony matter like that of the little canal which contained them. I could not discover any cavity in them, though there seemed to be something of this kind in the larger; for when these were examined with a very acute glass, they curled and continually moved about: this, I thought, must be attributed to the evaporation of the humour inclosed or contained within their substance. I could by no means, however, observe any other mark of their being hollow on the inside.

As to the use of these five aculei, they seem only to serve as so many very sharp lances to enter the pores of the skin; and afterwards to retract or draw themselves back into the inward case wherein they are kept: but then I should think that the acute and hollow extremity of this case is certainly introduced into the wound, and by means thereof the Gnat afterwards sucks the blood, which, running or ascending by suction between these sharp parts, is at length conveyed into the body of the insect. Hence there appears almost the same use of this sheath as there is of the silver pipes used by our surgeons, through which they pass their lancets when they are about to open ulcers that lie deep between the jaws, and are careful to wound no other parts but those they are to cut. The reason why nature hath made five aculei for this purpose, is, I confess, beyond my comprehension, unless one should incline to think that by the repeated agitation of so many things in the womb, the blood is better prepared to

ascend through this long and most slender tube wherein those stings are hidden.

I am firmly persuaded that when the Gnat has no opportunity of drawing blood out of animals, it sucks, with the help of its case, the juices of flowers, plants or fruits; being content with feeding on the latter when it wants the former: indeed, by what other means could it support itself, when it lives in the fields and woods? I would not now presume to affirm for certain, whether, when I first communicated to the public the figure of the Gnat's trunk, not knowing then that it had five stings, I saw one or more stings projecting or hanging out of its case; but I am not certain now that these five stings, viewed sideways, do not appear broader in the fore part next under their points than elsewhere.

After I had made the observations already mentioned on the sting of the Gnat, I often afterwards observed in the dead Gnats, that all their stings were broken off from their case, and appeared without the little tube, without my aid. And hence I began to consider, whether these integuments of the five stings resemble or not the sheath or case of a Bee's sting, and only or loosely contain the real sting, as a scabbard open on one side might hold a sword. But, notwithstanding the repeated pains I have hitherto taken to discover the truth in this matter, yet I could never find out any mark of such a structure. I therefore think I may safely maintain that both the case of the sting and its inward pipe are two distinct and entire integuments, the exterior of which contains the little tube, and the interior, which is the little tube itself, contains the five stings.

It has sometimes happened, that upon examining these things in other species of Gnats, I have observed that, like the stings of Bees, they were provided with a kind of crooked claws, or were at least serrated on their surface. But this I had not the good fortune to see when I was engaged in drawing and finishing the figures of these parts from the present species; only I thought I once saw something like it through the common microscopes, and therefore those who are fond of microscopes, must take care not to confide in one lens or glass only, and must not always view the object in the same manner and situation, for by this means many errors arise. In the third figure above mentioned is likewise seen the neck, Tab. XXXII. fig. III. *e*, of the Gnat, and the head *f* placed thereon, in which the eyes *g g* appear, as also the antennæ cut off *h h*, and the articulated setæ or bristly hairs *i i*, which are cut off above the stings.

As to the thorax of the Gnat, it carries the legs and wings, and also two little parts like hammers, and of an oval figure. The legs are of a brownish colour, and consist of seven joints, fig. II. *ffff*, which are larger in the hinder than in the fore legs: but besides these, the extremity of each leg is likewise armed

with two claws. Moreover, the legs of this insect are all over covered with scaly little feathers, between which appear some blackish setaceous hairs.

The structure of the wings *gggg* is so beautiful, that nothing can, in a manner, be invented more ingenious or artificial. They consist partly of pulmonary tubes, and partly of delicate membranes, which are perfectly pellucid. They are of an oblong form, and of a glassy colour; but they are obscured or shaded by a very great number of scaly rhomboidal figures, which are a vast ornament to them. All the membranes of the wings are interwoven with pulmonary tubes, which run through them like so many veins and nerves; and upon those pulmonary tubes, which are conveyed out of the body into the wings, are fixed these oblong and broad feathers for the sake of ornament. The same construction is seen also in the beginning, middle, and circumference of the wings, and is a very agreeable sight. In order to make this structure clear or more evident, I here exhibit the wings somewhat larger, in proportion to the other part of the Gnat, than they were formerly. But if these wings were represented as large as they can possibly be magnified by good glasses, the divine miracles that are presented to us therein would amaze all mankind.

We should then distinguish clearly that every series of the little feathers before described, likewise rests on a stalk or tube, by means of which, it is united to the pulmonary tubes: and also, that some of the feathers are here and there larger, shorter, or broader, and placed in a quite different manner from the rest, as far as regularity and beauty would admit. If broken feathers chance to occur any where, their quills will be found there still fixed in the pulmonary tubes. The structure of the little feathers would shew itself very admirable in this case, for almost all of them are interwoven with six regular little ribs like so many nerves, each of which consists of a great number of regular globules. This is seen more clearly by the help of a powerful microscope; all these little feathers being likewise transparent, though they are not altogether so clear as the membranes of the wings.

Further we may observe, in what a wonderful manner the very membrane of the wings is constructed in this creature, for it appears under the microscope beset with many prominent papillæ or little risings. If this part be viewed by help of the most powerful microscope, it will be distinctly seen that all these papillæ are so many crooked, curled, pellucid little tips or points, of most delicate, long or extended papillæ. In all this the omnipotence and wisdom of God shines brighter than the meridian sun. All these things cannot be expressed in the small compass of a single figure. I have therefore exhibited upon this membrane of the wings, only a few out of the great num-

ber of these inflected and sharp-pointed papillæ in the form of points. Nay, I would venture to assert, that however good the microscope made use of is, yet one cannot see these papillæ distinctly, unless we first tear a part of the membrane of the wings carefully for that purpose; for the sharp little tops or points which I have here mentioned, are only to be seen when all impediments are most carefully removed.

The malleoli, Tab. XXXII. fig. 11. *bb*, or little hammers fixed to the breast, whereof I made mention, are of a somewhat irregular shape, and at their extremities are considerably dilated: they are there smooth and of a whitish colour. I have observed such malleoli almost in all Flies which have only two wings. The surface of the thorax also shines a little, and being covered in a manner with red bristly hairs, instead of feathers, it is likewise adorned with a red colour.

The belly is divided into eight rings *kk*, in the same manner as I have exhibited in the Worm and Nymph. All these divisions are likewise as visible in the perfect Gnat, as in those states lately mentioned. I further, observe that the belly and tail are every where covered with feathers, which are black in some places; and this is the reason that the belly and tail appear divided as it were by black rings. The other little feathers intermixed with the former are of a white or yellowish colour, and are wholly transparent. Moreover, the whole belly is every where covered with fine hairs, the extremities of which curl, and seem to be in some measure entangled in one another, though in reality they are not.

I also represent the head of the female Gnat, fig. iv. magnified, which, in respect to the structure of the horns, differs from the male's head *aa* extremely. Those little parts of the head also, between and under which the sheath of the sting is extended, are much smaller in the female, and distinguished with greater difficulty *bb*. The horns in this sex are also divided as it were with twelve parts, and they are regularly covered with brownish hairs and little feathers. The sheath of the sting *c*, and the other little parts are of the same structure, and have the same integuments that I have before described in those of the male. Lastly, that nothing may be deficient, I likewise exhibit the female herself in her natural size, in fig. v. I have not yet accurately investigated the internal parts of the Gnat, and therefore shall say nothing of them here.

I have occasionally observed many distinct species of Gnats, but their principal difference consists in this, that some of them have and others have not a sting or trunk, and therefore seem to be harmless. They likewise differ considerably among themselves in respect to their magnitude, colours, and food; the place wherein they live, and the manner wherein they are produced; and in several other particulars worthy

worthy attention. At present I shall say nothing more of these insects, being already too much fatigued with observing and describing

those particulars, which I have hitherto advanced. I shall therefore conclude this treatise, and proceed to the history of Bees.

A TREATISE on the

# HISTORY of BEES;

Or an accurate description of

Their origin, generation, sex, œconomy, labours and use.

*O come hither, and behold the works of God: how wonderful he is in doing towards the children of men.*  
Pfal. LXVI. 5.

## INTRODUCTION.

**A**LTHOUGH the majesty of the immortal God is in its nature inaccessible to mortal eyes, his eternal power and divinity are most clearly and evidently seen in all created beings: some creatures, however, present the invisible God to our contemplation more plainly than others, as will appear from the subsequent treatise. Since, therefore, the most wise and great God has been graciously pleased to bless and crown my indefatigable and assiduous labours with some degree of success, I hope that his infinite power and immense wisdom, as well as our own weakness, will be thereby made clearer than the light at noon; so that whoever peruses this treatise, may find matter enough of wonder, and be led to proclaim and admire the magnificence and wisdom of God, and to bless his inexhaustible bounty. If these pages, which only exhibit as it were the shadows of things, and extremely defective descriptions of the secrets works of God, that are impenetrable and impossible to be fully investigated, should direct the reader to this true use of the researches, I shall think the pains I have taken, not only recompensed, but also sufficiently prosperous and blessed by the divine grace.

If any one accurately considers the disposition and structure of the smallest and largest animals, and compares them one with another, he will see that they agree not only in the above mentioned particulars, but also in that they spring from like principles, which are eggs of their parents, as well in the smallest as in the largest animals: and as these eggs increase and are perfected, as it were from very small and almost invisible points, they, in the same manner, come to the full period of their increase in the smallest animals as in the largest. Nor is there any creature excepted from this universal law of its origin. Since man also, the most noble of all creatures, and who is a rational animal, has his origin or beginning

from an egg, and therefore cannot, in respect to his first principle, prefer himself to the smallest insects, or, with regard to his natural disposition and structure, assume to himself any superior dignity, in preference to the most mean and contemptible creatures the Louse or Mite. That this is most certain in regard to the human species, I have learned from experiment, in the year 1667, as did also the celebrated Van Home. This may be seen in my book intitled, the miracles of nature. Further, it deserves notice, that as to the principles or rudiments of smaller as well as larger animals, the former are more conspicuous, and more clearly discernible in their first state than the latter. And further, since God hath prescribed certain limits of magnitude to the smaller animals, beyond which they cannot increase, and which limits are probably situated in the peculiar structure, or from the weakness of the heart, by the power of which all the other parts must be extended against the gravity of the atmosphere; the small animals, therefore, while in embryo, may be much more perfect than the larger.

To come nearer to my purpose; as I proposed in my book of insects published in the year 1669, at some other time to treat expressly on the structure of insects, and in that work to give the particular history of Bees; saying, by way of anticipation, that the king, as commonly called, was a female, the drone a male, and that the common Bees belonged to neither sex; I shall, to keep my promise with the publick, now treat particularly of the structure, disposition, and principles or rudiments of these three creatures, which are different in themselves, but of the same species. I shall also occasionally intersperse some other observations on the parts of some other insects, the whole constructions of which I shall, with the divine favour, at some other time describe more at large.

On the twenty-second of August 1673, I opened a Bee-hive, after the Bees had swarmed, I found some thousands of common Bees in it, some hundred drones, and one king. But as, properly speaking, neither king nor drones are to be found in the hives, as has been already observed; and since it happened, through a very great and inexcusable error, that those wrong names were given to those creatures, I would therefore here in the beginning inform the reader, that through this whole treatise I shall call that pretended king by the name of the female Bee; and to that which is commonly called the drone, I shall give the title of the male Bee, and the common Bees, I shall, for distinction's sake, denominate working Bees: I shall also in the following pages, shew the very clear and evident reasons which have induced me to make this innovation.

When I had opened and destroyed a hive at the time above-mentioned, besides the males, females and working Bees, I found therein three different species of cells, or little houses of the insects, which are called by the general name of honey-combs. In some hundreds of these cells the males were fed and grew, in some few, females were generated; and in the rest, of which there were some thousands, the common Bees were nourished, brought up, and finally changed. The cells of the males and females were at this time empty, but the cells of the common Bees, though they seemed for the most part empty, were many of them really full and covered with wax. When I broke these cells open with a small needle fixed on a skewer, I found some of the Worms of the Bees placed upright without any motion. In some other cells that were covered in the same manner, there were Nymphs or Worms of Bees, which, by due accretion, had already acquired the form of Bees, and were to be let out from thence. In others I found honey. The rest of the cells were open, and not covered or sealed up; and some of them had eggs, others contained Worms very lately hatched out of their eggs, and provided on every side of them with food: others again had larger Worms; and finally, others were arrived at their full bigness. These are called the offspring or stock, by the keepers of Bees in our country, and they had yellow excrements under them.

In the middle between these eggs and the stock, were seen some little cells also sealed up, which, when I opened, I found filled with honey; for the Bees never leave any place empty in their hive, but as soon as any Worm is changed into a Bee, they immediately fill its cell with something else. Therefore, if the combs in the upper part of the hive are first emptied

of the young Bees, they first put their honey into them; but if those in the combs in the middle of the hive become mature before the others, they first fill them with honey: and lastly, when the combs of the lowest part of the hive are emptied, they in the same manner fill them before the others with honey: but they afterwards carry the honey repositied there to the upper part of the hive. This Clutius observed, but I have not yet seen it. The Bees proceed in this manner, when the year is fruitful, in order to shorten the time, so as to enable them to gather the more honey, or when they are more numerous in the hive; for then they immediately lay the honey as soon as there is room, and afterwards, when the time of making honey is past, they carry it elsewhere.

This hive, therefore, as a common and fraternal habitation, contained the rudiments and stock, the males and females, with their labouring servants, that is, the common Bees; and lastly, plenty of food. Therefore it was well provided and prepared to bear securely, and, in a regular order, the inclemency of the approaching winter. The order under which the Bees that live in the winter months conduct themselves is this: they first open the cells and eat the honey deposited in the lowest part of the hive, ascending by degrees up to the upper parts. This they do in order to preserve a mutual warmth between them; and the female deposits her eggs in the little cells as they are emptied. Therefore about the beginning of March I discovered the stock and the Nymph. Let no one be surprisid at this, since towards the beginning of August I have seen some thousand eggs enclosed in the ovary in the female's body; so that it is natural for the Bees at any time of the year to lay their eggs, and increase their family: Bees are not therefore confined to the time of swarming in regard to the business of generation; indeed, they are always at this work, since they lose some of their fellow-citizens by the injuries of rain and winds, and other inconveniences and disorders; in the place of which they are obliged to substitute young ones by a continued generation.

Our keepers of Bees are wont to express by the following proverb, how soon the young Bees are hatched, when they say, that the first Swallow and the first Bee give notice of each other\*. There are some, indeed, who think this should be understood of the flying off of Bees, but this does not seem to be the proper signification of the proverb.

We must observe here, that some of the cells in the hives are filled with a matter of various colours, which has been gathered and

\* Among the wonders in the real œconomy of Bees, nothing more deserves our attention than the certain preface they have of rain. It has been supposed they see clouds gathering for it, and know where they will fall, but their eyes are not made for so remote objects. It is certain they have some notice, and that it never deceives them. They hasten to the hive and get in before the most sudden showers. One never sees a Bee in the rain, unless it be a lame or disabled drone. In all probability they feel the temperature of the air which brings rain; and if we observe the amazing structure of their pulmonary tubes, as described by this author, there will appear no wonder that they feel very suddenly all changes in the atmosphere.

laid together as it were into strata or beds, like Herrings or other merchandize put with great art into a barrel, which are by degrees and at different times heaped upon one another. This matter I found on examination was granulated, and tasted somewhat sweet. Some of the cells containing it were sealed up, and others open and only half full: others were scarce begun filling, and in others again began to decay. This substance is called by the Bee-keepers the bread or food of the Bees, wherewith they are said to cure themselves when they have a flux. But as credulity is often the parent of error, doubting about the truth of that received opinion, I have by various methods searched into and examined this substance: for it seemed to be rather the rudiment of wax. I have therefore first thrown it into water, in which it was quickly broken and dispersed, but it always remained in grains: this likewise happened when I put it on my tongue. If it be put on a piece of thin glass, and placed on a red hot coal covered with ashes, I have observed that by degrees it wasted, grew dry, hardened, and at last become black. Nor does it ever melt when thus placed on the fire; nay, if it be thrown naked into the fire, or applied to a burning candle, it never burns. From these experiments it seemed to me not at all to consist of the matter of fat, for the sake of examining which I had begun them, especially since I observed, that it was very like that substance which the Bees constantly carry home, and is fixed on the fifth joint of their hinder legs, and which is taken for wax by all the Bee-keepers. Upon examining this matter which the Bees carry on their legs, I discovered that it is absolutely the medicinal bread of the Bees. Hence it came to pass, that I could scarce persuade myself that the Bees carry the wax perfect out of the fields without any previous preparation; as I cannot be hitherto brought to believe any thing like it of honey, being rather of opinion that this is transformed into a better united and thicker liquid, by digestion in the stomach of the Bees: though it may, however, be possible that in the fruitful and hotter summers, the Bees may collect the honey as they find it prepared by nature in flowers into the cavity of their trunk: as the trunk is full of irregular parts, and as it were set or planted with glandules; hence it follows that the honey may likewise suffer some change in it. As to the wax I do not doubt but it is prepared by the Bees. However this matter may be, when I afterwards laid these doubts before the most intelligent Bee-keepers, they were all unanimously obliged to allow that no difference could be observed between the bread or food of Bees and the wax,

which the Bees had carried fresh into their hives\*.

I therefore mixed this bread, as it is called, with honey, in order to see whether I could gather any thing from thence, but the event of the experiment taught me that I had laid too great stress on theory. In the beginning, indeed, when it is first mixed, it becomes a very clammy and glutinous mass; and it runs more thin than the honey did before, and becomes still more soft when exposed to the fire: but when it sustains the force of the fire a little longer, it soon discovers its former nature. It likewise breaks in water, nor does it much recede from its former nature or disposition.

From that experiment I am inclined to believe that this is the substance from which the Bees prepare their wax. But I think they do this business by the help of their saliva or of the execrated and digested honey. And hence though what is commonly said may probably be true, that Bees use this matter as a medicine; yet I do not doubt but they gather it in the time of plenty, that when scarcity comes, or when wet and cloudy weather approaches, or when they cannot from any other cause fly out of the hives, they may take their time to perfect it. Any one may know by an easy experiment whether this matter be so. The Bees therefore seem to behave with respect to this, in the same manner as they usually do in regard to honey, of which they gather more than they have immediate occasion for, that they may live thereon in the time of necessity. This abundant quantity amounts to sometimes thirty, forty, fifty, or sixty pounds. Nay, their zeal and earnestness to gather honey urges them so far, that they sometimes throw their stock or young out of the hives and fill the emptied cells with honey: but I should think there is some other reason for this act, which yet remains to be considered and discovered.

I think that the Bees probably gather this matter in order to form and perfect it into wax in the times of scarcity, to cover up the little cells of the combs therewith, and to fasten it on the webs of the spinning Worms. This I shall afterwards explain more at large. I am likewise inclined to think that this matter serves also to close up the door or opening of the hive when winter approaches, or at least to make it narrower by way of defence against the inclemency of the cold: unless one should think it more probable that they separate the matter they use for this purpose from the rest of the wax, or gather this peculiar glue from beech and poplar trees; with which, as the Bee-keepers say, they afterwards not only make the door or opening narrower, but also cover all the lower part of the hive itself,

\* The French give with great propriety the name Bees-bread, *Pain des Abeilles*, to the farina or dusty substance lodged in the antheræ of flowers. It is certain that they eat this, and that it is afterwards converted into wax in their stomachs, for they collect vast quantities of it when they have no combs to make, and use it merely as food.

and plank it, and make a regular margin or border on the inside\*. The bread of the Bees appears therefore, in the opinion of the Bee-keepers, to be somewhat different from the wax; but in my opinion it is the very matter or substance of the wax itself, not yet prepared. In order to view and investigate the structure of the Bee-bread, nothing is more proper than to make use of a microscope in the manner following: the Bee-bread is to be put into a glass full of clear water, and then shaken a little, in order to separate it into a fine dust; and when this does not succeed quick enough, it may be accelerated by breaking it with a small fine pencil. This dust is afterwards to be put upon a very thin piece of glass, as near as possible to the flame of a lamp; then the glass is by a little starch to be fastened to a small piece of cork, which is afterwards to be fixed on the point of a needle and put under the microscope. Thus it will be found that the Bee-bread consists only of fine globules of equal form and magnitude; they have commonly three or four corners, but they are often also round: this angulated figure may probably be owing to the solidity and compactness of those little parts, which the Bees bring them into with their teeth: between these little parts are found some yet more minute ones. But though the particles of which that bread consists are very fine and delicate, yet one may, not the less manifestly, perceive them upon the tongue; for when this Bee-bread is tasted or chewed, it feels like a fine sand in the mouth, or as sugar undissolved, or divided only into little grains or angular little crystals. Moreover, when that bread breaks to pieces in water, it never dissolves; but the parts constantly retain their former figures, and are only separated and parted from each other. But whether these globules, when worked into wax, are ground, chewed or broken with the Bee's two teeth, and mixed with the saliva; or whether they are mixed with the fat or poisonous liquor of the Bee's sting, in order for forming the wax, is a matter which still remains to be investigated.

It is wonderful that the fat both of men and beasts also consists of such minute grains and particles, which when any person has a mind to see them distinctly, he must manage and view it in the manner abovementioned. The fat cannot be separated by water into small parts, and therefore in order to break it sufficiently, it must be shaken a little in spirit of wine: for thus it will very easily divide into minute globules. If it be afterwards put on the glass and examined in the manner beforementioned, it makes a very agreeable appearance.

This contrivance, wherewith we unite together such fine and small things, put on glass that they may be afterwards, when dry, viewed with a microscope, I here mention for no other reason but because it answers on many occasions: for a great many things which could not be otherwise examined, are by this means very easily discovered, as will be made more evident in the following pages.

To return to the Bee-bread, we must observe that many species of Mites seek after it; and those insects are also fond of unmelted fat. This may probably be owing to the many skins the fat is surrounded with; which are consumed in the melting, and which in the natural state principally serve those creatures as their food. One may sometimes observe certain globular particles in that wax, with which the little cells of the Bees are stopt, and as it were sealed up: and by this new argument the opinion which I have before proposed, that the Bee-bread is really of the substance and nature of wax, is confirmed. When wax has been for some time steeped in spirit of wine, it becomes very brittle, and separates into little particles, which seem also to be somewhat like the broken or divided bread of Bees; but that experiment ought to have been made with virgin wax, which I could not yet do, having been otherwise engaged.

Notwithstanding all these things, we sometimes see that the Bees carry real and perfect wax into the hives. This is composed likewise of globules; but they are four times, six times, nay, often ten times larger than the grains of the Bee-bread: these globules are likewise of an irregular figure. The Bees, no doubt, steal this wax, and bite it with their teeth from the wax made by other Bees; and afterwards fix it on their hinder legs in order to carry it into their hives. Therefore these little lumps are agreeable to the measure and magnitude of their bite, or are proportioned to the quantity which the Bees can take off a cake of wax, when softened by the summer heat.

But if we attentively consider the experiments that have been hitherto explained concerning the Bee-bread, and at the same time attend to its granular composition, it does not seem very probable that the Bees can live on it as their food in winter; for the Bees can take into their bodies only a matter that is not thicker than the honey itself, since they have a very narrow and slender trunk. Therefore, the Bee-keepers always reject granulated honey, or that which is crystalized or concreted into lumps, as unfit for feeding of Bees, nor do they ever give it to them to eat; but in winter time they fill split elder sticks with liquid honey, and draw them through from one side of the hive to the other. If any

\* Beside wax and honey, the Bees collect a certain resinous substance, which authors call Propolis. It is of a brownish red colour, very clammy, and a perfect vegetable resin. They use this to stop up holes or cracks in the hive, and to strengthen weak places. It is not of the nature of wax, for it will dissolve in spirit of wine; and we are not certain from what plants, or parts of plants they get it. The ancients were acquainted with this substance, but they say it was of a disagreeable smell; with us it is aromatick. Probably the scent varies according to the plants whence it is obtained.



person should object that the Bees can bruise or grind this bread with their teeth, and afterwards swallow it; the answer is, that the Bees can do the same with the granulated honey. My difficulty, therefore, still remains unsolved, unless any one should imagine that the Bees grind or bruise the grains of this bread in their jaws, and then, after mixing them with the saliva, or with fresh honey, by that help, attract and suck them through their narrow trunk; since, besides this, they have no other passage into the body for this purpose. From these reasons I am the more confirmed in this opinion, since the orifices of the trunk in Bees are so imperceptible, that they do not seem to me to be larger than the mouth of the meseraic veins, or lacteals, that open into the intestines, and which will admit only very thin liquids, and such as are purified to the highest degree.

We might further ask how this Bee-bread acquires its roundish figure? also, whether it be dew, or whether the effluvia of flowers and fruits, first resolved into vapours and afterwards condensed in this form? or, finally, whether it has its origin from any other concremented fluid, reduced to a globular form by force of the incumbent atmosphere? we have not yet sufficient experiments to determine these matters; for, as Bacon justly observes, we must not feign or devise, but find out and discover what nature produces, and how she operates. Something like this presents itself to our view in nature, as may be observed particularly in gums; between the petals of the flowers of hops, there are also seen a great number of such granules which are of a bitter taste.

My honoured father, the sooner to have ripe grapes, brought some vine branches into a little shed, built in his garden for that purpose, making openings in the windows to let them in. I observed that about these branches there was often an infinite number of white pellucid crystal-like globules, which were somewhat moist and clammy; nor could I ever melt those particles, or resolve them into vapours, because there always remained some matter from them, which hardened in drying. This I mention particularly, that I may be able to explain with greater accuracy the nature of that peculiar mouldiness to which the Bee-bread is subject; for though this mouldiness appears to be composed of hairy, or feather-like, or downy little parts, or, as the celebrated Dr. Hooke has delineated in his micrography, of a peculiar kind of minute plants, yet it really consists of an accumulation of globules that are some bigger than others. This was first shown me at Delphos by the industrious Leuwenhoek, by the help of a microscope constructed after the model of that invented by the honourable Mr. Hudde consul at Amsterdam. And therefore as to this matter, I think that bodies when they contract mouldiness, emit only effluvia

and vapours, which are propelled forward by force of the fermenting and heated matter; and which, being again condensed by the colder atmosphere, put on a globular figure, because they are on every side equally surrounded by the incumbent air; and as whilst some of these globules are following others, and continually propel each other higher into, or towards, the air; hence are produced those uneven, hairy, and oblong little parts.

The nature of wax should have been more accurately investigated, in order to discover whether any fattish or inflammable matter be originally mixed therewith out of the body of the Bee, which may be easily shewn from the structure of the adjacent parts: for the secretions of the body are very wonderful; here fat, there oil; in one place gall, in another insipid humours; on one side an aqueous or watry, and on the other, a clammy and glutinous substance; in one place volatile salts of an ill taste, and in another sweet, aromatic, and oily volatile salts. Of this last sort is civet, wherewith if paper be daubed it bears writing on it; and by this test we most certainly discover whether civet be genuine. But these researches would take up great time and very great labour, for there is not on every occasion a free admittance to all the secrets of nature; and the incomprehensible weakness of our strength is confined in every step within its stated limits and narrow bounds.

I pass now to the comb, or the cells and tubes of the Bees, which they form and construct with wax, then fill with honey, and again close up with wax; hence the comb properly signifies wax formed into cells and filled with honey. I shall first treat of the cells of the working Bees, then of those of the males, and lastly, those of the females. All the cells of the working Bees are hexagonal both above and below, but the angles of the upper part are equal among themselves; that is, they are equally wide, whereas in the lower part the angles are unequal; for three of them, in that part, are sunk deeper than the other three; the reason of which is, because every cell, if it be a regular edifice, is built on the foundations of three other cells. Since therefore the foundation of the Bees cells tend obliquely downwards, like a triangle, therefore two angles make only one descending oblique angle: and consequently the internal base of the cells constantly tends obliquely downwards, and is divided into three distinct parts, each of which answers to the two sides of the hexagonal circumference of the cell. The three angles just mentioned are commonly right angles; and when they are pierced with a needle, that is, if every angle of the foundation be perforated, so that each cell is pervious by three apertures or holes, then those three apertures penetrate on the other part into three distinct cells. It appears most evident from this palpable argument, that a  
cell

cell is founded always upon three other cells, and therefore has a common division with them; for none of the cells is circumscribed by any limits or partitions peculiar to it alone, since all things are common between the Bees as between brothers. If the edifice be irregular it sometimes happens that one angle of a cell rests, or is supported on a fourth cell: this does not happen frequently, though I have lately observed it in a work that was pretty regularly built.

The foundation of the cells is placed in the middle, and the cells on every side rest on this foundation, which is commonly like a wall, perpendicularly extended from the upper towards the lower parts; and then on each side against this kind of wall are placed cells lying obliquely on their sides. Suppose some empty ale or beer glasses to be piled upon each other against the side of a thin wall, and you will in some measure understand the disposition of these little cells: six, eight, or more such walls, furnished with cells, are sometimes found in one hive, and they are always placed at such a distance from each other, as to afford the Bees an easy passage between them. But, lest these combs should fall down when they are full of honey, the Bee-keepers fix little sticks in the hives when they are empty, about which the Bees form their works of wax.

All these cells, as well as their foundation, are formed of a continuous, but not contiguous, matter, so that all things are continued, nor can the cells be separated from each other by any artifice, but by breaking or cutting them, whatever some might have erroneously imagined, thinking that every Bee built its own respective cell. Of this matter we shall treat hereafter more at large in its proper place.

If the whole edifice be regular, then five of these little cells make exactly an inch, and fifty-five an Holland foot. Hence a French gentleman observing this, and imagining that these cells were constantly built after the same rule, thought he had discovered an everlasting measure, which as it could never be destroyed might be introduced among all nations. This invention would be certainly confirmed, and its importance proved, if these little cells were always so exactly constructed, and the combs in all nations were constantly of the same magnitude; but with us the combs are not always so exactly regular as is commonly believed, though if we view the cells only cursorily, they do not seem to differ a hairs breadth in measure from each other. If any one compares them accurately one with another, he will sometimes find them irregular; especially when they are made by the Bees in such a manner, as to fit them only for receiving the honey. The three parts of the foundation of the cells that tend obliquely downwards are usually square, but they are sometimes oblong, and sometimes of a rhomboidal figure; nay, I have observed that some

of them were longer or shorter than others, and were also sometimes narrower and sometimes broader. Nor does every little cell rest constantly on three cells, but sometimes on two and an half, and sometimes on three, and a part of the fourth. Moreover, these entire cells are sometimes twice or thrice as long as usual, and they are likewise sometimes crooked or sinuated, altogether like the cells of Hornets, which are commonly somewhat crooked, because they are extended little beyond their foundation or center. Bees never build in this manner, unless when very great plenty of honey offers to be gathered, for then I have seen cells full of honey, sealed up and suspended like large lumps of earth in the hive.

In regard to the cells of the female Bees, erroneously called the kings, and the parts where they are joined to others, considerable irregularities frequently occur; though all of them viewed cursorily may seem also to be very regular.

We must further observe, that the Bees never build their cells separately, that is, so as to perfect one before they begin another; they always enter upon building a great number of cells together with their foundation at one and the same time. In the beginning of the work, they lay that hollow triangular foundation which bends down obliquely, and terminates or gathers itself in acutely; then they construct the lower and hexagonal or unequal sides: so that in one and the same hive, may be seen at the same time, the beginning of the foundation, and the rudiments of the hexagonal divisions of the cell on one side, and the same cell on the other side, raised higher on the same foundation, and other sides again but just begun and rising. Moreover, in regard to this building of the cells, a very wonderful and artificial direction or management of the Bees is to be mentioned. This they put in practice when the rising hexagonal sides of the cells are very thin and weak; and when they have a mind to leave such cells imperfect for some time, which is the case when the female, in order to lay her eggs, goes to another part of the hive; as I shall explain more at large hereafter. When this happens, the Bees first fortify all the edges or borders of the hexagonal and imperfect sides, lest they should be broke or bent in the mean time, which might easily happen by the frequent running of the Bees over them. They therefore furnish the sides of the imperfect cells with a margin or border glued thereon in the upper part, and prepared of a thicker and more solid sort of wax, and they put this waxen border on the extreme circumference of the hexagonal sides, so that, by this means, the hexagonal figure of the cells, which was beginning regularly to shew itself, is again in a manner obscured. They sometimes also border the cells that are finished and perfected; from which this further good arises, that when such cell is to be afterwards closed up, there is no necessity for so much time or

wax.

wax. The Bees, therefore, use the same precaution in respect to their imperfect cells, as if any person should cover the extreme edges or borders of the tender and broken sides of a glass cup with sealing wax, in order to strengthen it and handle it with less danger.

The cells of the males are one third less than those of the common Bees, but they are made in the same manner; and they are commonly placed in the lowest part of the comb; for they are built after all the other cells are finished; sometimes there are three hundred, four hundred, or even more of these in one hive, but often fewer. The Bee-keepers attribute the smaller number of these cells to the dryness of the year, and the greater number to plenty of rain in the air: hence they say that a great number of males in a hive is a sign of a very wet year. But these are mere fancies, arising from a notion, that the Bees, when the seasons are dry, are intent only on gathering honey; and, on the contrary, in wet seasons, mind principally generation, but though those persons have kept Bees fifty years, they understand nothing of the business of their generation, nor do they know what sort of a creature the breeding Bee is, for they call it the male. I would not have it understood here, that the number of the cells which I exhibit is absolute and exact, for I have made the calculation in general from their numbers; nor have I even, very accurately, counted them all.

There are sometimes thirty female cells found in one hive few are perfect, but a great many unfinished; their structure is not regular, but they are for the most part oblong, and roundish, and somewhat pear-shaped: sometimes they are considerably straighter, and have a less swelling than a pear, but others again are somewhat more globular. Their external surface is unequal, rough, and marked or distinguished by little holes and exuberant prominences, and is conformed only to the figure of the comb. The inside of the cells of the common Bees has a very smooth and polished surface; but these differ again from them in that they form a cavity like that of a bottle or a scooped pear; from this shape, they are very capacious, and surpass in bigness the cells of the common, and those of the male Bees. The females therefore have a much larger space than the other Bees to turn themselves more freely in their cells; the reason of this difference I shall explain in its proper place. The cells of these females are usually, nay, almost always situated near the borders and prominent extremities and edges of the hive, and are seldom found placed in the center or in the middle between the other cells; all these particularities tend to certain useful ends, and therefore the laws of making them were not impressed on these little creatures without design, by the most wise Creator. I shall now endeavour to illustrate with figures what I have hitherto related. The first figure,

Tab. XXIII. exhibits a regular hive of common Bees, as it presents its hexagonal and regular sections to the eye, when viewed in the upper side; nor could it be possible to delineate these sections, without the assistance of some new-invented lines; which being allowed, it is then easy to describe the sections, for which reason I here delineate some of these lines. The second figure under the letter *a* exhibits three single cells of the common Bees, broken from the rest of the comb, with their triangular basis running down obliquely. The letter *b* represents one cell only, entirely separated from all the rest; in this, besides the obliquely descending triangular foundation *c*, are likewise seen under the letters *d d* two unequal or uneven parts or productions of the hexagonal sides. Now if you suppose this cell *b* placed on the cells *a*; it will follow that its three oblique angles agree with the three angles of these cells, and are supported by them. The third figure shews a little cell cut through the middle, in which may be seen the triangular foundation and the six sides; one of them is formed out of the oblique angles, as appears at the letters *b b*. Moreover, fig. iv. shews fifteen little cells, cut on each side, between which a part of the triangular foundation, which runs obliquely, is plainly seen in each cell. It is here also evident in what manner these cells *a b* are built upon the same foundation *d* whereon the cells of the other side rest *c*. Again, the letter *d* very exactly represents the triangular foundation, which runs in obliquely, as it really is seen in nature. The same is likewise delineated under the letter *g* between the cells of each side, but it is here divided by a section which passes through the two angles. The letters *f f f f* exhibit two long sides of the cells; but the letters *e e e e* the two shorter sides. For every cell, as I have observed before, has in its lower part three longer and three shorter diverging sides, which in the upper part are of an equal length.

The fifth figure which follows next, represents some cells of the males, which are a third part larger than those of the common Bees. In order to render this difference the more conspicuous, I have delineated them somewhat larger than they really are. Between each of these cells is seen that triangular obliquely diverging basis, each of whose angles agrees with the descending sides of the cell. But I have not delineated the cells that are built on one side of this basis, because it did not seem necessary. To the upper part of these cells is observed to adhere a pear-shaped lodgement of the nature of a cell: this is designed for the females. It is irregular in the upper part, and is adorned as it were with depressions or little holes, here and there impressed on the wax.

If the cells hitherto described have been lately finished, and have not yet any honey, or Bee-bread, or eggs, or Worms, or riper issue in them, in that case their substance is genuine virgin wax, which has no foulness among it,

and may be all melted. On the contrary, the wax that is whitened by bleaching, and which is sold in the shops by the title of virgin wax, has nothing but the name, since it loses a great part of its strength by being adulterated with powdered talc, and bleached in the sun.

The honey likewise which is collected pure in these virgin cells, and flows again out of them spontaneously and without pressure, is pure virgin honey, better and more perfect than any other honey whatsoever.

It is seldom observed, as the Bee-keepers say, that the cell of a female is joined to the cells of the males: but experience has taught me the contrary of this, having in my possession at this time a specimen, in which the cell of a female is built adjoining to those of the males. As many others, so this error had its origin from that imagined regal dignity, which they have wrongly ascribed to the female; for from this the notion was established, that the favour of coming so near to the king was too great to be granted to the drone. But the access of the drone to the queen is so necessary, that she cannot be impregnated unless she be first familiar with, and assisted by the spermatic virtue of the drone, who is the true and only male.

All the families of the tripple kind of Bees would therefore perish, unless there were this intercourse: since what is erroneously called the drone is the real male Bee, and therefore does not claim to himself a lower place in the hive than the queen herself the female parent. To this may be added, that the drone is more tractable and mild in its conduct and disposition than the two other kinds of Bees, for it employs its whole time in the labour of love and process of generation; nor is it armed with a sting as the others, nor to be dreaded for its mischievous qualities.

To conclude, how do the Bees make these cells? and by what art do they build them in so stupendous a manner, so regularly, that they cannot be simply or plainly delineated but with great labour, and by the intervention of some new species of lines, and not even then without committing great errors? He surely who sees all things, and promotes the generation of the wild herds; He, and He only knows this. I should think this matter may be probably investigated and brought to light, if any one would labour at it with the needful diligence and attention: nay, I am confident, that I myself could succeed in the inquiry, if I had an opportunity of feeding the Bees for six months, and enjoying the peaceful blessing of a country life. However this matter may be, I confess myself now as ignorant thereof as all others. However, I firmly believe, that the Bees make use chiefly of their teeth for this business: hence the common Bees which alone build all the cells of the hive, have much larger teeth than either the females or the males; nay, the males have still smaller teeth than the females, and probably the males have them for no other pur-

poses, but to bite open their little cells when they are come to full maturity therein, or to open those filled with honey when they want to eat. Whether the legs of the Bees, between the claws of which a singular kind of soft matter is produced in knobs, contribute in any measure to perfect and elaborate the wax, I am likewise hitherto at a loss to discover. Yet I scarce doubt, but that humour which passes through the sting of the Bees also conduces somewhat to prepare the wax, and fit it for building the cells. It would be worth while to examine all these points more accurately. It is very wonderful to see how instantaneously the Bees, when they are offended, emit all their poison through their sting. This poison may be seen at the end of the sting, and is like a little drop of crystal. But if this little drop, while still adhering to the extremity of the sting, be suffered to grow dry, it then remains pellucid and concretes, and is like the boiled crystalline lens of a fish's eye; it is therefore very easily condensed by the circumambient air.

Since I am treating of the wonderful industry of this little creature, which, however, is not more remarkable than that which all other insects shew, according to their respective dispositions, I cannot help here mentioning, to the glory of the great Architect and Artist, he wonderful works of a certain insect, the external form of which has been very clearly described by Goedaert in the first part of his *Nat. Metamor. Exper. x.* This insect is the nocturnal Butterfly or Moth, which glues its eggs so strongly and firmly in the form of a circle to the branches of trees, that they make an impression upon the bark, and often prevent the increase of the branches. What occurs here very extraordinary is, that the eggs of this insect are formed in the same manner as those hewn stones, which are adapted to build the arches and roofs of houses, and have one side narrow and the other broad, that they may be the more exactly joined together, and constitute one firm arched form. They may likewise be compared to the lines of a circle drawn from the center to the circumference, which are the nearer to each other the more they approach to the center, and diverge towards the circumference. In this manner has the supreme Architect, the Almighty, formed these eggs, which are artificially and in a spiral curvature so strongly glued together, and affixed to the tender branches of trees, by this insect, who for that purpose walks many times about the branches, that they cannot be loosened by rain, or any other liquid that I have yet applied. Out of these eggs, which, according to the accustomed order of nature, by which the egg of the Butterfly is only a Worm inclosed in its shell or case, should have produced Worms or Catterpillars, I have seen Flies wonderfully small, immediately issuing in their perfect state. This observation seems to me to be the most extraordinary of all in this part of natural

ral history; and therefore, I hope I shall, with the assistance of God, at some time write a particular treatise thereon. I have here given the history of this ring of eggs, because it will be hereafter made use of in its proper place, and produced for the sake of illustration.

I should never conclude this part of the work, if I attempted to exhibit the description, industry and art of these creatures, or to give but a rude delineation thereof. I cannot help mentioning here, the singular skill and address, not indeed of an insect, but of a sanguiferous animal, that is, of a young house Dog which I keep. This creature is afflicted with a running ulcer or fistula, which is situated so high at the lower part of the eye, that his tongue cannot reach thither to lick it. Therefore this creature follows a remedy happily invented and discovered, as it were, by reason, and applies it to this evil; it first wets its foot with its spittle, and then rubs the moisture with wonderful dexterity over the ulcer, endeavouring to cure it in this manner: nay, when the mouth or orifice of the fistula has at any time closed, the creature rubs it so long with its foot, that the surface becomes very red like blood.

To return to the Bees. They are about the beginning of August inflamed with so much hatred against the males, that they unmercifully and for no crime kill them: whereas, at the end of May, and sometimes sooner, they build houses for them, carefully nourish them, bring them there, and take all possible care of them. I shall afterwards endeavour to explain, in its proper place, the reason of their changing this love into hatred; since I have resolved to compose this history to the glory of God alone, without any other view.

Before I proceed further in this research, I shall describe the male, female, and common Bees together, and compare them one with another as to their external parts, beginning with the common Bees, which are most easy and familiar to be known, and which have been at one time or other seen and handled by every person. In the common Bees as well as, in all the other kinds, we are principally to observe the twelve divisions or rings of their body; five of them are placed about the head and thorax, and that slender and delicate part which connects the belly with the thorax, and the other seven in the body.

The head of the common Bee is oblong, somewhat rounded above and sharp below. The head of the male is throughout of a rounded form, and that of the female Bee is oblong.

The eyes in the head of the common Bees are of an oval or lunated figure. They are of the same form in the males also, but they are two thirds larger than those of the common Bees: this deserves to be well regarded. There is something like this in the Ephemerus or Day-Fly; the eyes of the female Bees are somewhat larger also than those of the common Bees. The eyes of these three species of Bees

are covered or surrounded with bristly hairs, and are separated from each other by a number of the like hairs. These hairs are twice, nay thrice as long as the diameter of the little spheres into which the eyes are divided. The same thing is likewise observed in other insects. In the upper part of the head somewhat higher than where the hairs just now mentioned are situated, we likewise discover many small feather-like hairs in the common Bees, and nearly in the same part also, three peculiar little eyes. These feather-like hairs are not found in the males, for their eyes are extended so far in that part that they touch each other. And this is also the reason, that three of their eyes in particular are situated much lower than they are in the common Bees, and just above the horns. The female agrees with the common or working Bees in these particulars, that her eyes are separated in the same manner from each other, and there are three peculiar little eyes likewise placed in her head in the same manner.

All Bees have two horns or antennæ. Those in the working Bees have only five joints, but those of the males have eleven, and those of the females the same number. The first joint, where the horns rise from the head, is oblong in the common Bees, but in the males it is somewhat shorter, and it is again somewhat longer in the females. In the common Bees there is a small quantity of short hair, under the horns, but the hair under the horns of the males is more in quantity, longer and feathery; in the females again it is observed to be like that of the common Bees.

Above the teeth in the common Bees is seen a remarkable kind of horny or bony lip, which is not so obvious in the males; but it is found in the females in the same manner as it is in the working Bees.

The common Bees have two long teeth, the males have very short and small ones; those of the females are somewhat larger than those of the male Bees, so that they hold as it were the middle place.

The proboscis is very long in the common Bees; in the males it is shorter by one half. I have hitherto missed the opportunities of examining it in the females.

The thorax is roundish in all the kinds of Bees, and in the upper side of the hinder part it is provided with a somewhat prominent border or margin. In the common Bees this thorax is covered with thin feather-like hairs: in the males these hairs are more close set together, and thicker, but not quite as long; they are also of a more gray colour than in the common Bees and females. The females have a less number of these hairs than either.

All the kinds of Bees have four wings. These are longer and broader in the male than in the common Bees; but in the females, though the wings be longer, and probably longer than even those of the common Bees, yet they seem shorter, because the lower part of the female's body is vastly larger and longer than

than either of the others, in order to give room for the eggs.

Each of the three kinds of Bees makes a noise by the motion of its wings, which is increased by the internal air propelled out of their bodies through the air tubes at the same time; for some of these pipes open with wide apertures under the wings. Certain cavities also, fit for receiving and vibrating the air, and formed under and between the wings, contribute to this. Nor must the shoulder-blades be excluded from their share in this music, they being placed just above the wings, joined to the thorax, and having under their breadth the gaping orifices of several air-pipes. It is thus the motion of the wings, with the assistance of all these parts, and by the force of the propelled air, make the humming noise peculiar to that insect.

All Bees are provided with six legs, each of which consists of nine joints; the thigh has three of these, the leg two, and the feet four. In the common Bees the hinder legs are broader than the fore ones; but this difference is not so remarkable in the males or females. On the fifth and broadest joint of the hinder legs, which is the first joint beyond the thigh, the common Bees on each side carry wax, or the Bee-bread, collecting it into a heap at the outmost side of the leg, for there the leg is not so hairy as on the inner side. In that part also the lower, and near the next joint of the leg, are placed some bristly and almost horny hairs which are neither found in the males, nor are so distinctly visible in the females. The third or last joint of the leg is longer than the two former, but the two next joints are smooth and somewhat broad, and those are closely covered on the inside with fine feather-like hairs. The least of the four joints of the legs is also somewhat broader than the three former; and in this part are inserted strong muscles, designed for moving the claws of the feet.

The feet are armed with two larger and two somewhat smaller claws; but the smaller are as it were jointed or articulated into the larger.

Between the claws of every foot is seen a very soft matter, of a membranous texture, from which, when wounded, there flows a clear liquor. The Bees in walking can at pleasure turn out this tender part of the foot, and therefore I should think, that having drawn back the claws of their feet, like Cats when they are playing, they are able in this manner to run over their young brood, or over the new formed wax, without doing the least hurt to either.

The four hinder legs are placed at the lower and hinder part of the thorax, the two others are fixed to the fore part. And this is the rea-

son why these two fore legs, when you take the head of the Bees from the body, are separated together with that, and remain with it, being fixed to it as it were by a kind of ligament.

In the common Bees the seven last rings of the abdomen are of a blackish brown: in the males they are yellowish, as they are likewise in the females, but more especially about the lower part, for there the rings of the abdomen are almost all yellow; and this is the reason the queen Bee is said to be of a golden colour.

The sting, which in the common Bee is protended straight from the body, is wholly wanting in the males, and in the females it is bent\*.

The common Bee is little more than of half the bigness of the male, the female is also smaller than the male or drone, but it has a much slenderer and longer body, in which, as well as in bulk, it considerably exceeds the common or working Bees.

The colour of the common Bee approaches to an obscure yellow; the males are somewhat grayer, and the body of the females is more of a gold colour.

The parts of the Bees hitherto mentioned are almost all hairy or shaggy, and when they are viewed with a microscope, we observe that those hairs are in reality very beautiful feathers, as is shewn in Tab. XVII. fig. VIII. This shall be explained afterwards more at large.

The common Bees may be considered as natural eunuchs as it were, belonging to neither sex; though, however, with respect to their structure and disposition, they approach nearer to the female than to the male sex. The males have very conspicuous and large genital organs. The females have an ovary, and in it an infinite number of eggs, as I shall describe in its place. But the common Bees are not furnished with either masculine or feminine genital parts.

As to the internal parts of the Bees, the three species have some common to each of them, and others peculiar to each. The internal parts common to all, are in the head, the brain consisting of the cerebrum and cerebellum; the beginning and globular dilations of the spinal marrow, which thence pervades the whole body from one extreme to the other; and lastly, the nerves issuing as well out of the substance of the marrow, as from its dilated little knots; all which I have described and delineated in the dissection of the male Bee. The internal structure of the eye is also in general the same in the three kinds; the tunica uvea, the inverted pear-shaped fibres, and the cortical substance which performs the office of an optic nerve, are very little different in

\* The best way of viewing the sting of the Bee by the microscope, is to hold the creature fast by the thorax with a pair of knippers, and it will thus thrust out the sting, often, in its fury. This should be cut off with a fine pair of scissors, and it may thus be preserved entire between two slips of glass.

Another way is, to make the Bee sting a thick leather glove. This will be easily obtained, by catching one with such a glove upon the hand. The Bee will strike with its sting, and it must be immediately frightened off. By this means it leaves its sting in the glove, which may be picked out and viewed.

either. This I have likewise exhibited in the figures of the male Bee. In respect to the muscles and nerves of the proboscis and jaws there is no difference. In the thorax each of the three kinds shews the muscles of the wings and legs, as also many pulmonary tubes and some fat; some of this is likewise found in the head. In the body is seen the continuation of the gullet, which descends thither from the mouth through the thorax: we may likewise perceive there the stomach, the small and great guts, and some valves; we distinguish also six peculiar glands, placed between the intestines, as I have described in figures in the common Bee. The lungs are also very particularly seen in the body, as are also their dilated bladders and branching pulmonary tubes; all which I have likewise delineated in the common Bee. The heart, together with its dilations and the pulmonary tubes which run all over its surface, is in great part also placed in the abdomen, though it may in part likewise be seen in the breast and neck, as I have delineated in the female. In fine, a great quantity of fat is also found there, and we perceive some membranes and muscular fibres situated under the rings of the abdomen, and designed for moving those parts; as also some small pulmonary tubes which pass through those parts. I have represented all these in the female Bee, and they are common also to all the three kinds.

The internal parts peculiar to each kind, are, first, the genital organs of the male; that is, the internal horny little bone belonging to those parts, the penis, the testicles, the vasa deferentia, and their dilatations, the seminal vesicles, a peculiar small part that is cut into five divisions a pear-shaped little part, and two appendages which terminate in a point. In the female are likewise seen the parts that serve for generation; the ovary, the oviducts with their divisions, the eggs, the pulmonary tubes appropriated to them, the two trunks of the womb, through which the eggs are conveyed, the neck of the womb, and the bag containing a glutinous matter.

The following parts are peculiar in the common Bee; the sting and its poisonous bag, with its tubes issuing as well out of the fore as hinder part thereof; the case of the sting, and also its supports, cartilages and muscles, none of which parts are found in the male.

By this general and particular comparison of the three kinds of Bees with each other, it is seen that the common working Bees approach nearer to the nature and disposition of the females than of the males; since the external and internal parts in general, as will be made plain hereafter, agree in both: excepting only that the common Bees have no ovary, and therefore, like women who have lived virgins till they are past child-bearing, serve only the purpose of labour in the oeconomy of the whole body. These are thus by nature rendered incapable of doing any other business but that of nourishing and educating the young

offspring, building the little cells for the Worms of the females progeny, and providing food for themselves and these their brethren, that they may have wherewithal to live in the winter season, and at all times in rainy and stormy weather. The female, on the contrary, and the males do nothing of all this; for the female lives in the hive for no other purpose, but to deposit, as occasion offers, her eggs in the cells: and it is the business of the males to impregnate those eggs before they are cast out, whilst they still lie in the ovary of the female: this they do during one whole year, that is in the time between the two swarms.

For these reasons the common labouring Bees maintain the males and females with plenty of honey. But as soon as this season of generation is over, and the males having performed their duty, the labouring Bees kill them as being entirely useless and unable to do any more good, though they might have lived longer. I could wish indeed that I had an opportunity of investigating this matter more exactly, and trying whether or not I could keep a whole hive, containing only males and one female for an entire year. This is indeed much to be doubted, for experience shews that many Bees die spontaneously, and without any violence, about the time of this universal slaughter. Sometimes when the female is unfruitful, or of a bad constitution, or when there is too small a number of Bees, or there are two females in the hive, the Beekeepers say that the males are sometimes found to live till the winter is far advanced: but they never continue to the beginning of spring; which, whether it is to be attributed to the natural shortness of their life, or whether they are then destroyed by the other Bees, is not hitherto sufficiently known.

From one female, which is the only one of that sex in the whole hive, are produced all the three kinds of Bees, in nearly the following proportion, ten, twelve or fourteen females, some thousands of the labouring Bees, and lastly some hundred males: more or fewer are occasionally found in the hives of each kind. I have described another species of insects in my general history of the insect tribe: the males of which is winged, but the female has no wings; which is also a wonderful kind of wedlock. The omnipotent God has been pleased to join several males to one female in this family of the Bees; whereas on the contrary among domestick fowls, and in many other instances, one male is sufficient for a great many females. This is likewise the case in many of the insect kind; that is, that one male should impregnate many females. This is observed with respect to the males of Silkworms. But the female among the Bees is impregnated in a peculiar manner, merely by odoriferous effluvia.

Six days after the time of swarming, the young female Bee newly got out of her cell,

deposits her eggs in the new-built cells of the combs: the labouring Bees which attend the female during the swarming, begin immediately at the very time when the hive is presented to them, or as soon as they have chosen a convenient place for themselves for, they have no guide or director, to make their combs; and the female doing her office as hastily, the fresh combs are in a very short time filled with her eggs: the female drops one egg into each cell; and what deserves great attention is, the female is so expeditious in this work, that she does not regard whether the cells be only just begun or perfected, or whether they have been built some time. It is enough for her the obliquely diverging triangular foundation be laid; there she immediately drops in her eggs, and the labouring Bees, which, for this purpose continually attend the female at that time wherever she goes, afterwards further perfect the unfinished cells. To execute this work, they are stimulated with an extraordinary sollicitude, love and industry, impressed on them by the supreme Creator towards those tender eggs, which are to afford the offspring of the Bees, as towards their natural brethren. We must particularly observe, that the earnestness wherewith they undertake the care of bringing them up, is not extinguished in them; though the female be taken from among them, as I shall explain in another place, where I shall also demonstrate that the whole society of Bees regard not any thing else but only propagation and rearing of their young; nor is there any other government whatsoever, nor any election, or any politic or œconomical discipline or order among them. The most wise, and all and every where adorable God, has implanted such ingenuity and wisdom in these insects, that they can bring up their issue and prepare habitations for them, which the same most powerful Creator has not been pleased to give to other creatures; whereof, among the rest, the Silkworms may be an instance; and it may be evidently proved that the cohabitation of Bees has no other end but to perpetuate their species; and thus, by the help of an exact order of production, to perpetuate their continuance.

From these considerations it therefore follows, that among Bees there is no wiser regulation than among domestic fowls; for they have their natural desire to fit; they make nests, and nourish their young, being compelled thereto by such laws as they cannot avoid nor suppress by any rational principle; because they are impressed on them by the eternal law of nature. These little insects are under as great necessity to perform all these actions, as the winter is to follow the summer. The only difference among the several kinds is, that some execute these functions in a manner more convenient, more orderly, and more agreeable to reason than others. This appears chiefly in the Bees, and hence there is no authority for the prevalent and common

opinion that the government of Bees is carried on with the scepter of prudence and judgment, under law, and with rewards and punishments: for in truth all that order which we so much, and not without reason admire, is impelled by nature, and is only designed for the propagation of their species. But we must not for this reason deny, that the Bees in performing their work, discover and exert the appearances of wisdom and the most prudent counsel; for the sacred writings teach us, that God has deprived those creatures of reason, to whom he has not thought proper to commit the care of nourishing their young. This office is not granted to the Bees only, but is given to the Hornets, Wasps, to humble Bees, and to Ants; which, as well as all other insects, would doubtless have perished as soon as they had laid their eggs, unless they had the care of educating their stock committed to them: for which reason it is necessary they should live somewhat longer.

Behold! God shews himself so stupendous in these small creatures, that I should almost presume to affirm that the ineffable miracles of God are sealed up as it were in the history of these insects. But these seals are at length opened, when we diligently peruse and often read over the book of nature, and natural theology, wherein the invisible things of God are explained to the eyes; then treasures of miracles which no tongue can worthily describe present themselves, and the unseen Creator becomes so manifest in these his smallest creatures, that the experiments I have made on them are to me the strongest and most irrefragable arguments, by which I constantly maintain his eternal Godhead and providence against all opposition. Atheists allow only a fictitious putrefaction, and a metamorphosis, invested in their own brain, and the fortuitous conflux of atoms; by the help of which they assert, indeed with very weak and sorry arguments, that these creatures are produced; whereas, on the contrary, the limbs and parts of these minute creatures are constructed with greater art than those of the largest animals. The Louse or Mite itself proves a deity, and the majesty of God is as stupendous and worthy of admiration in the minuteness and smallness of that creature, as in the unwieldy strong Leviathan: those who view him in these his works cannot but reverence and adore him. God himself speaks to man in this glorious manner in the magnificence of his works. And in what other thing can he be known but in his creatures only? Having named the Louse, I shall here add that the little part of that creature which is so elegantly moved up and down in the body, is only the stomach and the intestines annexed thereto, which produce such an effect by the force of their peristaltic motion.

The eggs which are laid by the female Bee in every little cell of the comb, are oblong, somewhat bent, and thicker on one side than



than on the other; but they are throughout transparent, limpid, and bright, and are full it seems with a watery matter, and fastened by a very small extremity to the wax. On the other extremity, therefore, the egg stands upright in its cell, and it touches not the wax except at one end. After what manner these eggs are so firmly fastened to the wax, I shall explain in its proper place. We must only observe here, that almost all species of insects, when they are about to bring forth young, affix their eggs by some means in that firm manner; whereof I can indeed exhibit many very uncommon instances. Among others, I have eggs of insects disposed in a ring, which are thus glued round the branches of trees; I have some other eggs hidden as it were in froth: others again which are covered very thick with hair, and so on without end. As to those eggs that are covered or beset with hairs, we must observe that Butterflies, which strengthen their eggs with such an integument, have those hairs originally situated in the circumference of the hinder part of their body: and therefore when they bring forth or lay an egg, some of those hairs naturally stick to it, because it is covered over with a viscid moisture; and thus all the eggs become at length shaggy: the creatures themselves become bald by this in the part just mentioned, which is a very remarkable observation. Thus we may learn something worthy of attention from every part of God's works: for that Almighty power goes through all lands and tracts of the sea as well as the highest heavens.

When the eggs of the Bee have been hatched in the comb, then in the bottom of the waxen cell there is observed a kind of web of a membranaceous texture, to which the egg afterwards adheres, or is firmly fastened.

But the egg is not always fixed in the same place, that is, in the bottom of the cell; sometimes it adheres somewhat higher and again somewhat deeper, according as the obliquely diverging cavity of the cell itself is variously constituted, or according as the hinder part of the female's body, can be most easily thrust into this cavity. However, the eggs are constantly placed on the obliquely diverging foundation of the cell, though they do not always stand perpendicularly upon it; but some more, some less obliquely: for the foundation always descends perpendicularly, though the angles are somewhat inflected.

If the egg of the Bee be viewed with a microscope, it appears somewhat wrinkled: but those wrinkles are regular, and are laid almost in the same order, as in the skin of Fish after the scales are off; which, the vestiges of the scales being still conspicuous, are yet distinguished in a regular manner. Something like this is also observed in the skin of Birds stript of their feathers.

I should think that the hinder part of the enclosed Worm lies in the thicker extremity

of the egg, and the fore part in the thinner extreme. This Worm in some days afterwards breaks open the membrane of the egg, and creeps out of it under the form of a crooked Worm, excessive tender, and without legs. But in this Worm the divisions or annular incisions of the body are immediately conspicuous, nor does it stand erect as the egg did, but lies on the foundation of the cell: the natural figure of the eggs may be seen in Tab. XXIII. fig. xi. for there six eggs are delineated in their natural size: they stand erect and oblong, are very slender, but somewhat thicker in the upper part; as may be seen under the letter *a*, fig. xii. Under the letter *b* a microscopic view of one of these eggs is exhibited, resembling the skin of a Fish new scaled; in which one may still see the joints, seams, or impressions where the scales had stuck. Further, I shew in fig. x. a little part of the comb, furnished with nineteen cells, nine of which are conspicuous with their erect eggs; four others contain some tender new hatched Worms, which have cast their skin a little before; and lastly, the five other cells contain Worms somewhat larger and more grown. I have cut off these little cells at one half of their height, that their triangular foundation on which the eggs stand erect, and which supports the Worms, may be seen more distinctly.

But I shall proceed, and taking up again the interrupted discourse on the Bee's eggs: observe, that they are, until the time of their being hatched, when a kind of very small Worm creeps out of them, left without the care of other Bees, and without any kind of sitting or incubation; though the contrary opinion has been hitherto established, which appears to be likewise in some degree supported by experience. I should think, at least, that the Bees go often to visit them, that they may know for certain whether or not the Worms are come out of them. But this they can likewise observe when they follow the female wherever she goes. The little cell also, in which the egg is repositied, remains often to be finished afterwards; so that in this case they may easily know occasionally whether the Worm has crept out of the egg or not. But as the internal parts of the hive are very dark in respect to our eyes, and the eggs with difficulty discovered in the bottom of the cell, I should think it follows from thence that the Bees can see as well in the dark as in the light, which is likewise the case with many other insects. The eyes of the Bees indeed seem much better accommodated for this purpose than those of any other insects whatsoever; as their structure will afterwards demonstrate. For the Bees do not see by force of collected rays, by which the image of the object is painted inwardly on the eye; as is the case to demonstration in an Ox's and Man's eye, when the external coats to the uvea are first taken off: but the simple touching and reflection of  
the

the rays on the external surface of the eye, evidently performs the act of vision in the Bee.

The incubation of the egg happens only by the heat of the external atmosphere, and by the heat which all the Bees enclosed in the hive, produce by their perpetual motion; for that business is performed here in no other manner than as it is with respect to the eggs of Silkworms and other insects, which are hatched by the natural heat of the season only: so that there is no necessity for any Bees to have the care of this; nor are there any in the hive that have the office of sitting to hatch the eggs. It is therefore an idle imagination, from which the male Bees are called brooders, or hatchers of the eggs, and has been received only, because the nature of Bees has been hitherto unknown; nor has it been observed by those who maintain this doctrine, that at every season of the year the Bees breed, and young just hatched are therefore found in the hive before these pretended brooding Bees appear, which do not come forth but on the approach of a swarm. Thus that error, at this time so universal among us, arose merely from want of observation. The ancients have likewise erred who called these Bees drones; and moreover, if we attend to what Goedaert relates of Bees in the second part of his *Natural Met. Exper.* 46, and which the learned Dr. de Mey also afterwards affirmed to be true in his annotations: we shall clearly see that the former, though he otherwise observes a tolerable method, is; however, so confused and void of all order on this occasion, that his narrative cannot be really called a detail of things, but only a disordered heap of words. He there confounds the humble Bees, Hornets and Bees one with another. For my own part, I esteem nothing in the works of Goedaert but the figures; though even those, notwithstanding that they have been drawn according to living specimens, have in many instances very considerable faults. But it is natural to men to commit errors, nor do I think myself free from them, and therefore we who follow the same studies are obliged to assist and bring each other into the right way, but at the same time remembering our own weakness, we should claim no superiority over others. But when a person will not scruple to darken the truth on purpose, in order to depreciate another, or to favour his particular opinion, he is unpardonable. It were much to be wished, that Goedaert had finished his own observations.

Those come nearer the truth, who, knowing more accurately the nature of the male Bees, called them the more noble kind, for they in reality live on the labours of the common Bees, and are at the same time of a more generous, mild, and tender disposition; but that the males exclude the rest of the Bees from the act of incubation is ridiculous. The eggs of Bees evidently stand erect, and they must not nor cannot be without hurting them: so far impossible it is to hatch them by sitting on them. To which may be added, that when

the egg is deposited in an imperfect cell, as is often the case, there is no place for the male Bee that is supposed to sit upon it, to rest its body, unless it should stop up the way, and be an insurmountable obstacle to the rest of the Bees; when they attempt to perfect that cell. When the egg is at length grown mature by the natural heat of the hive, then there is excluded from it a very tender and small Vermicle or Worm which did not want hatching, but needs now continual and perpetual nourishment: and not only the males, but even the females also are incapable of this business. To this may be added, that when these Worms have eaten sufficiently, if they afterwards lie in a warm place, they are spontaneously and without the assistance of any particular heat communicated by the Bees, changed into Nymphs, and then again into Bees. This I myself have experienced in my own chamber, with respect to a great number of such Worms, some few days after the beginning of September, before the nights began to grow cold. Nay, this experiment succeeded so far, that in some cells which I had opened, I already saw the eyes of the Nymph changing, and from a limpid or clear white, becoming of a beautiful but somewhat pale purple. This is indeed the first remarkable change the Nymph undergoes. I have likewise observed the same thing in the humble Bee described by Goedaert under the name of the *Apis*.

We should particularly observe here, that there is such a wonderful heat in the hives, even in the midst of winter, that the honey does not concrete or lose its original fluid consistence, nor is gathered into grains or crystals, unless in hives in which the Bees happen to be fewer than usual. The Bees, when they are fruitful, nourish, cherish, and warm their offspring in the midst of winter, and preserve a mutual heat amongst each other. But I do not know that this is the case in any other insects, for even the Hornets themselves, as well as Wasps, humble Bees and Flies, are all rigid and motionless in the winter; and in all that season neither move nor change place, nor do they take any nourishment, nor discharge any fœces. Something similar likewise holds in some species of the garden and other Snails, which, when they have been about that time cleared from all excrements, by continual abstinence become a cleanly and agreeable food.

The Worm of the Bee, excluded out of its egg in this manner, and stript of its tender skin, must be afterwards, as I have observed, nourished and fed. But as it never, like the Worms of other insects which creep about, or are conveyed elsewhere, changes that place wherein it was first repositied in its cell; hence this Worm wants a nurse: of this laborious care and attendance the labouring or common Bees take the charge on themselves, and nourish, cherish, and bring up this tender offspring, until, from a minute Worm, like a point, it is at length changed into a Nymph, and finally to a Bee

Bee by accretion, and when arrived to this state, it is no more increased in bulk. The Bees indeed daily procure and provide food for these Worms, with as much labour and sollicitude as birds do for their young. And it is necessary that it should be so, since the Worms of the Bees do not stir out of their cells till they are nourished so far, that, acquiring the form of a Bee, they increase no more. This is common to all insects, whether they are brought forth small or larger, they never increase further when arrived at this state. Nay, this law is so universally established among insects, that after they have acquired their last or most perfect form, which they retain for life afterwards, they always remain smaller or larger in their several kinds, in proportion as their Worms have by force of nutrition increased more or less while in that state.

However, it is necessary to observe, that it is not honey with which the Worms of the Bees are fed; it is indeed another and peculiar substance; it is of a white colour resembling the white of an egg when it begins to harden, or a white paste made of flower and water; it is somewhat thicker than honey, and is of so mild a taste that it scarce affects the tongue. From whence the Bees obtain or bring this food, or whether it be honey which is first changed in their own stomach or proboscis into this form, and which they afterwards cast out, as is usual with Pidgeons and other birds, which give a half digested food to their young at first, I have not hitherto discovered. Be this as it may, the Bee-keepers who regard nothing but gain, and have no knowledge in any thing else, tell us some idle stories on this subject, though they scarce know any thing else of Bees, but how much a year is to be made by keeping them. The most sensible of these people call that substance salival honey. Nor is it to be doubted but the Bees can, when they please, throw up the honey again. Clutius indeed confirms this by a very remarkable example, whereof Vossius makes mention in his treatise on idolatry. If the body of the Bees be gently squeezed on the under side, the honey will be pressed out again and make its way up through the trunk. But notwithstanding this, a doubt remains, whether the Bees discharge that honey out of their stomach, since they can hide a great quantity of it in the cavity of the proboscis or trunk: probably the same thing is the case here as in Pidgeons who discharge a substance like chyle out of their craw. But though honey is collected, not made by the Bees, being first prepared by nature herself in the parts of flowers, and is only taken into their bodies by the proboscis; yet I do not doubt but it is changed, digested, and converted into durable and good food for the young, not only in their body,

but even in the proboscis or trunk itself. This subject it would be worth while to examine more strictly: nay, what is here advanced is the more probable, because we observe, that the honey which the Bees gather from flowers is not always of one and the same consistence, but is found sometimes thicker, sometimes thinner, sometimes watry, sometimes aromatic in the flower, and therefore it is necessary that it should be afterwards prepared by the Bee to render it all alike\*.

To return to the salival or discharged honey. I remember that I have often seen a peculiar substance distilling from willow trees, which I am inclined to think is very like this salival honey, and which Hornets, Wasps, the diurnal Butterflies and Flies all greedily seek after. It is particularly beloved by the Butterflies, which by shaking their broad wings often drive away the Flies that then sit feeding thereon. It is singular that I never saw Bees busy themselves about this matter, which they might have easily carried into their hives to feed their young. When I further consider that the Bees in the midst of winter, and when they do not fly out, still nourish their young, I have no further doubt of this matter, but am convinced that the stock of young Bees are nourished with honey, thrown out or discharged in a very singular manner from the trunks of others, whatever the Bee-keepers say to the contrary.

How long the worm of the Bee feeds, before it is arrived at the perfect condition of a Bee, and has legs, I am not able to determine. But if what the Bee-keepers have assured me, as a certainty, be true, that is, that the young swarm may possibly swarm again in a month or six weeks, then it would be no difficult matter to compute that time, and I should think that according to this calculation it may be completed in about twenty-four days in summer. These Worms, however, do not increase in bigness so fast as those of Flies, for they are excluded out of a very small and tender egg, and have at first very little motion. We must likewise consider in this matter the hotter and more favourable constitution of the atmosphere; for the temperature of the air only is sufficient to detain a Worm or Caterpillar in the business of its change, ten days beyond the usual time. This I have often experienced. This is so true that the change of a Worm into a winged insect, which in the middle of summer is performed in the space of a month: is sometimes prolonged to eight or nine months; this happens principally when the preceding change happens in the last part of the autumn; for if in that case the winter cold comes on immediately after, the creature instantly becomes motionless, nor does it recover motion before the next year's hot weather comes, and

\* It is but of late that the substances of which wax and honey consists, have been distinctly known; but it is now perfectly ascertained. They are both collected from flowers. The antheræ or buttons placed on the filaments in flowers, contain a dusty substance, intended by nature for impregnating the seeds in the bottom of the flower, and of these the Bees make wax; they feed upon this substance first, and then discharge the remains, which have not been taken into the vessels as nourishment at their mouths, and with a little moulding this becomes wax. The honey they find perfect in the flowers, either lodged loose in the bottom, or in the glands called nectaria.

nourishment is ready prepared for it, and for its future offspring. This is also the reason why several species of insects do not die so soon toward the end of the year as in the heat of summer. Hence also, when the Butterflies of Silkworms are changed later in the year, they have sometimes remained alive with me for six weeks after their laying their eggs, which is certainly a very singular incident. So great is the effect of heat and cold on these little creatures, that the one seems to give them life and the other immediate death, for death is nothing else but the cessation of natural motions. In the examples just now mentioned, the life of these creatures is prolonged by means of cold, since the strength of life, and the fluids on which it depends, are slower dissipated, by reason of the slower motion. This is a fact that indeed deserves particular attention.

When the Worms of Bees are increased to some bigness, they begin to fill the whole cell in which they were placed, and turn themselves as it were into a globe, as a Dog does when he lies down to sleep; or, like that species of the Woodlouse which turns itself round like the Hedg-hog. Now that I am upon this subject, I remember a very remarkable story. One of our maid servants had at one time found a great number of Woodlice in the garden, contracted into round balls in the manner before mentioned, and thinking she had found a kind of coral beads, she began to put them one after another on a thread, but it soon happened that these little creatures, which roll themselves up in such a manner only for fear of harm, and appear as if they were dead, being obliged to throw off the mask resumed their motions. On seeing which the maid servant was so greatly astonished, that she threw away the Woodlice and the thread, and cried out, and run away.

If the Worm of the Bee is taken out of its cell about this time, there is found under it, in the bottom of the cell, a kind of yellowish matter of a somewhat thick consistence. This is the excrement of the Worm.

In the mean time, whilst the Worm is thus increasing in bulk, I do not doubt but it sometimes, like other insects, changes its skin, but how often it does this before it arrives at full bigness, I cannot determine. I have observed that when this Worm casts its skin, and is changed into a Nymph, its pulmonary tubes also, situated in the body, change their skin and throw out through the orifices in the body a thin pellicle. Indeed, it seems to me very admirable, that this change of skin is so common to all insects in general, that even Lice themselves and the minuter Mites undergo it: nay, Spiders and Locusts obey this law so perfectly that they cast skins from their eyes, their teeth, and the very claws of their feet; even the horns are not excepted, which, though as they are smaller than a hair in the Locusts, yet they likewise cast a tender skin. The crustaceous and testaceous animals also, as the Crabs, Lobsters, and the

like, change their skins. I have likewise observed, that when Serpents are casting their slough, a skin is likewise thrown off from their eyes, and the inner surface of the skin is turned outwards.

At length my curiosity went so far, that I was not afraid to taste and bite these Worms of Bees, in imitation of those, who, from a beastly and depraved appetite, do not fear eating the Maggots that grow in cheese, that is, that species of Worms which skip or leap by bending their bodies, and again swiftly extending them. The Bee-Worms are of a very disagreeable taste, like that observed in the pancreatic juice of fish, and they leave a very offensive or nauseous rancour like that of rusty bacon in the mouth. Of the same opinion with me was the very experienced and industrious Peter Adrianus, who had then come to make me a present of some male Bees, and by his assistance has also greatly advanced this history. When these Worms are boiled, they have a somewhat more agreeable taste; but if one continues chewing them, the former taste prevails again.

Before I proceed further, I shall exhibit the Bee-Worms to the life, according to the various degrees of their bigness, as they continue growing: the thirteenth figure serves for this purpose. The letter *a*, Tab. XXIII. fig. XIII. represents a Worm just come out of its egg, *b c d e* are Worms nourished longer and grown more mature; *f* and *g* exhibit others larger again and longer nourished, which are here represented in the same manner as they lie in their cells: *i* expresses the Worm on its back, and beginning to draw the hinder part of its body inwards, and to move its head languidly.

In the same figure under the letter *b* I have delineated the Worm lying on its belly. In the back of this is seen a furrow of a blackish or pale blue colour: this line shews the stomach, which appears through the skin in that part, which I found to be all stuffed with a yellow matter. In the second figure, under the letter *a*, Tab. XXV. fig. II. is exhibited a Worm, having attained its full increase, which stands up at that time in its cell, and shuts it up entirely: after this it remains very quiet and without any motion in the cell, and begins to swell at the 1st, 2d, and 3d annular divisions of the body, because its hidden limbs, and other parts, which had increased in bigness under the skin, are now insensibly swollen with humours, and therefore dispose the Worm to change its skin. This will be very distinctly explained below.

If any one afterwards more accurately examines the Worm of the Bee, and views it with a microscope, he will observe, as I have shewn in Tab. XXIII. fig. XIV. that it is composed of fourteen annular incisions, *a a a*, including the head. In the head *b* are to be observed the eyes *c c*, the lip *d*, two little parts *e e*, which afterwards become the horns, and two other little parts *f f*, situated under the former, which seem as if they were articulated and afterwards grow into the teeth. Moreover, between these

two little parts, and consequently under the lip *d*, is presented to view another small and somewhat prominent or extuberant part *g*, which resembles a tongue or trunk; and this increasing by degrees, at length indeed constitutes the trunk of the Bee. Moreover, there is something that hangs out of this little part above, like a small nipple, by which the Worm discharges its thread to make the web, when it has eaten for a sufficient time and is going to be transformed into a Nymph. In some other Worms I have seen besides the tongue *g*, the resemblance of a small and tubular proboscis, situate in the middle between the tongue and the lip *d*, by the help of which the Worm can probably take in its meat. But I saw this last mentioned tubular little part in the Worm, when I had first pressed its body a little, and forced it forward, between my fingers, towards the head. Again, in other such Worms, I have observed a horny or bony little part immediately under the lip. But those other little parts behind this did not appear so distinctly to me. We must view these parts with a microscope, and to that purpose first separate and clear them one from another; for their colour, which is of a whitish yellow, prevents their being accurately viewed together, and in order to see them well one must use a very powerful microscope.

The two eyes of the Worm *cc* are of a transparent white, and are limpid, so that they seem inflated as it were with a lymphatic fluid. In other insects the eyes are usually brown, blackish, green, red, blue, or yellowish; and in some few of a very full or faint purple, that is, according as the tunica uvea in the internal circuit of the eyes is coloured. It is evident from this example that the eyes are not alike in all insects; nay, this diversity with respect to the colour of the eye takes place equally in the larger and sanguiferous animals: this I have particularly observed in Rabbits, in which the whole tunica uvea has been placed at the bottom of the eye, and then seemed to me, for want of blackness, unfit in a manner to detain and collect the rays of light for vision; blackness, and even a deep brown, have this property, that they never reflect the rays of light that fall upon them, and for this reason also black paper takes fire much easier in the focus of a burning glass, than that of any other colour, which reflects the rays. But the ways or means of divine providence, which can bring all things to one and the same end, are innumerable. This I shall distinctly explain in the following pages with respect to the fight of Bees; and at the same time demonstrate therein the omnipotent wisdom of God, from the eyes of these insects.

Between the two eyes, and not far from the lip *d*, occurs a part of a yellow colour; nay, the lip itself and the tongue *g* are also yellowish. In the extremities of the succeeding horns *ee* there appears also a sharp pointed yellow and brownish little part. But as all these minute parts are of a faint colour and are pellucid, they

cannot be distinguished but with great difficulty.

In the other rings of the body, ten points of respiration are observed to be distributed on each side *bbb*, having no horny or bony parts of any other colour; as is the case in the Cossus, in Silk-worms, and in most other insects. It is therefore very difficult to discover these points, on account of the whiteness and general brightness of the Worm; indeed no person can accomplish his design in this case, but by frequent and carefully turning of the microscope to view the object in different lights. These points appear placed in a kind of long fissure or slit, and are somewhat depressed. The pulmonary tubes or branches of the windpipe, which are internally joined to these points, are of a clear or limpid white colour, and glitter like mother of pearl; and in some worms which are not very fat, and have therefore a very pellucid body, they are seen also distinctly through it; as is also, through the transparent body of the Worm, the stomach, which in this Worm is usually at that time filled with a yellow kind of matter like melted Bees-wax: the heart and spinal marrow are seen also distinctly through the body of the Worm, the former being placed in the back, the other in the belly.

This Worm has a very slow motion, and whenever it is disturbed, it draws its head and tail, or the posterior part of the body, a little inward. But if it be dragged out of its waxen cell, and any violence is by that means offered to it; then it will make other and more remarkable motions; for it sometimes twists and bends itself forward, and sometimes again backward. But if it be not moved or provoked, it lies without any visible or conspicuous motion; nor does it ever go out of its cell, until it hath grown into a perfect Bee.

I shall now proceed to the dissection of these Worms. The Worms of Bees, as well as other insects, may be dissected by the help of various contrivances, which I myself have often used: first, then, I killed these Worms by different methods; I boiled some of them in spirit of wine; others I steeped in the alkahest liquor of Glauber, and in divers other coloured liquors: all which I have done, the better to distinguish their internal parts, which are all of the same colour. But these did not answer with the expected success, because the Worms abound with fat. If the Worm be cast into spirit of wine, all its parts melt as it were and become watery. The parts are too much condensed by boiling, and in the alkahest liquor likewise they are in the beginning too strongly coagulated, but afterwards they change or turn into an aqueous fat or grease; therefore the best method that I know is, if one only suffocates these Worms in spirit of wine, and immediately afterwards prepare for the dissection of them. It is of

service

service likewise to macerate them in coloured liquors, till they become, as far as they are capable of it, black, red, or yellow; or they may be even left to themselves, that they may at length acquire a colour, by a spontaneous corruption: by this means, when the changes are properly watched, some of their parts shoot forth to view, which otherwise escape the sight, or at least cannot be viewed distinctly enough. It is indeed the nature of this Worm to have its body of a perfect white, and consisting of parts not very easily to be discerned; hence arises the vast difficulty of anatomizing it, unless we use the method mentioned above. All these things, however, need be of no consequence, if one knew how to dissect these Worms when alive, which yet is not easy to be done, since its parts contract themselves at that time most strongly, and also are in their own nature most extremely tender.

If the Worm be opened along the back, immediately there appears trickling out a sort of ichor or watery humour, gushing from the wounded vessels, and from the heart. This is the real blood of the little Worm: after this are seen the muscles situated under the skin, which move the annular divisions of the body, and some of which go into the very heart itself. Next is seen the fat, and among this, in the middle of the back, the heart swelling out shews itself; this is indeed a long pipe, running through the whole back quite into the head, out of which the vessels sprout branching to all the parts. This, however, I never observed in the Worms I am treating of, but have frequently in Silk-worms. In the anatomy of the female, I shall mention some other circumstances about the heart: if we pursue this dissection further, presently the stomach rises to view, furnished with numberless pulmonary tubes, which, being made up of fibres easy enough to be discerned, if it is cut, recedes very easily from its internal coat. This to appearance is membranaceous, and is three times thinner than the stomach itself; this same tunica, moreover, like the most transparent kind of glass, is perfectly clear, as well as most equally smooth, which indeed is found in other insects likewise, and more than all the rest in Silk-worms. In the last Worms I dissected, this coat, or internal part of the stomach, was always swollen with a sort of matter of a deep yellow colour, a little clammy, which not only filled the whole cavity of the stomach, but in the back, where the heart is placed, was distinctly seen through the heart and the body. In the Worms of Hornets, that inner coat of the stomach shews to appearance like a piece of net-work, the most curious that can be seen, and is of a purple colour. In the lower part of the stomach, where the pylorus lies, are four little vessels, through which there runs a matter of a yellow colour, a little inclined to whiteness: these are firmly knit to the fat and air-pipes, and appear here and there through the fat, and winding about are carried over the body in wreaths; to me, indeed, it seems diffi-

cult to find out what kind of particles these are, for they do not appear to be like the saffron-coloured vessels, which the illustrious Mapighius has described in Silk-worms, being what I have found hitherto in all insects, though not always tinged with this yellow colour. Whatever be the case, after long and unwearied search I at last perceive, that in their extremities, they, as the close guts or cæca of hens, are closed up: to discover this I use the following method, viz. with a fine forceps I take hold of the gut, or of the end of the stomach into which the vessels run, and then slowly and carefully draw them out from the fat and intertwined membranes, and pulmonary tubes; since they could not otherwise be disentangled without the utmost difficulty. If these closed vessels are macerated for a little time in spirit of wine, then they appear as if they were covered over with glandules, which kind of glandules may likewise be observed in other insects. I have called these in the *Cossus* saffron-coloured vessels. In Bees it is extremely hard to bring them into sight.

The fat also of this Worm, as in the *Cossus*, consists of globules, and these very globules in some measure resemble the globules of fat in the *Cossus*; but the fat in this Worm I am treating of is not lost during its growing state. Wherefore it may still be seen, after the creature is changed into a perfect Bee; if this fat be examined more accurately, besides numberless more minute particles, there are likewise to be observed in it some little oily lumps, such as I have before represented in the fat of the *Cossus*; but the structure of the fat cannot be more exactly examined, unless we view it laid on a very thin plate of fine glass, a single microscope being passed between, right against the sight. In the fat, which is mixed with extremely thin membranes, and with the pulmonary tubes, some small particles are here and there seen, wrinkled and contracted, and somewhat inclining to a pale purple, and in other parts nearly whitish. These are the beginnings of the air bladders, which afterwards in Bees are filled with air, and mix themselves with the pulmonary tubes, to which they have hitherto but a slight cohesion; just as the lungs in animals, that have not yet used respiration, so these air bladders are contracted in these subjects.

On the opposite side, near the head of the Worm, there appear some other vessels, which curl like the tendrils of a vine, in the same manner as the closed vessels just described; nay, and they are so firmly braced with membranes, fat, and pulmonary tubes, that I have found it impossible as yet to separate them; whence I have also been unable so accurately to discover their structure. These vessels are double, and at last meet in one little tube, which, after that, shoot on the outside under the tongue of the Worm, and there become stronger and tougher, and then swell outwards in a kind of soft pimple, pervious by an opening: from this prominence a glutinous humour, the matter of the filaments,

is sent out ; so that these vessels may be considered as the parts out of which the Worm draws its threads. When the Worm, having taken sufficient nourishment is soon afterwards to be changed into a Nymph, then by the help of these little threads it covers in its little cell, and at the bottom, and on the sides within, covers it over as it were with glue. I have seen in some Worms likewise, that these tubes, not far from the part where they issue forth under the mouth, have divided themselves into two branches, which, however, as I have already mentioned, I have not as yet been able to trace further. In the mean time I believe, that they end in the closed appendages, as is the case in silkworms. Whenever these tubes are pierced through the middle, in that part where they meet in one little body, there issues thence a glutinous matter extremely tough, and capable of being drawn out into long threads. The same thing is also observed in the glue of Silk-worms, not yet drawn out into threads, and in other insects, and even in spiders themselves. This, however, is to be observed only in those Worms that are near the time of their transmutation into Nymphs.

I have not perceived any other parts in the Worm, besides those I have already explained, since the vessels in it, which carry and return the blood, are so very delicate and transparent, that I was not able to discern them. For the same reason I could not descry these very parts even in the Coccus, though there are inventions of art, by the assistance of which we may come to the knowledge of them. In Silk-worms I succeeded by the following method, which I have represented in the fourth figure, viz. I provide myself with a little glass tube, such as is here delineated, which I take care to have made like a vial in the middle, Tab. XXIV. fig. iv. *a*, at one end *b* to be drawn out to the utmost smallness, and at the other end *c* made thicker and broader, in order that the air blowing into it, may be conveniently forced in at this end : this done, I fill the little pipe with some thin liquor coloured, not however of a very penetrating kind, let in through the thicker end *c*, and then with the greatest caution perforating the skin *b*, I thrust the thinner end into the heart. This may be done easily enough. By these means, and then gently blowing into it, the heart, and many of the vessels shooting out from it, may be filled ; and further, though no other parts are discovered in these Worms, still it is of use to take notice in them, both of the pulmonary tubes, and the spinal marrow. As for the marrow, indeed, though by reason of its excessive yielding and softness, I could not examine it with any exactness in the Worm, yet I had no difficult task to discover it in the male Bee, of which when I come to treat, I shall describe it as there delineated.

There are, as I said, ten points of respiration on each side of the body, in all twenty ; and there is the same number in Silk-worms, and

in the Coccus ; but there is this remarkable difference, that both in the Coccus, and in Silk-worms, only eighteen of these points with reddish tufts, of a substance between horn and bone, suffer themselves to be discerned ; but the tenth pair of them is not separated so plainly, which perhaps is the reason that the incomparable Malpighius does not describe twenty, but only eighteen of these points in Silk-worms. The twenty pulmonary tubes, which in the Worm of the Bee arise as it were from these points, are carried inwardly into the body, and have all a mutual communication with one another : a kind of little tube runs all along from one point to another, so that in this manner the anastomosis or inosculation of these vessels is propagated through the whole body. The structure of these pulmonary tubes is in truth exceeding wonderful, for all of them consist as it were of curled rings, which being twisted together in the closest manner imaginable, and intertwined with one another by the finest filaments and most delicate membranes, make the union so completely solid, that the air can no where pervade, except through the middle cavity, which is always open. These rings are also twisted closer in some of the tubes than in others, but indeed the fabric displays the greatest artifice in those places, where these pipes divide into branches and shoots, for there the rings are ranged with surprising skill one close to another, and are joined together by the intervention of the lengthening, abbreviating, and crooked rings. All these things may be seen very beautifully, if one puts these pipes on a very thin piece of glass, and afterwards views them against the light : this is indeed a very useful contrivance. They may also, in order to distinguish them the better, be placed on thin, coloured, black, or green glass. These pulmonary pipes or tubes are always open, as I have before mentioned, which is likewise the case in the human species, and in other animals, but principally in regard to or about the cartilaginous rings placed in the neck, so that therefore the air in the human body, or any other animal, which hath once breathed or respired, can never be entirely driven out of the substance of the lungs. We must further observe, that these pulmonary tubes are in this Worm distributed in such a manner, that the brain, the nerves, and even the eyes are furnished with branches of them ; this I shall afterwards shew in the anatomy of the eye, the structure of which, too delicate for all description, proclaims the infinite wisdom of the supreme Architect. Next we are to explain the sixth figure in this plate, which exhibits some of the viscera of this Worm.

The letters *a a*, Tab. XXIV. fig. vi. denote the stomach, furnished with infinite air-pipes *d d*, which are affixed to it : *b* is the gullet. *c* Exhibits some glandulous little parts, which are seen distinctly through the transparent stomach.

stomach. The stomach also has towards its hinder parts some muscular circular fibres *e*, which serve to move its contents. *g g g g* Are four vessels, intestina cæca, or closed guts. *b b* Shew the insertion of the closed guts or cæca below the pylorus *f*. *i* Exhibits the rest of the intestines of the Worm, the crassum and rectum, or the thick and straight gut, to the extreme end of which a small part of the skin is likewise observed to adhere. *l* Represents the delicate coat of the stomach, replete with coagulated contents of various kinds, which are designed by the darker parts in the figure. Fig. v. *a*, are the pipes appointed for the matter of the web, or the bags wherein the substance of the future threads is prepared. *b* Shews the place where these points are joined one to another. *c c* Exhibit the divisions of these pipes. *d d d d* Is the place where those pipes that contain the matter of the web are broken off, and beyond which I could not at this time prosecute their course: what increased the difficulty was, that other matters, which were likewise to be investigated, took up all the time I then had. I likewise find the same difficulty of tracing these vessels in the Worms of the Hornets; which however might have been conquered much easier in the latter; but it is as rare to get so great a number of Hornets, as a sufficient number of their Worms.

The first figure represents the pulmonary tubes of the Worm, as may be seen on each side, under Tab. XXIV. fig. 1. No. 1, 2, 3, &c. and the letters *a a a*; for twenty such tubes are seen in this creature. It likewise appears in this figure, in what manner the pulmonary tubes of the same side have a communication with each other *b b*, by means of tubules carried from one orifice to the other; and have the tubes of each side meeting each other from the opposite sides of the body, and are also united together *c c*. Finally, the branches are seen there, which spring from the middle trunks of these several tubes. The Worm is here exhibited and laid entirely open, and without its viscera, fat, and membranes, all which I carefully washed off with a little water, by the help of a fine pencil. Though the orifices *d d* of the pipes are situated under the skin, yet I have delineated them, as if they appeared or were prominent out of it; which particular, though it be contrary to nature, yet I have observed in this place, that my description may be the more easily understood. The other two spiral little parts, fig. II. and III. *e*, *f*, express the rings of the pulmonary tubes. One may very distinctly and beautifully see these, if a hair of a man's head be passed through a small part of a pulmonary tube, and both extremities of the hair be afterwards glued or affixed with wax; if that part of the tube be then separated or taken away, with small tweezers, or stretched out by needles, it will be seen distinctly how these

contorted or twisted rings are longer in one part *e* of the tube than in the other *f*. Without this contrivance, these rings may be easily discovered, by the help of a microscope.

But I shall proceed further. I must observe, that when the working Bees have maintained the Worms here described, until they are arrived to their full bigness, these Worms afterwards abstain from all food; and as they lay before in their little cells, contracted as it were into a globe or ball, so, on the contrary, they now stand erect, and thus fill the whole cell from top to bottom. These Worms about this time, cover the inside of the cell, from the lower to the upper part, with threads; in which work, however, this difference deserves particular notice, that is, that the web, which lines or surrounds the foundation and sides of the cell, is more membranaceous, but that which is on the extremity more thready. This difference arises because the Worms do not always spin complete webs, but sometimes discharge on the filaments, or thread already spun, a great quantity of the gluey matter, which should have made the threads, and by this means daub or wash it as with glue. This I have likewise often seen in other insects; nay, I have had the good fortune to observe it even in the Silk-worms, however rare or uncommon it may seem; for whenever any little knots occur in silk thread, these are owing to the discharged matter which has flowed out too plentifully together. Nay, if the imperfect Silk-worm when expanded, be glued to paper, it does not appear thready, but also membranaceous; this thread is nothing else but a soft extended silk, afterwards hardened by force of the air. It is remarkable in the Silk-worms, that water alone has the power to dissolve their unspun silky matter; whereas, on the contrary, spirit of wine, vinegar, and other such liquors will coagulate it immediately. In like manner as the Worms of Bees, and those of Hornets perfect their web from spun threads, it is indeed very beautifully and wonderfully finished in the end. It is perfectly white and fine above, but it is all membranous and yellowish below. In regard to their work, I observe this further difference, that the Worms of the Hornets do not draw all their webs to the same height, as the Worms of the Bees do; and hence it happens that their cells differ very much among themselves in respect to height. Their webs also consist of stronger threads, and are of a rounder figure, and usually drawn higher than the Bee-webs, nor are they sealed up with wax, as is common in Bees. The seventh figure shews the web, prepared by the Bee-worms; it is formed above into a spherical figure, and has very conspicuous filaments, Tab. XXIV. fig. VII. *c*; but on the lower part *a* it is membranaceous and much thicker; and at length it becomes triangular, towards the basis of the cell, and exhibits a transparent Nymph *b* on the inside.

After



After the Worms of Bees have brought their webs to this degree of perfection, the working Bees have new business, for it is then incumbent on them to cover with wax all these cases which are arched as it were over the head of the Worm, and consequently to seal up the Worm itself with the greatest circumspection and exactness in its cell. This case seems to me to be altogether necessary, for if the web was not covered and sealed up above with wax, it might possibly be pressed in by the Bees running up and down thereon, and consequently the subjacent young and tender members of the Worms which cast their skin a little before might be injured: besides that, the operculum or cover of wax contributes much to preserve the heat, by the assistance of which, both the evaporation of the superfluous moisture, and the subsequent change of the Nymph into a Bee are promoted. The web we have hitherto been describing has also this further use, that at the time the Bee-Worm changes its skin, and disengaging itself from the latter, is transformed into a Nymph, it is then prevented from slipping out of its cell, which might very easily happen if the cells were not covered or thus shut up, as I myself have learned from experiments. I at one time carried some of these Worms about me, which being as it were hatched by this heat alone, came to that perfection, that the Nymphs assumed the form of Bees: I then saw these Bees running quickly up and down in my box, so that I could not really help admiring what had happened: and from this experiment I learned one thing, and that is, that I might thus know for certain how much time was necessary for the Nymph to grow into a Bee; but I have not as yet been able to investigate this matter fully, being then engaged in other necessary business. I have hitherto only observed the changes which happen under the time of growth, and at the same time I have thus experienced, that heat alone will hatch Bees, and the incubation or sitting of other Bees is not necessary, as some authors have feigned. I began the experiments just now mentioned about the end of September. If the web I have described be cut open in that part where the head of the enclosed Worm is placed, the Worm afterwards will come out of it there, when upon changing its skin it is transformed into a Nymph.

The Worm after it hath covered itself with this web remains entirely at rest, and does not move in the least; it keeps the place which it at that time filled, and remains quiet to the end of its transformation. But if the dissection of the Worm be undertaken at that time, besides the cæca or closed vessels before described, there also appear a great number of very slender vessels, which are situated on the intestines near the pylorus, where the closed vessels are inserted, and seem to me to be of the same nature with those vessels which Malpighius calls *vasa crocea*, the saffron coloured vessels in the Silk-Worms. At the same time the cæca or closed vessels

themselves are seen. Whether these very delicate vessels are in the Worm from the beginning, and afterwards only increase with its growth, does not yet appear. But if they be, they are much larger in the Bee than they were in the Worm: I have never found them of a yellow colour in Bees, as I have done in the humble Bees. I have sometimes seen the excrements lie coagulated in these vessels in the females, and indeed occasionally in the common Bees. I find great difficulty to discover the real use of these closed vessels, whether they secrete a particular humour in their cavities, which must be discharged out of the body, or such a liquid as changes the contents of the other intestines; or are they analogous to the cæca which are found in other animals, but particularly in Birds and in Rabbits? The use of the cæca in other animals is not yet sufficiently known, yet it is certain that excrements of the same with those of the great guts are found in plenty in them. Had not these vessels been so regularly divided into four, and had they been of such a length, and inserted even into the intestine under the stomach, one would incline to consider whether they did not belong to the bladder of poison of the sting, which I shall afterwards describe in the common Bee; but this doubt may be easily solved, if one should dissect the Worm of a male Bee. The time for getting these Worms is now past, since I am now writing this on the first day of September.

Further, in this state of the Worm the stomach is much more contracted than it was before, and appears like a small gut: it is of a whitish colour, and its yellow contents now disappear, being totally wasted. We likewise observe, that when that Worm is but a day, or half a day older, its stomach becomes shorter; but the *vasa crocea*, or yellow vessels, are much stronger and more visible. A little below the place where the *vasa crocea* are inserted, the great guts may be seen more beautifully than in the Worm that is not yet covered in its cell. These are joined to the stomach, and now become somewhat longer, and begin to bend or turn themselves. Behind these are seen one or two parts so tender that they cannot be accurately examined.

The fat that is found in the Worm when in its web, very easily separates from its membranes: hence it happens that the contracted pneumatic vessels become at this time more conspicuous.

The Worm whilst at rest in the manner just mentioned, swells considerably about the breast, but not so much about the head; and after this it begins likewise by degrees to grow thicker, and to swell out about the second and third annular incision: the reason of this is, because the limbs of it which have increased inwardly, are insensibly distended with fluids. We likewise here see the legs and wings, afterwards the head, breast, belly and trunk, and finally, the whole form and structure of the

Bee that is to be produced from thence, all shewing itself under the skin. But the legs are bent together as if they were folded up, and are weak and very tender: the muscular fibres likewise are like glue, and they appear fluid like water, on account of their abundant moisture, so that they can by no means move themselves: so great is the extension and inflation which they undergo, so that for this reason, incomprehensible changes must afterwards happen in them. Nor are these following changes peculiar to the muscular parts alone; they are observed also in the nerves and in the spinal marrow, for they are likewise subject to very visible extensions, transmutations, contractions, and even translocations. This is no where more manifest than in the Perla, or Dragon-Fly, of Mouffet, and in the Ephemerus, when these little insects change their forms; for in the Perla the spinal marrow is extended so much that it becomes twice as long as it was in the Worm; and something similar is likewise observed in the optic nerves of the Snail.

The legs in particular, and also the horns and trunk \*, are then very conspicuous when the Worm of the Bee is distended so much; and by the same means the whole figure of the included Bee becomes, by degrees, visible through the skin, and all the divisions of the head, breast, and belly come in sight. But at length, when the skin opens along the back, and the skull of the Worm separates in three places, there the Worm assumes the form of a Nymph, that is, it after this change shews out beautifully, and more perfectly formed, the limbs and parts that were before hidden: hence all the parts may be seen there more clearly and distinctly than in the Bee itself; since that feather-like down which is seen on Bees, is at this time in the Nymph. The structure of the trunk is likewise remarkable, and is most manifest here in all its parts; and therefore it can, on account of its situation and immobility, be much more elegantly and clearly distinguished, than when this little insect is become a perfect Bee, or hath been transformed into the flying state, by a real growth of the parts, not a fictitious metamorphosis, according to the fanciful and visionary opinions of authors who have written to this time. All the changes of insects are no more than a slow accretion of the limbs and parts, and therefore are analogous not only to those of other animals, but also to those which we observe in vegetables, as has been before sufficiently explained and demonstrated at large.

The creature is in this state of the Nymph excessively, nay, amazingly tender; for almost all its limbs are extended and inflated with abundant humidity; the former skin is thrown off, the pulmonary tubes in the body have

changed their integuments, and are again swollen with new air; nay, it is wonderful and utterly incomprehensible, that the pulmonary tubes, whilst they are casting their integuments, do not put off simple membranes, but as it were entire vessels composed of annuli or rings; so that by this means the internal pulmonary tubes which have separated from the other, are thrown out of the body at the external orifices or points of respiration, having the same form with those which remain in the body. In the same manner likewise the stomach and gullet, and the intestines through the whole body change their skin; which, however, is very difficult to observe, unless one shall immediately examine the exuvia or skin when it is just cast off; or better, if we know how to take off the skin from such a Worm, at a fit time, by art. The stomach wonderfully shews this in the Worms of Hornets, for these in like manner discharge their contents or excrements, and together with them the whole inward coat of their stomach, which is of a purple colour, so that the little mass ejected weighs sometimes more than three grains. From the number of such coats as are found compacted in the cells of the Hornets, and laid on one another at the bottom of the cell, it may be very certainly computed, how many times the Hornets have brought up their offspring from the Worm state in the same cell.

In the Worms of the Bee it is particularly remarkable, that when they are changed into Nymphs, all their limbs and other parts, their legs, wings, horns, and proboscis or trunk, and all the rest of the body have pulmonary tubes: these tubes are likewise filled with air at the time their limbs and other parts are swelling, and by force of this air they likewise promote the due expansion of the several parts: this is seen most eminently, when the Nymph, by changing its last skin, becomes a perfect Bee.

In the Cameleon, which is the only sanguiferous animal that has lungs, which agree in some respect with the lungs of insects, by reason of their branching pipes, the propelled air is likewise of the same use in expanding or distending the parts. But it is only for the purpose of extending the creature's tongue that this happens in that creature, though there are, beside this mechanism, some muscles that likewise contribute to the thrusting out this tongue: it chiefly, however, depends on the air which is forced out of the lungs for that purpose, into the double cavity of the tongue. I have likewise observed the organs of hearing, and the spleen in the Cameleon, however boldly some very industrious gentlemen in France, who have published the anatomy of the Cameleon, may assert that it wants these parts. These authors have likewise committed great errors in regard

\* Since this author wrote, the French naturalists have made many nice inquiries into the structure of this insect. They in general confirm the doctrines he has established, but in some points they have improved on them. They have discovered that beside the trunk, the Bee has a real mouth. This is situated in the fore part of the head, and may indeed be seen without great difficulty. By means of this the Bees are able to feed upon the farina of flowers, from which afterwards is made wax. This author thought they could not feed on it, because it could not pass their trunk; but I have taken out of the stomach of a Bee the farina of a bean flower in its proper form.

to the cornua or horns of the uterus, since they have neither accurately delineated nor exactly described them. The pulmonary tubes also are not represented acute enough by them. I would not however have any person think I say this from a love of censure, so far from it that my sole view is that the true face and disposition of nature may be exposed to the eye. I wish others may pass the like censure where due on my works; nor do I pretend to doubt but I have committed many errors; it is sufficient for me that I can most freely assert, that I have not wilfully designed to mislead the reader in this treatise, I likewise think the same of some other, but very few authors; for the desire of writing is so prevalent now-a-days, that men publish books filled only with the fancies of their brain, and thus misrepresent God and his works; heaven forbid that I should ever do this, truth and a religious scrupulousness of mind ought every where to prevail in describing natural things, because they are the books of the divine miracles, unless he who writes aims to deceive himself and others, and such a one should know that all things are revealed in time.

Let us now return to our subject. These Worms then weave over or cover the inside of their cells with threads, they also discharge their excrements into these cells, and there at the same time, cast a thin skin and their old pulmonary tubes: hence if all these things be done several times over, that is, if in the cells of the same hive, fresh eggs be laid and young Worms be continually hatched in a succession for several years; the cells must necessarily become from time to time less and narrower, and the Bees must be obliged to leave the old combs, and to build themselves a more convenient edifice: the honey also that is lodged in such foul and dirty cells, is not to be called virgin honey, nor the wax of the combs virgin wax. Since both of them abound with a great deal of filth, which ought to be separated before they are fit for use. The honey which the common people use is very impure, for it is pressed out of wax, after the purer part of the honey has run out, and it is accordingly sold at a low price\*.

If any person is desirous to examine the web before mentioned, let him steep only part of it, together with the wax adhering to it, for some days in rectified spirit of wine; thus the wax will fall into little lumps, and the web will be manifest alone: if an entire waxen cell, while it is yet sealed up with its Worm or Nymph in it, be put into rectified spirit of wine, then all the Nymph's little body, which is enclosed in the web, and cannot be taken out of it, but by cutting the web, pre-

sents itself to view. This contrivance whereby we steep and dissolve the wax by steeping or soaking it in a proper fluid, in order to see the web, has this further advantage, that one may by this means know very exactly how many times the Bees have brought up their progeny in the same cell, for it is certain that as many webs as are found in one cell, so many eggs have been hatched there. When the wax is thus carefully separated from the web by steeping it so that the delicate texture of it is not injured, the web will then be found to represent or express very beautifully the hexagonal figures of the cell, particularly in the lower part, as may be seen in Tab. XXV. fig. III. under the letter *g*. This web is likewise about the basis and angles of the little cell, always somewhat thicker and blacker than at the upper part, being there more membranaceous and of a yellower colour: from what cause this difference proceeds is still a secret to me. If any one desires to discover very suddenly the web so often mentioned, let him make the waxen cell boil for a moment over the fire in spirit of wine, or in oil of turpentine. If an old cell be cut open with a dissecting knife, we sometimes observe the foundation of the cell, which is otherwise wonderfully thin and delicate, half as thick as the silver coin called an imperial, on account of the several webs, that have from time to time been laid on it. This condition of the web has imposed on some so far as to make them believe, that every Bee builds its own respective cell, for they saw that all of these webs were severed from each other, when the broken wax was separated from them, as one may easily try if he steeps or soaks the little cells for some days in brandy.

The webs are also of this further advantage to the combs, that they make them much firmer and stronger, and hence one may with less danger remove and carry elsewhere the hives in which the Bees have engendered for some time, than those in which the wax is new. Besides that the combs, strengthened with these webs, do not so easily melt in very hot weather, or blend together, when they are turned upside down. That the filaments or threads of the web may come in sight more distinctly, there does not require much labour in preparing it, for if one only cuts off the upper part of one of the cells, which is covered with wax, with small scissors or a fine knife, strips it of the waxen cover, and then places it under the microscope, it will appear most evident, from the disposition and manner wherein the threads are placed over one another, that the Worm of the Bee does in reality spin. If an entire cell, steeped

\* What is called rock honey in some parts of America, is the produce of a peculiar kind of Bee, lodged in a very singular manner. This Bee makes no regular comb, but notwithstanding that, it preserves its honey in waxen vessels: the honey is clear as water, and very thin. The Bees hang their clusters of cases to a rock; one is first made, and is very securely fastened; then others are hung to that, in the manner of grapes in a bunch. These cells or cases are larger than the biggest grapes, and of an oval shape; each has at first an aperture at the upper part, in which the Bee puts the honey; when it is full they close this aperture: forty of these cases will sometimes hang together, and the honey is excellent, and in large quantity.

or soaked in spirit of wine, throws off the wax, then both parts of the web, as well that which is discharged in the form of threads, as that which is like a membrane, being now joined together, nay, the whole figure of the web, which is hexagonal below, and spherical above, may be seen.

Before I enter upon the description of the Nymph more accurately, I shall beg leave to observe, that the Cochineal insect if steeped or soaked for some time in spirit of wine, appears almost like our Bee-Worm; its body being divided by many annular incisions: but there is this difference, that it is shorter and thicker than the Bee-Worm, and it also exhibits some vestiges of legs. The Cochineal Worm, as I have heard and been assured by some who spoke positively, is produced out of an egg, which the parent insect lays on the leaves of that very well known American plant called Tuna. When these Worms are first come out of their eggs, they are as small as those minute Worms which are newly produced in cheese: they are increased afterwards so much by means of the food, which they get from the leaves of this plant, that in a short time they cover the whole surface: nay, they multiply to such a degree that in the space of one year, they will occupy or possess a field that has an hundred such plants, and may be collected from thence for exportation four or five times yearly. There must only be care taken that the plants be clear of all other insects whatsoever, and that no fowls be admitted into the place; for both will greedily hunt after and feed upon these Worms. When the owner is inclined to gather these Worms, he first considers whether they are arrived at their full size, and then some throw ashes on them, and brush or gather them off the plant, and then dry them in the shade: if these Worms are left longer to themselves, they then fix themselves to the leaves when they are about to change into Nymphs by accretion: and the Nymphs, casting off some time after a thin skin, are changed into very small and almost orbicular winged Beetles, of a brown black colour, adorned with bright purple spots, and distinguished into males and females, who soon after coition lay eggs again. These Beetles are not, like the Worms, used in dying, though they are sometimes brought to us mixed with Cochineal, as I myself have seen, and now have some that I picked out of that drug in my custody.

In our country also on the leaves of the lillies, Worms are often found which are somewhat thick and of a pale red colour, like Cochineal, but they differ from it in that they are furnished with six remarkable black legs, and have a very conspicuous head. These Worms are transformed in a very short time into an oblong bright red Beetle with black legs and horns. This Worm has one thing peculiar to it, which is that it covers itself with its own excrements against the sun's heat,

and by that means renders itself in a manner invisible; since it walks over the leaves of lillies covered with its excrements. I have likewise in my collection of insects some little creatures not unlike the Cochineal Beetle, only that they are somewhat less and in some measure different in regard to their colouring. Hence I am inclined to think that the Cochineal may probably be discovered and fed in our country, though I have never yet found it. This species of Beetles, which have all knobbed horns, are by our country people called Lieven Heers Haantjes, or Onze Vrouwen Haantkens: but I shall now return to the Bees.

The Nymph of the Bee-Worm contains nothing else but an elegant disposition and well-ordered representation of all the limbs and parts of the future Bee; which, as they have been to this time increasing, at length become externally conspicuous; but they are immoveable until the humours with which they are filled and distended are exhaled and dissipated: after that the creature can move them. Hence it is that the Bee while in the Nymph weighs considerably more, than when it is changed into a perfect Bee. Before I exhibit the parts and limbs of this Nymph, I shall describe its parts while yet in the Worm, with more accuracy and method than has been hitherto done by others. In doing this I shall follow the order according to which the Worm insensibly and naturally approaches to the change of its skin, or to the disclosure of these hidden members: it is as follows. The old skull, which is to be immediately cast off, becomes insensibly filled with a limpid humour, by force of which it is separated by degrees towards the foremost parts from the head; hence the horns, teeth and trunk, which lie folded and complicated together under the skin, are disposed in such a manner, that they may be extended and inflated by the imbibed humour, all which happens gradually; in the mean time the head, which insensibly and in a manner scarce to be perceived, recedes or goes back from the skull, is gently extended and expanded; this is principally occasioned by the eyes and their adjacent parts being inflated or distended with air, blood, and other fluids rushing in; the thorax likewise now becomes extuberant, by reason of the air and fluids introduced; as do also the legs themselves in like manner swelling considerably both above and under the thorax; they are placed in a very elegant manner under the skin: the first or foremost pair of legs adhere underneath near the proboscis, which together with all its parts is stretched upwards, to the head in such a manner, that the extreme ends are in the upper part, and the thighs in the lower place; then follows the second pair of legs which are deposited in like manner; near these the wings are situated, whereof the less are placed by the sides of the greater and a little under them; then follows the last pair  
of

of legs, which is deposited in the same manner as the first and second were under the skin; all these parts, as far as they lie under the skin, are somewhat wrinkled or folded, and they are by this means above one half shorter than afterwards when the creature is changed into a perfect Nymph; for when the Worm casts its skin, these parts are considerably and wonderfully inflated and extended by force of the air, the fluids, and particularly of the blood: this extension of these parts is performed at the time when the Worm, by the means of a kind of peristaltic motion, breaks open the skin by rolling it down, and is incredibly promoted by the parting exuvia or cast skin; for since all these parts by means of delicate and minute fibres and filaments adhere loosely to the skin; hence the skin carries them with it as a kind of moveable cords, and the parts themselves being by this means extended, roll in their turns from the skin in the same manner as a cord runs out of its pulley. This is the true reason why these parts are so regularly digested and extended in the Nymph, and are disposed in so beautiful and firm an order and so wonderful a situation as I am now going to describe, according to the figures which I have given. I shall first then shew in a somewhat smaller figure the disposition of the parts under the skin, a little removed from their first situation. Tab. XXV. fig. iv. *aa*, are the horns, *b* the proboscis with its parts, *ee* denotes the first pair of legs, under which is seen a second *ff*, and then a third *gg*; *bb*, *ii* are the larger and smaller wings of each side: *k* denotes the rings of the abdomen. I shall in the ninth figure represent the situation of these parts in the Nymph in a larger scale.

Fig. ix. *a* Represents the Nymph's head, which being then distended with humours, and expanded by force of the impelled air, resembles in softness and tenderness, milk that is just curdled. In this manner the whole body and all the rest of the parts are circumstanced at this period. All these parts are of a milk-white colour, and the whole insect is without any the least visible motion; so that in reality, it resembles a dead carcase.

*bb* Exhibit the eyes of the Worm, which now appears under the form of a Nymph. Its three smaller dispersed eyes cannot be seen in this view, being placed more backward and higher in the head, in the middle between the larger eyes. The first change observable in this creature, when it becomes stronger by the evaporation of the moisture is manifested about those smaller eyes, and about the large ones here figured *bb*. Their change consists in this, that the eyes, by degrees and as it were, insensibly assume a faint purplish colour: at the same time is also discovered the semi-lunar figure of these large eyes, which one cannot otherwise discern, on account of the intense whiteness which obtains here, and the brightness of the surface.

*cc* Are the antennæ or horns which spring from the middle of the head, and are bent by force of the skin that is drawn down towards the belly; they are very elegantly placed near the proboscis and its adjacent parts. Under the extreme ends of the horns are disposed the three first joints of the first pair of legs *ii*. In the middle of these one may see numerous pulmonary tubes through the covering.

*d* Denotes the lip, which is not yet remarkably increased in its size, or distended.

*ee* Are the teeth or jaws, which are covered in some measure by the lip.

*ff* Shews the first pair of those parts which belong to the trunk or proboscis: they have likewise their pulmonary tubes, but above them and under the teeth is seen a certain portion of the third or last pair of these little parts belonging to the trunk, which are the shortest and smallest of all.

*gg* Represent the articulated pair of little parts that defend the proboscis, which are divided on each side into three joints.

*b* Is the proboscis itself, very beautifully situated between and under the said parts. But we must observe, that all these little parts are now furnished with transparent pulmonary tubes. When the little insect is approaching to its last change, and is in a short time after to obtain the form and name of a Bee, then all these pulmonary tubes become again for the most part invisible. And the same thing obtains about the vessels of the wings: which are then bound or tied up in such a manner, that you would conclude them not to be pulmonary tubes but nervous fibres.

*ii* Exhibits the first pair of legs in the Bee, while it is still called a Nymph. The three extreme joints of these legs may be seen under the extremities of the antennæ *cc*.

*kk* Are two very beautiful, stiff, translucent little parts, situated at the lowest joints of the first pair of legs, and which seem to serve the Nymph only as an ornament; for upon casting the skin, they are thrown off and entirely abolished.

*ll* Another pair of the Nymph's legs, which likewise are full of transparent pulmonary tubes. These legs, being, by means of the skin when drawn off, and by the power of the impelled air and forced humour, depressed and stretched beyond the middle of the body, are there very regularly placed.

*mm* Are the wings of the Bee, still constituted under the form of a Nymph, a part of which only we can hitherto see. These likewise have many pulmonary tubes, which, when this Nymph is casting its last skin, are also, together with all the other parts, once more to throw off their exuvia: after which, when these tubes are again distended by the freshly impelled air, and the pneumatic vessels which have been hitherto contracted, are inflated and distended with the same air; it follows, that the whole wing afterwards expands itself and becomes

becomes thrice, nay, four times larger than it was before. But this expansion of the wings is not to be attributed solely to the air, but in a considerable degree also to the blood; for at the time when the air is impelled into the wings, and a considerable quantity of blood is likewise driven into the blood vessels of the wings. This blood in the Bee is a limpid humour or ichor, as may be observed, if a little part be at this time cut off from the wings; for then this humour flows from it, appearing by reason of the extreme smallness of the blood vessels, under the form of little pellucid globules, which, insensibly and by degrees, increase into considerable little drops. We must observe here, that some of the Nymphs of Flies, when they are casting their skin, not only expand their complicated wings, but also distend vastly their whole body: hence it arises that they appear twice as big as the *exuvæ*, wherein they were before enclosed. The expansion of the wings in Butterflies is the most elegant of all the phenomena of this kind that occur in nature; for in these creatures, the wing in the space of a quarter of an hour, though at first not bigger than half the nail of one's little finger, becomes as broad as a half crown, and at the same time all its colours are augmented, extended, and regularly diffused: and hence indeed, an admirable sight is produced, which would appear the more wonderful if one had but the least knowledge of the cause of it. For we certainly can know nothing of the magnificence of nature's secrets, unless by the help of an infirm and weak reasoning we are able to pass our judgment on the more evident and palpable effects; but even this is subject to many errors. When the wings are displayed in the Butterfly, their air-pipes or pulmonary tubes are soft like warm wax, and the wings hang down that they may the more easily be distended with air and humours.

Tab. XXV. fig. ix. *nn* Are the scapulæ or shoulder blades of the Bees Nymphs, which are somewhat sharper a little lower. Under these are seen a pair of orifices, by which the air-pipes open into the breast. The air which is expelled through these orifices assists in producing the humming noise which the Bees make with their wings.

*oo* Exhibits the last pair of legs, which are likewise furnished with transparent air-pipes like little veins.

*pp* Are the rings of the abdomen, in which seven apertures of air-pipes open on each side. But I have not delineated these apertures in the present figure; since I do not yet know their true situation, for they appear very obscure, because only one colour is seen here. However, I have observed in dissecting the Nymph, that the mouths of these air-pipes terminate in the rings of the abdomen. I have seen also three such orifices in the breast. I shall now mention some other things in the anatomy of the Nymph, which are pertinent to this matter.

*q* Exhibits the hinder or posterior parts of the Nymph. The sting of the future Bee is seen there somewhat protuberant out of the body, as are also those two little parts *r*, which accompany the sting in the common Bee and in the female. And lastly, the arms appear underneath *s*.

If all these parts be afterwards removed out of their places, then the divisions of the head, breast and abdomen appear very beautifully in the Nymph, but most particularly those of the breast: and thus we may at the same time beautifully see how the legs are jointed with the breast, which cannot be distinctly seen in the Bee state of this little insect, on account of the great quantity of down rising there. If the creature be then inverted so as to lie on its belly, the three great divisions of the body are manifestly seen in it: and in the horny or bony parts of the thorax, which are still membranous, and very tender numerous air-pipes are likewise observed.

The first external change observable about the Nymph consists in this, that its eyes insensibly become of various hues. First of all are distinguished those three remarkable separate eyes, which, when the insect lies on its back, are seen fixed between the semi-lunar curvatures of the larger eyes, as I shall hereafter explain more at large. And at the same time, the semi-lunar figure of the eyes is conspicuous by their variety of colours. Nor can any other remarkable change be observed at that time in the Nymph, besides this of colour, which occurs in the three separate and in the semi-lunar little eyes.

When the eyes by degrees have grown purplish, then some small changes are likewise seen about the body and legs; that is the horny or bony parts of the shoulder blades begin to acquire a yellowish tinge, somewhat inclining to a brown red: the horny or bony parts of the wings, legs, and the rest, then afford also some small signs of their transformation.

Whilst the colour of the limbs and parts is changing in the manner I have mentioned under their accretion, the purple colour of the five eyes become more and more brown, and at the same time we observe, that the claws of the feet become also horny or bony, and of a brown red: and this change is also observed about the teeth.

In the mean time the eyes become, by little and little, more blackish, nor is there yet any division in the coat that invests them on the outside, though one may then easily see the divisions which appear through the coat. The horny or bony parts of the trunk now also begin to grow black, and the horns, which are situated under the eyes, and the distinct eyes above are more plainly seen.

The thorax also is about this time from a gray, manifestly changed into a brownish colour: and we also see the whole body under the skin, distinguished by some blackish

some blackish points, which are the rudiments of feather-like hairs.

Whilst the whole body is changing in this manner, it is altered or disguised, and becomes more robust as it is increasing; so that even the claws of the feet now evidently move within the skin wherewith they are surrounded; but the most remarkable changes are observed about the sting. For this sting is hitherto an external part, though it may afterwards be, and actually is drawn back into the body: therefore, since it is conspicuous in the Nymph without any previous dissection, one may easily observe its increase and perfect formation. The better to understand my observations on this part, I think it necessary to observe before-hand that the sting, as well as all other parts of the body, changes its skin when the Nymph throws off the last exuvia: for this reason, the changes of the sting may be distinguished as clearly as those that happen in the claws, legs, and the teeth. The first change, therefore, which is observed about the sting, consists in this, that its crooked little hooks, which necessarily remain fixed in the wound given by the sting of a Bee, come in sight. For while the two side-pieces, and the case or sheath of the sting are yet membranaceous, or as it were cartilaginous, these little hooks are distinguished by their yellowish red colour; and this colour is afterwards diffused by degrees through the whole sting, whilst in the mean time the sharp-pointed ends of the two side-pieces of the sting, are acquiring a horny or bony substance, and more dusky colour. The circuit also, or extremity of the case or sheath of the sting, in like manner changes its colour, grows hard, and becomes horn-bony. And as the other parts still retain their white colour, the said changes strike the eyes the more plainly: for we must observe that the sting is, with regard to its colour, more conspicuous in the Nymph, than it is afterwards in the Bee itself. Moreover, the two side-pieces, as well as the sheath of the aculeus, are enclosed in peculiar membranes, which are thrown off in a most singular manner: hence one may very distinctly see these side-pieces in the Nymph placed near each other, which is by no means the case in the Bee; since these parts of the sting in that state of the insect are hidden in the case or sheath, as I shall hereafter describe at large, and represent in figures. About this time, also, these several parts, as well as all others, acquire each their last perfection; that is, the eyes, teeth, legs, claws, horns and the rest: nay, the thorax itself insensibly becomes during this time more brown, and approaches nearer to a horny nature, and grows very shaggy with strong hairs.

The last change happens in regard to the strength and colour of the wings: at the same also the proboscis or trunk in like manner presents itself to view in its ruddy or bright brown colour, and shews the hairs wherewith it is adorned. Thus all the superfluous humidity of the Nymph being at length evaporated, it casts

a skin from all its parts, and after gnawing a passage through the web, creeps forth at length from its cell, in which it had hitherto lain, in its perfect form of a Bee. The wings indeed are at that time usually complicated or folded up, and yet I sometimes have seen them expanded; that is, when it hath been for some time detained in its waxen habitation, and hath not been able to creep out of it with sufficient speed: in that case we find that its wings have been first displayed within the little cell: all the species of Flies appear in like manner, when fresh from the Nymph, with complicated wings.

When I dissected the Nymph of the common Bee, at the time that its colour just began to be visible, upon opening the outer skin, I observed the fat separated very easily from the air-pipes or pulmonary tubes; which was likewise the case about the outmost coat of the eyes, which has no divisions. All the contents of the eye also were very soft. The inverted pyramidal fibres hereafter to be described, resembled jelly made of veal. The brain was likewise so soft that being only very lightly touched, it immediately separated from the beginning of the spinal marrow. The spinal marrow itself was there as well as in the body very soft and tender. Nay, and the three separate little eyes, which, as shall be made more evident hereafter, are placed in a triangular form between the divided eyes, after I had taken off the skin from them, and can be distinguished very clearly. The teeth were as yet membranaceous, nor did they shew any sign of hardness, or of their being of a horny or bony nature; they abounded within with a mucous humour, upon pressing out which they seemed hollow. The jaws in human abortions six months old, likewise shew membranaceous teeth, which however in various places are observed to be growing into bone.

In the thorax all things are at this time amazingly soft and tender. The muscular fibres may be seen very distinctly, and in some measure as if separated from each other; but they are still so excessively delicate, that being but very gently touched, they immediately quit the place where they were fixed: moreover, they are at this time shorter than in the same insect when it is changed into a Bee. Indeed, I observe that all these muscular fibres are at first contracted in the same manner by nature, and that in spite of her, as it were, they are afterwards extended by the blood and humours. This is probably the reason why these fibres endeavour to contract themselves continually, and that even a long time after the death of the creature. This shortness of the muscles in creatures not yet brought forth, is occasioned by the investing membranes binding up their bodies; and hence it happens that the blood and air are prevented from distending the muscles sufficiently. We have before mentioned some singular and obvious examples of this matter in insects, which are seen as soon as those creatures come into the open air. The

fat also very easily in this dissection of the Nymph quitted its connecting membranes and the pulmonary tubes, and, by its friability, presently hid the other parts from sight, for it divided and diffused or spread itself into innumerable white parts of different bigness. Between this fat were likewise seen the pneumatic vessels, not much changed from that appearance which they had before in the Worm, when it was about to cast its skin.

The stomach in this Nymph appeared still somewhat long, for it had not wholly contracted or drawn up the length which it has in the Worm, into the pyriform figure which it wears in the Bee. All the rest of the viscera of the body were already formed and considerably increased. The intestines were very elegantly conspicuous, and of moderate strength, but they were filled with watery contents, nor did they yet contain that green substance, which is to be found in the intestines of the more mature Nymphs, and thereof the green colour is evidently seen through the body and heart in the back. The same thing obtains in calves whilst still in the cow's belly, and the contents of the intestines in them in like manner change colour. It is also very remarkable here, that such hairs are found intermixed with those excrements, as the mouth and body of the calf is covered with; and this argument most evidently demonstrates, as I have observed before, that these animals convey the food while in the uterus through the mouth; nay, and take in the hairs which they licked off the surface of their body, together with the fluid of the amnion. The vasa crocea, or yellow vessels also may be very easily distinguished in this Nymph, and separated easier from the intestine, than in the Bee arrived to its full maturity; for, besides the friability of the fat, the membranes are yet very tender, and the pulmonary tubes, to which these vessels are connected, are very weak. The internal parts of the sting also, which are not visible on the outside, may be now very plainly distinguished. It was further admirable to see in this dissection the aculeus or sting, which afterwards becomes so sharp-pointed, hard and formidable for wounding, is still very soft and tender, like a thin membrane, and is likewise filled with an aqueous humour, which naturally flows out of it. The poison bag \* of the sting was contracted, and its closed tubes, by the help of which the poison is secreted and conveyed into the bag, may now also be discerned.

But as all the parts hitherto mentioned were extremely soft and yielding at the time of this dissection, so, on the other hand, the productions of the wind-pipe, or little pulmonary tubes, presented themselves more distinctly to the view. The reason of this, as I have before observed, is certainly that the fat and the

membranes which connect it, recede from these parts with the utmost ease: we lay open the Nymph from the bottom quite to the top with a small pair of sharp-pointed scissors, all the fat, the little membranes and the rest of the contents may be without any difficulty, in a basin filled with water washed out so thoroughly, that the pulmonary tubes alone, though they indeed, with respect to their larger branches, are not removed from their natural situation, shall remain behind in the skin. The same experiment may also be made in another manner, viz. a fine glass tube may be thrust into the body of the Nymph, and by the help of water injected through it, all the contents, except the tubes that convey the air, may be washed out of the body. This may likewise be done also in the Worm, when it is on the point of changing its skin, and then being blown up with air it may be dried and preserved. The same experiment may be made with the utmost ease in the melts of oxen; for if you wash off the outermost substance of the melt through the vein, and then cut away with a fine knife the exterior coats from the melt when dried, you will have a most curious preparation. At this time we have a most beautiful view of the pulmonary tubes, and their ramifications in the Nymph of the Bee; so that they may with very little trouble be counted and distinguished from one another; seven appearing plainly in the belly, and three in the breast on each side. The first pair of these open with fair apertures on the outside in the breast near the neck; but before these two tubes ascend from thence towards the head, having first taken a wider circuit, they join together, and then in two very distinct branches, like the carotid arteries in man, they again ascend towards the head, inserting themselves in the brain, the eyes, the horns, and the teeth. The next two orifices are opened under the shoulder-blades, and the last under the wings. Some branches likewise, and those very discernible, run different ways out of the breast towards the legs and wings; and these at the last changing of the skin assist greatly in the unfolding of these parts, as I have already observed. In the belly I could not so accurately distinguish the orifices of the pulmonary tubes on the outside, for there they seem to be inserted obliquely, like the urinary passages in men and quadrupedes. But however, in the inside of the body their insertions are extremely obvious: this may be seen also even on the outside, if we free the Nymph from its coat or strip off its skin with due skill, and then draw the air-pipes out of their orifices. As for the position of these pipes in the body, I have already spoken of it elsewhere, and shall explain it farther in a succeeding chapter.

\* The poison of the Bee seems to owe its mischievous efficacy to certain pungent salts. It may be easily seen to contain such. Let a Bee be provoked to strike its sting against a plate of glass, and there will be a drop of the poison discharged and left upon the glass. This is to be placed under a double microscope, and as the liquor evaporates the salts will concreate. They form oblong, pointed, clear crystals, but the quantity of fluid is not enough to let them form distinctly.



The Nymphs of Bees, after they have continued shut up in their little waxen cells for a sufficient time, and till the entire evaporation of the redundant moisture, shed at length their last skin of all, which accordingly is found in the bottom of the cell, together with the former, which they have thrown off during their existence under the form of a Worm. Having thus cast their coats, they then break their web, by the assistance of their teeth, and at the same time forcing their way through the wax that is fastened down above to the web, and bursting it into several jagged pieces, they throw it off on all sides; after this other Bees carry these broken pieces away, and clear the cells so thoroughly, as to make them quite smooth and even. The male, as well as the female Bees, force their way also out of their cells, in the same manner as the common or working kind, and all undergo the same change. This remarkable difference, however, is to be observed, that the common Bees, and of the male kind also, usually come forth, as already observed, with their wings then folded up; so that after they have burst through their webs, their wings remain yet to be expanded, by the force of air and humours impelled within; for, as has been already observed elsewhere, those large vessels, which are perceived in their wings, after the manner exhibited in Tab. XXV. fig. x. are without doubt the tubes that convey the air. Close to them also are placed the blood vessels, which bring the nutriment to the wings. This observation I have made is highly worthy of notice, since it most evidently displays the wonders of God, in the insect world, and at the same time utterly overthrows those impious notions, that these creature are generated from putrefied matter, and by a certain fortuitous concurrence of particles; for if we grant that, the espousers of these notions take occasion thence most perversely to carry on the argument to large animals, and in a most offensive and indecent manner lessen and detract from the providence and omnipotence of God, which are universally and equally manifested in every species of animals without exception. In truth, if the most minute creature is capable of being generated from putrefaction, nothing hinders but that the largest of all may likewise.

The female Bees do not, as the common Bees and the male, come forth with their wings folded up, but expanded and displayed: they come out of their cells in a state of flying. On this account, the all-wise Author of nature has provided for them a more spacious mansion, in which they may expand their wings conveniently and properly, so that after they have burst from their cells, they may be prepared for swarming immediately, if there be a necessity for it, or that the young female may be in a condition to drive out even the mother Bee herself, that is the old female, and to take her place, if there be occasion.

I am fully persuaded that the rest of the Bees know beforehand, by some sure sign, when

the new female is employed in breaking through her cell; and, accordingly for some days before they form a new colony or swarm, we see a great many Bees hanging about her cell, which are no doubt waiting for the female's issuing forth, and when she is just on the point of coming out, they make a buzzing with their wings, which is the song of Bees, receive and salute her at a distance as it were with marks of joy. I make no doubt but that the males are most concerned in this business; not unlike wanton horses, who, when they see the mares, though at a distance, neigh after them, and instantly prepare themselves for leaping. This is the case likewise in the males of Silk-worms, which, before they so much as see the female, yet immediately, as soon as they get the scent of her, by the help of their wings set up an agreeable humming; and so irritated are they with a burning desire for copulation, that they will frequently copulate with the females even when dead, nor can they without force be torn off. However, I do not believe, that the male Bees actually copulate with the female, though indeed they love to get as close to her as they can, because thus they feel a titillation arising from the emission of their sperm. For I am firmly persuaded, that the male Bees eject their sperm in the same manner as Fishes, who only shed it upon the spawn, nor have any thing further to do with the females. It would be no difficult matter to make certain experiments, in all these particulars; as to try for instance whether the female Bee, enclosed in a little net made of fine thread, or in a small glass vessel covered with a piece of fine linen, or in a box with holes in it, could be impregnated by the bare scent of the male. But of all these things I shall hereafter treat more at large. I think it necessary, however, to add this single observation, that the last humming or noise which is heard in the hive, a little while before the Bees are going out to swarm, is raised by the female Bee alone, arising to be sure from her joy in feeling herself then impregnated, and being sensible that she is soon to make an excursion; since the sound, which is then heard, is owing only to one Bee, and that no other than the new queen.

I once found a female turned quite upside down in her cell, and yet perfectly formed with her wings already expanded for flight. She had been attempting a passage on the opposite side of her cell, endeavouring to break through the middle wall of the comb itself, great part whereof she had already eaten through: she seemed as if she would be able to get out of the cell in a few days. In these difficulties I came to her assistance, and at the same time got myself a proper subject for dissection. When the Bees begin to perceive that the female is near coming out of her cell, I make no doubt but there must arise a very remarkable commotion in the hive, as  
well

well amongst the younger as the older Bees ; for the young follow the new-born female, and the others remain with the elder ; nay, many both old and young hang together idly round the same female. This division into parties is not owing either to choice, or any ruling power or authority among the Bees, nor is it performed with those fancied ceremonies of honour, and a numerous retinue of old and venerable Bees ranged in order, accompanied with the harmonious sounds of trumpeters, hautboys, and musicians, or in the tremendous presence of executioners standing around, as authors have feigned, ingeniously indeed, but derogatory to nature. Nothing like this is the case : there is doubtless implanted in them a concern for breeding up their young, which instinct makes the Bees flock in this manner round the female : nor have the tribe of slaves, I mean the working Bees, any other task assigned them, as they are capable of being moved by that incentive only, and direct all their actions to that end, though in truth the labour is very great, which they must undergo in breeding up the young, and continually building the cells destined for them. However they are amply repaid, since in their turn, in place of a rich reward, they feed on delicious honey, which they collect with indefatigable diligence ; for nature, in this their wretched state of life, makes every thing to be purchased with labour. I could wish therefore that this example had the weight it deserves, in instructing and teaching us that God might be glorified in all his works.

Were the working Bees furnished with the organs of generation, or any thing analogous to them, we might conclude, not without probability, from their actions, that they were actuated with the most ardent lust to the act of generation, and solely by this incentive animated to perform the several tasks assigned them. But since they are supplied with none of the parts requisite for that office, they can have nothing else in them, but an innate desire for the propagation of their species, which inflames them with so earnest a concern for breeding up the young, and with so singular an affection towards the female, the common parent of all. This will appear evidently, if you take this queen out of the hive, and tie her to the end of a stick, by a thread run through one of her wings, and then suffer the swarm of Bees to fly about her ; for they, following the queen closely, will all of them by degrees settle on the stick, and by the help of their legs cling to one another most surprisingly, so that they resemble, as it were, a complete bunch of grapes. When they are piled up together after this manner, they will suffer themselves quietly to be carried up and down over a whole garden, nor do the working Bees in the mean while stir from their queen, as I myself found by a careful experiment I made. If at this time any other Bees fly up to this numerous cluster, an observer

will see plainly, that they immediately search after the queen with such anxiety, that even from hence sufficiently appears the prodigious affection they have for her, and for the propagation of their species ; for they endeavour to make their way through the middle of the bunch, as it were, that they may reach the female. In a little time afterwards they give over their attempt, and then, without intermission, continue flying from and back again to the cluster. From these observations therefore it is altogether manifest, that the actions of Bees of the three kinds, male, female, and eunuchs, spring from no other cause, but from a vehement and ardent concern, by which they are carried to the generation, preservation, and raising of the brood, which, as it is alone the principle, so likewise is it the end of every thing the Bees do. If after this the female be loosed again from the stick, and immediately put into a drinking glass, placed on the ground, or on a piece of tile, the rest of the Bees, to a single one, will instantly surround her again, and beset the place where she is in such throngs, that one can see nothing but Bees covering it on every side. From all this I think it may be inferred, not without an appearance of truth, that the female emits a very strong scent, by which the rest of the Bees are attracted to her. I observed this most evidently when I had shaken the stick, and had laid the female in the manner above mentioned on a table, in an open arbour, at some distance from them. For this reason I formerly, before I was acquainted with the true structure of the common Bees, compared them to a parcel of Dogs, which follow the female in her time of lust, excited by the bare scent ; however, I will not deny, but that there may perhaps be something else besides the scent in this affection of the common Bees, by which they are so greatly affected : they seem to imitate in some manner creatures that have been gelt, which, though they can do nothing, are notwithstanding inflamed with a prodigious lust for the female.

As therefore it is generation alone by which the Bees are excited to all their actions, so this great cause, whenever it happens to be interrupted, is the sole motive from whence all the confusion at times observed in the hives arises. If the female Bee be barren, or maimed, crippled, blind, or deprived of its wings, neither honey nor wax will be collected, nor will the eggs be laid in the cells. There is in this case no occasion for building cells for rearing up the brood. But if the female be properly perfect, every thing is done in due order, and as the poet says,

“ While the sovereign is safe, all live in  
“ perfect harmony.” Virg.

A great disturbance is also to be observed, whenever there chance to be two females in one hive, and one after another lays its egg  
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in the same cell, for from thence arises not only a vast confusion about the article of raising the young, but a mighty inconvenience likewise about the building of the cells. It should be here considered further, that Bees, for two necessary reasons, namely, the building of the cells, and the rearing of the Worms in them, attend, and of necessity must attend, the female, at all times and every where; for if she has by chance deposited her eggs in an imperfect cell, the rest of the Bees are obliged, by virtue of their office as it were implanted by nature, immediately to make it complete, that the worm to be hatched may have room wherein to move itself, to eat, to change its skin, and to spin its thread: whenever therefore, which I would have observed particularly, the two females, each with her retinue, meet one another, and the Bees are hindered by it in their attendance and work, is it not easy to be imagined, there must arise a prodigious confusion? where is the wonder then that they burn with fury, and, urged by love to their offspring, violently attack one another, determined upon killing and destroying one or the other female? This is falsely ascribed by authors to the divided government of two fancied kings, as if they could not live together with a joint power; but this is an idle tale: all this fighting is caused solely by the propagation being hindered: take away this impediment, and the two females will live very amicably together; for as they have not the use of reason, they are unacquainted with Virgil's maxim, that a kingdom does not admit of two rulers\*;

“For two pretenders oft for empire strive.”  
 DRYDEN'S Virg.

That this matter may the more easily be understood, I shall insert here a rude kind of a similitude. The republick of the Bees may be compared in some measure to a house comprising five thousand bed chambers, in which there is only one woman, who yearly by the scent of the sperm in some hundreds of men born within this house, and living in it for the space of some weeks, is impregnated with a triple brood. Suppose there were beside in the same house some thousands of natural eunuchs, or virgins, who, employing themselves in the finishing of the chambers, and staying in the passages between the said bed-chambers, constantly attend that woman, that they may see in which chamber she first brings forth a girl, a boy, or an eunuch; let these maids or eunuchs take care of and nourish this child that is born, as likewise all the rest of them, which that single woman afterwards in order, by going into each of the bed-chambers, is yet to

be delivered of, and let the bed-chambers not be a whit larger than may be able just to contain the children, till they have arrived at their maturity. These circumstances being rightly understood, it is easily to be imagined what a horrid confusion and discord would arise, were another woman likewise to get into this house, and the body of the eunuchs being divided into opposite parties, to fight against the former woman and her attendants, resolutely striving to lay yet another child in any of those small bed-chambers. Must not thus the settled order of the oeconomy be necessarily subverted? and must not all the inconveniencies and broils that can be imagined inevitably arise?

Behold! this is the true state of the Bees government. It may be proper to take notice also of this single particular, that in this house yearly by that one woman alone are brought forth three or four younger females, some hundreds of males, and some thousands of eunuchs; and that then some thousands of these new-born eunuchs and males together, join themselves either to the elder female, or to the first-born of those four younger ones, and having left their original house, they build a new one solely for their own habitation; but at last that these eunuchs kill all the males, as soon as the female, who came out with themselves, is impregnated by the scent of their sperm, and after that they live with the female alone for the space of an entire year. If all these things are rightly applied to the republick of the Bees, it will be no longer difficult to assign a reason for every action of the Bees, whatever it be, such as their building, raising their offspring, collecting of honey, and all the rest.

From what has been here said, it evidently appears, that one female, and only one, is necessary to, or can be suffered to subsist in one hive; therefore a hive that has no female in it, if it be provided with a due number of eggs, will continue in a better state, than if two or more females dwelt in it; for in that case, one female innocently subverts and disturbs the whole order, whilst the other with her working Bees is labouring to perform the great business of producing and rearing the young, and building cells for them. I cannot but praise on this occasion the wisdom and circumspection implanted in the Bees, that they on this occasion always kill one of the females, but preserve the other in safety; for without doubt it has appeared best to all-wise nature, that one female should perish, rather than that both of them, together with the hive, the eggs, the Worms, the Nymphs, and the rest of the Bees, be involved in an universal ruin, since all this must necessarily be the consequence of such a disturbance.

\* Nothing is less understood in the history of the Bees, than those battles we see often about the entrances of their hives. From what I have observed they appear to be of two kinds; sometimes between the Bees of the same swarm; sometimes between them and strangers: any irregularity in their work may occasion their scuffles with one another, and these terminate without mischief. But in the other case, when strange Bees attempt to force their way into the hive, the conflict is fatal, and there are usually many killed; but the superior number always gives the victory to the proper possessors of the hive.

But as nature, all-powerful in herself, is tied down by no laws, in other nests of insects, and even in different species of Bees, a different order and other regulations have place. This is manifest in Hornets and Wasps; for these insects suffer many females at once in the nest. It is proper to observe here this remarkable difference, that each of these females lay only a few eggs, and that they fly abroad together with the males to catch less insects; with which, after the manner of sparrows, they feed their young; for of them only two kinds, namely the male and the female, live in one house: whether among these insects the male too, on account of getting food for the young, flies abroad, and so is not, like the males among the Bees, exempted from labour, I have not hitherto observed; though I make no doubt but that the male likewise contributes its help towards bringing up the young; for though Hornets are much fewer in number than Bees, they have sometimes no less than 1500 young to rear at once. In a Wasp's nest, which I keep by me, there are more numerous cells than these, and I found an infinite number as it were of young ones, eggs, and Nymphs in it. This male Hornet, like the male Bee, has no sting. From these examples it is manifest, what wonders are displayed to our eyes in insects, and with what ardency the searching into them should influence us to magnify the glory of God: "For he doeth great things past finding out; yea, and wonders without number." Job. ix.

That the office of rearing up the Worms, or the young brood of the Bees, is really intrusted to the common or working Bees alone, and that all their care, and every thing they do, is directed to that end, this signal observation shews plainly, which was communicated to me by a certain breeder of Bees yet living, who is thoroughly skilled in the management of them. He told me, that by a certain and infallible method, a prodigious number of females, vulgarly called kings, might be procured, and that from hence, in the space of one year, three or four times more swarms might be obtained, than otherwise is usual in our cold climate. It is done in this manner, viz. in the month of April, when on inverting a hive you shall find some eggs or Worms in the peculiar cells destined for the females, take out the elder female, together with some few Bees, and put them into another hive apart; these will settle in this new place, build their cells, lay their eggs, and raise up a progeny: then sometime afterwards look again into the first hive, and if you find there a female newly come out, sprung from the egg left before in the hive, take this likewise in the manner mentioned above, out from thence, and, in company with some other Bees, put her into a hive of her own, that she may bring forth there. If in the same manner you shall manage afterwards the rest of the females, which shall be one after another produced

from the eggs deposited in the first hive, in the space of one fruitful summer, from a single hive, you will thus be able to get ten, nay, sometimes fourteen females, each together with a stock of Bees, their subjects as it were, that is so many swarms. It must be observed that this can only be done in a fruitful year, for at other times the Bees not only will not multiply fast enough, but they will not be able to provide a quantity of wax and honey to subsist themselves during the winter: care must also be taken to prevent that first hive from swarming, since each female, which with its working Bees is taken out from thence in the manner here mentioned, should be looked upon as constituting a separate swarm. I shall finally subjoin this caution, that almost all these hives will prove barren, unless males likewise are admitted into them at the same time with the females. The breeder of Bees who told me this, did not know how, according to their received opinions of the Bees sitting on their eggs, to solve this difficulty; he allowed only this, that it might easily happen, that some of the Bees that are the fitters, for by this names the males are called, might fly over, from the first, or the other neighbouring hives, to those before mentioned; for unless the females were impregnated by these, no generation, as I myself think also, could follow.

It appears evidently from this experiment, how industrious the common working Bees are, and that they continue to perform their office, though the female be taken out of the hive; but if you carry off the brood from the hive immediately, they will give over their labours: so long as they have the eggs or young ones, you will never see the least appearance of confusion in the hive. Hence I demonstrate clearly what is the office of the working Bees; they, together with the female, have no other office: but to nourish the young, and build little cells for them; whatever time they can spare from this work, they employ in collecting honey and Bee-bread. These common Bees are in truth kept in slavery, and appear to have been created by God to labour incessantly.

In countries that are warmer and more fertile than ours, the Bees swarm more frequently, without the artifice mentioned before. This is confirmed by the following incident, which a creditable breeder of Bees now living related to me as an absolute fact, which had happened to himself. He told me, that when the count de Mansveldt about sixty years before had over-run the province of Embden, he had left him after that irruption one hive of Bees, from which the following year thirty swarms issued forth: that hive proved indeed extraordinary fruitful, after the rest of his hives, as well as those of his neighbours, were destroyed, for on that occasion a vast multitude of Bees had betaken themselves to it. The first swarm from this hive he saw on Ascension day,  
and

and on the same day, a little while afterwards, another swarm also issued forth; the first of these two, after a month, swarmed again twice, and the other swarm that quitted the hive on the same day, after six weeks were past, swarmed three times. That same year there issued also, as well from the first hive, the parent of all, as it were, and from the other hives he had obtained from it, three and twenty more swarms, which with the former seven make thirty. It appears manifestly from hence, that these insects are very prone to venery and extremely fruitful.

It is surprizing as well as pleasing to see in what numbers, and with what assiduity, the Bees beset the mouth of the hive all around and without, when they are going to swarm: the elder female, who is at this time impregnated for the year by the new-born males, often begins the swarming. In the second swarm, or when the Bees happen to swarm for the third time, sometimes you may observe two or three females at once, each of which we distribute into peculiar hives, if there be a sufficient number of Bees for them, but we kill some of them; if these are too few, the males for the most part remain in the old hive, since these, as I am fully persuaded, have the most convenient opportunity of impregnating the females. Sometimes, however, you will find males even in the late-formed hive of the new swarm. This perhaps is the case when the female has not yet been impregnated, but that work is still to be done.

Bees may be hindered from swarming, if all the males and females are taken out from the hive, and though there should by chance some young female remain in the upper part of the hive, yet the whole swarming will be stopt, for this younger female continues barren. Whoever is desirous to extirpate from the hive in the manner mentioned the Worms and Nymphs of the males, must go about it so as by no means to cut away all the combs but those only which lie in the upper part, for thus the Nymphs and Worms of the males are lodged, and the Bees will be able then to carry out with activity the dead brood of males, and to cleanse their combs again in a little time. Hence, indeed, this advantage arises to the Bees, that they have nothing to do afterwards but solely to gather honey, because there are already in the hive a sufficient number of cells prepared, which only want cleaning, and require but a little labour to repair them.

The swarming being finished, when the Bees which have flown out have settled and fixed themselves upon the bough of a tree or some substance, it is astonishing to see in how singular a manner, by the help of their legs, they stick to one another, and form as it were a perfect bunch of grapes, hanging on one another by the assistance of their claws. At that very time they can fly off from the bunch, and perch on it again; nay, even make their way out from the very middle of the

cluster, and rush into the open air, though they seem to stick to one another so extremely close.

Bees that have weathered out the winter, begin in the month of March following to lay their eggs in great abundance; from that time they continue this work incessantly: first, the female lays her eggs in the cells of the common Bees; next, in four or five or more particular cells, from whence the young females are to come; and lastly, she deposits the rest in the hottest part of the summer, or near the time of swarming, into the cells of the males. If it should happen that there are not in the hive any of these cells made for the males, for sometimes they are cut away with the honey at the end of the year, then the common Bees, endued as it were with an unaccountable prescience, build some expressly for that purpose; nay, these same Bees nourish the male brood in these cells with a care and affection no less than the hatred and fierceness with which they kill the said very males, when, after the swarming time is over, the female is impregnated by them. Nor, indeed, is it difficult for the Bees to kill these males, for they are not furnished with any weapon to defend themselves, and besides they have wasted their strength in the act of generation, wherefore it is easy to overpower them: indeed, they die otherwise naturally, for they are not fit either for collecting wax or honey for rearing up the brood, if they are not destroyed before that time by the other Bees who have been their nurses, and atone by a violent death for the pleasures they have enjoyed. Something similar to this is perhaps also the case among the Ants; for the males which are winged are found among the rest only at a certain time of the year.

To return from my digression; it is proper to take notice that the working Bees, when they have first crept out of, or rather burst from their cells, are of a much paler colour and more inclining to dun than the old ones; these being browner and ornamented with a yellowness not so deep as gold. Their sting at that time has not come to its full strength: the bag that contains the poison is as yet empty, from whence, if they are even then handled, they not only do not sting, but do not so much as attempt it. After a very few days these young Bees acquire as strong a colour as the elder; nor do they ever, as some idly fable, learn from the old ones the art of making wax and collecting honey: this is implanted in them by nature, and to perform it rightly they need no more than follow their own instinct. The reason why the Bees are paler at first than afterwards is this, that those parts which are of a substance between horn and bone, in the head, breast, and body, being but lately stript of their skin, have not yet in the new-born state their full hardness: their down is at that time more of a Mouse colour, but afterwards their parts gain both hardness and colour, when more of their fluids

fluids have evaporated thence, and the pores of the parts mentioned are contracted clofer.

Enough has been said of the outward form, and of the generation, disposition and actions of the Bees: I proceed next to the internal parts contained in the head, breast and belly, which I shall explain in the same order that I observed in treating of the Worm and Nymph. Those parts that are inclosed in the head and breast, I shall expressly treat of when I come to describe the male Bee. This only need be particularly observed here, with regard to the head in common Bees, that their teeth or jaws are larger than in the others, and are furnished with two strong muscles, the one larger, the other smaller, which are indeed of a very firm construction, and take up great part of the skull, which is of a substance between horn and bone. The tendons of these muscles are cartilaginous, approaching to a substance between horn and bone, and being enclosed within the flesh, they there adhere on each side in the manner that we see the plumage on both stick close to the quills in the feathers of Birds; but we may more properly compare this fabric with those muscles in Crabs and Lobsters, which move their claws; for in those the flesh in the same manner is observed to be joined with the great hard tendons of those muscles; wherefore these small muscles of the Bees agree with the muscles of other animals in their structure, and are exactly such as the distinguished Steno has described them.

Since I have mentioned here the mutual similitude which there is between the muscles of Bees and those of crustaceous animals, I would have this further observed, that, as in those animals the bony parts are placed on the outside of the body and within, so this obtains also after the same manner in the Bee; and this structure is directly contrary to that which we observe in larger animals and men, whose flesh is placed outermost, but the bones within, in the flesh, or between the flesh. However, the structure just mentioned in the Bee, as also in Lobsters, does not constantly obtain throughout, for in those places where the hard or horny bone, by which the joints of these animals are supported, is to bend, or where the articulations are placed, these tendons, together with a part of the muscles lie bare; since, were it otherwise, there would arise from thence a great obstruction in moving. But again, all powerful nature does not use this method in all the articulations, as may be seen about the joinings of the horns; for in these, all that is muscular is enclosed entirely within the cavity of the bony or horny matter; consequently the motion in these parts is observed a little less distinctly.

There remains another thing to be considered even in the common Bee, I mean the trunk or proboscis, it being, like the teeth, much more remarkable in these than in the males. In this proboscis we are to observe principally seven little parts; one of them, which is placed in the

middle, Tab. XVII. fig. v. *i*, has no fellow, and is pervious like a hollow tube: this properly constitutes the tongue or the trunk itself: the other six little parts, disposed in three pairs, surround the former on each side, being destined for assisting the trunk in the act of suction, that it may be able with so much the more ease to draw out of flowers, and pour in by suction, the natural honey found in flowers. In the trunk itself its divisions are to be considered, which are extremely elegant and regular, and are beset all around with bristly, and as it were triangular hairs, distributed in an elegant order. Some of these divisions at first sight I took for articulations; there are above a hundred of them, and some of them do not go through the whole thickness of the trunk. The structure of the trunk also, together with its muscles, and the manner in which the suction is performed, are very worthy to be observed: but before I proceed to explain these, I shall first describe those three pair of little parts which are placed above and near the trunk.

The two first little parts of the proboscis *a a*, are partly of a substance between horn and bone, and partly membranaceous: they are set round with hairs, and are furnished with air-pipes distributed through the whole texture of them, though it be of a substance between horn and bone. These tubes appear through it *bb*; the tips of them *c c* are a little bent, but where these parts are united with the root of the trunk *d d*, there they have a kind of an appearance of an articulation, by the help of which they may be bent; near the trunk and the rest of its parts, quite within, and as it were under the chin of the Bee, if I may so speak, I represent them in this draught drawn a little outwards and sideways, but the natural situation of them is just as Tab. XXV. fig. ix. under the letters *f f* in the Nymph shews. The use of these several parts is to contribute their assistance towards the moving of the trunk downwards, and underneath against the head, and a little towards the breast, as well as to assist in closing and confining it, together with the other four, or rather the two pair of little parts; and also towards defending, covering, and guarding it from injuries. I should think that they also assisted towards swallowing the native honey, drawn up by suction when the trunk is filled with it, or thrusting it further inwards towards the stomach, since they have power to squeeze the snout below and inwards strongly enough.

The two other little parts of the trunk, Tab. XVII. fig. v. *e e*, which figure ix. of Tab. XXV. representing the Nymph, shews in their natural situation under the letters *g g*, are placed a little higher than the first pair, but they are nearly of the same structure. There is, however, this remarkable difference, that each of them has in the upper part, at their extremities, three joints, one, Tab. XVII. fig. v. *f f*, lower and longer, and the two others *g g* higher and something shorter, which are all surrounded with

with fine hairs. These little articulated parts do not, like the former, embrace or cover the trunk, but are only placed near it on each side, and, where they rise up about the root of the trunk, they are also articulated. As to the use of this pair, I am entirely of this opinion, and without any hesitation conclude that they are of very great assistance to the trunk in the act of sucking; since they as it were in the manner of two fingers assist the trunk, open the leaves of the flowers, and remove whatever else might chance to obstruct it: therefore I compare these two little parts to the two fore feet of a Mole, by the help of which it pushes the earth from the sides both ways, that it may be able with its sharp trunk to search for its food the more conveniently. The two last little parts *bb* are much less than the first and second, and are of a texture a little partaking of horn and bone, but rather membranaceous, and they are rough likewise with hairs: these, together with the trunk itself, are drawn inwards, and, as I myself think, the little articulated parts are assisted by them in their operations, since they remove themselves a little from the sides of the trunk, and may very happily assist to push aside the leaves of the flowers. Even by their motion they seem as if they were contrived to help also towards carrying the honey upwards, and pressing it towards the stomach.

The structure of the trunk *i* is partly membranaceous, and partly of a substance between horn and bone, or gristly; but its hairy skin, full of cuts, must be considered particularly. Here, before I proceed any further, it is necessary I should mention first, that I shall describe and represent the trunk here in the under part, as it shews itself in the Bee when laid flat on its back. As to what regards that part of the trunk *kk* which is of a substance between horn and bone, it is formed in such a manner, that it can fly off from the rest of the trunk arch-ways, and spread itself in the shape of a circle, Tab. XVII. fig. vi. *b*; from whence it is that the membranaceous part *cccc*, which lie most beautifully folded up under the gristly part, fig. v. *kk*, and joined with it, may be considerably expanded on each side like a sail, in the middle of which a mast is fixed. This mechanism, however, does not shew itself plainly, unless we circumspectly and nicely, with a very fine-pointed needle, raise that horny bone a little up: in that case it is at length seen how the membranaceous part of the trunk is folded, and how it expands itself; so that the internal cavity of the trunk *i* is prodigiously enlarged and widened, insomuch that a very great quantity of native and undigested honey, in proportion to the size of the insect, may be received into the trunk. Indeed, nearly the same course of nature is seen here, that we observe in Monkeys, which can hide nuts and what other fruits they have gathered, in two membranous bags, which are placed on each

side of their jaws: something like this obtains also in some kinds of Birds, which in the membranaceous and expanded part of their bill, where the beginning of the stomach is inserted, preserve a Fish they have caught. Amongst other water-fowls this is most obviously seen in that sort of Cormorants, which in our way of speaking we call Schoffers. These birds once every year frequent the forest of Sevenhusen, not far distant from Leyden, and are shook down from the trees in great numbers, and as soon as they fall into the water they are able to swim immediately, and to dive quickly under water, though they have never before either flown or swam. In the same manner Bees also have implanted in them the art of making wax, and gathering honey in their proboscis or trunk.

Before I proceed further in the description of the trunk, I shall insert an account of the manner of their catching fish in some parts of Europe, by means of the just mentioned sort of Cormorants: some few years ago many of these birds were carried to England and sold for that purpose. In the first place then they make them tame, so that they may be brought to perch and stay upon the hand of their own accord: when after this they are inclined to go out a fishing with them, they tie to one of their legs a thin but strong cord, which they keep rolled up in a ball: afterwards they hold this ball, which is wound round a little steel pin, by a wooden handle, as our girls do their bobbins, while they roll off of them the threads made on the reel: these things being prepared, they put a ring round the Cormorant's neck, and being now come to the fish-pond, they let the Cormorant fly down into the water; then the cord is rolled off of the ball with a whizzing twirl, and the Cormorant, to the great amazement of the spectators, quickly seizes some fishes: these, however, are stopt at the ring that has been put about its neck: therefore when the Cormorant is afterwards drawn out by the cord, he may easily be made to throw out again the fishes it had taken into the mouth, only by squeezing its stomach and throat upwards. A person of great credit and ingenuity told me this story, who has himself sometimes seen this manner of fishing. When I was in company with Mr. John Oort, an old friend of mine at Honflardik, I observed with astonishment that certain water-fowls there, when any fishes were given them, would always turn them expeditiously, so that they could take them in head foremost: this was done through great caution in them, that they might not be hurt by the fins of the Fishes, as they went down their throat. Whatever we could do to make these fowls swallow a fish tail foremost, they could not be brought to it; for they always used, by the help of their beaks, dexterously to turn the fish over. To return to the trunk of the Bee; it is to

be observed, that the membranaceous part of the trunk has no hair on it, but in its place is covered all over with little protuberant pimples; these are transparent, and are placed there in regular order, and at equal distances from each other, and in some degree resemble the little risings observable on the skin of birds when their feathers have been plucked off: these little parts seem to be in reality glandules, which have perhaps a power considerably to change the honey that is swallowed down, and in some measure to forward the connection of it. This also is to be observed in regard to the structure of the gristly parts of the trunk, or that which is of a substance between horn and bone, that in the middle it seems to approach nearer to the nature of an horny bone, than it does at the sides, which are of a little deeper or dusky red colour. This part of a substance between horn and bone, Tab. XVII. fig. v. *kk*, does not every where retire outwards from the trunk; for a little below the orifice or mouth of the trunk, it tends inwards *nn*, and, uniting with the other hairy part of the trunk in a narrower and thinner canal as it were, is then carried altogether inwards and forwards *oo*. But in the same place the whole trunk in its circumference is then crowded with small hairs, like little claws a very little bent, which, whether they are open canals, or serve by way of little claws or hooks, to keep the trunk during the time of sucking in its situation and place, I will not determine; for as yet I have not so clearly discovered how it is, though I make no doubt but it may be found by time and application. That portion of the trunk which is of a substance between horn and bone, at the end of that part where it verges outwards, has a globule or little head, which appears very remarkable; and in the middle of this an opening is seen, which seems to me to penetrate quite into the cavity of the membranaceous portion of the trunk; nevertheless I now find this opening is not, as I have before said, so small as the apertures of the lacteals, though under a microscope it may appear so: indeed the beginning of it in this place, in proportion to the part, is so minute and narrow, that scarce any thing certain can be advanced about it to clear up all doubts. In Butterflies I am confident that the trunk opens with many lips, which imbibing the nourishment, appear at the end of the trunk like so many little hairs: but in the Bee a different structure is observed; that little part or diminutive head of the trunk, Tab. XVII. fig. v. *oo*, together with its little membrane, in which the hairs are fixed, is able to contract itself into a narrower compass, and likewise to move itself inwards, as is manifest if this part be touched and examined at different times, and especially if it be carefully examined in the younger Bees, and then in the more perfect. I have represented this in the form wherein I

can shew it at any time. Further, this portion of a substance between horn and bone, at the lower part spreads into two legs as it were *p*, which are connected with the other lower portion of the trunk: where this connexion is made, there are discovered three more little parts of a substance between horn and bone *qqq*, perfectly black like pitch, shining, and joined to one another by several articulations. The middlemost of these is the sheath as it were of the trunk, within which it at that time, when it is not employed in sucking, by the help of some muscles, is drawn back and concealed; at the same time also the other little parts likewise of the trunk bend themselves, and retire inwards. In this sheath of the trunk those muscles also are enclosed, which belong to the two pair of the articulated little parts of the trunk *ee*. The muscles next of the first pair of these little parts, Tab. XVII. fig. v. *aa*, are placed a little lower, and are implanted with two horny little parts *qq* towards the outside, of a blackish colour: but the two little parts themselves, together with the sheath of the trunk, are joined by four distinct articulations *rrrr*, to the extremities of the bony or horny parts, which together constitute the head of the Bee: so that the whole sheath, the trunk, and its little parts, are, by the help of two strong muscles *ff* moved inwards at once; on which occasion the parts just described bend themselves backwards and inwards, and at the same time hide, cover, and shut in the sheath. These beforementioned muscles *ff* here appear through a little thin membrane *t*, and under this the throat *l* also is seen, which, together with these muscles, and the membrane covering them, is cut through in this figure.

We come now to the act of suction, which the Bee performs in the following manner; it gradually draws the gristly part of its trunk, or that which is of a substance between horn and bone *kk* from the hairy skin and its divisions, which done, the membranaceous and wrinkled part of the trunk *m* is stretched out and made smooth, but the gristly part is distended arch-ways: when this is performed by the help of the muscles of the trunk, the ambient air is necessarily forced out of its place, and by the pressure of it the honey is carried inwards, and through the cavity of the trunk.

In Butterflies, on the contrary, this is performed in quite a different manner; for as much as in these the trunk is not single, as in the Bee, but double; which also, after the suction is ended, is wonderfully curled and rolled up together, by numberless most minute articulations; so that Butterflies must execute their suction in a quite different method, namely, by pinching close the points of respiration, and swelling out their body, they repel the air, and this being driven out, pushes forward into their trunk the sweet moisture for which they gape in sucking. The doing this.



this is very easy to the Butterfly, so that I should think even the Bee too, while it is sucking, does the same thing, for what hinders, but that this or something similar may be performed by the Bees, since their points of respiration, though membranaceous within, have a horny edge, by the force of which they can open themselves into an oblong slit, and close themselves again, in like manner as the Frog stretches out and shuts again the upper part of its wind-pipe, as the most renowned Malpighius has observed with the utmost exactness? I might now describe all the muscles of this part, one by one, and represent them in figures; but that would involve me in a work requiring both a vast length of time and endless labour: this is the reason also that has hindered me from pursuing many other particulars, which I have here delivered to the utmost, and with the strictest accuracy.

Should any one now ask me, whether the Bee can suck no other way, than by stretching out or moving arch-ways the little gristly part of its trunk, I answer, that it entirely appears to me, that even by barely pinching close their points of respiration, and swelling out their body, the Bees may be able to perform their suction; for nothing hinders, but that even by these means alone the air that is driven out may push the honey inwards. We observe also that the Bee, when going to suck in the air in its little pulmonary tubes, moves the rings of the belly within and without, in the same manner as we do our breasts in the act of breathing; but because the thorax in Bees is immoveable, therefore their belly performs this office. This little part, which has been now described, is worthy of the highest notice; nor can I here forbear owning, to the glory of the immense and incomprehensible Architect, that I have but very imperfectly and superficially attempted to describe and represent this

little part; for to represent it to the life, in its full perfection, as truly most perfect it is, far exceeds the utmost efforts of human knowledge: and in very truth, our intellects and abilities fail us every where, when we venture even no further than to contemplate the divine wisdom in the works of God, which can never be worthily magnified. Think then how much more excellent they must have been before they became obnoxious to destruction! in reality, this single little part is formed with such exquisite skill, that it may justly be ranked among the chief instances of the omnipotence of the Deity. But I would have this understood according to the narrow limits within which our capacities are confined, for we see the works of God only as through a glass darkly, since our understanding resembles an ignis fatuus, a Will-with-a-wisp, and is utterly unfit for discerning these things, which so surpass all mortal comprehension.

In other sorts of winged insects approaching to Bees, for example in the Wasp, the trunk is much slenderer, nor is it of so remarkable a length; the reason of which difference seems to me to be this, that in these insects, besides the trunk, there is another way still by which they can draw in their food, since they are little creatures of a very rapacious, savage, and greedy nature. This is especially manifest in that larger kind, which we call Hornets, which are rapacious to such an amazing degree, that even when cut through the middle of their body, they do not refuse to eat; and if then you give them honey, or sugar moistened with water, which is much the most proper, they suck it in so greedily, that you may see it again running out at the wounded part. I have considered the trunk in the largest sort of Wasps, a draught of which, for its great elegance and particularity, I shall give in this place.

*A delineation of the trunk or snout of the Wasp, as seen from underneath.*

TAB. XVII. FIG. VII.

*a* Is a part of the horny substance at the bottom of the head; it is shagged at the sides with yellow hairs, is marked also with two yellow spots, but for the rest it is black, and shining.

*bb c* Are three little horny parts, at the root of the trunk; these are of a shining black, and two of them that are at the side *bb* contain in them those muscles, which move the articulated bristles *dd*; but the little horny part in the middle *c* is, as it were, the sheath of the trunk itself *f*, in which, besides the muscles of that organ, those of the other two articulated bristles *dd* also are deposited.

*dddd* Are four articulated bristles, that assist the trunk during its action.

*ee* Is the place where the teeth have been broken off.

*f* Marks out the trunk itself, in which are seen four delicate white little parts, furnished toward their tops with round and yellow globules. All the parts hitherto mentioned are covered over with hairs, which indeed I have not exhibited here with them, lest it should create confusion. It is to be observed also, that all these parts are represented as in the Wasp laid along on its back, from whence it is, that we can see but half of some of them.

If a Bee is opened on the back, there first presents itself a limpid or clear humour issuing from the veins and the heart, which are wounded; for the heart is placed oblong in the back, as it is in the Cossus, Silk-worms, and many other insects.

The muscular fibres also are seen, which move the rings or incisions of the body of the Bee, and are the same both in situation and structure,

structure, as I have shewn them in the *Coffus*.

The fat also appears, consisting of little round parts, which have been fixed to their membrane.

The lungs are more than all other parts remarkable; these are two white and transparent little vessels, fig. ix. *aa*, consisting of the pulmonary tubes dilated, and running together. These lungs are entirely membranous, and fall together when the air is out of them, which is by no means the case with the tubes that proceed from them, inasmuch as they, consisting of rings curled around, remain always open. The lungs, composed as I have observed of dilated ramifications of the wind-pipe, terminate again in little tubes, Tab. XVII. fig. ix. *bb*, which are annular; and these, then here and there widening, grow into little bladders *cc*, and these also contract themselves again into little tubes *dd*. This alternate mixture of bladders and tubes, however, is not so frequent in the Bee, as in the Rhinoceros Beetle, whose lungs consist of numberless little bladders, which may in some measure be compared to the pods of the plant called *Honesty*, while yet hanging from their stalks. In Bees the lungs are principally composed of two large bladders; there are likewise beside them some smaller, and the remaining part is made up of little tubes, which then, as in the Worm of the Beetle, or as in the Worm of the Bee itself, are dispersed over all parts of the body *ee*, &c. so that the lungs, by the intervention of the little tubes which they send out, communicate every where with themselves by mutual inosculations *ff*.

When a Bee is opened along the belly, immediately the spinal marrow comes in view, and this I am now going to describe: nor shall I here stop to mention either those parts which are seen in this view besides, and have been mentioned before, or the extremities of the rings, which are membranaceous and terminated by black edges of a substance between horn and bone. The spinal marrow is the principal part, which now presents itself to be considered; it consists, as in the Silk-worm, of nerves and little knots, which owe their rise to two nerves as it were proceeding from the brain, though there seems to me to be besides these some substance of a different nature from them in the same place, which, for the sake of strengthening them, binds the little knot and the nerves together: this is seen also in Silk-worms; nay, and in the human species, these nerves, which are swallowed up as it were in little knots, are separated from one another here at a more considerable distance, and open much wider asunder, than in the marrow of Silk-worms; indeed, the marrow in Bees is almost every where open or split into two parts, while in Silk-worms it opens only at distances. What are distinctly called the nerves by anatomists, are those shoots which arise from the sides of these little knots. If we trace the course of

the marrow near the lower rings of the belly, there the nerves, springing from the little knots, are seen, and they disperse themselves among the muscles designed for drawing the sting inwards and thrusting it out. The other viscera most conspicuous in this view, are the stomach, the guts, and some parts belonging to the sting.

The stomach, the gullet leading to which is most excessively narrow, seems to me membranaceous and thin, though it has some fleshy fibres. It is often filled with honey, which is easily distinguished by the taste; the pylorus follows the stomach, and after this comes in view another little part, somewhat more protuberant, and inclining to a colour between yellow and red, which however, when more accurately inspected, proves to be only something shut up within the hollow of the intestine, and shining through in that place.

Next follows an intestine, which in some measure resembles the colon in other animals: this gut is much thicker than the stomach itself, especially when it is full; it has moreover strong muscular fibres, which, when they act, turn it up in many wrinkles and folds; its cavity is commonly full of a whitish matter, which seems to me to resemble the white of an egg that has been steeped for some time in rectified spirit of wine, and is just beginning to curdle; or it is like starch mixt with a small quantity of water. If this little gut is pricked with the point of a lancet, the matter just mentioned flows out.

Further down this gut is considerably contracted and made smaller: but there, where this contraction begins, an infinite number of whitish filaments are seen, like those which in the *Coffus* I have called saffron-coloured vessels. These filaments or minute intestines are fastened to the gut, in that part where it is contracted, as well as elsewhere. This close connexion of them with the gut is extremely strong, and is effected by means of the pulmonary tubes, which, as they run through the whole body, so in this place particularly they are an insuperable obstacle to the disengaging these little guts. I believe it would take me up some months to search this matter thoroughly to the bottom, which truly seems to be by no means despicable, nor unworthy that so much pains should be employed upon it, as I shall hereafter shew.

The gut, after it has been contracted in the manner already mentioned, dilates again on a sudden, though here it seems to be altogether membranous; but as it is at the same time transparent, some little, whitish, and oblong parts are seen on the outside, as shining through it: these, when the gut is opened, are found to be six in number, and are glandular, and they are not every where uniformly whitish, but are filled with watery and transparent qualities. These six little glandular parts swell out very considerably on the inner surface of the gut, within its hollow, and are there very conspicuous

cuous. I have also perceived little parts of the same kind in the intestines of Hornets. It is observable besides, that the extreme part of the intestine, in which these six little parts are found, is sometimes swelled, almost beyond what could be believed, with excrements. These are of a pale yellow colour, and are divided into small pieces, like bee-bread, though their little lumps are neither round, nor of any other regular figure. One may further remark, that the intestine, in which these six oblong glandular little parts are placed, is sometimes found as fully distended with an aqueous humour, of a yellowish colour, as with the yellow and more solid matter beforementioned. But this is only in very young Bees just produced from the Nymph.

This gut is again contracted where it ends, but from that part it again dilates itself, and at length forms the rectum or last gut. This extreme part of the intestine sometimes wants the last contraction, and in that case appears rather like rumpled linen, or a cotton handkerchief, drawn through one's hand. The intestine finally terminates under the point of the sting where the excrements are voided, and the rectum arises from it.

If these guts joined to the stomach are laid on a thin plate of glass, and heated by the flame of a lamp till thoroughly dried, then you may see not only their circular fibres, but even those valves which have been called by Kerkering in the intestines of men, the *valvulae conniventes*, and which were described and in some manner delineated by Spigelius. Ruysch first, in the year 1667, demonstrated them in an inflated human gut. I have made the same observation also in the Bee and Wasp.

Behold! these are the entrails of the common or working Bee; there does not appear among them the smallest trace of spermatic organs or the genital parts, or of any thing which can answer the purpose of, or even be compared to a penis or ovary. Hence I think these Bees may most justly and properly be said to be natural eunuchs, and such as can only work and feed, cherish and rear the progeny of others as their own. On the contrary, as I have beforementioned, the genital organs are very plainly seen in drones, as they are the true males of the Bees: their whole belly is in a manner filled by the testicles, as I shewed to his serene highness the grand duke of Tuscany, among other wonders of nature, in the year 1668, when he graciously condescended to approve of my labours.

I shall now proceed to the sting, that wonderful work of nature, and eminent example of the wisdom of the great Creator. It is placed in the hinder part of the body, its point lies just over the end of the rectum or straight gut: the sting is therefore placed in the last rings of the belly, with which it is also very remarkably jointed, by means of some cartilages. But as the sting is worthy of the greatest attention, I shall describe it at large, toge-

ther with all the parts subservient to it, having in view only the praise and glory of the most wise and excellent Creator. In the sting there are discovered, first, the channels through which its poison is conveyed to it: Secondly, its cartilages. Thirdly, its muscles. Fourthly, its two pieces called legs. And lastly, the sheath within which the legs which properly constitute the sting are hid.

That the sting has poison in it, R. Hooke, a writer of great experience and learning, has in some measure laboured to demonstrate in his inestimable *micrographia*, written in English, thinking that the poison lay hid in the hollow thickness of the sheath of the sting, which however is never the case, unless by mere accident.

Let any one with a forceps or little steel tweezers take hold of the legs, wings, or which last will be most convenient, the breast of the common Bee, and he will generally see a small clear drop as it were of water hanging on the point of the sting. In this water the poisonous quality of the Honey-Bee is properly contained. This, as soon as it drops into the wound, produces the pain that follows the wound; for the sting itself is not in the least degree venomous, nor does its puncture hurt more than that of a needle. For experiment's sake I have often wounded myself with the sting, and felt no other ill consequence from it than a slight itching in the wounded part; but the sting must be first thoroughly cleansed and well squeezed and wiped for this trial, for it might otherwise probably happen that the injury would be more considerable.

To proceed in order, I would have it observed, that the venomous liquor which only passes through the sting is originally deposited in the belly of the Bee, and there contained in a little bladder nearly transparent. This little bladder is of an oblong figure, and of a very strong texture, so as to bear the force of the fingers pressing it without any damage: nay, so great is its firmness, that the belly of the common Bee being opened, let this little bladder be taken hold of, and the whole sting and all its parts may be easily drawn with it out of the body, without the bladder being broke. I have found this bladder of poison so strong, even in the smaller kinds of Wasps, that by pressing it with my fingers as hard as I could, the poison might be thrown to the distance of two foot from it through the sting. It is further remarkable, that a very strong muscle twines about this little bladder, and has its tendril in the middle, as it is in the muscle called the temporal muscle in the human species. When that muscle contracts itself, the poison is by its force squeezed out and thrown into the wound, so that the sting may be compared to a small syringe; the little bladder or rather the muscle of it just mentioned serving it in the stead of an impelling plug. But I have not hitherto distinctly examined this muscle in the common Bee: I have seen it in the Wasp,

and most conspicuously in the Hornet, after I had first kept that insect a whole year in balsam. This method I some years since discovered, and by it the parts may be most happily and distinctly viewed. There comes out of this little bladder, in every species of Bees, a small thin tube, which is extended as far as the sheath of the sting, and this at length runs between the two open legs of the sting, enters into the sheath, and terminates in the thickest part of it. It is by this channel that the poison is conveyed from the little bladder through the sheath into the sting, and passing from the hollow part of the sheath between and under the legs of the sting, it is darted into the wound when the Bee gives the stroke.

On one side of the little poison-bladder in the Bee, is seen a small, oblong, thin, crooked tube. Of this kind I have observed two in the Hornet, in which creature the poison-bladder is also twice as large as in Bees. I have seen besides other small tubes growing laterally out of that I mentioned, but I could not immediately discover whether they terminated. I afterwards however observed in Wasps and Hornets, that in the body of these animals there are two distinct little tubes, Tab. XVIII. fig. iv. *cc*, inserted into the hinder part of the poison-bladder *a*, through which little pipes the poison is conveyed into that bladder, and in which the poison is properly secreted. These small pipes appeared unequal, with little swellings here and there, as is seen *ddd*, and terminated in closed endings *ee*, as the blind guts of Hens, which same thing I have observed also in Bees. These small vessels are much wider towards the hinder parts than in the fore parts, and about their extremities where they are closed, they are very thickly surrounded with fat and pulmonary tubes, for which reason they cannot be separated from the other parts without great difficulty. I have also remarked, that these poisonous vessels in Bees very nearly resemble those which are found in Wasps, and are just such as I have in the third figure, Tab. XIX. *z*, drawn to the life in a female Bee: *z* denotes the poison-bladder in the female; *γ* the sluice of the bladder; *z* the small tube in which the poison or venom is secreted, *ββ* are the closed ends, the small tube in which the poison is concocted. These appear to consist of a two-fold substance; the one glandulous, of a whitish colour, and not of a very firm texture; the other is membranaceous, with something like a filament quite transparent, which sticks within the former substance, by which it is shut in and surrounded, like the small tube of the vessel called the *vas deferens*, which is in itself extremely slender, and is also compassed about by a glandulous and nervous substance. The former substance is very easily separated in the handling of it from that within, which is skinny, transparent, hollow, and very much like a fine hair. This small tube is besides very strongly joined to the saffron-coloured vessels by numerous pul-

monary tubes, so that at first sight I should have thought these vessels were productions of the small tube; but as they are most strongly fixed to that part where the gut contracts itself, and the substance they consist of curdled in my balsam; whereas, on the contrary, the humour contained in the small pipe of the poison-bladder remained clear and bright in the same balsam, I was thoroughly convinced from thence, and from what I have before mentioned, that this small tube has no communication with the saffron-coloured vessels.

When the poison-bladder is put into my balsam, it is sometimes tinged with a purple-colour or redness. I likewise have seen it green, in the Hornet. And we must further observe, that the poison-bladder in Bees, as I have often observed, is not contracted in a globular form, like the urinary bladder in the human species: so far from it, that its sides are like two planes pressed together. This may be seen if you cut off the Bee's wings, and then greatly irritate or provoke the creature; for then it will, in revenge, throw its poison out of the sting, being every moment eager to strike and wound.

Let us proceed. The sting then, as I have shewn, is situated under the rings of the posternal parts of the body, and is there moved in and out by the help of certain muscles; and as these muscles are affixed to some horny or bony little parts, I shall therefore briefly describe these parts. There are chiefly six principal little parts, together with two others less conspicuous. The legs or shanks of the sting are articulated with these horny or bony little parts, which are likewise joined with each other, so that by means of this structure they may be moved in and out, and up and down, and on either side. This motion is performed by the force of the muscular parts, which I find to be eight in number, four very manifest, but the rest less conspicuous. The horny or bony parts, and even the shanks of the sting, are inserted in all these muscles. Two of the muscles, which are somewhat less conspicuous, encompass or surround that side of the sting which is the thickest, being connected with the case or sheath. There is likewise a small horny or bony part there, constructed or formed in the same manner as the little bone in Birds, called the *perspicillum*, which is properly produced or originated from the collar-bones conjoined together. This little part is particularly articulated, and by the help of its muscles seems to move the sheath or case of the sting regularly outward.

I shall now describe the shanks of the sting, and shew that it is not a simple but compound part; that it consists of two shanks, and a sheath wherein the shanks are kept, like two swords in one scabbard. These shanks of the sting are not constructed in the manner of the *crura* of the penis or clitoris, which arise each from a distinct place, and at length meet and constitute one body; for the shanks of the sting continue all the way distinct from each other, though

though their points be so near to each other, that the intermediate space can scarce be observed, and no body thinks he sees any thing but one point. Each of these shanks is furrowed on one side, but on the other it is strengthened by certain hooks: hence, whilst the equal sides and points of both shanks are joined together, the sting is provided from each side armed with hooks. But, in order to understand this matter justly, one must know the structure of the sheath of the sting; and therefore I would have it observed, that this case or sheath is not in reality disposed in such a manner as the scabbard of a sword or knife, or like the case of a rocket: by no means, for the sword, knife, or other weapon are on each side hidden in their scabbards, and surrounded or covered entirely by them, nor is the case of the sting made like the small open tube or canula, through which surgeons pass their instruments, when they are to cut a particular part in such a manner as that the adjacent parts may remain unhurt. The case of the aculeus is more like the horn-book made in our country for children, or one of those cases, the verge of which is furrowed and receives a moveable cover. The sheath is formed nearly in this manner: its inner side each way is prominent, or has a rising back, or it is somewhat bent with a double margin; but these backs, like bolts, agree with and are joined to the furrows of the shanks of the sting, and therefore these shanks are very easily and conveniently moveable up and down, like the operculum or cover in the furrow of the cases just named. But the sting itself is situated in such a manner in this sheath, that its points lie as it were in the open cavity, but the crooked hooks shew themselves out of the sheath's cavity; except when the sting appears beyond the extreme verge of the sheath, and is consequently thrust out: therefore, the lower side of the shanks of the aculeus or sting lies always in the cavity of the sheath, and the upper side is out of it. These sides of the shanks have crooked hooks, hang out of the case, and receiving in their furrows the internal ribs and prominences of the sheath, they are moved easily along the latter; whilst, in the mean time, their upper sides being smooth, are applied to each other, and with their united extremities they form the point of the sting.

Further, it is proper to observe that one of the sides of the case or sheath is not open through its whole length, nor does it resemble the instrument before named, equally extended without its valve: it is rather on the hinder part, where it is broadest, and united together, under which part the shanks afterwards pass. This is very particularly and plainly observed in the sting of the Hornet, in which the sheath entirely coalesces in the hinder part where it is thickest. But in Bees these minute and narrow passages are no where entirely united; therefore the sheath in that place embraces the shanks of the sting, at least in part, by that means preventing those shanks from moving

out of their places, as may be seen, Tab. XVIII. fig. III. unders the letters *d d*.

Each shank of the sting has usually ten crooked hooks near its point, and some others which are less remarkable: but the sheath or case has no hook at all; because if it had, the sting itself could not move backward and forward in it. Since therefore each shank has ten hooks, the sting, when the Bee has given its stroke, is kept in the wound, being fixed there by twenty bearded hooks; and the more the Bee endeavours to draw the sting out, the deeper its hooks penetrate into the wounded part. But if the sting be taken out of the body of the Bee, together with the intestines and other parts, as I have mentioned, it may notwithstanding then insinuate itself more and more deeply into the wound, being in this respect like the heads of vipers, which will bite after they are cut off. This we are clearly taught by experience, since we see that when the sting is drawn out of the body of the Bee, it penetrates still deeper into the wound, trembling, and as it were shaking in all its parts. The reason of this is evident, for the sting is thrown out together with its sheath, and all the cartilages and muscles belonging to it, together with the poison bladder. I have often made the before-mentioned experiment in tan-leather gloves. The Bee must first be suffered to fix its sting in them, and then it must be taken by the wings and pulled away forcibly, so that the sting may be drawn out of the body. One may see that the sting penetrates deeper and deeper into the leather: nor indeed is there any thing to hinder the doing of this, since the sting consists of the two shanks before described; which, as their tops or ends are united together, so both and each of them separately may be moved: therefore, whilst one shank is fixed in the wound, the other may be thrust further and deeper; and where this latter lies firm by means of its crooked hooks, the former, on the contrary, may be insinuated deeper into the wound, or thrust into it deeper than the former. By this means the sting and its sheath penetrate further into the wound. Therefore it frequently happens, that the shank of the sting is drawn further back into the case, and the other thrust out of it in proportion. Thus when the Bee hath struck the glove, and the sting is then taken out of it, it is frequently found that one shank appears further stretched out of the case than the other; that is, the two shanks of the sting have been then unequally fixed, and one is struck in more deeply than the other, and fixed there by means of its crooked hooks. When the sting with its appendages has been just pulled out of the Bee, if it be lightly put into any callous part of our skin, the same consequence naturally shews itself: for it is then plainly observed, that the sting penetrates every moment deeper and deeper into the wound; but however it does no harm, provided the callous part be thick enough to prevent the poison from reaching or entering

entering the blood-veffels, for that naturally difcharges its ftrength into the blood.

It is now time to treat more particularly of the beards or crooked hooks of the fting. If you put them under a powerful microfcope, you will fee them almoft like Cats claws, that is, they are fomewhat bent inwards, and their extremities are entirely transparent, but they are not moveable like the claws of beafts: the fhanks that constitute the fting and their crooked hooks are all plainly cartilaginous and fufficiently flexible, but they are connected by no articulations.

No joints are obferved either in the fheath or the fting itfelf, though I was once of the contrary opinion. My error arofe from hence, that upon handling it the air run into the cavity of the cafe, and by its clearnefs or brightnefs, and by the bubbles it formed, rendered conspicuous the poisoned liquor, which ftill remained in the fheath, fo that it appeared to me as if the cafe itfelf of the fting was articulated or jointed.

If the fting be feen ftretched or protruded out beyond the extremity of the fheath, and at that time the Bee difcharges its poison, then this poisonous liquor is not thrown out beyond the cafe, but appears upon it like a little drop. But when the fting is moift or wet, the poison alfo is further diffufed, as it happens when the Bee gives any perfon a ftroke, and afterwards infinuates its poison into the wound. Nor can it be otherwife, fince the fting, the hinder part whereof is thicker, ftops or closes up the wound fo entirely, that the poison has no entrance or paffage into it, but through the interfice of the fhanks of the fting itfelf.

Therefore the proverb applied to Bees is very true, "There is no honey without fome gall." Though I can find no bile in this infect, yet the poison thus called gall may be diftinguifhed very clearly in it; nay, a great quantity thereof may be eafily collected: this I fhall at fome time endeavour to do, when I fhall make experiments on this poison. It would indeed be eafier to obtain it out of the Hornets, Wafps, and Humble-Bees, the poison-bladder of which is larger; but one cannot get thefe creatures in fuch numbers as Bees. If any one defires to examine the Bee's poison-bladder filled with poison, he muft kill the Bee, which may be done by throwing it into a bottle of fpirit of wine. The Bees may be otherwife killed without handling them, by the fmoak of that kind of fungus called *crepitus lupi*, or the puff-ball, or with that of linen cloth folded as in making tinder. The latter, in my opinion, is the beft way of killing them: for though you handle Wafps, Humble-Bees and Hornets ever fo little, they immediately difcharge their virus or poison out of their formidable fting, and then none of it is found in the bladder, which is otherwife full of it. I preferve fome fuch bladders in my collection, as moft extremely meriting the infpection of the curious.

The poison is collected in the following manner: draw the fting and poison-bladder together out of the body, and then the bladder, as I represent in Tab. XVIII. figure v. being taken with the tip of the fingers, put the point or top of the fting into a thin glafs tube, and then prefs or fqueeze the poison into the latter through the fting out of the bladder: you may afterwards blow the poison together into another glafs vefel, and make the experiment thereon; but all this muft be done very speedily, fince this poison is eafily coagulated when out of the body. Another method is to wound the bladder a little, and then to immerge or put into it the top of a thin glafs tube; and thus the humour will defcend fpontaneously, or be forced into the tube: but the former method is better than the latter for thofe who are expert in thefe things.

When the poison is expreffed out of its bladder, it very eafily exhales, by reafon of its fubtile and fpirituos nature, leaving a confiderable cruft on the glafs, which when fcraped off appears like duft: whether this duft has ftill any poison, is yet unknown to me. The poison which the Bee difcharges through its fting in the form of a round drop, fometimes concretes about the fting itfelf, preferving the fame round fhape, and thus affords a very agreeable fpectacle, for it refembles a little drop of clear water; hanging as it were out of the fting.

When the Bee hath given a wound, the fting, as I have obferved before, ufually remains in the wound by means of its hooks. But whether the Bee can wound or pierce the fkin with its fheath only, and fo not leave its fting in the wound, is ftill unknown to me. The fheath is indeed very fharp. The Bee therefore feems able to wound with this alone, if it draws in the fting at that time; fince we likewise obferve, that this fting is not always equally prominent out of the cafe; it fometimes lies entirely out of the extremity of the fheath, and is fometimes lower and fometimes higher up in this its cafe.

When the fting remains fixed in the wound the Bee muft die; for, befides the fting itfelf, the Bee then lofes its intefinum rectum, or the ftraight gut, and the parts annexed to it; nay, even the horny parts and their ligaments are broken off from the extreme rings of the body, to which they are united. And we are particularly to obferve here, that the whole poison-bladder, together with the fting, is then drawn out of the Bee's body; and as it remains out of it, it ftill compreffes itfelf by the laft action of its muscular fibres, and drives its poison deeper into the wound. For this reafon, if any one be ftung by a Bee, it is by no means proper to take the fting by the hind part in order to extract it or get it out, becaufe, by this means more poison is always thrown into the wound. It would be better to cut off with a pair of fciffors all the parts of the fting which hang out of the wound, and then to take out  
the

the rest with a small needle. I have sometimes seen the stomach itself drawn with the sting out of the body of the Bee.

If you would render the poison of the Bee ineffectual, and the Bee itself tame, make it thrust its sting into a piece of leather, and then cut off the top of it; by this means all the poison flows out of it, and the creature becomes tractable and gentle whilst it lives, nor can it afterwards, though it should probably generate poison anew, do any mischief.

From what has been here said, it appears how dangerous it is to irritate Hornets, since they have very formidable arms, and always carry poison about them.

In Hornets the poison-bladder is excessively firm, and is twice as big as in Bees. The learned Mouffet relates a very remarkable thing of these creatures: he says, the very accurate Penny saw a Hornet kill a Sparrow with a stroke of its sting. These are his words: "Whilst Penny was at Peterborough in England, he saw in the street a Hornet in pursuit of a Sparrow, which it struck at last with its sting and immediately killed it, and, to the great astonishment of the spectators, fed itself with the blood of the dead Sparrow." How terrible these creatures are on account of this poison which they carry about them, is likewise evident from the promise formerly made by God to the Israelites in Exod. xxiii. "I will send, I say, my terror, like a Hornet before you, who shall drive out the Hivite, the Canaanite, and the Hittite from before thee." But God has no need of these hosts to chastise his people; he can do it even by the smallest insects, and convert the dust of the earth into Lice, if the number of other plagues should chance to fail: for what is above the power of him who shews himself adorable in all his works?

The queen or female Bee is furnished with a sting, as I shall afterwards describe in the dissection of that kind. Among the Hornets the females only have stings, which are longer, sharper, and stronger than in the Bee, and armed with several frightful hooks. How the males of the Humble Bees and Wasps are circumstanced, in this respect, I have not been yet able to examine, on account of the variety of business wherein I am engaged. I would only have it observed here, that the males of the Hornet have no sting, in like manner as the drone or male is without it among Bees; that the males of these two species agree in this respect, and are very peaceable creatures, free from all mischief and injurious designs, and delight in love and generation only. There is the like meekness observed also in the males of Ants, and their teeth are therefore much smaller than those of the females: among Ants

also there is a third species which do not contribute to generation, but serve only to rear up their young.

I have before given my opinion of the principal use of this poison in the Bee, that is, I think it contributes to prepare what is called the Bee-bread into wax: this, however, requires to be yet more accurately investigated. The whole sting, nevertheless, great as it is, seems to be appointed only to do mischief, and formed by nature solely for that purpose, that the Bees may, by the help of it, defend their young against the insults of other creatures, and feed them in security. Since therefore the nourishing of the stock is committed to the common working Bees, hence it seems probable that they, particularly about the time of swarming, and a little after, are as furious and as much inclined to sting and do mischief with their poison, as they are eager to preserve as well the issue committed to them, as their own proper food. It would not be improper to conclude from thence, that the sting and the power of doing hurt with it, are given them on that account. The truth of this will be more evident to any one who considers that the females of the Hornets are likewise provided with such weapons, though they never form any wax, but build their habitations principally, as it appears, of the bark of trees fastened together. Hence various colours are observed in their nests, according to the variety of the bark of trees which they have used in building them. We likewise see in the time of copulation with what fury the Stag storms and rages if any one comes near him: this Harvey very accurately describes from experience. Nay, even the otherwise inoffensive domestic fowls will fly in the face of those who endeavour to take away their young, and even Bitches and Cats, however mild and gentle they are, yet cannot endure to have their whelps and kittens touched. These are the arguments which nature supplies for establishing the use of the poison. But that the poison, in preference to any thing else, is given to these insects with design to hurt mankind and all other animals by it, and that their sting also, as some think, is made to torment and harass the human species for the hereditary stain of mortal sin, is most absurd, and plainly contrary to the infinite goodness of God: he does not vex or torment but kindly chastises, unless when the number of their sins voluntarily committed are increased beyond all measure. I shall here conclude this dissertation on the working Bee, since it is not granted to us to search perfectly into the divine works with our limited shallow understandings\*. I have proposed the matter, and with my own hands described and delineated the situation, structure and use of their

\* The Bee has been honoured with the notice of philosophers from the earliest time. What Virgil has said of this insect is principally from Aristotle. Theophrastus has also wrote expressly on them, and we read of a greek naturalist who retired from human kind, and passed a long time in the woods to observe them. But the labours of all these answered little purpose: it is not till very lately that we have understood their nature, and we owe more to Swammerdam than to any one author in this inquiry.

parts; and therefore these various observations may be of use to us, until it pleases God to throw more light on our knowledge of the subject; for in this way we may at length most easily know the Architect of nature, from whom we are the further removed, the further we proceed, if we only indulge our own vain reasonings.

The order I have prescribed to myself requires that I should now exhibit the anatomy of the female Bee: I say, the female, which, as it is a distinct insect found in the hive, so it is by a common error generally dignified with the glorious title of king, though by some it is more properly called the Mother-Bee. I shall endeavour to follow such a method in this history, that, as the female has many parts in common with the working Bee, I shall only describe those which that kind has not, together with some others, which I have observed more clearly in the female. Among these I mention in the first place, the heart. Tab. XIX. fig. 1. *aa*. This is a tube pretty strong and fibrous, it is oblong, and here and there dilated, it is extended in length from one end of the body to the other, and then turning about, it passes through the narrow little part or horny tube, which, like a thin filament connects the breast with the belly. In order to discover the heart in the abdomen, as in that part it may be best seen, it is necessary to dissect or lay open the horny rings of the body with scissors or a knife, taking care at the same time not to hurt any of the parts that are under these rings; for the outermost part of the rings of the body is so thin and tender, that not only the pulmonary tubes may be seen transparent through them, but one may also distinguish, though obscurely, the motion of the heart under it. The pulmonary tubes in the female are not so frequently divided or expanded into bladders as in the working Bees, which difference is so ordered by nature, that the working Bees may fly the more conveniently and expeditiously; whereas the female is understood to fly but once a year, that is, when they swarm. However, I cannot entirely agree with this tradition, but rather think the female goes out of the hive in fair weather, in order to breathe a purer air. It must be observed, with respect to the dissection of the body, that its rings are at their origination of a full redish brown colour; but of a yellowish red where they become membranaceous. In the midst of them are seen two or three blackish lines, and the extremities of the rings grow black again, and are very thin, and provided with a horny verge. This obtains only in the lower parts. If the upper part of the ring of the abdomen be broken and carefully raised up, as I have before advised, the heart, Tab. XIX. fig. 1. *aa*, immediately comes in sight, and appears to be situated in the uppermost region of the abdomen, and is furnished with many small and delicate air-pipes *bbb*, which issue from each side, and are inserted in the substance of the

heart. These air-pipes or pulmonary tubes are supported by some tender and very delicate membranes *cccc*, which keep the fat that lines all *dd* about and underneath them in its place. Through these little membranes, and on each side of them, in some places, a subjacent ovary *eee* is found to shew itself. If the dissection be made in the manner I have directed, about the fat of the little membranes that connect the extremities, there will be seen also some muscular fibres, broken off from the rings of the abdomen, which serve to move the muscles *ffff*. Under the sections also, between the fat, some muscular fibres present themselves, which seem to contribute very powerfully to dilate and constrict the heart, and at some times to push the air through the compressed pulmonary pipes towards the heart. Even the membranous fibre which connects the fat, likewise embraces the whole ovary underneath, which by this means comes in view; when that membrane is carefully cut, the heart removed, and the great number of pulmonary tubes which are connected with the ovary and heart, and this membrane and the fat are removed. The numbers Tab. XIX. fig. 1, 1, 2, 3, 4, 5, 6, denote the rings of the abdomen, under which, as in the back, the heart is situated.

The greatest part of the ovary is lodged in the uppermost region of the abdomen, and stands as a partition between that part and the breast, so that the other viscera, that is the stomach, intestines, vasa crocea, or yellow vessels, and others, are placed much lower in the body.

The ovary is divided into two parts, fig. III. *ac*, in the same manner as it is in the human species, in quadrupeds, fish, and many other species of insects, and even in frogs. These parts of the ovary are more or less separated from each other in those different animals, but here they lie contiguous to one another; one part indeed is placed in the right, another in the left side of the abdomen; besides, the ovary here is so firmly connected by the pulmonary tubes that run through it, that it cannot without difficulty be separated.

The ovary appears to the eye as a membranaceous little part, so wonderfully delicate and tender, that the containing membranes are scarce any hindrance or impediment to the enclosed eggs being distinctly seen through them.

The ovary, as I have observed, is divided into two parts, and each of them is again subdivided into two single parts, which, for distinction's sake, may be called the oviducts, though they in reality constitute the ovary itself, and give to the eggs which lie in their cavities both coats and substance, and whatever else belongs to their nature. This, however, is otherwise in birds and some of the quadrupeds. In the larger animals, and in the human species, there is observed a considerable difference as to this matter; for the human species, as also quadrupeds, Cows, Sheep, Dogs, Cats, Rabbits, and



and the like, acquires their full perfection in the ovary, and are from thence afterwards conveyed through a passage made for that purpose only, the fallopian tube, at once into the uterus, nor do they suffer any change in all this journey. In Birds, on the contrary, the egg is but half perfected in the ovary, the yolk only being formed there; but the white and shell is afterwards added to this in the oviduct called their uterus. In some quadrupedes, as Frogs, the whole animal, which appears at first in the form of a round egg, acquires its full perfection in the ovary, but it is afterwards covered over in the oviduct or tube, with a viscous matter, with which it descends into a kind of hollow enclosed membrane, which is their uterus: this viscous matter is the first food the animal swallows. In Bees the egg obtains its beginning and perfection in the ovary, which performs the office of an oviduct, tube, and uterus or womb, all in one. This ovary appears to the observer at first like a small and simply membranaceous tube; but in reality there is a necessity for much more apparatus. But our imperfect researches can go no further than our eye-sight reaches.

Behold, then, after what manner the omnipotent Architect hath retrenched, as it were, several parts here from the usual oeconomy of nature, and contracted them into one!

In the Silk-worm's Butterfly, the ovary is in this manner also divided into two parts, and each of them again divided into four others, which I call oviducts, whose ends or extremities are of a similar structure with those of Bees. In the Rhinoceros Beetle also the ovary is in the same manner divided into two parts, each of which is again divided into six oviducts. In the Humble Bee I found each side of the ovary separated into four parts. In the Wasp, which lays more eggs than the Humble Bee, I saw the ovary, Tab. XIX. fig. iv. *aa*, divided on each side into seven oviducts. But here in the female Bee so many oviducts occurred, that I was not able to reckon them; for not only the great number of the divisions prevent the counting them, but also the extreme tenderness of the texture; whereby they are very easily destroyed under our hands: to this may be added the very strong knots, by which the pulmonary tubes bind these oviducts to them. Nor could I any more reckon how many eggs there were in each of these oviducts; but this is very easily done in the Humble Bee, in whose oviduct I computed ten larger, and some smaller eggs. In the Silk-worm Butterfly I have sometimes counted sixty or seventy eggs in each oviduct; but in the Bee I could by no means determine the number of the eggs: in another ovary I counted fifteen or seventeen large and small eggs in one duct; so that the Bee has a smaller number of eggs in each oviduct, than the Silk-worm Butterfly. I afterwards attempted to count the oviducts in another female; but here again I had as little success, both on account of the strong

connexions of the parts one with another, as because I could not spare the necessary time. Upon comparing the numerous oviducts, which I had found with the greatest labour, with those in the other part of the ovary, which I had not computed, I think I may venture to affirm that there were more than three hundred oviducts in the ovary of the Bee. And hence, if this number of 300 oviducts be multiplied by the number 17, (for there were so many distinctly visible eggs in one oviduct, when the female was entirely perfect,) it will result from the whole, that there are five thousand and one hundred visible eggs in one female Bee, and yet these so different from each other in size, that one would be surpris'd; for those that are to be laid last, are no more than rudiments so small as to escape not only the eyes, but even my best microscope, and are to be numbered by Him alone who formed them. The extreme points or ends of the ovary, which contain these minute eggs, are placed in the uppermost and highest region of the belly, and are there as it were folded and turned back. The same thing is seen in the Humble Bee, and Wasp, and also in the Silkworm Butterfly; but in the Wasp the ovary terminates in wonderfully long productions, Tab. XIX. fig. iv. *bbb*, which are so interwoven with the pulmonary tubes, that one would think them a little net composed only of those tubes. It is to be observed that I here represent a double ovary, and that one of its sides, fig. III. *a*, is taken out of a fully pregnant female; the other out of one *c* not so far gone: and hence a great difference arises in the form of the ovary. The eggs, *ff*, *iii*, which are represented in the extremity of the Bee's oviduct, that was not so far gone in her pregnancy, are by far more numerous, smaller, paler, shorter, and more oval, as also more pellucid and tender than those which are situated in the lower part of the oviduct; out of which the eggs finally issue and are produced. This is conducted in the same manner by nature in other insects, I have observed it in the ovary of the Louse, but in the ovary of the Frog all the eggs are of the same size: in the human species, in quadrupedes, and birds, they always differ in magnitude. And it must be here observed, that in the ovary of the less forward female, some eggs appear larger than others, fig. III. *llll*; though they be already come down to the lower parts of the ovary. But this, as I have observed, I never saw except in females, which did not increase their colony as they should have done, and when there was some confusion in the hive: therefore I really think that the female's ovary has then some species of a disorder. And hence I have, in order to prevent the necessity of two figures, on one side *a* delineated part of the ovary of the real pregnant female Bee; for those are now called queens or females by our Bee-keepers, which enrich the  
hive

hive with a numerous off-spring, and plenty of wax and honey ; and it is there observed that the eggs *g g*, *b b*, are almost all of a size, and by degrees decrease the higher they are situated. The extreme ends of the oviducts resemble in the real prolific Bee *f f*, delicate, fine and scarce visible filaments, which are likewise crooked at their extremities, and are furnished with rudiments of oblong and almost equal eggs, which at last become scarcely visible.

Where the ovary is more protended or stretched downwards in the lower region of the abdomen, it there terminates in two very considerable ducts *b b*, *n n*, which resemble the two cornua or horns of the uterus in quadrupeds. All the other oviducts open into them, and bring their eggs thither, which is the case not only in the true female prolific Bee, but also in the others, though in a less regular manner. These two ducts are dilated by degrees, and become so considerably larger ; that they appear at length like a globular mass *p p* ; but when I opened them there, in the real prolific female, I found in each side nine or ten eggs *q q q q q*, which had descended so far, and are there probably covered with a stronger coat or tunic, or are changed and prepared in some other manner, so that they may be afterwards emitted with safety out of body ; for the Bees do not lay their eggs as they naturally fall, like hens, but set them upright. These eggs, Tab. XIX. fig. III. *q q q q q*, here likewise appear though faintly through these horns of the womb if it be proper to give them that name. For the uterus or ovary is in that part fibrous or muscular, and therefore is of a proper texture to push the eggs forward, and expel them out of the body ; nor do I doubt but the oviducts have also some muscular fibres. A little lower, near the extremity of the body, these two horns of the uterus become narrower again, and at length they unite in one canal, which is likewise fibrous, and has a kind of peristaltic motion *f*. The spinal marrow passes through the extremity of this aperture, which is left between these two ducts near where they are to unite *o*, indeed just above the place where this union happens ; and there give some nerves to the ducts, by the help of which they acquire a power of moving, and the insect is enabled to discharge its eggs at its pleasure. This is the method wherein the spinal marrow passes through the ducts of the ovary in Humble Bees, and the same is seen in Wasps. Many pulmonary tubes are also fixed into those two horns of the uterus *r r r r r*, and the whole ovary is in like manner furnished with many such pipes : it receives them on each side from the dilated pulmonary tubes, which are the pneumatic bladders or lungs of the Bee. I exhibit such an oblong bladder *d* in one side, where the ovary of the not fully perfected Bee is exhibited, that it may be seen by what means that bladder transmits its ramifications

into the part of the ovary situated on that side. These pulmonary tubes are distributed through the whole surface of the ovary, but they are seen chiefly about the eggs themselves : this I have represented in a very small egg, as may be seen under the letter *b*, in fig. v. The egg is there delineated magnified together with all its pulmonary tubes. In the extremity of the body is afterwards seen a small part exactly globular or spherical, fig. III. *t t*, containing a slimy matter in it, by means of which the ends of the eggs are fastened in their waxen cells. About this globe part two other exuberant parts are to be observed, like crooked horns *u u* terminating in one foot-stalk or tube. These are afterwards inserted in the uterus. This tube draws the matter contained in the spherical particle out of it, Tab. XIX. fig. III. *t t*, and with this matter afterwards moistens the eggs that pass through in order to be laid. Those two vessels *u u* have their extremities closed up, and seem to me to secrete the glutinous matter found in the spheric bag, and to deposit it into the latter ; unless the glue be rather secreted in the bag itself, which I rather believe. These closed vessels are likewise very remarkable in Humble Bees ; but the bag has a different figure in that insect. In the Hornet the bag is likewise spherical, as it is here in the Bee. In Wasps it is of a pear-shaped figure, fig. iv. *c* ; but the closed vessels, or those which secrete the slime, if it be so, are not so large, or remarkable there as in the Humble Bees or Bees. In the Silk-worm Butterfly these vessels are very conspicuous, but there is no such bag of slimy matter there. The spheric particle or the bag of slimy matter in the Bee, has two coats, the outermost whereof is whitish, muscular, and in a wonderful and very beautiful manner interwoven with an infinite number of pulmonary tubes, so that one would say it was wrought with a needle. The outward coat may be easily taken off from the under one ; and when this is done, that little part appears more exactly globular, and becomes of a faint purplish colour, variegated with white spots. If the inward coat, which is thicker and more glandulous than the former, be opened with a small pair of scissors, a turbid or thick moisture flows out of it, which is like glue ; it sticks to the fingers, and may like silk be very easily spun out into threads, which immediately grow dry in the circumambient atmosphere. By the help of this slimy matter the female Bee fixes its eggs in the cells : the Hornets and Wasps also glue their eggs so firmly in their places, that they cannot be afterwards removed without injuring them ; but the eggs of the Humble Bees are not so firmly fixed. I have observed something singular in these, and therefore I shall delineate the method whereby this fixing of them happens, after I have finished the history of the female parts. The Silk-worm Butterflies likewise have their peculiar closed vessels, which contain the slime that serves to fix their

eggs. I have likewise observed the same thing in lice of the human head, which differ from those of other animals greatly. These have a considerable ovary, likewise divided into two parts, each of which is again divided into six oviducts containing a great number of eggs or nits. These eggs likewise differ from each other in bigness, and when they approach to being laid, those that are first laid and fastened down are much larger than the latter ones: this is likewise the case in Wasps, whose eggs are small and oval, Tab. XIX. fig. iv. *dd*. The bag of slime has, as I have observed, on the lower part or otherwise on its side, an oblong duct, by the help of which it is connected with the excretory passage of the eggs, fig. III. *x*, and therefore when the eggs pass through their excretory passage in that part under the tube of the bag of slime, they are covered over with its slime, which makes one end of them afterwards, when they are discharged, adhere to the wax; but how or where the orifice of this excretory passage is *x*, and what parts are to be seen there, I have not yet observed, since very few females are to be found in these unhappy times, whose wars and slaughters have destroyed even the Bees in our country: to this may be added, that what has been laid down cannot be seen so exactly, unless the hinder parts of the body of the Bee are taken out, which I would not attempt, because the rest of the parts were in this experiment to be preserved; therefore I have nothing more to say on this subject. I shall only observe that the letters *yy* indicate the external muscular parts of the sting, as naturally bent *s*, when broke off. *z* Exhibits the poison bladder with its tube *a*, and closed appendages *β β*, and its tube *γ*, protended or stretched towards the sheath of the sting. *ζ* Represents the last gut called the rectum; all the parts before recited are here expressed in their natural form, but greatly magnified. There are likewise seen two little parts *ε ε*, wherewith the sting is furnished on each side; these we have seen described in the history of the common working Bee, which has them in common with the female.

As to the stomach, intestines, vasa crocea, or yellow vessels, and other parts, all these are constructed in the same manner in the female, as I have before described them in the working Bee. I thought I observed some small difference in respect to the colour, as well as structure and situation, in these little oblong parts, which I examined in the cavity of the working Bee's intestine, where this is at length dilated.

The poison-bladder is likewise very remarkable in the female Bee, being throughout pellucid, clear, and perspicuous like a diamond; it is as large again as in the working Bee. The tube, being conspicuous in the hinder part of this bladder, may be more easily discovered here than in the working Bee: and the other

tube which is extended from this bladder towards the case of the sting, is also stronger and somewhat longer in this than in the working Bee, but as the humour contained in this bag appears to be so perspicuous and agreeable to the sight, I have endeavoured to taste it, taking care at the same time that I should not taste so much of it as that it could do me harm. This liquor first affected the tongue with a bitterish taste, which afterwards became more acrid and pungent, diffusing itself through the whole cavity of the mouth unto the jaws, and forcing the saliva out of its ducts, and indeed the tongue was affected in the same manner, but less violently, as with the root of pellitory of Spain. There was likewise a great motion made by it in all parts of my mouth, as if I had tasted ten or twelve drops of the most highly rectified spirit of wine; after this, becoming more bold, I tasted the poison of other Bees, and of Wasps: all were alike, only that I discovered that the poison in the working Bee was not so vehement as in the female; and again, that what is in the female is more mild or gentle than the poison of the Wasp. What wonder is it that a very small drop of this poison being violently driven between the skin and flesh, and immediately mixed with the mass of blood, should produce so much pain, pulsation of the arteries, swelling and inflammation to that degree, that not only a fever, but death also would ensue thereon, if many stings were inflicted at once. If a small piece of glass, or a little wooden splinter, be struck or fixed in the finger, it causes the most violent pain, what must be expected therefore from this sharp and most penetrating liquor, which corrodes at the same time, fixes itself violently in the parts, dissolves their continuity, and at length creeping into the blood-vessels, diffuses itself, and circulates with the mass of blood through the whole body? it is a common observation among the vulgar that six Hornets are sufficient to kill a horse.

The sting, together with all its parts, is constructed in the female almost in the same manner as I have before described it in the working Bee; the only difference I observed was that it is more remarkably bent in the female, though at the same time it is very sharp; this is probably the reason, that the female does not naturally wound with its sting, nor can it do it easily: from this was afterwards framed the fable that the king, for so they called the female, has no sting, and is of a mild disposition. The female certainly threatens a stroke, at least, when she is provoked, as I have learned from experience. But what the real use of this poison is, if we are certain that it is given to Bees for some other purpose besides that of defending their offspring, in doing which they lose their lives, I scarce see how it is possible to discover. I formerly thought it might possibly serve to

make the wax ; but the Wasps and Hornets destroy this opinion, which are furnished with a sting and poison, though they make no wax. Nor does the female Bee prepare any wax, nor even defend its young ; so that this use

also may be questioned or disputed. Behold then, reader, how difficult it is to investigate nature in her works, and learn with me, to close your lips, and candidly confess our general ignorance and weakness.

*The first observation on the female Bee.*

**T**HE better to illustrate what has been here advanced of the sting and its poison, as also of the ovary, I shall add some particular observations, which I have since the writing the former account made on the female Bee. On the 16th of June I opened a hive, and I found in it several sovereigns or females, which were soon after to swarm, yet lying covered in their waxen cells. Of this I was very certain, because I found them with their skins cast, and with expanded wings, nay they were ready to arise out of their cells. In the first of these which I dissected, an ovary occurred, but was not very distinctly conspicuous. I was obliged to make use of a powerful microscope to examine it, but then I saw that there were numerous oviducts in it, and the eggs themselves

as it were innumerable on account of their smallness : I really think there were ten or twelve thousand of them. I could distinctly have counted them, if I had had a mind to have undertaken the laborious office of separating them from each other : the eggs themselves, compared with those which I had before observed in the female Bee, at the time she is engaged in laying eggs were still very small, nay, those which were in the extreme ends of the oviducts were so wonderfully minute, and so thick placed together, that I could not distinguish them, but by the help of my most powerful microscope. I have likewise observed the ovary invested here as with a common membrane, which I confess I never before saw so distinctly.

*The second observation on the female Bee.*

**I**N a similar female Bee, produced at the same time, but more mature, which, with some thousand of other Bees had swarmed out of its native hive, and was received into another, I saw that the ovary was likewise yet considerably small, nor did even the eggs appear much larger, than if they were yet in their rudiments ; and hence I concluded, that this female was but just excluded from her cell, when she flew away in this swarm out of her native hive. I could not in that subject observe many remarkable things further, nor in others, though I had many females ready, for all of them died in the space of one or two days. But though I threw them into spirit of wine to keep them from drying, yet many of

the viscera were, to my great concern, spoiled : the reason of which was probably because I did not make use of a spirit sufficiently rectified. I observed that the poison in some of them was converted to a white matter, nearly without taste or strength, which when exposed to the air dried up and evaporated. In another I saw the poison separated and condensed into irregular white grains, and I could very distinctly see in that Bee the whole poison duct, which is connected with the hinder part of the poison-bladder, and which perhaps secretes the poison, covered over with coagulated particles of fat, which could not be easily wiped off.

*The third observation on the female Bee.*

**I** OBSERVED in another female, which I dissected about the same time, that one of the extremities of the poison duct was subdivided into two other closed but short appendages. When I measured the poison duct, from the bag to its first division, I found it to be a quarter of an Holland inch long, and that one of the branches of this divided duct

was almost half an inch long ; and the other almost two inches. However, these things cannot be observed, unless one has first very cautiously separated all the curvature and serpentine windings of these ducts from the rest of the viscera. Though this Bee had likewise lain in spirit of wine, yet all these parts were very distinctly conspicuous and strong in it.

*The fourth observation on a prolific female Bee.*

IN a truly prolific female Bee which had swarmed on the 24th of July, and had laid many eggs, I observed ten or eleven days after that I dissected it, that the beginning of the ovary was furnished with a great number of perfect eggs; but the eggs that still lay in the appendages of the oviducts, were not of that size or perfection which they are observed to have in the oviducts of the prolific Bees dissected in the month of May, at which time they are mostly employed in laying their eggs; nor were they so perfect as the eggs of the females examined in the months of autumn, as will be made evident in the fifth observation. From all this I discovered, that the female which had swarmed was young, and newly produced from her cell. But whether all those that swarm are young, I cannot yet presume to affirm for certain. Not only those eggs which were in the lower part of the beginning of the oviducts, but those which were situated higher had arrived to their perfect size. This ovary likewise had in it an infinite number of eggs, so that in only fourteen little parts which were broken off from the appendages of the oviducts, I reckoned one hundred and seventy four eggs. Hence it is not difficult to judge what a stupendous number of eggs one female contains. But there was a necessity for such a formation and construction, since a whole host of Bees of all the three kinds were to proceed from one female, as is actually the case. This numerous family not only contains three, four, or five thousand Bees, but sometimes nineteen thousand, as hath been observed elsewhere. I likewise in this subject distinctly saw all the oviducts on each side of the ovary unite in five principal branches, with which the rest of the oviducts were connected, and through which each conveyed its eggs into the common ducts.

Notwithstanding all the pains I took, I could not discover the orifice of the ovary or vulva in this Bee, because I was in the country and had not all my instruments at hand, and because I did not take the vulva out of the hinder parts of the body, fearing lest I should hurt any of the parts which I thought necessary to examine. However, I saw very distinctly that the excretory duct of the eggs, Tab. XIX. fig. III. *f*, where it approaches to the last ring of the body, dilates itself into a muscular globule, and then growing narrower, at length becomes again wider and more membranous; but I could not prosecute this inquiry any further, because I designed to keep unhurt the poison bag, which is situated in that part, together with some particular muscles that belong to the several parts of the sting. In another female I thought I observed that the orifice of the vulva, when the Bee lay on its belly, opened under the sting in the last ring of the abdomen, and that it is very difficult to

penetrate into this orifice, unless the parts be expanded and raised at the time the Bee is laying eggs. I likewise saw the fundament very plainly, and its orifice opening above the two appendages of the sting: it was placed in reality just over the sting and the two little parts just now mentioned. I further discovered that the rectum or straight gut had a kind of cavity there, which was full of red and yellow excrements, but that the intestine itself was formed in the manner exhibited in Tab. XVIII. fig. 1. letter *l*.

I have moreover observed that these two obtuse appendages, which the aculeus has as it were for ornament *oo*, are in reality the productions of those cartilages, which I have figured in Tab. XVIII. fig. II. *ll* and *mm*. But the true use of these appendages seemed to me to consist in this, to try beforehand whether objects be soft or penetrable to the sting, that the Bee may not in vain dart its sting against harder bodies, and spoil it to no purpose. I observed also, that one side of these little parts was covered with a cartilaginous integument, and set round with fine hairs.

Since the sting with all its parts was here in the female considerably larger than in the working Bee, I could therefore discover some singular things about it which I had never observed before. I first observed, that the sheath itself of the sting had two shanks, to which the shanks of the sting itself were closely applied, so that the latter may by the help of the former, be more regularly moved. These shanks of the sheath were in this Bee also very beautifully bent like the shanks of the sting. It is scarce credible how beautiful the structure of these is near the sheath; for there I observed likewise two small parts, which being at their origin bent into an oval form, had a verge or border of a brown full red colour; but afterwards acquiring by degrees a paler tinge, and uniting in a point, they were on one side articulated with the cartilages before exhibited, Tab. XVIII. fig. 1. *nn*, with which the extremities of the joints of the shanks of the sting were likewise connected in the upper part. The little bone also, which I have before described to be like that in Birds, called *specillum*, was observed to be articulated in the hinder part with the case or sheath itself; but the poison duct passed there only higher up, and immediately terminated after it had advanced a little way in the sheath. Whether all these several particulars be circumstanced in the like manner in the working Bee, I have not yet examined.

I further learned from this dissection, that the two little parts fig. III. *rrr*, which I have before exhibited in the common Bee, as situated on the outside of the shanks of the sting, were here in reality placed on the inside of them. I likewise saw very distinctly, that the muscles

moving

moving these shanks upwards out of the sheath, and again drawing them downwards into it, lie in reality in the female between the margins of the sheath in the hinder cavity of it, and are there inserted in the two parts just now mentioned. Thus I at length found that these two little parts principally and chiefly contribute to keep the shanks of the sting; whereof they contribute a part, in their places and prevent their slipping out of the sheath; and this they can do more easily, as they themselves are contained in the cavity of the case, out of

which I have, with the assistance of a microscope extracted them, and afterwards put them into it again without the least hurt to any part.

I have likewise at length discovered the true reason why I had not before discovered in the working Bee what I have just now said: and it was this, that the shanks of the sting when drawn out of the sheath, instantly bend themselves, and hence it then happens that these two little parts always appear on the opposite side.

*The fifth observation on a real prolific Bee.*

**I**N a female Bee brought to me in autumn, at the time when the honey is taken from the hives and the wax also, and for which reason two hives are sometimes then formed into one, I discovered the whole ovary to be still full of innumerable eggs; so that I have from hence learned that the Bees never lay all their eggs together, as is the case with Hens, which commonly clear their ovary entirely, leaving only some small rudiments behind. I therefore think, since the eggs in the ends of the oviducts of the Bee are innumerable, and lie disposed in an delicate order, that they are continually discharged out of it, and succeed in the place of those eggs which were before laid. In this female, which I preserved for the space of a whole year in spirit of wine; the poison was likewise coagulated and stuck in its bag like an oval particle of wax, but so as that the inward surface of the bag was separated all round from the surface of the contained poison.

As I had many Bees at the time when these females were brought to me, I had an inclination to try what would be the consequence if the poison was mixed with the Bee-bread. The following was the event of the experiment. The friable and otherwise very easily separable Bee-bread, which is not naturally fit for working or kneading, nor is at all glutinous, was, by the admixture of the poison, insensibly rendered tenacious and clammy, and having lost all its friability, began to melt in some degree at the fire, but it grew black after some time, exhibiting its former appearance of bread, which never catches the flame, but only grows black in the fire. The same mass thrown into water was not dissolved, but being somewhat agitated in the water, returned to its former disposition, and at length began to melt. Some particles of Bee-bread kneaded or wrought with the poison, and kept fourteen days, retained their acquired tenacity, nor did they again become friable; but whether any thing can be inferred from this experiment I

would not yet presume to determine\*. It seems at least in some measure to follow from thence, that there is no reason to deny the Bee-bread, or that matter which the Bees carry fixed in their legs, and which is of a similar nature with the Bee-bread, may be made into wax. But when I began this experiment, I had not the matter now mentioned at hand; nor could I get it, as the hives were carried at that time into some fields of buckwheat which was then in flames.

I have frequently offered the Bee-keepers a considerable present, if they would shew me real wax adhering to the legs of Bees: but though they readily undertook this, they never could perform it. Therefore the method whereby wax is made, must it seems yet be referred to or reckoned, amongst those things which we are hitherto ignorant of, and which ought to be investigated. The same doubts may be raised concerning the making of honey, though this difficulty may be more easily removed. I have not hitherto been able to make all the experiments concerning this matter which I had designed. I shall therefore conclude these observations on the female, after I have first exhibited the manner of seeing distinctly how the Bees make the wax. For this purpose I ordered a wooden stool with three or four feet to be fitted into a straw hive, in such a manner that the hive might be conveniently taken off and again laid on it. I covered the edges of this stool with paper, and then in swarming time I put a new swarm into the hive. When I afterwards saw, that the Bees in the inside had made wax and propagated young ones, which happen in ten or twelve days. I immediately removed the hive from that stool, and also took away the paper, and thus I could very distinctly see the Bees working in the sun-shine. But though I have never gone through with this experiment, yet I know the effect of it, for I have often seen that the habitation of the Bees which had made

\* In fine weather the Bees constantly go out in search of the matter of wax, which they collect from the antheræ of flowers. They eat some, and lay up the rest in certain cells of the comb where it is pressed down by other Bees, and this serves them to eat in bad weather, when they cannot go out. After they have swallowed this, and it has passed the operations of their stomach, it is wax, which they complete by more working and moulding; but though the farina of flowers be the real substance of wax, human art can never make wax from it.

their nests in the holes of old walls and ruins of houses, was a full square foot wide at the mouth, through which their making of wax, and other operations might be seen conveniently. We should not therefore fear that the Bees when exposed thus openly will desert the hive, which is the only objection that one can make against the proposed experiment. The fear of their flying away will be the less, as they will have placed their offspring there before the operation, which they never afterwards relinquish. If any one should fear lest the Bees should be injured by the nocturnal cold, he might cover them at night with a larger hive or any other larger cover. And in the day time they might be put in such a place that they should not be exposed to the injuries of the heat or rain.

I shall now proceed to the history of the male Bee; and here shall first briefly relate some things of Humble Bees and their eggs. The Humble Bees, as far as I have observed, do not build nests or live together, but in the winter; like most other insects they abstain from food and motion, and therefore they are properly solitary Bees. I have seen, however, that about the end of May, or sooner, some few male Humble Bees, and one female which is of a larger size, gather together in the pastures and corn-fields about Amsterdam. The place they choose to build in is between the stalks of corn or grass, and is not deep under the surface, but only a little hole burrowed under the grass, in which hole there is found either naturally or heaped together by them, a tender soft sort of down or moss, on a small part of which, formed in a kind of bed, with brown wax or a flexible matter like it, the female lays her eggs. With this matter also the eggs themselves are all sealed up underneath and on the sides. But in what manner these eggs are deposited there, and how the young and tender Worms creep out of them, and whether they eat this substance, I have not yet learned from experiments. I have lately however, namely, on the 22d of June this year found a perfect nest, in one side, Tab. XXVI. fig. 1. *a*, of which there were eighteen cells, but in the other *b* only eight. Between these was seen one cell entirely empty *c*; and there occurred in several places here and there *d e f* some particles of the same kind of waxy matter: in this the eggs were all closed up. I shall now distinctly describe what I could observe upon this occasion. I found one female and several males in this nest, all which shewed by their humming and their running anxiously up and down, that my curiosity was by no means pleasing to them. When I afterwards carefully viewed eighteen cells, and opened them by cutting off the piece *g*, I found them all full of little Worms, which were to be transformed into Nymphs *b*. Upon observing the structure and substance of these cells, I found that they were all composed of threads or filaments, and were of an oval figure, and of a colour some-

what approaching to yellow. This I looked upon as a strong argument that these little cells were not made by the Humble Bees, but by the Worms themselves: nay, a certain, though not very exact order, was observed in their composition, since one cell was placed in the middle and surrounded by five others. They were all fastened together in the same manner in which the Silk-Worm is accustomed to affix itself to paper or wax, by the help of her threads. And one of them was more elevated, another more depressed; on the lower part where they rested on the down or moss, they had contracted some dirt or mouldiness, by reason of the dampness of the soil. I drew some of the Worms that lay on the inside out of them and left others. And I found that those which I had left in their cells, were in some days changed into Nymphs, and these afterwards in two or three weeks into Humble Bees: these however did not creep out of their webs, but died in them, together with the Worms that I had drawn from thence. The eight cells of the other side did not appear to be made of this waxy matter: their figure was likewise less regular and orderly, and I therefore imagine they were made by the Humble Bees themselves; but as I thought that honey or Bee-bread might be found in them, I indeed greatly admired, when I found only Worms of various size, and all closed up. In each of two of these cells I found two large Worms *i*, and in another only one *k*, but this was much larger. These Worms taken from thence and put into a cornet of paper, covered themselves with a web of an oval figure, and in the mean time discharged a large quantity of brown regular excrements, divided into equal parts, and very like the matter wherein they were deposited. In another cell I found a waxen partition *l*, and in one of the apartments thus separated were two small Worms, and in the other two that were somewhat larger. I likewise afterwards found in another cell three Worms *m*, and in another four *n*. From what has been here said, it is sufficiently evident how greatly this cohabitation of the Humble Bees is different not only from that of the common Bees, but also from the nests of the Hornets and Wasps, which are made by these insects themselves, and are admirably constructed. But what seems to me most wonderful of all is, that these Worms of the Humble-Bees which should still be in a state of nourishing, are really sealed up and covered with the waxy substance. Perhaps it may not be improper to conclude from hence, that these Worms use that matter wherein I found them covered, in the place of other food, and that the parent Humble Bees when the first quantity is consumed, again lay another new parcel over them. This is in some measure the case in some Worms, which being deposited in cheese, flesh, fruit and plants, lie as it were covered up in their food or nourishment; for those protuberances and knots, wherewith the whole insect is covered, rise

in excrecences, in plants and fruits, in the same manner as the Worms in cheese and flesh, at length intirely enclose themselves in those aliments. And hence it is very probable, that these Humble Bee Worms likewise feed on the wax wherewith they are covered and surrounded, nearly in the same manner as the Wolf-Caterpillar uses the wax for food, and supports life: this I shall hereafter describe in its place. Otherwise it would be necessary that the Humble Bees should, in order to nourish their Worms, continually open and again close up these cells, which would be a work of tedious and needless labour, such as cannot be any where found in the works of nature, which are every where perfectly simple. The method of nourishment I have supposed becomes more probable, if we consider the order in which the Humble Bees enclose their eggs in this matter; for I do not think it possible that the Humble Bees can so exactly know the time when the Worms are to be excluded from the eggs, and when these cells should be opened, because they may be in want of food. To this may be added, that the matter wherewith the eggs are covered, can scarce be torn open any way without hurting them: but I shall leave this matter in uncertainty, until repeated and more successful examinations determine it. That I may proceed in my intended method, I shall observe here, that I likewise saw an empty cell in this nest. This was likewise made of filaments or threads, and it seems to me probable that a young Humble Bee had crept out of it. At length I also broke those irregular particles of wax, which were in divers places found affixed to the woven cells of the Humble Bees: in one of these I found six eggs, Tab. XXVI. fig. 1. *d*, in a second seventeen *e*, and in the last twenty-three *f*. These eggs were pretty large, somewhat crooked, and were fastened to the pointed extremity of the substance on which they were placed. When they were viewed with a microscope, they appeared like that kind of rough skin which we call shagreen. They were of a milk white colour, and full of moisture, and they all stood erect and so near each other, that they were almost contiguous; this made a very beautiful appearance. I a long time preserved them as well within as out of the matter wherein they were enclosed, but they grew dry in the mean time, nor were any Worms hatched from them. Many Lice of unequal size, and which are very tenacious of life, crawl upon the Humble Bees themselves. I observe also, that the Ants, and almost all other insects, are tormented with their respective Lice. Goedaert calls these Lice the Humble Bees excitatores or provokers, and has invented several amusing stories concerning them, but he relates a fable rather than a true history.

It is time we now describe the parts of the male Bee. I shall here follow the same method I observed in the history of the female, and shall describe only those parts of the head,

breast and body, which either are not in the working Bee, or are seen plainer and more perfect in the male.

About the head are principally to be considered the eyes, horns, teeth, and the feather-like hairs, wherewith the head is every where covered. I have already elsewhere treated of some of these parts; therefore I shall now describe the eyes, in which the following particulars are to be observed on the in and outside: the number of the eyes; the external figure; the hairs fixed on their upper part; the tunica cornea, and the uvea; the internal pyramidal and inverted fibres; the pulmonary tubes which run between these first and second membranes, wherein the pyramidal fibres terminate; the transverse cortical fibres, conspicuous under these membranes; the cortical substance of the brain, situated under those fibres; the brain itself with the three singular eyes over it; the origination of the spinal marrow just under it; the origins of the pulmonary tubes; and lastly, the internal surface of the eye.

As to the number of eyes, there are here two principal or large ones, one in each side of the head; and beside these three singular small eyes which are here in the male, Tab. XX. fig. 1. *a*, in a triangular form between and below the larger eyes, in that part where these larger eyes are contiguous to, and again diverge from each other in form of the letter Y. In the females and working Bees, as has been observed before, these three eyes are situated higher up in the head, and lie pretty exactly between two larger eyes. But I shall say something more of this matter hereafter.

The two larger eyes resemble as it were a crescent, with this difference, that in the upper on the head they are sharp-pointed, but somewhat rounded *bb*; towards the lower parts *c* near the teeth, they again meet in a point. They are in form like a segment cut from a flattish rounded mass, one side whereof is somewhat acute, and hollowed or bent inwards, and the other converges in a crooked form. In the upper part of the head toward the neck and back, these eyes are contiguous in their convex extuberant part, which is not the case in the two other kinds of Bees: but they again, on the lower part toward the teeth, where they become still more acute *c*, considerably diverge from each other on each side; the smaller eyes, the horns, which are here severed *ff*, the teeth as they are called, and some feather-like hairs *d* being situated in the intermediate space.

Both the eyes are also very thick covered with hair *eee*, which, in order to avoid confusion, I here represent only on one side. These hairs serve the eyes instead of eye-brows or eye-lashes; but because their situation cannot be exactly understood, until after that coat of the eye which supports them is described, I shall therefore now first treat of that coat, the cornea, in which these hairs take root.

The



The outmost coat of the Bee's eyes, is the cornea; by which name authors have likewise called this same tunic or coat of the eye in man, and in quadrupedes, birds, fishes, and serpents. This appellation is more particularly appropriated to this tunic, since by its stiffness, hardness, flexibility, and clearness, it approaches to the nature of horn. The eye of the Bee differs, however, from that of men and other animals, in that as the cornea appears in these smooth and equally polished, it is in Bees and in all other insects that I have examined, divided by various and manifold divisions: and as these divisions resemble globules or little spheres, hence it is that some subtle and sagacious geniuses, among whom may be reckoned the illustrious Dr. Hooke, believed that the insect's eye was only a congeries of innumerable little eyes, each of which, in respect to its structure, agreed with our eyes and those of other animals: this structure of the eye, however, I have not hitherto seen in any insect but in the Snail, which on one side exhibits two distinct eyes, furnished each with its three proper humours. In order to explain the divisions of the cornea in Bees a little more accurately, I would have it observed that they are by no means spherical, but rather hexagonal, Tab. XX. fig. 11. *kk*; but notwithstanding this the masses themselves are on the upper surface perfectly rounded, and consequently exactly like the sealed cells of the Bee; which being likewise circumscribed by six sides, yet rise convex, and swell up in a globular surface, or are as it were arched. The woven cells of Hornets much more accurately express this construction of the cornea in the eye: for these have also six sides, and are very beautifully enclosed in an arched or spheric web. The eye of the Bee, and most other perfect insects, considered in this light, is really like a little net; which appears most perfectly when examined in the light by a microscope: for then the most obscure or opaque hexagonal interfections appear in the form of a net to any person who looks through the spherical tops of the divisions. We must further observe here that these hexangular divisions *kk* of the cornea, upon a more exact comparison, do not perfectly keep the resemblance of one of the closed up cells in the comb; for the lines which distinguish the cells of the comb from each other, are upright or straight, whereas the hexagonal divisions, on the contrary, which occur here in the Bee's eye, are intercepted by crooked and sinuated lines. To obtain this form for them, the all-wise Author of nature makes use of the following means; that is, he gave the cornea a spherical convexity, by means of which some of the lines, together with their divisions, are here and there broke off; and at the same time He also placed *kk* an hexagonal division between six other divisions of this kind: hence it is, that these hexangular divisions appear as it were oval or arched, as I

have in some sort delineated between the annexed letters, Tab. XX. fig. 1. *c, eee, bb*. And in what manner every hexagonal division is surrounded with six others, may be seen magnified under the letters *kk*, fig. 11. Some curious persons, to whom I shewed these, were of opinion, that in the structure of the eyes reasons might be found why the Bees make their cells hexagonal; that is, because they exercise the sense of vision by hexagonal eyes. Behold; how far we are led away by fictions, when, being ignorant of the foundations of things, we follow our vain fancy as a guide! It would be as natural to say we should build only round houses, because the pupil of our eyes is of that figure. I have not yet counted how many divisions there are in the Bee's cornea, nor do I know any method of doing it, unless one could cut the cornea into small pieces, and afterwards count the divisions in them singly by the help of a microscope; observing at the same time that every two of these cut divisions are to be reputed only one. However this matter be, the accurate Dr. Hooke hath computed in the eye of the Perla of Mouffet, which he calls in his own language Dragon-Flies, but in the Dutch language Romboud, Puystebyter, Naeyer, and Glaseschryver, fourteen thousand such interfections; this is indeed a great number. To this we may add, that these divisions are so beautiful, so regular, and formed with so much art, that it by many degrees surpasses the most exquisite human workmanship. Indeed, could any one think this could be done by human powers? since we cannot separate or divide those things which nature formed only as it were in sport. This is the external form of the more than stupendous cornea of the Bee's eye.

As to the internal structure of the cornea, it is divided within just into so many hexagonal little holes, or as it were round spoons, as on the outside it is geometrically distinguished into hexagonal spheres. But if this cornea, turned to the light, be viewed with a good microscope in the manner before described, then at length its true and delicate hexagonal reticulation may be finely observed: for as the cornea is very pellucid and thin where it is hollowed or excavated into these little spheres, but considerably thicker where it is intersected; hence it happens, that the interfections only seem to shew themselves to a person who looks through them: and this is the true reason why the cornea then exhibits itself like a net pierced by small hexagonal apertures. But its surface is not always the same; sometimes it appears divided into triangular, and sometimes into quadrangular figures: this diversity must be attributed to the variety of reflexions which the rays of light occasionally produce in their passage. This obtains principally when the angles of the divisions of the cornea are not all directly under the microscope,

scope, for then only one part of the convexities can be seen, and the other not at all; and thus false angles are exhibited. Almost all concave bodies, if viewed in the light, appear to our sight sometimes globular, and sometimes roundish and convex: this is illustrated very particularly by the engraved agats. For this reason the greatest circumspection must be always used in viewing objects by microscopes, lest we should deceive ourselves, which has commonly happened on these occasions. I shall hereafter explain what produces these hexangular divisions in this net of the eye. The thickness of the cornea in the Bee is pretty considerable, and indeed more so, considering its size, than in many other insects which are equally small: this may in some measure be comprehended from a small piece of it delineated as it appears under the microscope at the letters *lll*, Tab. XX. fig. III. Between the divisions we have been hitherto describing, are placed those hairs which I have before said are planted all over the eye. They are very firmly fixed to the cornea, for they pierce it all through in the same manner as our hair does skin: but they rise sharp-pointed, and are three or four times longer than the diameter of any one hexagonal division: in structure they resemble bristles, and are of a round figure, thick below and sharp above. Their number is likewise very considerable, though less than the number of the divisions; they are, however, so thick and so close set together, that they seem to constitute a very close forest of bristles, like so many fir-trees planted upon the eye: this may be seen in some measure under the letters *eee*, fig. I. where I have represented them only in the circumference of the divisions of the eye: of the other divisions that are exhibited in the same figure, I have delineated a less and determinate number, they being very numerous, and hitherto beyond any account I have taken. Finally, I should think these hairs are principally fixed here to guard the eye against any thing falling on, or striking against it; to keep off the dust, and, in case any of these annoyances should slip in, to assist the Bees to throw, or brush it out the more easily, by a friction, which the Bees perform with their feathered legs: Flies also use the same method to wipe themselves. These hairs seem also to serve the Bees instead of eye-brows or eye-lashes. I had first thought that only the long-lived species of insects, such as Bees, had these hairs: but I afterwards observed that they are not so peculiar to the Bees, as not to be found in many other species of insects. I have found them among others in the coloured diurnal Butterfly: I have likewise found them on the eye of Goedaert his Bee. This eye, however, is not covered all round with these hairs, but only shews the oval orbit planted with them. Goedaert describes the Bee I have just mentioned, in the second experiment in his first part; but

if any one examines this more accurately, he will find it is only a dunghill Fly, with no more than two wings, and constantly produced or generated annually in the same manner. It is produced from a Worm with a long tail and very short legs, found in dunghills and common-shores, and belongs to the fourth order of our natural transmutations. The Bee, on the contrary, is to be ranked in the third order, as I have already sufficiently proved. I shall proceed to describe the uvea, which is the other coat of the Bee's eye. Of the other three remarkable little eyes I shall treat at large hereafter.

When the cornea is removed from the internal parts of the eye, the tunica or coat, understood to be the uvea, comes in view. This, therefore, is not placed in insects at the bottom of the eye, but next to the surface; nor does it any where appear perforated as in large animals. This consequently prevents the rays of light penetrating further into the eye than through the cornea only. When the cornea is taken from the eye, we usually see that a more opaque matter, which entirely takes away the perspicuity or clearness of the cornea, is carried off with it. This matter is of different colours in different animals; in Bees it is of a deep purple, in other insects it is green, in some blue, in others black, and in others again it has a very beautiful mixture of various colours, which are elegantly and agreeably seen through the cornea. But this is to be found only in the inner surface of the cornea, where the uvea adheres next that coat, without any thing between. The two parts of this matter which constitutes the uvea, both that which is applied to the inner cavity of the cornea, and that also which is observed to adhere to the internal parts of the eye, are commonly of a blackish colour, and the last likewise stains the fingers when touched, and is a kind of black paint, as our uvea and that of other animals is: and hence it arises, as I have before observed, that the perspicuity of the cornea is darkened or obscured by this matter. Therefore, in order to shew the cornea pellucid, this matter must be first wiped off with the help of a pencil or a small piece of paper folded up. If you press the head of the Fly between two folds of paper, the paper acquires a purple colour from it, which is owing to the more diffused colour of the uvea. But perhaps some one will ask, if the matter hitherto described seems only to be the uvea, but is not so in reality, what is it? To this I answer, that this matter is nothing but the tops of some broken fibres, which are placed close under the cornea, Tab. XX. fig. I. *gg*: for no humours, properly so called, are found in any part of the Bee's eye, which is a thing well worth observing: though the celebrated Dr. Hooke, for want of a sufficient number of experiments, hath been led to imagine there were such in the eye of the Libella; because no other method occurred

to him, by which the sight of insects could be explained. However this matter be, the coloured part of the Bee's eye, though it be not an uvea, serves the use of that coat in the eyes of larger animals.

Immediately then under this uvea, as it has been called, are seen so many fibres, as there are divisions above in the cornea. These fibres very exactly agree with the cavities of the spherical divisions of the cornea: and they are likewise hexagonal and broad, but thinner in the middle and sharp-pointed underneath where they terminate. They are all nearly of equal length, thickness, and breadth. But above the margins and extreme sinews of the eye, these fibres are somewhat bent and seem shorter: they are above, where they are joined to the divisions of the cornea, much thicker *bb* than below *i*, where they are only united together by their ends: and hence they almost resemble so many inverted hexangular pyramids, thick and broad above, and thin and acute below. In order to constitute the convexity or arch of the eye, they are placed together in the manner of those eggs of insects which are circularly glued round the branches of trees. These fibres stand erect on the bottom of the eye, in the same manner as the hairy filaments lie under the leaves of an artichoke on its disk or receptacle. I have above described the colour of these fibres; I shall only observe further, that this paint, with which their larger extremities are tinged, is likewise diffused deeper downward: and the other parts of these inward fibres are, as I have said before, tinged with a red or purplish colour. Those fibres which stand in the middle of the eye are straight *bb*; but those that are on the sides appear somewhat oblique, and the rest run a little crooked also; but all terminate in a subjacent membrane, with which they are naturally united, but from which they are easily broken off when handled. This membrane, therefore, very finely exhibits almost the same divisions in dotted figures, which the omnipotent Creator hath been pleased to make on the cornea *cbb*, with such stupendous and inimitable art. Concerning these fibres we are further to observe, that if the cornea be separated from, without hurting or breaking them, they very beautifully represent the hexangular divisions of the combs: but when the cornea is pulled off in such a manner as that some particles of these fibres adhere to it, then their figure is not so distinguishable. These fibres are very easily broken, when the cornea is separating from them; for they are connected with the cornea, and are received into its cavities: but this union is rendered stronger by means of innumerable pulmonary tubes, which ascend near those fibres towards the cornea, and, as I think, constitute its hexagonal divisions: nay, they likewise probably contribute to expand the eyes at the time when they are casting their skin, and are very soft and tender,

by force of the air impelled within. Hence near the divisions of the eyes, the pulmonary tubes will have the same use and situation as I have before attributed to the same tubes, in regard to the wings of Bees. I would not, however, have my opinion in this case considered farther than as a probable conjecture. One of these fibres is likewise united with another immediately under the cornea; and a little lower some clusterings and knots are observed among these fibres. But where these fibres are broken off, when the cornea is not regularly taken from them, their full purple colour, as hath been said above, is found not to terminate there, but descends deeper. It is indeed very wonderful, in what manner and in what numbers these pulmonary tubes ascend near these fibres, and are united together. I must own that I should be very glad to examine, of what nature these fibres are, whether muscular or nervous; as also whether or not they have any motion, and of what kind of particles they are composed: but it has been absolutely impossible for me to examine all these things, for both my sight and instruments failed me. However, I have again seen the Creator conspicuous with human eyes in this stupendous constitution of the most admirable and unsearchable little parts, which exhibit, as it were engraved thereon, the real image of his inexhaustible power and wisdom.

That I may proceed in the order wherein I began, I shall now describe that part, Tab. XX. fig. v. *x*, towards which all the fibres hitherto mentioned converge, as towards a common center, and to which they are united, as the threads of velvet with their web; this part is white and fibrous, and is situated within the eye: but the pulmonary tubes before described ascend through and on each side of it towards the fibres. The figure of this membrane is exactly like the external figure of the eye, one side of it being lunar or like a crescent, and the other semicircular. It is white in the middle, but in the border it partakes somewhat of the colour of the superior or upper part of the fibres, the impressions of which are seen thereon.

This membrane, being removed from its place by the help of a fine instrument, there appears close under it another membrane, much more delicate and tender, as also clearer: and this, by means of pulmonary tubes, is connected, though not very strongly, with the former.

There is placed under or behind this membrane, but a little lower or deeper in the eye, another or second species of fibres, fig. iv. *nnn*, and fig. v. *qq*, which being transversely applied to the lower surface of the membranes, are like so many beams or transoms, which support the pyramidal fibres laid over them. These also differ from the former pyramidal fibres, both because they are fewer in number, and by far less delicate; though notwithstanding

ing their thickness I could not easily divide them. Some of these fibres are laid over others, Tab. XX. fig. iv. *o*, in the same manner as they are wont here at Amsterdam to pack beams or pieces of timber on board of ships to be exported; that is, they were here and there separated from each other, and spaces were left between them; and by this means was exhibited an object, like the course of the muscular fibres in the papillæ of the kidneys. These things appear more beautifully when the dissection of the eye is begun in the lower part, as may be seen fig. v. under the letters *q q*, which represent the same fibres. Of what nature these fibres are, and whether they communicate with the brain *s s*, I have very anxiously investigated, and, if I am not mistaken, I have found that they are joined to the brain, nay, they are of the same colour with the brain, that is, somewhat grayish in part, and elsewhere fresh coloured: hence I call them the cortical fibres, because they are like the cortical substance of the brain. In the Wray-fish, there is seen a very remarkable nerve, issuing out of the brain, and terminating in a large inflated extremity. This is conveyed towards the bone of the head, and is there admirably divided on each side into many filaments, to which those fibres in the Bee's head likewise answer, and it may in some measure be likened; though these nerves in the Wray-fish do not all seem to contribute to the sense of seeing, but rather to that of hearing or smelling: this matter therefore still remains to be inquired into.

Between these fibres is seen the cortical substance of the brain, the nature of which these fibres do not seem to be unlike. It is manifest that this substance *s s*, as well as the matter of the fibres *q q*, remarkably communicate with the brain, indeed that they both rise out of it.

The brain of Bees consists of four pair of distinctly conspicuous parts, to which, as a fifth may be added, namely, the spinal marrow within the skull, or the principle or origin of these little parts *r*; nor can I besides these find any others in this insect, not even the so famous pineal gland\*. The two foremost of these little parts, fig. vi. *c*, are somewhat globular or pyriform, and emit two nerves on each side, which are divided again into two parts *d d*, but their course, or the way they are sent off, is still a secret to me. The other three pair of little parts I have not yet so plainly discovered, as the first here described, because they communicate and are connected with the three particular little eyes before mentioned, which are placed in a triangular form, fig. i. between the larger eyes here explained, and divided in the manner just laid down, though I could not

so distinctly as I could have wished explain the method whereby this connexion and communication are performed. The first thing that I have observed distinctly with regard to these little eyes, is that they also have pellucid cornea; and secondly, that in their cavity there likewise appears a coloured little part, which may be called the uvea. But of what nature this substance, which is under the uvea, is, and whether it likewise consists of numerous fibres, or is itself a single fibre, I cannot determine, though it seems to me to be a continued substance. Thirdly, below this we see those three pair of little parts, which are as it were enclosed within it: these are the reasons why I call these parts eyes. To which may be added, that the eyes of Spiders and Scorpions are externally formed exactly in the same manner, and are smooth, glittering, and without divisions, and they are dispersed as those that are disposed at random over the body. The Wolf Spider, which catches its prey by leaping on it, and not by means of webs, has its eyes placed in the same manner. But this species has a very exquisite and incredible sharp sight, compared with other Spiders, which seem almost blind and, as it were, destitute of motion, that they may catch their prey, if any falls into their snare, with greater certainty. I have not yet discovered the internal structure of these three eyes of the Bee. The letter *b*, fig. vi. likewise shews the brain, or rather one pair of those parts of the brain. We have before described and explained by what means the cortical substance of the brain, is shewn when the fibres are taken from it. The letters *e e* severally shew the third and fourth pair of little parts, or the cerebellum, and also the manner wherein these parts communicate with each other. The cortical fibres, fig. iv. *n n* that issue from these, are represented in their situation in the fourth figure. In order to observe the principle or beginning of the spinal marrow, fig. v. *r*, it is necessary to begin the dissection of the eye at the lowest part, or where the head is joined to the thorax. But then if you only remove the horny head, you will immediately see the fat, and the originations of the pulmonary tubes, which are here very numerous, and the larger branches of which are distributed towards the upper parts; but the smaller are connected with the fat, in the same manner as the scapus or stalk of a bunch of grapes is with its berries, and hence is produced a most agreeable sight: one or two membranes also must be there separated from the brain, before the marrow comes in sight. But then one may see there very beautifully that other species of the fibres of the eye, Tab. XX. fig. v. *q q*, which I have called the cortical fibres, and represented under the letters fig. iv. *n n n*, in

\* The Bees have probably all that delicacy of smell, for which they are celebrated; but it is not true that they distinguish perfumes by their fondness, and stinks by their aversion: certain smells excite and others offend them; but their notions of sweet and stink are not the same with ours. They are fond of places where urine stands to putrefy, than which there is scarce any smell more offensive. It had been said they would fly in fondness to a man who had a nosegay of sweets about him, and that they would sting any who carried stinks; but Mr. Reaumur made the experiment and found it false. There are wonders enough in the real history of these animals; 'tis wrong to disgrace them with false and fictitious tales to make all suspected.





for they are so minute that neither the eyes, the hands, nor the understanding of man, nor our instruments we use can examine them justly. The same must be acknowledged of the muscular fibres of the jaws or teeth, since we are incapable of discovering their excellent construction and beauty, or of justly describing or delineating them. I shall, however, say something of the feather-like hairs of the head of the Bee, when I treat of those of the thorax; which I shall now proceed to describe.

The external figure of the thorax is in the upper part convex, but towards the hinder parts it is sinuated, and is adorned with a somewhat prominent margin about its extremity. On each side of the anterior part there appear the scapulæ or shoulder-blades, by which the wings are joined: a little lower on each side under the wings and scapulæ are seen the points of respiration; whereof the orifices are oval, and surrounded with a horny margin. The under face of the breast is divided into two parts, which are stretched somewhat obliquely and bent downwards, and give insertion to the last pair of legs joined to the lower edge, as the first pair of legs are articulated with the fore parts of the breast: these, when the head is drawn from the trunk of the body, adhere to the head, and are pulled off with it. The breast is of a horny or bony substance, and is thick set above, below, and on the sides with feather-like hairs, which are of equal size and length in the upper region of the breast. These hairs, which are distributed over the whole surface of the body, and are found even in the head of the common or working Bee, as also between and under the horns of the males, are all of them, as hath been said before, perfectly like downy feathers, and particularly like the down of Swans, or those remarkable hairy feathers conspicuous in the tails of Peacocks; the middle stalk of which feathers is surrounded with many scattered lateral hairs.

Before I proceed to the dissection of the internal parts, I must repeat again that Bees produce their humming noise with their wings only: since the small, membranous, moveable wings at the shoulders, may easily produce such a noise, by means of the air propelled from the subjacent pulmonary tubes: for no points of respiration open into the mouth, which is to be well observed: to this may be added, that the narrowness of the trunk is not adapted for modulating the air; if any of the latter should be impelled thither out of the stomach, in which indeed I have found air. The wings of Flies are wonderfully formed in that part where they make this noise; though this structure is very different in the various kinds. Some Locusts indeed make a noise by the rushing together of the wings; and for this purpose nature has given them near the hinder part of the wing towards the breast a singular small part, which,

when moved, forms a distinct sound like a thin plate of metal. Other species of Locusts make a noise by rubbing their wings against their legs. Crickets and Mole-Crickets modulate the air in such a manner by the help of their wings, that the chirping noise they make is produced from thence. The Grasshopper has two peculiar small drums, like the drum of our ear, which, being struck by the help of two lunated cartilages, vibrate the air in such a manner as to produce that sound. Beetles make a noise by rubbing the horny parts of their head against the articulations of the breast, and the parts about the tail with the cases of their wings. All the insects to which nature gave singular organs for making a noise are of the male sex: this may be seen distinctly in the Locusts, Grasshoppers, and others, the females of which make no noise. In regard to the wings of Bees, we may observe they are here and there bristly, and that the veins and nerves conspicuous in them, are only scattered pulmonary tubes, by the help of which, as we have before expressed in words and figures, the wings are for the most part expanded.

The contents of the thorax are various: they are the moving fibres of the legs and wings, and also some which are designed for moving the abdomen, and others for moving the neck. These muscular fibres fill almost the whole thorax. The other parts to be found there are the pulmonary tubes, some fat, the gullet, and the spinal marrow: all these I shall now pass by, and only say something of the muscular fibres, and shall then proceed to the contents of the belly. On this occasion I shall give a description of the spinal marrow. The muscular fibres of the breast, as we have already related, fill its whole cavity, and may be divided easily into those which move the fore, middle, and the hinder legs, and into those which serve to move the wings: for where these parts are situated, there are seen the tendons of those fibres, which are afterwards expanded and fleshy in the thorax, and afterwards becoming tendinous, above in the upper region of the breast, are there fixed as it were into an horny little part. The fibres which are implanted in the middle of the thorax stand almost perpendicular, but those which are inserted somewhat lower towards the sides, are more oblique; and those that are in the anterior part united to the legs, run entirely oblique and are almost flat. Where the muscles are fixed to the wings, there is a kind of distinct articulation, besides that by the help of which the greatest motion of the wings is performed. If the fibres of the thorax are separated from each other, they divide into oblong hairs, as it were, which are connected with delicate, white, nervous, and transverse fibrillæ, and are at length here divided so minutely, that I must desist from further search; being filled, as before, with admiration of the divine Architect, who here





Next the vasa deferentia are placed the feminal vesicles *dd*; these are wonderfully large, and are full of feminal matter; they are whiter than snow, and are of a very fine texture. They seem, indeed, to be of a glandular construction, only that the muscular fibres also, by the help of which they are contracted to cast out the sperm, run through them; such a contraction is common to all the other muscular fibres, after they are drawn out of the body: I have seen even these vesicles, after being taken out of the body of the Bee, contract and wrinkle themselves up by degrees. Here we should well observe, that near the beginning of the root of the penis two remarkable nerves *nn* are inserted in the spermatic vessels, and which give many branches both to these vessels and to the root of the penis, contributing to the motion and titillation of these parts. That part of the spinal marrow *m*, from which these nerves arise, is here delineated somewhat laterally. Near these nerves likewise, there appear two other little parts or ligaments *ll*, by the intervention of which the genital parts are tied or fastened in their places in the abdomen, so that they cannot go out of their proper situation without force: this, however, I would not have understood of the root of the penis, and some other parts which are moveable, as shall be shewn hereafter.

Near the orifices of the feminal bladders and vasa deferentia, when the latter are more contracted, the root of the penis shows itself, Tab. XXI. fig. 1. *ee*; it is a considerable long and crooked tube; it becomes the more dilated and distended, the more it advances toward the outside, until at length it expands itself into a globe of considerable thickness, and being then somewhat contracted again, it forms at last a more considerable oval tubercle or swelling. On the inside in this dilatation of the root of the penis, there adheres a pelucid horny part, of a deep brown, but somewhat ruddy colour, and set with small cavities *f*. This part appears to be divided in the middle, and in that place is seen the limpid and clear colour of the penis. In the anterior or fore side, but a little on one side of the part just now mentioned, may be observed two other horny, shorter, and smaller parts, which seemed to be joined together. The structure of the root of the penis is nervous or cartilaginous, not yet hardened. Where this root is distended with sperm, it is much whiter than where its substance is more plainly seen, being in such parts limpid, and not so white, but rather resembling glass. This is the case likewise in the feminal bladders; where these, not yet swollen with the feminal matter, present their proper substance to view.

Under the little part just now described, and somewhat on one side of it, appears the penis *g*, or the part that seems most analogous to a penis; of this I shall speak more largely hereafter. On the other side is seen *b* that the genital vessels, which appear to be distinguished into five

divisions, and a little lower, and as it were on the other side, there is seen another similar but undivided little part *i*, which when dissected is found to be shaggy, unequal, and as it were bristly. The former little part which is divided by five rings, appears also to be of the same structure. These three hinder little parts, as well as the subjacent and hollow appendages *kk*, appear wrinkled and contracted, like compressed, tender, and delicate membranes; the reason of which will be soon shewn. The feminal vesicles therefore, as has been observed, and the vasa deferentia, as well in their beginning near the testicles, as where they terminate after they have grown narrower, as also the root of the penis, every part of these is pellucid: wherefore, whenever they are discharged of seed, they appear like white glass, or like veal, or any other jelly: but when the sperm is separated in the vesicles or root of the penis, there is then a very fine appearance, as of glassy marble or agat, distinguished or variegated with white spots. This is a short description of what belongs to the structure of these parts: many things more may be observed, which I shall defer to another opportunity. If we consider the use of these parts in coition, and the manner the sperm is secreted, these are indeed so admirable that they almost surpass all that has been hitherto said. For the little part which we have called the penis *g*, as also the other part with its five rings *b*, and the closed and pointed appendages *kk*, are all of them erected, and in the erection turn and invert themselves in such a manner, that their internal surface is turned perfectly out: this is done in the same manner as we take off our glove, or pull the skin off a Hare or other such animal, by turning the inside out. Hence I am in doubt whether this should be called an erection, rather than an inversion, produced by the heat of the parts; all these parts are at the same time also distended with air. Indeed I do not remember to have hitherto seen any thing in nature wherewith I can compare this action. I am sensible that Snails turn out their horns, and take them in nearly in the same manner; but the air contributes nothing to this, the whole action is evidently performed by the help of conspicuous and elegantly constructed muscles; but this does not happen in regard to the erection in the Bee. If many Bees are kept together in a box, it frequently happens that these parts are observed to turn themselves out of their body in the manner just mentioned: and on this occasion I have also found that the same thing may be effected by art; that is, by taking the body between the fingers, and then expressing or squeezing these parts out at the hinder part.

When the male is about to discharge the sperm, or to erect or rather evolve the penis, then, that I may now speak in general of the extuberance of the genitals, the closed and pointed appendages are turned out. This is performed in these as well as the rest of the parts,

parts, by the air which is impelled inwards, for at that time they are all inflated with wind. The inversion of these parts is performed in this manner; the extreme and hairy part, Tab. XXI. fig. III. *r*. of the pudendum is first forced out by the Bee, and then the horny *q q* extremity of the same pudendum is likewise advanced out from the last rings of the body, and at the same time the root of the penis *e e*, together with the said horny part *f* contained in it, starts or is thrown forward, and the vasa deferentia *c c*, and feminal vesicles *d d*, are likewise drawn somewhat towards the fore parts. Afterwards the four distinct little parts begin to swell and throw themselves out of the body; that is, the two pointed appendages *k k*, the pyramidal particles *i*, and the fine ringed little part *b*. Before these four parts are erected and thrust forth, one may see in what manner they swell forwards through four distinct little cavities, such as are seen in the fingers of a glove, when you have just begun to invert them. And further, one of the closed appendages, as also, the little part with its fine rings are seen through the skin.

The appendages, as I have already observed, are first inverted, and their basis is then turned out, Tab. XXI. fig. IV. *l l*, when we see their closed extremities still lying between them and not yet inverted. But the pyramidal little part also *i* is then unfolded more and more upwards, as well as the fine ringed little organ *b*; the horny part also situated at the root of the penis *f* is then propelled or pushed further forwards, and is fixed higher in the horny little part of the pudendum *q q*; but the hairy part of this is no way changed in its situation.

Then the appendages being by degrees entirely inverted, appear distended and swollen, Tab. XXII. fig. I. *k k*, at which time the root of the penis *e*, together with its interior little horny part *f*, are moved yet farther outwards, and this begins to penetrate somewhat deeper into the cavity *g g* of the horny or bony part of the pudendum: the pyramidal little part *i* also is now turned further out, and the little part with fine rings *b*, which is then partly inverted now appears to the eye: however, the shaggy part *r* of the pudendum as yet suffers no change.

But at this very time the pyramidal little part fig. II. *i* is at length all turned out and expanded, and the other little part likewise shews itself: it has five divisions, and short bristly hairs; and it now appears very elegantly and beautifully bent *h h*. This makes the more agreeable sight, as these five divisions are of a bright red colour, but the rest of this little part is membranaceous and whitish. The closed appendages *k k* retain their figure, and only the horny little part situated in the root of the penis, is by degrees more and more thrust out, and is further introduced into the horny part of the genitals. Hence it happens that the root of the penis *e* becomes straighter, whilst the

shaggy part *r* of the pudendum still remains as it was.

If one continues to press out these parts further, the skin being the pyramidal little part, and that which has five divisions, is by degrees widened and distended; and hence it afterwards happens, that what is called the penis, fig. III. *g*, appears there in this manner; it turns itself entirely out, exhibiting a membranaceous structure, and beautiful corrugations in the head *t*. Then the pyramidal particle *i* likewise becomes entirely unfolded and expanded; and the horny little part *f* enclosed in the root of the penis, is entirely, with a great part of the root itself, pressed out of the body. This is forced through the middle of the horny, Tab. XXII. fig. III. *q q*, and hairy *r r* part of the genitals: hence the little part with fine rings is then likewise dilated and extended so far, that on each side it appears wholly reclined towards the hairy part *r r* of the pudendum. As these parts are pellucid, the horny little part *f* is seen through the skin of the penis, whilst in the mean time the little part with fine rings being plainly drawn down under it, resembles as it were an expanded membrane, and appears marked with some lines or bright red grooves or furrows, between which are seen its five divisions. I do not think it necessary to delineate all and each of these: but the closed appendages *k k* are then, without any regard to these several changes, observed to remain in their former figure and situation.

Whilst these parts are in this state below the penis as it is called *g*, is seen a considerable aperture *u*, which appears underneath and between the divisions of the horny little part situated inwardly at the root of the penis; through this aperture, not only the said little organ but a great part of the root of the penis may be forced, and thus will cause the sperm to flow plentifully from thence. The before described cavity of the genitals seems from hence, therefore, to be the true passage *u* of the sperm, though for some time I have attributed that office to what is called the penis *g t*; but I observe that this as well as the other parts is closed and has no orifice. Wherefore I cannot imagine what use this little part is of; as I do not yet conceive the purpose of that other little part, which one may take for a penis. On the contrary, I think I very clearly see that the internal horny particle *f* is made in order to dilate the root of the penis with its stiffness, and to preserve it when opened, by which an easy passage is given to the semen through the latter. Indeed, in my opinion there was a necessity for such a caution, on account of the great impetus wherewith these parts are forced out; for if that little part were not hard as horn, the said passage would be easily squeezed together, and consequently the ejection of the seed hindered. But whether these particles which are inflated with air, contribute to propel the rest of the parts out of the body, and whether



males themselves, or the cells whence they are excluded. To which may be added, that other creatures impregnate their females only by contact, or by asperion or sprinkling, as is plainly the case in Fish. In the fish kind we see plainly, that the eggs or spawn cast by the female into the water, are only sprinkled or dashed with the melt or sperm of the male, and are by this means fecundated. The same thing holds with respect to the Ephemerus, whose female flying in the air drops her eggs into the water, and the male then seeks after them, and sprinkles and fertilizes them with his sperm. As therefore the water serves Fishes as a medium, through which the impregnating virtue of the sperm is communicated to the eggs, shall it be thought improbable, that the air is a medium of the same kind to the Bees, by means of which the subtile particles of the seed dispersed through the hive, are transferred to impregnate the ovary of the female? Indeed the whole constitution of the genital organs of the male confirms this opinion. The same is likewise intimated by those very strong feminal vapours, which are perceived by the nose, when even but a few males, at the time of swarming, lie enclosed for some hours in a box. To the reasons hitherto advanced may be added, the golden or incomparable observations of Harvey, by which it is indeed evidently demonstrated, that even in man and in brutes the sperm never comes to the uterus, but that the more subtile and scarce perceptible particles of it change the whole body at the time of coition, and according to what I observed in the human species, impart or give a more perfect animation and motion to the eggs, while they are still in the ovary. That the semen never comes into the uterus, appears most certain from the following experiment: let the penis of a Dog in the act of coition, be tied behind the knot which it then forms, and immediately cut off, and let the female be instantly opened, all the sperm will be found sticking in the vagina. In domestick fowls the Cock only emits his sperm through two small apertures, and rubs it to the vulva of the Hen; for he has no penis nor any remarkable production of the vasa deferentia: in other instances these unite in one common channel, or, as in us, are produced out of the body by the help of the urethra: but in the mean time the subtile particles of this gallinaeous sperm thus rubbed on the body penetrate through the membranes, nerves, vessels, nay, through the whole body of the Hen, though they be intended to affect and impregnate only her ovary. In the same manner nearly the seeds committed to the earth, or being only on its surface, we see are affected by the earth's moisture; so likewise a little barm, or yeast, ferments, moves and prepares the whole mass. The little part which appears like a penis in the Bee, is wonderfully small and delicate, and of a very beautiful structure; and hence I preserve it in my collection as a thing very worthy of contemplation. One doubt

may be still objected to the hypothesis that I have advanced concerning the odiferous impregnation of the female Bee, and that is, that the female at the time of coition may thrust the extremity of the vulva into the body of the male, as is evidently the case with some species of Flies. But I answer to this, that the extremity of the uterus in this female is not made in the same manner as it is in those Flies: besides that these arguments, by which I have before alledged that the male cannot easily approach the female, and that no coition can be performed amongst the whole swarm of the busy and noisy Bees, still remain unsolved. To which add, that it must be first very evidently proved, that the aperture observed by me about the horny little bone in the root of the penis, out of which I expressed the seed, is natural, and in its natural state is emitted so far out of the body. Nay, and if all these suppositions were taken for granted, yet it would be hard to demonstrate that this coition of the Bees is like that which obtains among those Flies. The coition indeed of the Hornets, which is nearly related to the Bee kind, seems likewise to contradict this opinion. But, perhaps, some will rather maintain, that as soon as the female hath broken its cell, the male immediately creeps into it, and begins to copulate with her while yet in the cell. And among many other reasons this may be alledged as one, why the cells of the females are much larger than those of the other Bees. But all these matters are merely conjectural, and they are not only contrary to the structure of the genital organs, but they ought not, nor can ever be admitted as certain, only so far as they are established by trial; nor can I think it is impossible to know by experiments how this female is impregnated. However, my opinion is, that this impregnation happens by means of the effluvia only; it remaining thus far sufficiently ratified and confirmed. The female, therefore, at the time of swarming, becomes fecundated by only the seminal effluvia of the males, which diffuses itself in the hive; and hence the tripple seed in the ovary of the female acquires its fertility; that is, some thousands of the eggs, out of which the working Bees are produced, then some few eggs out of which the females are excluded, and some hundreds which produce males. But the two latter species of Bees are not generated in the hive until the year following, unless when the hive is to swarm again the same year; for then the males issuing from thence perform that business again for the subsequent year.

If the reader views the admirable structure of these genital organs, and the exquisite art conspicuous therein, according to their worth and dignity, he will indeed see that God, even in those minute insects, and their parts, has concealed from the incurious eye, stupendous miracles; nor is it difficult to discover and illustrate these things, provided one sedulously applies to their investigation. Consider, therefore, what a progress acute and sagacious geniuses may make











Bees, and a quantity of honey in the Lion's carcass \*. However strange this event may appear, even to the ingenious and sagacious observer of Bees, I can discover nothing like a paradox in the relation. The context clearly proves that the thing happened in the midst of summer, at which season the carcass of any animal that had perished by a violent or natural death, would in a short space of time be so entirely cleared of its flesh, as to form no more than a skeleton. In this the Bees might find a commodious habitation. Is it not a common thing to meet on the roads with the ribs and other bones of dead animals, so thoroughly stripped of the flesh, and at the same time covered with part of the skin so dried, and in a manner tanned, by the weather, that insects may find under it sufficient shelter and convenient lodging? No doubt: the text runs as follows: After some days Sampson found a swarm of Bees in the Lion's carcass. We must, indeed, understand by these words, that the interval between his killing the Lion and finding the honey in its carcase was not very long; nor is there any occasion for understanding them otherwise, since at the time that Bees swarm, there are many insects, especially the Worms from which the common Flies spring, which, from their ravenousness and great numbers, may devour, in a few hours as I may say, the carcasses of dead animals to the very bones. There are many species of Flies that will smell a carcass at a great distance, and immediately deposit their eggs on it, as a proper place for their little Worms when hatched, as they very soon are, to find a food suited to their nature. It is almost incredible how fast these Worms will grow, and how suddenly they will eat up all the flesh of a carcass. I have experienced this by hanging a dead Duck to the branch of an apple-tree, at the season when Bees swarm: in three days after the Worms have suddenly broke from their eggs, the Duck's flesh and entrails have been entirely consumed, nothing remaining but the bones and a few tendons, so that with very little pains it might have been formed into a perfect skeleton. We see in this instance how greedily these Worms devour, and how fast they grow, immediately upon leaving their eggs. The same observation also has been before made by that curious naturalist, the illustrious Redi, in his experiments concerning the generation of insects. His words are these: "What was most surprising, the Worms were so much grown by the next day, that they each weighed about seven grains; whereas before twenty or thirty of them did not exceed one grain. The other Worms that still continued to come from the eggs began, as I may say, in the twinkling of an eye, to devour what

" flesh remained on the Fishes, soon leaving the bones quite bare like so many skeletons, that would not have shamed the hands of the best anatomist in Europe." I remember that as I was once travelling on a very hot summer's day through the province of Utrecht, in my way to Culemburgh; in order to make some observations on the Ephemerus, I took notice of a dead Horse that lay by the side of the road, and was so full of Worms, that no part of its flesh could be any longer distinguished; nor was the number of these insects more surprising, than the waving motion they produced in the remains of the flesh; bowels, and other parts of the carcass, which by that means appeared in a manner still possessed of life and motion. A great number of the Worms, unable to find room and nourishment in it, were then crawling on the road; where the heat and dust soon stifled them. Another time I had an opportunity of observing to what a degree of perfection these are possessed of the sense of smelling; for having put some little Worms hatched from the eggs of Bees into a box, in order to trace and examine, if possible, their change into Bees, a few of them died; they were no sooner dead, than, the box not being well shut, some little Flies took notice of their carcasses as a proper nidi for food and shelter to receive their eggs. Accordingly I had Worms produced in them in a very short time, which at length changed to that species, which I call the fourth order of natural mutations, and in a few days after perfectly resembled in size, structure, and form, the Flies from whose eggs they were originally produced. Things of this kind occur most frequently in very hot summers; for then both the Flies and their Worms are multiplied in a surprising manner. When the bones of animals have been once cleared from their flesh in the manner already mentioned, it is no difficult matter to conceive how they may in a little time be so washed by rain, as scarce to be distinguishable from the purest ivory.

As then it plainly appears by the history of Sampson, that his adventure of the Lion happened about the time when Bees swarm, make their combs, and fill them with honey, we must of course suppose it was during the great heats of summer, when Flies lay their eggs; so that the offspring of these eggs might, in all probability, have devoured the flesh and entrails of the Lion, within the time requisite to solve all the difficulty that can be started upon this occasion; besides, alternate rains, sunshine, and dew, may be easily supposed capable not only of bleaching, as already said, but of purifying also, and freeing from all manner of stench, or disagreeable smell, the bones that remained, so as upon the whole to make the carcass, or rather

\* The construction of the cells of the Willow Bee is very extraordinary, nor are these found in combs: they are frequent in our fen countries. I have seen thousands of them in Lincolnshire; the Worms make themselves cases of the leaves, and bury themselves in the rotten part of the wood. The Worm of the working or hive Bee is a very weak creature, but these are vigorous and active: they wrap several entire leaves round their bodies, and fasten up the ends of this hollow cylinder with pieces of other leaves gnawed off for that purpose, and stuck together with a kind of wax, made principally from the buttons of water flowers. Thus they lie covered and buried till their change. This shews nature uses various methods.

the skeleton of the dead Lion, a proper place of reception for those little cleanly animals. We are not to imagine with the generality of mankind, that Bees at the time of their swarming send out before them as it were some of their nobles or courtiers, to prepare lodgings for the rest of the company; by no means: the whole cluster seizes the first opportunity of fixing themselves, be it house or tree, or the corner of a wall, no matter whether high or low; and if they do not find their situation agreeable, or if no body comes with a hive to receive them, they soon fly off again, and so ramble about from place to place, till they find of themselves, or till some one offers them, a convenient habitation. And thus it is probable that Sampson's Bees had acted, till they at last settled in the Lion's carcase, where they built their combs and deposited their honey: God himself, who governs all things, and from whom this work, or, as the holy writings express it, Sampson's conduct proceeded, directing the motions of these little insects, so as to afford a subject for a riddle, and consequently a just excuse for delivering his people. I had once an opportunity of observing how irregular Bees will swarm, in a house belonging to Mr. John Oort, now magistrate at Nieuwenrode, that had greatly suffered by fire. I found the swarm in one of the remaining walls, where they had made both wax and honey; but their choice of this place was highly imprudent, for the hole by which they were to go in and out of their habitation was so large, that they could not by any means keep off the winter's cold, and their number also so small, that they had not provided food enough to subsist them at home on the severe days when they could not go abroad. Sometimes I have seen swarms of Bees hanging to the topmost branches of the loftiest trees, and at other times, content with so humble a situation, that the cluster their swarm formed in a manner touched the earth.

It is probable that the not rightly understanding Sampson's adventure of the Lion, gave rise to the popular opinion of Bees springing from dead Lions, Oxen and Horses; and this opinion may have been considerably strengthened, and indeed in a manner confirmed, by the great number of Worms that are often found during the summer months in the carcases of such animals, especially as these Worms somewhat resemble those produced from the eggs of Bees. However ridiculous this opinion must appear, many great men have not been ashamed to adopt and defend it. The industrious Goedaert has ventured to ascribe the origin of Bees to certain dunghill Worms, and the learned de Mei joins

with him in this opinion; though neither of them had any observation to ground their belief upon, but that of the external resemblance between the Bee and a certain kind of Fly produced from those Worms. The mistake of such authors should teach us to use great caution in our determinations concerning things which we have not thoroughly examined, or at least to describe them with all the circumstances observable in them. Therefore, although this opinion of Bees issuing from the carcases of some other animals by the power of putrefaction, or by a transposition of parts, be altogether absurd, it has had notwithstanding many followers, who must have in a manner shut their eyes in order to embrace it. But whoever will attentively consider how many requisites there are for the due hatching of the Bee's egg, and for that insect's subsistence in the Worm state, as has been particularly explained in the preceding pages; whoever, I say, considers all this with the attention it deserves, cannot be at a loss for a clue to deliver himself out of that labyrinth of idle fancies, and unsupported fables, which, entangled with one another like a gordian knot, have even to this day obscured the beautiful simplicity of this part of natural history. Nor need we complain that by overturning this system, we lose examples by which many moral precepts may be enforced; there will remain a sufficient number of solid observations to answer the same purpose. Thus mutual love, friendly cohabitation, and uninterrupted course of good offices, observable amongst Bees, who behave in all this as if they were actuated by christian principles, and lived in a real communication of all good things, with their industry, by which their happiness is constantly increased, are powerful motives to engage us in the same practices. It is this love, this communion and diligence, that governs, supports, gives motion and life to their little republics; and if we contemplate the institutions of the primitive christians, we shall find they lived in the same manner.

It is a difficult matter to determine any thing in regard to the period of life which nature has allotted these insects\*; at least I must own that I have not as yet been happy enough to hit upon any satisfactory experiments on this head. Some persons who have made Bees their study, affirm as a certainty that working Bees live but one year, and I am not averse to their opinion, though I do not think they have as yet any sure observations to ground it upon. On collecting all the Bees that die in a hive in one year, we find their number equal to that of the surviving. In autumn and winter, when the Bees neither fly abroad, nor carry their dead out of the

\* The Bee, which is so able to defend itself in the perfect state, is, while in the condition of the Worm and Nymph, liable to destruction by that most contemptible creature the Mite. Millions of these get into the hive, whose passage would be desperately defended against larger assailants; and they make their way into the cells and devour them. This was first observed of a kind of Bee that breeds in rotten willows, and the account is given at large in the Philosophical Transactions. It has since been discovered in the common kind; and the mischief has been often done where it was not suspected how.

hive, an idea may best be formed of the degree of mortality that prevails amongst them: at those times their dead carcasses are found at the bottom of the hive by handfuls together. Now, if by adding to those that die in this manner, all such as fly off and never return, or that perish in the fields in cold and rainy weather, or are devoured by Swallows and Dragon-Flies, dashed by the wind against the leaves and branches of trees, or entangled in the webs of Spiders, we may easily guess that a far greater number of them perish within the year, than those which are to be found alive in the hive. We likewise observe in the autumnal season, that the wings of Bees are often mangled, broken and wounded, and they appear so also in the beginning of the spring; whereas at the time when they swarm, their wings are found, entire, and in good order: all this makes it more probable, that Bees live but one winter, or from one season of swarming to another. They may sometimes, however, be observed to continue in the same hive for years together, provided part of the wax is now and then taken away; but this happens in the same manner that in great and populous towns the number of inhabitants is kept up by those who come by degrees into the world, and insensibly succeed such as sickness, accidents, or old age, carry off. Besides, the working Bees which have outlived the swarming season and the winter, have performed the task assigned them by nature, namely, that of keeping each other warm in the cold weather, and nursing the rising generation: which necessary tasks being done, it is found that all other insects hitherto observed, and some a little sooner, and others a little later, perish. Those for example which immediately shed all their sperm, disappear before the rest; as is plain in the Ephemerus, whose eggs are arrived at their full perfection from the very birth of the parent, and so provided for by nature, as to render the parent's care of them altogether needless, whereas other insects must live longer, either because the maturation of their eggs requires some time, or because their eggs require a slow hatching. This is the case with the female of the Bees, and some other insects; hence we may very probably conclude, that the female of the Bees lives longer than the working kinds, as it is impossible that she should lay all her eggs at one time. However, it is not yet so certain as we might wish how long she lives. I believe it might be easily known by following the advice of Clutius, and contriving to make her so that she could be readily distinguished; and the best way to do this, would be, I imagine, to make a very little puncture in her wings, or else to cut off some inconsiderable portion of them with a pair of scissors, or otherwise to stain the edges of them with some oil colour. Thus we might soon learn in a certain manner, what space of life nature has assigned to this little creature. I am of opi-

nion that she either dies, or grows barren at the age of two years. But it is by no means so easy to try this or any other experiment I can think of, upon other Bees, on account of their numbers, and our not knowing the exact time of their birth. The working Bees come into the world at almost every season of the year; and although the young Bees appear in greater numbers at the swarming season than at any other, yet they are hatched some earlier than others by one, two, three or four months; for some of them do not creep out of their eggs, till a long time after the swarming time; and this I have likewise found to be the case with the males. Add to this, that the female is very assiduously employed in laying her eggs so early as the month of March, which makes it necessary that some of them should be hatched sooner than others; and consequently this renders any judgment we should form of the length of their lives altogether uncertain; for how is it possible, where there are such numbers, to distinguish between the old and the young? Certainly no one can do this: nor is there any possibility of alledging any thing certain concerning the natural extent of life allowed the male Bees, though I believe it scarce exceeds six or eight weeks: but I cannot affirm that I am supported in this opinion by any sufficient experiments; and I fancy that if any can be made to ascertain it, they will cost a great deal of time and trouble. Some persons have assured me that they have seen male Bees alive in winter, when the female Bee had not been so fruitful as she generally is. Be this as it will, I can only say, that all these things deserve to be more attentively examined; for as the male Bees every season suffer a violent death, nothing as yet can be determined concerning the natural extent of their lives. In the mean time, as I have, said I am not against the opinion of those who suppose it but six or eight weeks. There are some observations which induce me to think it is thus, besides those general laws of nature, by which these little animals are doomed to die, as soon as they have executed the commission given them by her of propagating their species; for this business being over, the male Bees become altogether useless. This is plain in the Ephemerus, and likewise in the Silkworm Butterfly, which generally dies the third day after laying its eggs, unless the season happens to be cool, for then these insects will live longer. I believe this is owing to a plain cause, that the vital juices of those little animals who eat nothing during their appearance in this form, do not exhale so readily in cool as in hot weather, and consequently the means of life longer remain.

I have made a collection of about three thousand insects, such as Butterflies, common Flies, Beetles, Locusts, Caterpillars, Worms, Chrysalides, water insects, and others; amongst which I must not forget to mention, six kinds

of wild Bees \*: the first of them is that which builds its nest with small stones, grains of sand, and clay; and in this respect so much resembles the Humble Bees, that we may indeed reckon it of their number. There is another species, Tab. XXVI. fig. iv. of a singular structure: its head and thorax differ scarce at all from those of working Bees; but its belly is altogether different, for this part is thick set with hairs of a yellowish red, so as to look as if it was sprinkled with some liquor of that colour; its last ring is armed with three sharp prickles, and there are two more points of the same kind on the second of the rings forming the belly. Its legs are covered with yellowish hairs, but that which grows under the horns, on the fore part of the head, and between the divisions of the breast and belly, is almost white; as to the length and bulk of the body, it nearly agrees with the female of the working Bees, except that it is somewhat shorter. The third species, fig. v. is of a thicker and more compact body, and in size and stature nearly resembles the male of the working Bees, but it has shorter wings; its head and eyes are formed in the same manner with those of the working Bee; but under each antenna there is a yellow spot, which may serve as a mark to distinguish this species; besides, the upper part of its trunk is coloured. The breast and head are covered with gray hairs, and the extreme joints with pretty long hairs of the same hue, but somewhat darker. The fourth species, fig. vi. is remarkable chiefly because its antennæ or horns are three times thicker and four times longer than those of the working Bees. Its trunk also exceeds that of the working Bee in length and thickness. Moreover, all its back, or the upper part of the thorax, and some parts of the belly, are adorned with bright red hairs inclining to yellow. This circumstance, with the extraordinary size of the horns, is the best distinguishing mark of this species. It is also one third larger than the working Bee. The fifth species, fig. vii. is on the other hand somewhat less, and differs in its colour, and the hairs growing on its limbs, from all other Bees. The hairs of its breast and legs are of a deep gold colour, and the two upper joints of its hinder legs, which are likewise the largest, are quite covered with hairs of the same kind and colour, but much longer; whereas there is no hairs at all on the lower joints. The extreme borders of the rings that constitute the belly are also adorned with the same kind of hairs, only that they are of a flesh colour, and much shorter. The sixth species, Tab. XXV. fig. x. is somewhat less than the working Bee; the hairs of its head and breast are of a more

dusky colour than those of the Bees before described. On the other hand, its belly consists of blackish rings of a substance between bone and horn, and streaked on each side with little lines at some distance from each other. The coverings of the legs, which are of the same substance with the rings of the belly, are yellow, and the legs themselves are thicker than those of working Bees or Wasps, which makes me imagine that this little creature is provided by nature with no small degree of strength. All these six species of insects agree with the three other kinds mentioned before, in this, that they have all six legs, four wings, and two antennæ or horns, and are divided into the head, thorax, and body. There appear also in some of the species three small and separate eyes, besides the two great ones. The six last species are very seldom found in swarms together; they generally ramble alone and by themselves, which makes it probable that they do not dwell together like working Bees. They are seldom found in the fields, but often in flower gardens, where the flowers supply them with honey. As to their gathering of wax, some appear quite unfit for that task, on account of the great quantity of hairs that grow on their legs.

I preserve also two kinds of Hornets, of different sizes, which I therefore distinguish by the names of the greater and lesser Hornet. They are eight times as large as the working Bee, and resemble it much less than they do the Wasp. They have four wings, fig. ix. *aa*; the outer pair are fixed to the shoulder-blades, of three times a greater extent than the inner ones. They have also six legs joined to the fore part of the breast, and the extreme joints are armed with two sharp claws *bb*. The head *c* is somewhat oblong, especially when the teeth or jaws lie close together. The eyes are formed like a crescent, and above in the interval between them there are three separate small eyes, under which there are two horns. The Hornets have likewise two very strong teeth or jaws, divided into a great many very small ones, and between the two principal teeth they carry a very short trunk. The body is joined to the breast, which is pretty broad, by means of a very slender thread as it were, and consists of six pretty stout rings of a substance between bone and horn. These are yellow at the edges, but red on the upper part, and equally marked with dark brown furrows, from which on each side run eight spots formed as it were by the sprinkling of a brown liquid, but on the second and third ring, reckoning from the head, there appears a ninth spot, so as to form something like a

\* Besides the addition careless authors have made to the Bee kind, by ranking two winged Flies among the number, we have eleven distinct species in England. Mr. Ray, who was indefatigable in these researches, counts nine; and since this two others have been found. They are very small, one is black entirely, the other black and red on the body: they make regular combs, and are found principally in the west of England. They build in cracks of rocks, in walls, or in very dry banks of earth.

triangle. The head, breast, and legs, are almost of the same colour, and they are covered with very delicate hairs. The sting is produced from the opening of the lower ring, Tab. XXVI. fig. ix. *d*.

Of the Wasp kind I preserve nine different kinds, amongst them is that which I found in the nest I have already mentioned, as made by the Bees that use little stones for that purpose. The greatest difference that occurs between the various kinds of Wasps, consists chiefly in size and colour, though in one or two kinds there is besides a great disagreement in their structure. But I shall not dwell long upon these particulars. The larger kind of Wasp is above three times as big as the working Bee, and has like them and Hornets, six legs, a proboscis, two eyes, two horns, and four wings. The body of Wasps, as well as Hornets, converges to a point, and is shaped in the same manner with that of the particular Bee which vulgarly goes by the name of the king Bee. The rings of the body are variegated with blackish spots, and circular furrows upon a yellow ground. This general description will, I hope, be sufficient to shew what kind of an insect the Wasp is. That represented in fig. viii. is somewhat less than the largest species of all. Under it is to be seen another of a very singular structure, fig. xi. \*

I have besides these eight kinds of Humble Bees or Bombylii, which differ from each other in size and colour. One kind has its body exceeding black, and is furnished with most beautiful wings of a colour between azure and purple. The largest kind is seven times as big as the largest working Bee; and this has a pretty long trunk. Its legs notwithstanding are small in proportion to its size. The head is somewhat oblong: the eyes are formed like a crescent, and the horns lie directly between them. The breast is very broad, and it is covered thick with rough hairs; from the bottom of it spring six hairy legs, which if compared with the body, are very short, and from the upper part of it rise four wings; the inner pair very small. The belly is very broad and hairy, and somewhat pointed on the lower part. The hairs that grow thus on the belly, are placed principally near the rings of it, and they are of a great variety of colours, as white, yellow, red, black, and others in some kinds; whereas in other species they are only of two. The Humble Bee, or Bombylius, of which I here give a drawing, Tab. XXVI. fig. xii. is of a middle size.

Of the Pseudosphecæ Ichneumon, or bastard Wasps, I have by me twenty-five kinds.

These differ from each other in size, colour, and structure. I refer them to the Wasps merely on account of the external resemblance which some of them have to real Wasps, from which, however, in generation and disposition they widely differ: most of these proceed from a Chrysalis, after having lived some time in the form of a Worm. These alterations are performed in a very surprising manner; and as that from a Nymph to a Wasp takes up three or four weeks, the several gradations of it in point of colour, growth, and expansion of members may be very accurately traced. Some of these bastard Wasps which I preserve in my collection, prey upon Flies; others upon Spiders, whose legs they break to pieces and then devour them. There is likewise amongst them the Fly called *Unifata*, or one bristled, having one hair at its tail, and that which is distinguished by the name of *Tripilis* or three-haired, fig. xiii. for these Flies are all bastard Wasps: I cannot now treat particularly of them, as it would require a large volume. For the same reason I omit speaking in this place of the disposition, nature, method of propagation, and structure of Hornets, Humble Bees, or Bombylii, and of the true Wasps; nor do I choose to say any thing of the insects called *Vespatæ* or short Wasps, their building, houses, and other remarkable particulars, of which I have some specimens. I am possessed of a most curious Hornet's nest, fig. xiv. and xv. as likewise of the male and female Hornet, the Worm from which they originally proceed, the web in which this Worm is enclosed, the exuvia it casts off on becoming a Nymph, and all the excrements it voids, together with the internal coat of the stomach and intestines. I can likewise shew the Nymphs of Hornets at various periods of their changes, and the rudiments of those new colours which they by slow degrees attain. As to the internal parts of Hornets, I have the membranaceous net-work of a stomach of one, some pulmonary tubes, one of the silk or spinning bags, and a spinal marrow.

In my collection also are various kinds of Flies so like Bees, that some authors have called them by that name. Such is Goedaert and J. de May's Bee, which has only two wings. This is a sufficient mark to distinguish these insects from each other, though there are some Flies that have two pair of wings. Such is one in my museum, which is very beautiful, furnished with tufted antennæ, and in other respects like a Bee, only that it is a great deal larger. What is most singular in this Fly, is its proceeding originally from a water insect. But as I have already said an

\* Some of the Bees breeds with us in the free air, not in a hive or comb. The young are bred up in the cases of the lilac or other leaves; and there is something very extraordinary in the manner of their hatching. The cells seem to close up the passage of one another, and it would be thought the young creature in the hindmost must eat all the rest to pieces to get out, for they are built in succession after it: but though the whole case of cells be the work of many days, the young all hatch together; the eggs laid latest having obtained a forwardness in the body of the female, which make them disclose their young as soon as the first.

entire volume would be requisite to describe all these particulars; for which reason I shall here make an end of this treatise upon Bees. Certainly the nature, disposition, and structure of these insects are so surprising, that they without ceasing loudly proclaim God's goodness, wisdom, power, and majesty; and indeed all other animals, according to their several ranks, do him honour in the same manner, and constitute in the air, the water, and upon the earth, so many instruments and voices to

publish his praises. I will join the universal choir, and say with the four and twenty elders in the Apocalypse, "Thou art worthy, O Lord, to receive glory, and honour, and power; for thou hast created all things, and for thy pleasure they are and were created." I shall conclude this long essay upon Bees with the words of the royal Psalmist.

"Praise him all ye angels of his; praise him all his host." Psal. cxlviii.

## Some peculiar observations relating to the history of Bees.

*A description of a hive opened the tenth of March, with an account of the number of cells it contained.*

ON the tenth of March last I opened a hive \*, in which a young swarm of Bees had been settled during the month of June, the preceding year, but they all died in the intervening February for want of honey. I examined the cells built from the month of June till the winter season, that is in the space of about four months, and counting them one by one, I found them to amount to 22,574; and the whole of this prodigious number was only of that kind of cells, in which the working Bees are hatched and nursed, or the honey and Bee-bread is stored up. Those in which Bees had been already hatched, amounted to 7814; for it was very easy to distinguish them certainly from the others, by means of the skins and webs found in them, such things being always left behind by Bees that have been hatched. All the other cells were formed for keeping honey, and the other cells are made to answer the same purpose, as soon as the young Bees contained in them have acquired wings to fly abroad.

It appeared likewise that all these cells were contained in nine combs, as they are generally termed, or nine portions of the whole wooden structure, and these portions were large, oblong; of different forms, some diverging equally, others running out into two, three, or four angles. This variety in the figures of the combs is owing to some of them being built alone by themselves, and others close to each other; or to the necessity the Bees were under of keeping clear of the sticks placed across the hive to support the wax, for this occasions them to make their combs sometimes of a triangular, and sometimes of other forms. Nor can we perceive, that in this business the Bees observe any certain rule or order, since the figure of the cells themselves does not suffer by this liberty they give themselves.

Many of the little cells in which the honey was stored up, were twice as long as those intended for nests and nurseries, and were also irregularly built, crooked, and full of angles. Even the sides of the hexagonal cells did not every where exactly correspond with one another, but here and there might be seen a gap large enough to contain a pin's head, a thing never to be met with in a truly regular comb.

All the half combs of cells on one side of the perpendicular foundation, which runs through the middle of them, and against which the cells are horizontally placed, were built full one half as long again as those on the other side. There appeared here also many other irregularities, not to be seen in the cells that had served the purpose of hatching, such of them at least as had been quite finished.

From this prodigious number of cells, built between June and September, or October, we may entertain some idea of the great number of those that the Bees construct from the month of March to the June or July of the following year. I believe they may amount to 50,000, as this is the time for supplying with cells the male, female, and working Bees: but as yet I have not counted them.

A person fond of Bees, and whose account I could credit, once told me that he had a hive placed upon the bare ground, and exceedingly well stocked with Bees, insomuch that to make room for their combs, they had hollowed out the earth under their hive, extended their constructions very deep into this hollow, and thereby increased their numbers to a prodigious degree. But this is oftener practised by Wasps and Hornets, as these insects naturally make their nests under ground.

\* The danger of being stung by Bees may be in a great measure prevented by a quiet and composed deportment; and even when they have given the wound, the same sedateness is the best conduct. A thousand Bees will fly and buz about a person without hurting him, if he stand perfectly still, and let them alone: but if he strike at them, probably he will be stung. If this happens, he should suffer the Bee to rest upon his flesh in quiet: if it be let alone it will draw out the sting, and the consequences will be less troublesome; but if disturbed, the sting is left in, and the wound is much the worse.

*A hive opened the 14th of June, the number of Bees and Nymphs found in it, with a particular description of many other singularities not as yet known.*

IN the beginning of June I bought a hive of Bees, it produced a swarm the 14th of the same month. I received the young Bees in another hive, and put this hive in water the day following, with all its new inhabitants. By this means I found the swarm consisted of one female, four males, and 2433 working Bees, who had not made any wax since they swarmed.

The 16th of the same month, I likewise drowned in the same manner the Bees that remained in the original hive, from which otherwise a second, and even a third, swarm might have been expected. In this hive I found one female, 693 males, and 8494 working Bees. While I was employed in counting them, I let the water run off from the hive, that I might afterwards satisfy my curiosity in ascertaining the number of their cells, but I found the amount so great, especially that of the cells belonging to the working Bees, that I thought proper to desist, for fear of losing the opportunity of making some other observations, that I imagined better deserved my attention.

I therefore reckoned with great care and exactness the little dwellings of the female Bees, and found nineteen of them as yet building, but some a little more forward than others. There were besides fifteen more, in shape resembling a pear, and quite finished, which were all closed up with wax, and curiously disposed on the edges of the combs. Some of them stood by themselves, others lay close to each other, three, four, or five together. Others again were built quite close to the cells of the male Bees; some were situated obliquely; others horizontally, so as to resemble a beer glass lying on its side; and, in the same manner, all the cells of both males and working Bees. Some on the other hand were built in an inverse position, with their openings looking downwards, as the cells of Hornets are generally found. Finally, I discovered the cell of a female eat through on the fore part, being that out of which the young queen Bee had escaped that led the swarm of the 14th of June.

In nine of the cells belonging to the females, which I found closed up as just now mentioned, there were as many female Bees arrived at their full size, and furnished with wings ready expanded; and some of them were still alive. Some of these females were quite gray, and others of a somewhat darker colour, according to the time that had elapsed since they had changed their skins, and that which they were still to continue within the cell. Not one of them had as yet attempted to open itself a passage to fly abroad.

In the other five of the covered and closed up cells belonging to the females, I found as many Nymphs of females. One of these five cells contained a Nymph, which already begun

to grow gray on the back, and was upon the point of throwing off its old skin; but in the other four Nymphs there was no appearance of this colour, they being as it were still in their infancy, and for the most part resembling in whiteness the curds of milk. The eyes alone had by degrees acquired a watry purplish colour, and the same might be observed of the three distinct smaller eyes, which are more conspicuously perceivable in the insect, while it remains in this state, than afterwards when grown to its full perfection.

Under the belly and tail of these Nymphs, I found the exuviae and air tubes that had dropped from them, on their exchanging the form of Worms for that of Nymphs. I could also perceive the remains of their food, which on pouring water upon it looked like soft starch, or gum tragacanth, beginning to swell; it was of the colour of pure amber, and of a somewhat subacid flavour.

In the upper part, under the wax with which these fourteen cells were closed up; I could discern the web which the Nymphs spread in that part, while they continue in the form of Worms. The upper web was very strong, and made of distinct threads, but in the lower part of the cell it looked like a membrane; for at the time these Worms labour to shut up their cells with such webs, they are obliged to move their bodies in every direction, and thereby rub their food, and perhaps too their excrements also against their work, so as to fill the intervals between the threads that compose it with a kind of glue, and thereby reduce its surface to an evenness like that of a natural membrane.

I opened besides all the closed up and covered cells of the males; many of these cells were situated near those belonging to the working Bees, and contained in a single comb, hanging at the bottom of the hive. The rest of the male's cells were built in the midst of those of the working Bees, with common party walls or partitions. Of these closed up cells belonging to the males, I reckoned in all 858. In 234 of them I found as many Worms, which had not as yet changed to Nymphs, but some of them were nearer that period than others. In 146 cells there was the same number of milk-white Nymphs, which had but just thrown off their skins. In 44 more cells the eyes of the Nymphs were just beginning to acquire a watery and light purplish colour. In 414 other cells I found as many Nymphs, whose eyes were of a deep purple. And lastly, in the 20 remaining cells there were Nymphs just upon the point of shedding their skins, and appearing in the form of male Bees: the gray and hairy members of the young males appeared plainly in these, through the transparent membrane which still enclosed them.

After this I reckoned all the other male cells, and found them to amount to 1508, of which 720 were entirely empty, the male Bees sometime before hatched and bred up in these, having taken their flight; 268 more were not as yet perfected, nor had been used for hatching; 520 of the same cells, in which also no Worms had been yet hatched, were full of the purest virgin honey. I counted besides all these 1701 empty oblong cells, which, though considerably bigger than the male cells, were not unlike them: neither had any hatching been performed in these, their form not being regular enough for that operation; therefore they could only serve to lay up honey. This circumstance likewise makes me imagine that these oblong cells are not to be looked upon as male cells, but to be reckoned amongst the store houses which the Bees build for their winter provisions; for we find they make cells of the same oblong form, but like the cells of the working Bees, to answer that purpose.

The number of closed up cells belonging to the working Bees amounted to 6468, and in all of these I found Nymphs under the same variety of circumstances with those which I had found in the male cells. It is therefore needless to waste words in explaining their different appearances, nor had I leisure to count the numbers at every period of growth and step towards their perfection: besides some of these Nymphs began to have a very disagreeable smell.

I reckoned also 210 cells full of Bees-bread, which was also heaped up here and there in the combs of the working Bees, in particular cells disposed between those which had Nymphs in them, or which were full of honey, but none of these bread-cells were closed up.

As to the remaining cells, those newly built, as well as the empty ones, in which Bees had been hatched, and those constructed the year before as store-houses for honey, or nurseries, I had not time to count their prodigious numbers. Neither did I count the closed cells, which were disposed in the upper part of the hive, and were now ready to burst with honey. But my curiosity led me to weigh the honey itself, and I found it amounted to seven pounds.

In all this hive I did not meet with a single egg, nor with any Worms, but such as were full grown; so that by this time the working Bees must have got over the heaviest part of their yearly labour, for there was no longer any necessity for building cells, or nursing of young Bees, nothing more remained but the agreeable task of gathering honey for the support of themselves, and of the males and females, and making preparation for the second, third, and fourth swarm, which I could easily see were to be produced from the different stages in which the Nymphs of the future queens appeared, and from the different periods at which it was of consequence necessary these should make their appearance abroad. This induces me to believe,

that the old females continue, even during the intervals of swarming, their labours for the propagation of the species, as I have already observed in describing the hive opened on the 22d of August.

Many of the working Bees belonging to this original hive were still of a grayish colour, which is a certain proof that they have not been long out of their cells. Nor did I observe one amongst them that had lost its wings; whereas such crippled Bees are frequently seen in spring or autumn. This circumstance makes it probable, that most of the last year's male Bees had been taken off by a violent or natural death, and succeeded by a new generation. Nor need this opinion appear improbable to any, for if on the 14th of June I could count 6468 Nymphs in one hive, and 2433 Bees in one swarm, we may easily guess what a prodigious number of Bees must be produced in the interval of time between March and June; and that between June and September; no doubt a multitude sufficient to supply a hive with a number of new inhabitants, three times greater than that of those which had possessed it the preceding year, or summer months, supposing them all to have unfortunately perished: the queen alone survives a longer time, though I can scarce believe her life is of above two or three years.

As by what I have here observed, it plainly appears, that fifteen young female Bees had been produced in one hive, and in the space of time required for one swarming; and as experience informs us that Bees seldom swarm in this country above three or four times, and that after the last swarm they kill their queens, which are then no longer of any use, we may conclude that at this time the old and impotent queen undergoes this fate, and is succeeded by a young one, better able to propagate the species. This opinion indeed stands in need of more experiments to confirm it, and such experiments may be easily made by any one who is willing to sacrifice a few hives to his curiosity.

It is surprising how tenacious of life Bees are; after the hive and all its inhabitants had, in consequence of my orders, been kept under water for a considerable time, and I had begun to count them, as if they were perfectly suffocated, they began by degrees to recover life, as it were, and fly about the hive, so that I found myself under the necessity of causing them to be again put under water, and though I had reason to think none of them could outlive this second submersion, yet there appeared many after it with signs of life, and some of them recovered themselves so well as to live after this three days and two nights without eating.

That I may now exhibit at one view every thing, that I observed in the original hive, and in the swarm produced by it, and that the sum of both Bees and Nymphs added together may be more distinctly known, I shall subjoin the following account:

One



One full grown queen in the swarm,	1	at which time 2438 of them issued forth in search of a new habitation.
One full grown queen in the original hive,	1	The number of cells, the old and new built ones, those which were shut up and contained Nymphs; the empty cells, and those of working Bees full of honey*, or Bee's bread, all excepted, was as follows:
Full grown queens in the closed up cells,	9	Cells of queens begun or finished
Full grown working Bees in the swarm,	2433	Cells of males shut up, empty, and those which, after the Bees had left them, were filled with honey,
Full grown working Bees in the original hive,	8494	In all
Full grown males in the swarm,	4	Do not all these particulars display in a surprising manner the instinct, diligence, and dexterity, which it has pleased the all-powerful Creator to bestow on these little insects?
Full grown males in the original hive,	693	
Nymphs of queens,	5	
Nymphs and Worms of working Bees,	6468	
Nymphs and Worms of males,	858	
These numbers added together make	18966	
for the total number of all these little animals contained in a single hive before it swarmed;		

*An account of several wonderful particularities discovered on opening a hive, that had a few days before received a young swarm.*

**H**APPENING to be in the country on the 25th of July, I observed a great swarm of Bees, which, on its hanging to an Elm, I ordered to be received into a hive; but in a little time they all left this new habitation, and fled back to the elm, where they hung entangled by each others legs. The female Bee had not dropt into the hive with the others: I was therefore obliged to have recourse to another shaking; when having brought the female into the hive, all the rest soon followed.

On the 26th of July the weather was tolerably good, with a bright sunshine; the 27th cloudy; the 28th and 29th rainy: on the 30th on examining the hive, I found at the bottom of it upon the ground where it stood, a piece of a honey-comb, which had fallen thither, either because it had not been strongly enough fastened to the top of the hive, or because too many Bees had lighted upon it at one time. This piece of a comb contained 418 cells for the working Bees, some were building, and others were finished, and there were also ten eggs sticking to the wax by one of their ends. All the forenoon of the 31st it was rainy and about midday very cloudy and windy, with some rain. In the evening I ordered the hive to be taken into my chamber, in order to examine what the Bees had done in the space of these six days.

But as I was afraid of being stung in this enterprize, I resolved to have all the Bees killed before I went to handle or inspect them, for this reason I fumigated them with a bundle of lighted matches rolled up in linen rags, to such a thickness, that it would just fit in the upper opening of the hive. All my endeavours to kill these Bees this way were however to no purpose; for after plying them with this fume, from eight o' clock to eleven, lighting the matches from time to time, as they went

out, the Bees continued alive; but they seemed grievously complaining of, and resenting the injury offered them, with the most horrid noise and loudest buzzings.

The next morning all was quiet again, so I removed the hive, at the bottom of which I found some hundreds of Bees lying dead upon the ground; but the greatest part of them were still alive, and some of them were beginning to fly away. I therefore resolved to fumigate the hive a second time, and I gave its inhabitants liberty to escape while it was doing. For fear of being stung on this occasion, I took a half pint bottle, and having rolled some soft paper about the neck of it, thrust it into the opening of the hive, taking care afterwards to stop all gaps between the door or opening of the hive, and the neck of the bottle with more paper of the same kind. As soon as the sulphureous vapour began to fill the hive, the Bees in the greatest hurry and confusion and with the most dreadful buzzing, rushed to the number of 1898 in a manner all at once into the bottle, which I then removed to substitute another in its place; and by repeating the operation in this manner, I at last so thoroughly accomplished my purpose, that not the least noise could be heard in the hive.

Having then turned the hive upside down, I found the queen lying dead, in appearance, upon the ground, and some of the others which had fallen upon the ground, killed downright and wet all over; whilst some other Bees that had remained in the upper part of the hive, were quite dry, and when put into the bottles flew about as briskly as if they had not received the least harm.

I next poured some water upon the prisoners I had in the bottle; by this means they were all drowned in a very short time. I then made my examination, and found the swarm con-

\* Maroldi, by the most careful examination, and on the result of the strictest calculation, has proved that the pyramidal figure of the bottom of the cell in a honey-comb is determinately and exactly that, in which the substance of the cell takes up the least room, and the space contains the greatest visible quantity of honey.

sifted of 5669 Bees, and was therefore a very good one, according to the judgment I had formed of it on its first appearance. Nevertheless, as the season was very far advanced, and the spot the Bees lighted upon very ill furnished with materials for making honey, I thought it worth while to sacrifice them to the curiosity I had of knowing what work such a number could perform in so short a time, and withal in so unfavourable weather.

Among this great multitude, there was but one female Bee. The greatest number of them were working Bees, which are neither males nor females; and there were besides these and the female Bee already mentioned, only 33 male Bees, preposterously called by the vulgar hatching Bees; for the young Bees are hatched by the mere heat of the summer, and that which is caused by the perpetual hurry and motion of the old Bees flying about, or working in the hive. It is very remarkable that the bottle into which the first 1898 Bees driven out of the hive had been received, was thoroughly heated by the perpetual motion of these imprisoned creatures, and the warm vapours which exhaled from their bodies.

The number of waxen cells begun and finished, including those of the comb I had found on the ground on my first examining the hive, amounted to 3392: they were all of the same size and form, and were intended only for nests to hatch the working Bees. In 236 of the cells some honey had been stored up, but it had been afterwards made use of, as very little could be then gathered abroad. It was no difficult matter to distinguish the cells thus made use of from the others, for they had received a yellow tincture from the honey deposited in them; whereas those which had not as yet been employed this way were of a shining white.

There were also 62 of these cells, in which the Bees had already begun to lay up their ordinary food or bread called erithace. This substance was of a changeable colour, between a yellow and a purplish red; but perhaps this tinge might be owing to the fumigation: the whiteness of the unemployed wax was in some parts also impaired by the same means; coloured and covered besides with black spots.

In 35 cells I found as many eggs fixed in them at one end, so that including the eggs found in the comb, which had fallen to the ground as already mentioned, there were 45 eggs in all. There were besides in 150 of the cells so many new hatched Worms, but these lay almost insensible and motionless. They were of different sizes, the largest of them being very like that represented under the letter *c*, fig. XIII. Tab. XXIII. All these Worms were surrounded with that kind of food, which the most expert observers of Bees think is honey thrown up by the old ones, out of their stomachs. This kind of honey is white, like a solution of gum traga-

canth, or starch dissolved in water, and is almost insipid: it shews nothing remarkable on being viewed with the microscope. In the Worms themselves I could perceive pulmonary tubes of a silver whiteness running most beautifully on each side through their little transparent bodies.

I examined attentively the wax cemented by way of foundation to the top of the hive, but I could find no difference between that and the other wax of which the cells consist. They appear both to have the same nature and properties. I could not, however, but admire this strong union or fastening; this substance being just spread upon the hive like a crust, and consequently fastened to it by a very small portion of its surface; whereas the rest of the wax hung perpendicularly from this foundation, without any lateral or other support whatsoever, as if a wooden bowl were fixed to a plain ceiling by a small part of its circumference.

This hive contained the rudiments of a great many more such combs of wax, of an oval form, and full of cells on each side: the empty spaces left between the combs, for the Bees to pass and repass, did not exceed half an inch in breadth, so that it is plain the comb I found open upon the ground, and in which I reckoned 418 cells, had been torn from its foundation by its own weight, and that of the Bees walking upon it. Hence it appears, with what good reason those who keep Bees, place sticks crossways in their hives, that the combs may have the more support; and accordingly we observe that in these hives, the Bees themselves on each side suspend their combs to these sticks.

Considering the great multitude of Bees employed in building the waxen cells, which I have been just examining, there is no great reason to be surpris'd at their having done so much work that way, though the time they had to do it in was so short; and the weather so unfavourable. But it is really astonishing to think how a single female could lay so many eggs in the same small interval, and withal deposit every egg in a separate cell, and there firmly fasten it. We must also allow some time for laying the perpendicular foundations. It is, moreover, very surpris'ing how these eggs should so speedily turn to Worms, and how those Worms should grow so very suddenly to their state of change. But I must now conclude, and I shall do it with the following account of what the hive I have been describing contained.

33 males.  
1 female.  
5635 working Bees.  
3392 wax cells, for the use of the working Bees.  
45 eggs.  
150 Worms.  
62 cells containing Bees bread.  
236 cells in which honey had been laid up.

T H E

B O O K of N A T U R E ;

O R, T H E

H I S T O R Y of I N S E C T S.

P A R T II.

---

*A catalogue of the insects, which are referred to the second method of the third order or class of natural changes, called the Chrysalis.*

**I** Now proceed to describe those insects which belong to the third order, as the preceding; but which present their several parts less conspicuously. For this reason, I judged that the present order of transmutations might be properly divided into two kinds or modes; though the one of them differ from the other only, as the schoolmen say, by accident.

Among those insects, which pass through the second method of the third order or class of transformations, and by force of the increasing and swelling limbs, and other parts, by which the skin is at length torn or burst open, assume the form of a Chrysalis, which exhibits to view all its parts, though more obscurely than they are seen in the Nymph; I reckon, in the first place, the diurnal or day Butterflies\*, which are called Ulinders and Pennevogels by the Hollanders; and are distinguished also by two or three peculiar names of Albuli (Witkens), Papiliones Butyracei (Botercapellen), and Cerdonus (Schoenlappers).

Of these diurnal or day Flies, some are heavy and slow, others lively and swift; so that they cut the air, and move various ways. I preserve in my collection eighty-five species of those; among which, there are thirty-four foreign ones from Africa, America, Brasil, Spain, France, and elsewhere.

Among the day Butterflies beforementioned, there are twenty-two very large ones, thirty-three middle-sized ones, and thirty very small.

I preserve also some of their Worms or Caterpillars, several of their Chrysalides, and some

of their Worms, which are partly Caterpillars, and partly Chrysalides. I can demonstrate, in the state of nature, in what manner the Butterflies are placed within their last skin; in which, when enclosed, we call them Chrysalides; and their parts, though still very minute, may be yet distinguished by their respective colours. I can shew how their wings begin to grow protuberant, after casting this skin. I likewise preserve separate the claws, intestines, stomach, and trunk of the Butterflies. I can likewise exhibit to the eye after what manner all the colours of the future Butterfly are seen through this skin, when the Butterfly is about to cast it, this being its last skin. I can also demonstrate all the parts of the Butterfly already in the Caterpillar. I pass over the mention of a great many other things worth observing, which I preserve, on this subject, there being now no time to enumerate them at large.

On a proper occasion, I shall explain the method by which Butterflies, with their wings at large, may be expressed and formed, in all their beauty, in plaister of Paris,\* without any colours. This I think an important piece of art, and it has not yet been described by any one that I know. I shall at the same time shew how Caterpillars may be filled with suet, with plaister of Paris, with air, and the like, and by this means be preserved. This is effected in none more conveniently than in the rough and hairy Caterpillars, the colours of which are permanent, as I can exhibit to the eye by several specimens.

\* The Flies produced from Caterpillars are of two kinds, distinguished by the time of their flying abroad, and the form of their antennæ, or horns. They are called diurnal and nocturnal Butterflies, or more distinctly Butterflies and Moths. The Butterflies appear by day; and they have naked horns, terminated by knobs or buttons. The Moths fly only in the night, and their horns are feathery, and have no buttons at the end. The Fly represented Tab. XXXIII. Fig. vi. is a Moth, that Tab. XXXV. Fig. xii. is a Butterfly.

I shall likewise give the several methods whereby the wings of insects may be variously expanded and displayed, in a form perfectly agreeable to that they have in nature. Upon this occasion, I shall also teach by what means the wings of insects, which are as yet hidden in their original folds, may be produced to light; and, when expanded, may be dried and preserved at pleasure.

If I further have leisure and opportunity, I propose to describe an art or management, to shew in what manner monstrous and deformed wings are made to grow; and shall propose, with these things, various operations, relating not only to the accretion of these wings, but to the motion of the humours, which are conveyed through their vessels. Finally, I shall also shew in what manner pustules, tubercles, pimples, and the like irregularities, may be raised in these kinds of wings. I shall likewise subjoin many other, hitherto unheard of, curious experiments, which I hope will be useful to natural philosophy, and to medicine. All these I am now obliged to pass over with this slight mention, since they cannot here be treated of at large.

Whether or not the accurate Fabius Columna found out, with certainty, from the examination of the aliments, on which the Caterpillars, that are to be changed into Butterflies, live. What plants are like each other, in respect to their virtues? Is a question worthy the inquiry. He tells us, that whatever different plants the same Caterpillar eats, are of the same nature and virtue. Other naturalists also affirm, that each species of Caterpillars has only one kind of nourishment suited to it; so that hence its own peculiar Caterpillar seems to be assigned to every plant on which we see them feed. From this, if it be so, it necessarily follows, that the different plants, which one and the same Caterpillar eats, must certainly agree in regard to their virtues; and many species of plants may by this means be considered, so far as medicine is concerned, as one. Others, on the contrary, deny the fact: nay, and experience itself teaches, as Mouffet very well observes, “ That there are  
“ a sort of strolling Caterpillars, which do not  
“ suffer themselves to be tied down to any  
“ particular leaves or flowers; but boldly run  
“ over and taste all plants or trees, and feed  
“ thereon at pleasure.” I have myself seen a Caterpillar, which eat the Brassica, or Cabbage: likewise feed upon the leaves of a Mulberry-tree. I found it feeding on both, of its own accord. I still preserve also the egg of the Butterfly, into which this Caterpillar was changed. It is grooved or channelled, like an elegant piece of workmanship, and surrounded with a purple circle.

We see Aldrovandus has described one hundred and eighteen species of Butterflies, of the nocturnal and diurnal kind. Mouffet exhibits eighty-six. In the figures of Hoefnagel are found fifty. And the ingenious Goedaert, has given us designs of seventy-seven nocturnal, and

eight diurnal butterflies. However, there is nothing to be found relating to these insects in those authors, beside the simple metamorphosis. Nay, Hoefnagel has given us only the figures. Goedaert has indeed described the Fly, hatched from the maggot found in cheese; but he explains it no further, than by a figure of the Worm, Nymph, and Fly; and he has given an inaccurate figure of the Worm.

But, what illustrious, what prodigious, what ineffable miracles of nature, present themselves to the careful observer in the changes of these several insects! It would have been much more useful, to have exactly, and according to nature, described only one transformation of any Nymph, for an example to be applied to all the rest, than to have delineated the changes of all these Caterpillars, with their various colours, and their Nymphs: for, according to the other practice, the things which were most useful and necessary, remain untouched and neglected. I have, however, some reason to know, from my own peculiar observations before related, what may be done in this study; in these I have laid open, in some degree, the mysteries of nature, and clearly exhibited to view the adorable wisdom observable in them. Indeed, if we seriously consider what admirable phenomena remain to be further investigated, and observed; and with what splendor, clearness, and beauty, nature exhibits herself in these insects; and how swiftly, yet how regularly she performs these great operations, we must own, certainly, that she appears, as it were, to have expended the utmost strength of her wisdom on them, and to have no where so liberally, and clearly presented her impenetrable and inexplicable miracles, to be viewed by those who worthily study her works.

Whilst the preceding sheets were at the press, the incomparable anatomical observations of Dr. Marcellus Malpighius, professor of physic and philosophy, in Bologna, on the Silk-Worm, and its Butterfly, which the Royal Society of London, instituted to promote natural knowledge, caused to be published this year, 1669, were kindly sent to me by the noble Thevenot, whose merit and zeal to promote natural knowledge, are sufficiently known to all who happened to be at Paris, and present at the weekly disputations instituted by him. And as the celebrated physician, just mentioned, seems to have attained, by his extraordinary accuracy, the end he proposed to himself in these celebrated observations; we may particularly remark, that after that exact observer, Andrew Libavius, he is the only person who excludes the fancied metamorphosis from the natural course of the changes, which the Silk-Worms undergo; and has published several things agreeable to truth: these, he confesses, became known to him by chance. I shall insert his words, as being most true, and worthy of perusal. “ And at length, within four  
“ days,” says he, “ in which time the heart of  
“ the Silk-Worm continues moving slowly,  
“ and the body is growing bigger, having  
thrown

“ thrown off the outward skin like a slough, the Aurelia appears as a new creature. The throwing off the old, and assuming this new form, is completed in the space of one minute and ten seconds; and it is thus done, as I happened to see it. The motion of the heart is very quick at first, and the whole frame of the body appears convulsed; so that the several circular folds of the segments emerge, and by the transverse construction of the sides, the external skin is separated from the inner; hence, upon making an effort, and thrusting the body, which now appears particularly thick towards the head, the skin is driven backward, and downward; and the portions of the trachea, being separated from their external proper orifices, are thrown away with the skin, which is then cast off. By this motion, a cleft or opening is made in the back near the head, and through the aperture, the rest of the body makes its way out; the skin being, by degrees, drawn back towards the fundament: This process is assisted greatly by a yellow kind of ichor, or fluid, which breaks forth from the cavities of the skull; and the Aurelia, or Nymph, appears then free and disengaged.

“ Whilst the insect is making its passage out, the horns, or antennæ, which are thicker and more slimy than the rest, are separated from the Aurelia’s body, and are torn, as it were, out of two cavities of the skull, beyond the place where they are inserted; and their length, as they become unfolded, occupies the same place, which the two muscles of the jaws formerly had. The wings also, and the legs appear to be circumscribed in their limits; the wings are drawn from their situation near the fore-legs in the Silk-Worm; and the legs, from the lateral parts of the back, which were before of a purple colour. But as these unfolded parts are yet mucous, they easily stick to each other, and, insensibly growing dry, they become so closely united, that the Aurelia appears like one entire garment. Now, as these parts are peculiar to the Butterflies, and are destined for their use, the nature of the Butterflies seems to be, to emerge sooner from the state of the Worm, than is commonly believed, and to be earlier implanted in it; for evidently in the Silk-Worm, the beginnings of the wings, may be seen under the second and third ring of the body, before the texture of the web. The antennæ, or horns, are likewise delineated on the skull; and the web being finished, they have their own termination; nor will it be improper to doubt, that the new kind of life in the Aurelia, is only a mask or veil of the Butterfly, which is already perfect within; intended that it should not be struck or destroyed by external injuries, but might grow strong, and ripen, as a fœtus in the womb.” Thus far Malpighius, whose last-recited words answer to those most evident experiments, which

I have formerly exhibited to the noble Laurence Magallotti, when he was travelling through our part of the Netherlands, with his most serene highness the Grand Duke of Tuscany, as I have before related. In this treatise I advance nothing particular concerning the Silk-Worm, except the figures of the brain, spinal marrow, and male organs of generation, which may be seen in Tab. XXVIII. fig. III.

Among the Butterflies which I have caught in the woods and fields, or on trees, flowers, and plants, and which I keep in my cabinet; there are several, which have been already described by Aldrovandus, Mouffet, Goedaert, and others: I shall therefore pass these over, without enumerating their Caterpillars in this place. Among Caterpillars, some are hairy, others naked; some have tails; others have antennæ, or horns, spines, wreaths, spots, grooves, tubercles, tufts of hair, and, as it were, brushes; some are distinguished by many, others with fewer colours; and a like difference is found in their feet. Some have heads like hogs, cats, and mice; others carry on them marks, as it were, of distinction; and some again are formed in different manners, and exhibit incomprehensible representations; so that they cannot be described by any detail of words; for which reason, Goedaert published them in their native colours.

In the mean time, whilst we are considering the glittering beauty of the Butterflies, we cannot but declare, that the conspicuous and beautiful tails of peacocks, and the showy feathers of the Ostrich, cannot be compared with the ornaments of these little creatures. Are not the wings of Butterflies most beautifully set, as it were, with pearls and diamonds, and with the turquoise, sapphires, and rubies, which increase their splendor to such a degree, that their base being made, as it were, of the substance of mother-of-pearl, and covered with plates of gold, silver, copper, or molten brass, surpass the colours of the rainbow, by the bright reflexions of the rays? That these little creatures might be exalted to the utmost height of beauty, nature has favoured them with four wings, one of which beautifully represents the other, as it were, in a mirror or looking-glass; whereas they might have flown with only two, and that most swiftly, and have cut the air in infinite meanders, surpassing all imagination; as any one may see on opening the under pair of wings. Some of the Butterflies, which I preserve in my cabinet, have oval, others round wings; some oblong, and some serrated; but, which is a very rare thing, one of them has wings on one side membranous, and on the other, only covered with the feathery or scaly dust; so that they consist partly of a bare membrane, and partly of one set with these feathers. I have likewise some, the lower wings of which terminate, as it were, in an acute tail; and in others they terminate in balls, or as if they had knobs on their tops: all these are diurnal. I proceed now to the nocturnal Butterflies.

In the next place then, we likewise refer to this order called the Aurelia, the nocturnal Butterflies, Phalænæ, or Moths. I preserve, and can shew the curious, one hundred and ninety-three species of these creatures; of these, thirteen are very large; twenty-eight of a middle size; eighty-six smaller; and sixty-six very minute. In this number there are thirty-five nocturnal, or night Butterflies; which, together with their respective Caterpillars, and their changes, have been described by Goedaert, and painted in their natural colours. I have likewise fifteen or sixteen species of the Chryfallides; some of which are naked or smooth; others rough, having cast the hairs of their outward skin; others are distinguished with wreaths and various colours; others are colourless and naked; and others are, as it were, interwoven, and exhibiting a representation through this web. I can likewise shew many of the eggs of these Butterflies; some of these are covered with hair; others surrounded with a kind of froth, and others again are hidden in other manners. I likewise preserve some singular and very beautiful webs, nets and membranes, wherein they enclose themselves, with the greatest circumspection, and in a most wonderful manner, when they are about to change: it is, indeed, hard to comprehend, how these little creatures can confine themselves in such close and narrow prisons; and can, though completed or folded up in these, perfect their webs\*.

The industrious Goedaert has delineated fifty-seven species of Chryfallides; but I am sorry to say, that among them all there is scarce one accurately represented, as I shall hereafter shew beyond a doubt. Indeed, a great many things occur, occasionally, in the figures of Goedaert, which should be corrected.

It is certainly worth observation, that, as well by the night as in the day, we observe innumerable living little creatures fluctuating in the air. This is not peculiar to the nocturnal Butterflies; for immense swarms of Beetles, and very many species of water insects, betake themselves to the air after sun-set. 'Tis for this reason we observe flowers, trees, fields, and gardens frequented, night and day, by innumerable insects, which seek for food upon them; that is, the great and supreme Creator, whose providential eye is always open on all created beings, appoints these creatures night for their day, and day for their time of rest, since all things are at his pleasure, and in his power. If at night you carry before you a lighted torch, you will entice towards you many species of such insects; and, when allured and deceived by the light, you may easily catch them.

Among the nocturnal Butterflies, which I preserve, there is one, a Moth, the largest that

has been taken in Holland. It is produced from a very destructive Caterpillar, with thin hair, which eats the bark, and even wood, of the Willow. This Caterpillar is called *Spondyla rubra* by Mouffet. I have sometimes fed it for a whole year on white bread only. Mouffet relates, that the largest Moths kill with their wings, and afterwards devour, the smaller kinds: but this, I have found, is contradicted by experience; for the Moths are provided only with a hollow trunk for their mouth. To which may be added, that many of these insects, as soon as they become fit for generation, entirely quit their former mischievous disposition, and, taking no food afterwards, apply themselves only to propagating their species. Indeed, some do it more late, others earlier; according as their eggs become more or less mature, whilst they lie in the habit of a Nymph, nay, and in the Caterpillar-form. Those kinds must be excepted, which have the care of feeding their young; for it is absolutely necessary, that such should be longer preserved alive also by nature, for the sake of their young. Those which are not obliged to rear their young, as the Butterfly kind in general, we observe, die very soon after they are produced in their winged state. So that hence we see, the whole change of these creatures is begun and finished by nature, with regard to their generation only; as is more evident from those singular observations I have made on Bees.

In the Ephemeri, nature has ordered the business of generation in a different manner; for, as she has denied coition to these insects, the females are obliged to cast their seed into the water, in the same manner as fish cast their spawn: this they do in the time when they beat and fly up and down on the surface of the water. On the other hand, the male Bees have air, instead of water, into which they discharge their sperm.

I preserve also that species of Butterflies, which the celebrated John Bauhinus has described in his treatise of hurtful winged animals, published in French in the year 1693. I have represented the Caterpillar of this species, the Chrysalis, and the Butterfly itself, in Tab. XXIX. Fig. I. II. and III. and have given it the name of *Pernix*.

I preserve likewise various species of those nocturnal Butterflies, known particularly by the name of Moths, because they are produced from worms of the same name, that eat cloaths; and others that feed on paper, books, and dust, as well as the leaves of trees. Among these worms there are some which, like Tortoises, carry their houses about them: this will appear in our succeeding particular observations. Between these Moths and the other nocturnal Butterflies, which are called also by the same general name, there is this difference, that the

\* All that is required to produce the perfect Fly from the Chrysalis, is the evaporation of the abundant moisture; and this will happen in a shorter time in hotter weather, and will require longer in cold. Hence, the period of the same species lying in this state, is varied by accidents; and that of different species, is also in its nature extremely various. Reamur has found, that eight days is sufficient for some, and that others lie as many months.

former rise immediately, and suddenly fly into the air; but the others, before they can fly away, make a noisy and tremulous motion with their wings. This we observe also in other creatures, which, after they have rested some time, are obliged thus to prepare themselves for flight. I have given the true figure of the Tinea or Moth of cloaths, in Tab. XLV. fig. xxxi. to which is subjoined in fig. xxxiv. of the same Table, another kind of Moth, generated from a Worm that goes in its theca or case. And in Tab. XLIV. fig. xx. I have delineated a third Moth, produced from the leaf of an alder-tree. Finally, I have delineated the honey-comb Moth in Tab. XXVI. fig. ii.

I can likewise shew in my collection that species of Butterfly, the male whereof is winged, but the female without wings: this privilege of the male is very singular and remarkable in this species. I have likewise observed, that the males of the Ants live free from labour, and have also four wings. Among the Bees the male has likewise this prerogative; it is discharged from all care of nourishing the young, and seems to be appointed by nature for generation only, not for nursing: it is for this reason probably that this creature's life is so short; and for the same cause we observe, that when the time of generation is over, these males are murdered by the working Bees. I preserve two kinds of males and females of the Butterflies, just now mentioned;

the former of which have larger eyes than the latter: this we likewise observe in Bees, Ants, the Ephemeri, and other insects. The female of the Brasil Caterpillar that eats wood, is likewise without wings; this appears to me plainly, from its Chrysalis which I preserve in my collection. I have likewise a second species of Butterflies, whereof the male only is winged: It was taken in France; and I have represented it in Tab. XXXIII. fig. viii.

I can in the next place shew some Butterflies, the wings of which are formed like feathers. Indeed we are to observe, that all the colours and different representations, which constitute the splendid pride of the Butterfly's wings, consist only of little feathers, differing among themselves with inexpressible variety of construction: this will be made manifest, when we shall treat of the manner, whereby those wonderful protuberances of the wings are formed in the Butterflies, and, with many other curious incidents, shall explain that most delicate increase of the wings. Finally, I can likewise shew the small Butterfly, which always flies in a straight line, having an oblong tail for that purpose; and therefore it does not, like other kinds of Butterflies, describe by its motion an oblique and unequal course in the air. Of this opinion is also the very learned Arnoldus Senguerdus, who, in his physical exercises, affirms, that the tail may have power to give an even, or uneven motion to those creatures. We add here,

*An example of the second species or method of the third order of natural changes, which I call the Nymph-Chrysalis, or Aurelia, exhibited in that species of the nocturnal Butterfly, or Moth, whereof the male is winged.*

TAB. XXXIII. No. I.

THE Caterpillar of this nocturnal Butterfly, or Moth, lying in its first coat or skin, which is called the egg-state, and is represented to the life. The first figure exhibits the egg magnified.

No. II. The same egg, or rather the hard or indurated shell of that egg divided into two parts. A microscopic delineation of this is again exhibited in the second figure.

No. III. The Caterpillar of this Butterfly having attained its full size, it is very worthy of regard, on account of its wonderful form. Behind its head are seen, Tab. XXXIII. No. III. *a.* four bundles of hairs, like so many cloaths-brushes; clipped even at the tops: these are of a white colour inclining to yellow. In the fore part, near the head, are also two prominent bundles of hairs, which resemble horns. These are hairs, *bb.* of a black colour, and consist of long, ragged, and uneven hairs; the tops whereof are adorned with a kind of branching feathers. On the two sides of the breast are seen, *cc.* two other feather-like bundles of hairs, placed very beautifully like oars. Just before these are placed, *dd.* two such other hairy oars; which, however, are much infe-

rior in the beauty of their structure, to the second pair just now described, and are of a yellowish white, being almost of the same colour with the four former even-clipped brushes of the back. The whole skin of this Caterpillar is here and there beautifully variegated with fine colours, which are constituted, *ee.* by certain scaly and short-haired little feathers, among which, the longer and loose hairs are every where interspersed; whilst, in the mean time, the skin itself is observed to be of a bright red colour. At the hinder part of the body, this Caterpillar has a superb feather-like tail, which resembles the antennæ or horns of insects, in form and colour. This creature has sixteen feet; the six fore ones are placed near the head under the thorax; eight are placed under the middle of the body, and the other two at the end, just above the tail. These Caterpillars are found plentifully in the gardens of Holland, living among the leaves of plum and cherry-trees, and in several other places.

No. IV. This figure exhibits the manner, wherein this Caterpillar has wound itself up, *aaa.* and settled itself quietly in its web. It begins in that to be somewhat immoveable about the thorax; and it is to be observed, that





## FIG. VI.

After delineating, under No. VI. the male Butterfly, together with its most elegant horns, its fine and slender body, and four expanded wings; I exhibit under the same No. VI. all these parts, but much more imperfect; viz.

*aa.* Two uncouth horns or antennæ.

*b.* A thick and distended body.

*cc.* Four short wings, or rather only rude portraitures of wings.

Hence it is evident, that it may be truly said that this female has no wings. We may, for this reason, see all its six legs without any impediment; though in the male they lie so far under the wings, that only the two fore ones are occasionally seen between the horns and superior wings; as is manifest under N<sup>o</sup>. VI.

In respect therefore to this species of insects, it deserves notice in what a wonderful manner the adorable Creator has established distinctions between the males and females; and what noble prerogatives he has given to one, and denied to the other, of them. Whilst beautiful antennæ, an agile and light body, and very swift flying wings, raise the male to the thrones and sceptres, as it were, of kings; the female, being deprived of all those remarkable privileges, and scarce able to bear the load of a swollen, tumid, and thick body, seems to be condemned by the most wise Nature, who has given sovereignty and dignity to the male only, to keep her nest perpetually, and take care of domestic affairs. Hence it likewise is, that this female, like a most prudent housewife, never goes out of her habitation; but is always fixing the fruits of her matrimony, that is, her eggs, to the surface of the web out of which she herself crept; as may be seen in Fig. III. Indeed, this custom of fastening the eggs to the web in a constant method, and, by the immutable law of nature, is so peculiar to this species of insects, that I have never hitherto observed it in any other kind whatsoever. This female, therefore, affords a beautiful instance of industrious housewifery; and, therefore, she deserves to be dignified with that name. The male, in due time, revisiting his female, and paying her the proper tribute of benevolence, shews, in his species, that he never deviates from the character of a chaste and honest husband; since he gives the assistance of his excellence and dignity to the female, and supports her weakness\*.

## FIG. VII.

The female is here represented, according to nature, so full of eggs, that her whole belly is distended with them; and as the integuments of this part is very thin, the eggs are distinctly visible through it. Nay, it is likewise seen how the skin turns and insinuates itself round the convex windings of the eggs, and runs into the little spaces between them;

so that it is like a cluster of grapes. In order to produce these eggs very clearly to view, the skin needs only (Tab. XXXIII. Fig. VII. *a.*) be dissected in the belly and back, and raised from the body towards the hinder parts; for then one may distinctly see after what manner they are placed within. These eggs are found to be of a round figure, when taken out of the body; and have on the upper part, as I have already observed, a purple ring: but, on the lower part, they are of a white glittering hue, like pearls. Their shell or skin is so hard, that when they are dried in the air, they are not liable to break; and, therefore, the natural preserved specimens of them will be always agreeable to the person who sees them.

It is very remarkable in this creature, that, when it is yet in the condition of a Caterpillar, one may, even then, manifestly see in it the rudiments of eggs. These, when the Caterpillar is changed into a Chrysalis, shew themselves much more distinctly, and, having acquired their utmost perfection, are at length seen thus elegantly in the Butterfly itself; that is, they seem watery in the Caterpillar: they appear in the Chrysalis, as it were, membranaceous and flexible; but in the insect itself they are hard, and resemble a real shell, very little different from that of hen's eggs; and, for this reason also, they will crack and break like an earthen vessel. From hence appears the reason, why these eggs retain their figure, when dried; for this is the case, with respect to all eggs that have a hard shell: whereas the contrary obtains, in all those that have a thin and tender skin; as may be seen in the eggs of Bees, and many other insects, which are almost entirely destroyed by drying them.

Before I conclude this history, it may be necessary to add something more concerning the parts of the Aurelia, that these may be the more appositely compared with the parts of the Nymphs, and the difference between them understood. When these and other Caterpillars are casting their skin, and presenting their before hidden parts to outward view, in the beginning of this change we observe them soft, tender, and somewhat moist; and this is the case likewise about the parts of the Nymphs themselves. But, a little after these several parts in the Chrysalides approach toward each other, they are then joined together; and indeed so closely, evenly, and equally united, that they represent, as it were, a continuous, smooth, undivided, and varnished skin. This is by no means the case in the parts of Nymphs: for they are not at all joined; but are only disposed near each other in such a manner, that one may distinctly see each of them. This is the true difference between the parts of the Nymph and those of the Chrysalis.

\* The progeny of the same species of Butterfly may, under favourable circumstances, be hatched at two seasons of the year; and consequently two generations, instead of one, may be produced in one year. Reaumur has observed, that the eggs of the Butterfly, which would be hatched in a few days if laid in summer, will, if deposited in autumn, lie till the winter; and, unless the cold have been severe, hatch the following spring. The Butterflies produced in about six weeks from the Caterpillars of these eggs, will lay their eggs in so warm a season, that they will hatch, and pass through all their changes into Butterflies the same year.

The reason why the limbs in the Chrysalis unite, and are, as it were, glued and fastened together, is, because the skin, investing the Chrysalis in that part where the union or junction is made, is considerably thinner than where it is exposed to the air. And therefore, on account of this inequality of the skin, it was absolutely necessary to preserve all the members from the drying air, and to defend them from injuries by their mutual compactness.

These things are circumstanced in the parts of the Nymphs in a contrary manner; for their skin is found to be equally thick in all the parts, so that it would be superfluous to unite them together. But, even in Nymphs, some parts sometimes occur, which are covered with an equal skin. This holds chiefly when some parts rest upon or are supported by others; and it is observed principally about the cases of the wings, which have a much thinner skin, where they receive the wings, than where they are turned to the air: therefore, in this respect, they entirely agree with the Chrysalides.

It certainly deserves great notice, how delicate and thin the integuments of those parts are, where they are found to lie on each other: and hence even the continued skin, which covers or incloses these parts, has its external part thick, and is strong and hard; but in the internal part it is thin, tender, soft, and formed like a spider's web. This skin sometimes also is so fine, that the rays of the sun exhibit therein various colours to the eye, especially where it is in any degree folded: as is observed in very thin and fine blown glass, and in the slender filaments of a spider's web.

This being well considered, it is easy to understand why many Butterflies are produced deformed; that is, when their limbs, under the period of the transformation, are not well united together, as frequently happens. Indeed I have, more than once, seen that they have dried and perished, by reason of this defect of a proper union. The same effect may be performed by art, and a certain operation: I mean, we may thus produce Butterflies that are deformed. I can also very easily disunite all the limbs of the Chrysalides; for, naturally, these parts in the Chrysalides will then never separate themselves further, not even at the time they are stripped of their skin: for the skins to be cut off from thence, have only three or four cracks or openings, since the thinner sides of these investing parts are then very easily broken further, with the least motion; so that there will be no need to move the respective limbs out of their places.

As those who search into the secrets of nature have not observed this, I am therefore inclined to think they have imagined, in consequence of this oversight, that the continued skin of the Aurelia consisted of a texture of the parts united one with another. They have therefore fancied, that the insect lies in that uniform and undivided skin, in the same manner as the chicken lies in its undivided shell.

But this is contrary to all truth; for every part of the Chrysalis, as well as the limbs of the Nymph, is invested with its respective integument. And this is the more incontestably certain, because these limbs, together with the skin wherewith they are surrounded, are found entirely perfect in the Worms and Caterpillars, and may be even there separated or disengaged; so that one of these insects is, in reality, always in another: as I shall hereafter describe, and absolutely prove.

Another remarkable thing in these Aureliæ, whereof we are speaking, is, that even the hairs of the Caterpillar cast a skin, and are afterwards seen in the Chrysalis. And hence arises another invincible argument, most clearly demonstrating, that the Aurelia is not a creature newly transformed, but is really the former creature, which has cast its skin. The whole change, or rather accretion of the parts and limbs, consists indeed only in this, that the investing membranes or skins, which are so many veils that obstruct the sight, are removed by degrees, and thrown off; so that the limbs, which, from the first, lay hidden in the inside, are, in the end, seen on the outside. In all these changes, nothing is more wonderful than the motion by which alone they are severally produced, and perfected by means too difficult to be investigated. The deeper we here look into nature, the more we are obliged to confess our blindness, and our ignorance. Indeed, there is nothing more true, than that all these things, which I advance and publish, are no more than the naked shadows of the inexplicable mysteries of the Great Creator: the internal nature, and true disposition, of these meanders are above the reach of our limited understandings.

I should never conclude, if I attempted to prosecute minutely all the wonderful things that occur in these Chrysalides: and, indeed, I should weary out the reader's patience by a prolix recital of them; since he must first have some knowledge of the history of these insects, who would properly understand what is delivered. I shall add but one thing more concerning the eggs of these insects: this is, that as the rudiments of these eggs may be perfectly seen in the Caterpillar, there arises from thence a still more powerful argument to prove, that there is no real metamorphosis or change, or real transformation of parts in the creature; but only a simple growth, or accretion, as in all other animals; only, that it is more considerable, and more admirable, than in the other creatures. I shall also add, that the egg itself is, in reality, no other than a little insect, the strength of which, by degrees, increases in its skin or coat; until it has at last acquired sufficient strength to break through this skin or shell, and cast off its first integument. It is therefore, from what has been said, clearer than the meridian sun, of what infinite use such experiments are to us; as those I have proposed, by way of specimen, at the end of the third chapter.

In the webs, which Caterpillars form, there is observed a wonderful variety; for as they serve them in the place of nests, every Caterpillar, according to its peculiar nature and disposition, forms and perfects its web its own way. Though these webs are constructed with wonderful art, yet those Caterpillars, which are enclosed in no web, excel all others in art and invention. Some of these, which bury themselves under the earth, are instructed to make caverns or holes in it so artfully, that they seem to have a more secure habitation there, than others in their walls. Some others, that remain above the earth, have the art to fix their webs with such stupendous dexterity to plants, trees, walls, and in hedges, that they safely hang with it, though exposed every way to the surrounding air; and are at length changed, after casting their skin, into very beautiful Butterflies. It is most wonderful, that these little creatures, at the time of their change, know how to disengage their claws from the web, and to change the skin of these their smallest parts, together with the separating exuviae; whilst, at the same time, they remain fixed by those claws in the web. Indeed, in this art, the Caterpillars by far excel the most active of the human species in their gesticulations. I have likewise seen some Caterpillars, which knew how to bite off a certain part of the leaves of trees; and, as in a safe habitation, afterwards have enclosed themselves therein, by the help of the threads they have spun. Others weave oval nests; others exactly round ones; others oblong ones; others make them channelled; others such as are like a delicate network; others angulated; some weave into their work wood, sand, shells, stones, and other matters: others simply, tho' very artfully, roll themselves up in the leaves of plants and trees. In a word, the wonderful ingenuity of Caterpillars is manifested in a thousand inventions; and in all of them the hand of the Great Creator is most clearly seen, who has infused so much prudence, as it were, and wisdom into those creatures, exhibited in order, weight, and measure.

I have particularly treated of the Butterflies hitherto described in the third chapter of this work; and I have shewn there, that the industrious Goedaert, in Part I. Obs. 59, and Part II. Obs. 30, has given a short description of them, and exhibited their figures; though he did not perfectly know these creatures, nor could distinguish the male from the female.

## FIG. VIII.

I have found these creatures, here treated of, not only in our part of the Netherlands, but also in France; but they were of a different species. This will appear by the eighth figure, wherein I represent these insects in the act of coition. The female of this species is absolutely without wings, (Tab. XXXIII. Fig. VIII. *a.*) and has two short horns, six legs, and a body divided into several rings. The male, on the contrary, is exhibited with two beautiful horns and four wings, *b.* and with a body somewhat larger than that of the Holland Butterfly, delineated under N<sup>o</sup>. VI. These were also nocturnal Butterflies; but their bodies were more swollen than those of Holland; the male whereof is distinguished for its smaller body and smoother wings. These French Butterflies are variegated with a gray and blackish colour, mixed with white. This mixture renders them very beautiful. The divisions of the back are tinged with a browner black; and there are, moreover, observed some yellowish rings in that part, consisting of hairs. From what Caterpillars these Butterflies are produced, I do not know. I found them in a field in the act of coition; so that, from thence, I could affirm for certain, that the male and female are the two sexes of the same species.

The remarkable nest, which I have delineated in the history of the Ephemerus; first published separately, and which I proved at the same time to be constructed of small bitten pieces of wood, laid together, and joined like the beams of houses in Russia; this nest, I say, is built by the wood-eating Caterpillar, which inhabits it, and carries it about on its back in form of a pyramid. These Caterpillars are likewise changed into a winged male, and a female without wings. This appeared very evidently to me, when, upon opening the nest, I found the Chrysalis of the female and the Exuviae of the Caterpillar in it. Therefore, several pairs of little creatures seem to exist in nature; the males of which have this peculiar privilege above the females. It likewise appears from thence, how much the insects of one and the same species may differ from each other. Perhaps the same thing likewise holds in some quadrupedes, birds, or fishes; particularly in those species, the males or females whereof we have not yet been able to distinguish. Some say, the Snake has no difference of sex, which others again deny. I cannot presume to decide this controversy, as I never took any particular pains about that subject.

*The anatomy of the common diurnal and variegated Butterfly.*

## T H E I N T R O D U C T I O N .

**T**HE history I am about to give, under the second mode of the third class or order of natural changes, is so amazing in all its circumstances, that it might very well pass for a romance, were it not built upon the most firm foundations of truth. Facts alone support it; so that, how much soever our comprehension may fall short of the things to be related, we must assent to them notwithstanding; and we should study them also, as some of the most shining miracles of God's power and goodness.

In this history we shall see most surprising changes in the limbs of these insects, growing under one another, that anatomy has ever discovered; such changes, indeed, as no human wit could contrive, or could even think of, had not God, the great Author of these wonders, been graciously pleased to reward our industry with the disclosure of them. In this history we shall behold a poor and wretched insect lose by degrees all motion, and, in appearance, stand consigned to death and the grave; in which seemingly hopeless condition, however, all its former limbs acquire an extraordinary degree of perfection, till, at last, rising from the sepulchre in all the gaiety and magnificence of the richest ornaments, and most resplendent colours, it no longer continues a reptile, creeping upon the earth; but, soaring into the air, changes its slow and heavy pace into the most nimble and unrestrained flights.

This creature, in its painful and humble state of life, supports itself with crude and undigested food; and, ordinary as this refreshment is, the insect is obliged to earn it with much labour and danger: but when freed from the jaws of death, and after passing through a second infancy, the purest nectar becomes its portion, and the air its element. It raises itself boldly toward the skies, and roves at pleasure from meadow to meadow, and enjoys, without care or concern, the exquisite juices which bounteous nature has prepared for its use, and presents it from the unful-

lied cups of the most fragrant and beautiful flowers.

It has now put off its old body; and the entrails, which were before supplied with coarse food by the painful operation of the teeth, and which digested this food by a violent trituration of the stomach, are become more tender, delicate, and fine, so as only to suit a more pure and elegant aliment: and often the happy creature is enabled to live several months successively, without the least want of nourishment.

To sum up all these wonders in a few words, the creature, that heretofore crept upon the earth, now flies freely through the air; sips its food, instead of chewing it; and, far from creating our aversion by its frightful prickles, and foul appearance, it attracts our admiration by the most elegant shape and cloathing; and from being scarce able to move upon the humblest shrubs, acquires strength and agility to tour in its lofty progresses, far above the tallest inhabitants of the forest.

All these surprising, and indeed almost incomprehensible changes, from indigence to affluence, from contempt to glory, from labour to ease, will be amply described in the following history, and every one may easily understand how they can happen, and are actually effected.

By comparing these strange vicissitudes with the wretchedness of our own present life, our death, and resurrection; and examining likewise the causes of our misery, and the best methods of subduing, and even eradicating in ourselves, the latent seeds of decay and destruction, in order to prepare our souls and bodies for a glorious resurrection; we shall, besides the most innocent and becoming pleasure, reap very considerable and lasting advantages, by being powerfully excited to praise God, without intermission, as he deserves, from these surprising effects of his wisdom and power, now clearly laid open to our inspection.

## C H A P. I.

*A description of the external parts of the Caterpillar, and a dissection of the internal, so as to give a satisfactory account of the blood, muscles, kidney-shaped parts, stomach, gullet, intestina cœca, or closed guts, silk-bags, fat, pulmonary tubes, heart, brain, and nerves.*

**T**H E R E are a great number of Caterpillars that become, after their change, diurnal or day Butterflies, that are found feeding on nettles, with which they support themselves; sometimes devouring that plant to such a degree, as to leave nothing but the stalk remaining. It is of these I intend to speak in this place. They are very common in Holland, during the summer months. The skin of this insect appears thick set with very sharp prickles, Tab. XXXIV. Fig. 1. *a*. At its full growth, it is almost an inch and a half long. It is of a deep brown colour, except on its sides, which are of a yellowish green, something inclining to white. These Caterpillars differ so much from each other in this respect, that, in point of colour, it is impossible to describe them distinctly. This little insect has six legs on that part of the body which is next its head: of these legs, I have here delineated only the three that belong to one side, *b*. The middle part of the body is furnished with eight legs more, four on each side, *c*; besides which there are two others that spring from the division forming the tail, *d*. That the construction of this Caterpillar may be the more perfectly understood, I shall represent it as it appears, somewhat magnified by a microscope. Thus we shall see, that, counting the head a tail, it is composed of thirteen annular divisions, Fig. II. 1, 2, 3, 4, &c. The head is of a horny substance, or like bone, and of a shining black colour; and, here and there, it is covered with a kind of hair like bristles. On each side of the head are six black eyes, *aa*, and under the eyes the antennæ, *bb*. There is a lip on the lower part of the division which constitutes the head, and under and near the lip are placed the teeth, *cc*. Near the teeth are three little protuberant spots, the middlemost of which is a nipple, or papilla, *d*, from which the Caterpillar emits a kind of thread; which will be hereafter considered.

There are some bristly hairs on the second ring, and under these hairs is a black spot, above the first pair of legs. This is the first of the puncta respiratoria, or points of respiration, by which the insect breathes. The legs, *e*. consist of various joints, composed of a bony or horny substance; and each is terminated by a claw of the same substance, and of a deep red colour. There are no openings for respiration on the third and fourth rings, as well

because the wings of the future Butterfly lie against those rings under the Caterpillar's skin, as because such breathing-holes would greatly obstruct the motion of the limbs. The third ring has on each side two sharp and bristly hairs, which, at some distance from their roots, produce many others. The two lower of the original hairs, which are likewise the least, are of a white, and the two upper ones of a black, colour.

The fourth ring is of the same form with the third; but as I have represented it a little sideways, there appears on it only one pair of bristles. The legs, Tab. XXXIV. Fig. II. *fg*, placed on both these rings, resemble exactly those of the second ring. Between the hairs already mentioned, there are others, which I have been obliged to omit in the figure I have given, for fear of rendering it confused. These last hairs are white, and they spring from whitish spots in the center of a black ground.

On each side of the fifth ring there are three bristly hairs, with one exactly on the middle of the insect's back, *b*. The first and largest pair of these hairs, *i*, lies a little slanting, on account of the single hair on the middle of the back. The second pair, or that next to the first, rises over the points of respiration; and the third pair, *k*, under those points, on the declivity of the belly. I have, to avoid confusion, omitted the lateral prickles; but have represented the others just as they appear, covering almost every ring of the body. The rings that follow, all to the thirteenth, are exactly of the same form, with breathing-holes in every one of them; so that the insect has no less than eighteen of these openings disposed along its sides, with a blackish edge or border to every hole.

The fifth and sixth rings have no legs annexed to them; but the seventh, eighth, ninth, and tenth have each a pair, springing from the lower part or belly of the insect. These legs are covered with a fine membrane, consisting of many joints, and are armed with little red claws, *llll*, set round the extremities of their legs.

The eleventh and twelfth rings are likewise without legs. The only pair, in this part of the insect, springs from under the tail, *mm*. The ring, constituting this part, has but one pair of sharp hairs.

*The anatomy of the Caterpillar.*

HAVING thus succinctly described the external construction of this Caterpillar, I am now to exhibit and demonstrate its internal parts. The first thing that presents itself, on opening the back of this insect, is the blood, which flows freely from it. This is of a transparent green, and may be made use of as a paint for that purpose; though, as it dries by being exposed to the air, it loses much of its original lustre, and by degrees turns yellowish. There next appear, immediately under the skin, the muscular fibres, which serve to move the rings of the body. On raising of these fibres, the fat appears, as likewise the heart, known by its panting motion: this I shall presently describe. On the hinder part, upon the back, and between the last rings of the body, there are two spots or particles, with some divisions in them, Tab. XXXIV. Fig. III. not unlike the kidneys of men or quadrupeds. On opening these spots, they are found to contain some vessels, and to have a connexion with the lower rings, by means of some slender filaments, and certain pulmonary tubes. In my opinion, these particles do not attain their full growth and perfection, till the insect becomes a Butterfly. This appears plainly enough in Silkworms, whose testicles spring from this part. I shall therefore reserve what more I have to say, on this subject, for my description of the Butterfly, as they appear only in an embryo-state in the Caterpillar.

Removing the parts already mentioned, we come at the stomach. This almost entirely fills the Caterpillar's body; and, though it be so very capacious, is always as full as it can hold, the insect being extremely voracious, so that it hardly ever desists from eating a single moment. During this part of its life, it seems entirely confined to the two operations of taking in its food, and discharging its excrements; by which means it acquires its proper size in a few days. The gullet, Fig. IV. *a*, is a small and slender tube, which running from the forepart of the stomach to the mouth, through a slit in the spinal marrow, just under the brain, and growing larger and larger in its progress, it forms a communication, for the insect's food, between the mouth and stomach. I have represented only a few of the pulmonary tubes, *bbbb*, in the forepart of the stomach, where they appear like so many vessels, elegantly dispersed over its surface, and supply it with the vital air from every side. Amongst these tubes is to be seen a tendinous ligament, *cc*, which runs, both above and below, from one end of the stomach to the other. It arises from the tendons of the muscular fibres belonging to this part. These muscular fibres are seen distinctly through, and I have represented them on each side of the stomach, *ddd*; but, to avoid confusion, I have been obliged to leave out the pulmonary tubes, that are to be

seen in the insect in the same place. The stomach consists of three coats. The outward coat, upon which the pulmonary tubes are distributed, is very thin: the next is thicker, and muscular; the third, which immediately contains the substance that is to be digested, is very delicate like the first.

On the upper and lower parts of the stomach are placed six closed guts, which, descending towards the thick gut, there terminates in little tubes, that have no passage. These six little guts, which are here represented out of their natural situation, by returning upon themselves, and running back towards their origin, form, as it were, twelve intestines; so that, on parting them from the stomach, and disposing them orderly along its sides, there appear six on each part. These little guts arise on each side, from a trunk, in form of a knot, Tab. XXXIV. Fig. IV. *ff*, which springs from the intestine that immediately succeeds the stomach; and then again, being divided into six tubules, these run back towards the thick intestines, *gg*, against which they are folded and curled in a most surprising manner, *bb*. One of the thick intestines, *i*, in which the excrements are reduced to form, is here represented also; and this thick intestine ends in the rectum, or straight gut, *k*.

On removing the stomach, there appear very plainly two little canals, Fig. V. *aa*, which before had several windings, and lay against the sides of the stomach. These canals ascend to the forepart of the head, where I traced them very high, as far as the brain; but could follow them no further, so that I cannot assign their absolute origin. On the forepart they are very fine and slender, *b*; but afterwards dilate greatly, *c*, till at last they terminate in two sharp filaments, *d*, which have their insertion near the cæca, or closed intestines.

It is no easy thing to determine the use of these little parts from the dissection of the Caterpillar: to pretend to guess at it, would be folly. Our business is to find out the intentions and operations of nature, not to contrive them. At first, I took these for the silk-bags of the Caterpillar, on account of their great resemblance to those of the Silkworm. But I was afterwards convinced of my mistake, by finding them unaltered in a Caterpillar, that had made its web. This circumstance may serve to convince us, that they must be of some use to the future Butterfly.

The real silk-bags of the Caterpillar are not more than one fourth part so large as the vessels, which at first passed upon me for such; for the Caterpillar spins but very little; and I have therefore omitted, as not much worth notice, the repositories of the matter with which nature has supplied her for that purpose.

After the foregoing parts have been examined, the fat becomes conspicuous. This substance,







closed wings and legs, that the rest of the body, drained of its juices, must of course become proportionably shorter. The same alterations take place in the trunk, the forks, the eyes, and horns; all which equally swell and expand themselves, and endeavour to make way for their last increase.

By the time the Caterpillar has hung in this manner fifteen or eighteen hours, it so entirely loses the power of all its sixteen legs, as not to be able to make the least use of them to crawl, or stand. The rings of its body then begin to move up and down, in a very sensible and surprising manner. Then the eight legs, *c*, in the middle of the body, grow less and less by degrees, cast their skins, and are turned towards the tail, Fig. iv. *a*. The six fore legs, Fig. i. *d*, move upwards in like manner, and separate themselves from each other, Fig. iv. *b*. Soon after the black horny bone of the skull becomes split into three distinct parts, by the swelling of the trunk, horns, and the other parts lodged there, that lie under it. Of these three parts of the skull, one is in the middle, *c*, and the other two, *de*, are on the right and the left. This being accomplished, the first observable change is the breaking out of the forks, or furcillæ, from under the skin that covered them, *ff*.

As the Caterpillar still continues to move its body, the four pair of legs in the middle of it, Fig. v. *aa*, are by degrees thrust quite up to the tail, with the rest of the skin; and the same thing happens to the two pair of the six legs of the first series, *b*. By this means the forks, *c*, become still more visible, and the trunk, horns, and wings, begin to shew their form. Lastly, the three pieces of the skull, *d*, into which it burst, are found to be drawn up higher over the body.

The skins being at length entirely deposited, all the parts, now mentioned, appear very plainly expanded over the body, Fig. vi. *a*, which, by this means, acquires a form altogether different from that which it before had. The wings, horns, trunk, and forks, which before were folded up and hid under the skull, and the horny substance of the legs, are now displayed; and the rings of the abdomen are also gathered up closer to one another. The Caterpillar is now dignified with the name Aurelia, remaining all this time fixed to the web, *b*, by its claws. But as this cannot be so well made to appear by a figure no bigger than the insect itself, I shall give a drawing of these parts as magnified by the microscope.

In the first place appear the furcillæ, or forks, Tab. XXXV. Fig. vii. *aa*; then the middle part of the head, placed under the skull, *b*: the root of the trunk, *cc*. The proboscis, or trunk itself, divided into two filaments, *dd*, and stretched lengthways upon the body, *e*. Under the trunk lie the first pair of legs, *ff*, whose articulations are placed a little lower. Next to these are placed the second pair of legs, *gg*, which are stretched out to a greater length, and these shew their articula-

tions at the extremities. Near these are placed the little horns, *bb*, whose articulations also are very conspicuous. It appears that they are very thick near their points, *ii*, and on the forepart they bend themselves back under the eyes, *kk*; but this circumstance appears better in the third figure, under the letters *aa*. The wings are stretched along the sides, in the same manner with the parts already mentioned, *lll*, and shew very plainly the little ribs or nerves that go to form them, *mm*. The rings of the abdomen appear drawn toward one another, *nn*, with some little prickles stripped off their skin, which look like so many little prominent nipples, or papillæ. This best appears by inspecting the left side of the figure, where some of these prickles are represented growing upon the insect's back, *oo*. Above these prickles there appear four breathing-holes, or puncta respiratoria. Lastly, the tail, *p*, is very conspicuous, as well as the claws, *q*, that grow to it; and by means of these the Chrysalis hangs to its web. The hind legs are not to be found in this figure, because they lie hid under the other parts which it was drawn to exhibit. The same must be understood of the under pair of wings.

On turning the insect, thus changed and stripped of its skin, Fig. viii. *a*, on its belly, it appears of a very extraordinary figure, the surface of it looking exactly as if covered with prickles and nipples; which is owing to this, that the sharp-pointed hairs of the Caterpillar have cast a skin, as well as the other parts. A person, unacquainted with this branch of natural history, might, by giving in this place a little loose to his imagination, represent to himself the nose, eyes, and other parts of the human face, as some authors have already very ignorantly done; nay, they have given drawings of their idle conceits.

Ignorance is fruitful in false opinions, and is usually accompanied with so much self-sufficiency, as makes it in a manner impossible to overcome its prejudices; whereas those who have a tolerable share of knowledge, are in the readiest way to discover their mistakes.

The Caterpillar, stripped of its skin, in the manner now related, is of a green colour, especially in those parts which are distended by an extraordinary afflux of the blood. But after ten or twelve hours passed without its skin, it turns to the most resplendent and beautiful gold colour. This is the reason of its being called, in this condition, an Aurelia or Chrysalis. And as it is found so common by every pathway, sticking to nettles, and shining like polished gold, fastened to the leaves of the Pervinca, or periwinkle-plant, authors have, from this circumstance, taken occasion to give the name of Aurelia to all Caterpillars, changed after the same manner in point of shape, tho' the greatest part of them do not in the least partake of this rich colour, and the rest have nothing of it more than a few spots.

It now remains that I should shew, in a few words, in what manner all the last enumerated parts

parts are extended, and disposed over the insect's body, in the orderly manner in which I have exhibited them. All this will become very intelligible to those, who will call to mind what I already said, viz. that the extremities of the four wings, with the two hinder pairs of legs of the first series, are enclosed in one and the same skin; that the horns are folded up in membranes full of ligaments; and that the trunk is in the same manner firmly fastened on the forepart of the skull. This being the case, it is impossible but that, on the pieces of the broken skull, the withered legs, and the other skins, rolling up towards the tail, all the new limbs, here mentioned, must display and arrange themselves in the most beautiful manner, and by the justest and most orderly evolutions; for the membranes I have named, that are so full of ligaments, act the part of so many ropes and pulleys to extend these new parts, in proportion as the old are thrust over them. Now, if this change was to happen in some creature of a larger size, one, for example, equal to a Sheep or a Calf, is there any one so insensible, as that he would not be struck with the deepest astonishment at the

fight and contemplation of such wonders of the Divine Power? Certainly, God reveals himself as much and more in those mysterious and delicate operations, which the microscope alone can discover. Thus then, we at length see evidently in what the change of the Caterpillar into a Chrysalis consists, and what that Chrysalis or Aurelia, or the Caterpillar which has cast its skin, really is; though the great Harvey most preposterously considered it as an egg, and, enthralled by vulgar prejudices, seriously affirmed the succeeding Butterfly to be generated by a metamorphosis, which, after all, he could neither explain or comprehend.

When the little creature has hung in the open air for some hours, its external skin hardens by the power of that element; at the same time that the enclosed limbs are, in a manner, fluid like water, on account of their great delicacy and tenderness; so that it has no power to move its wings or legs, till the superfluous humidity, that clogs them, is evaporated: then bursting its prison, it appears in the shape of a Butterfly; as shall be presently explained\*.

*The anatomy of the Chrysalis, two days after it has cast its skin.*

**T**HE eyes were yet so tender and delicate, that they dissolved with handling. The forks likewise were very moist; but, notwithstanding this, the articulations were very conspicuous; though, for the greatest part, they appeared like membranes, just beginning to harden. The legs were in the same condition with the forks; but, on account of the pulmonary tubes which appeared through their surface, they looked somewhat more firm. The same thing may be said also of the horns. The wings within were quite colourless, and like a jelly; shewing, through their transparent substance, pulmonary tubes, composed, as it were, of mother of pearl.

As to the internal parts, the change in them is much more sensible. The stomach is considerably shortened, whilst the gullet is grown twice as long as it was in the Caterpillar, and runs in the form of a slender tube through the thorax into the abdomen. In the hinder part, the stomach is reduced to a slender gut, and becomes so very tender, that it breaks with the least touch: within this is found a fluid matter, of a deep red colour, inclining to purple, but not very thin. Under this there appears a kind of chalky sediment, of a somewhat paler

colour. The six cœca, or closed guts, that before joined the stomach, are now wasted away, and no longer to be seen.

The heart and the spinal marrow are become much shorter; and this is all the considerable alteration that appears in these parts. The particles, which I once mistook for the Caterpillar's silk-bags, are now become more slender, but more compact. The muscles of the thorax, and those which are to move the legs and wings, have not the least strength or firmness, so that on disturbing them, they immediately fell to pieces. The fat is grown yellower, thicker, and more friable, so as to crumble with the lightest touch. The pulmonary tubes are become smaller, and they are carried in the most elegant manner through the legs, wings, and other parts. There is a purple nodule, or knot, in shape nearly round, sticking to the lower rings of the body. I could not now discover the kidney-like particles, though I searched for them carefully in three distinct Aureliæ: but I have observed in Caterpillars of another kind, that these particles at length unfold themselves, and then seem to form some other parts, which administer to the spermatick organs.

\* The repeated experiments of succeeding naturalists have, in every instance, confirmed the doctrine of this author on the present subject. The indefatigable Reaumer proved the truth of this evaporation of the abundant moisture from the Chrysalis, by different experiments. He enclosed the Chrysalis in a glass tube, and he found the evaporated water collected in drops at the bottom of the tube: he covered the Chrysalis with varnish; and this making the evaporation more difficult and slow, the Butterfly was two months longer than its natural time in coming out of the case. The same author found also, that laying the Chrysalis in a warm room, hastened the disclosure of the insect; and keeping it in an ice-house, in the same manner, delayed it. Warmth acts, in this case, in a double capacity, invigorating the animal, and evaporating the moisture.

*The anatomy of a Chrysalis, six or eight days after it has cast its skin.*

THE external limbs, and other parts, as the trunk, horns, legs, and wings, are by this time grown somewhat more dry and firm, though still they are of a white colour, which is changing by degrees to gray. The alteration in the internal parts is now much more considerable. The stomach, which before might be considered as forming several distinct parts, is now so wrinkled up as to be all of a piece, except that here and there appear some globular swellings above the surface. These prominences are very observable on the forepart; but not so distinctly to be seen, by a

great deal, where the closed intestines took their rise in the Caterpillar, about the hinder region of the stomach. The moisture contained in this part is changed to a deeper purple. The muscles of the thorax are become more conspicuous, distinct, firm and solid; and the fat is still more and more contracted into a simple mass. I could now plainly perceive, that the purple nodule, or knot, was nothing more than a dilatation of the rectum, or straight gut, changed to this form. The rudiments of the genitals are by this time very visible, and have begun to acquire firmness and strength.

*The anatomy of a Chrysalis of twelve or thirteen days.*

THE trunk, at this time, has acquired a considerable solidity. The horns shew their little scaly feathers; and the legs, in like manner, very plainly exhibit their stiff hairs, resembling bristles: but the scaly little feathers are far from being so conspicuous. The legs are also now of an obscure gray colour, especially about the joints nearest the thorax. The hairs and little feathers of the wings are likewise very discernible; but, as yet, they are very moist, and are laid so close one upon the other, that it requires some industry to get a sight of them. They resemble, in some measure, the hairs of a Cat; in which, after the skin has lain in the water for some days, they are fastened together by the moisture they imbibe. The wings now will admit of being extended, and shew, if they be torn, their pulmonary tubes, and other vessels. Their colour is an

ashy gray, but obscured by a dusky tinge. All the parts I have mentioned are quite complete, and perfect, in a Chrysalis of sixteen or seventeen days old. By repeating this dissection every day, we may, no doubt, observe the most extraordinary transitions, that can be imagined, from one colour to another; for, from a pale and whitish or faint gray, these parts change to a dark colour, a deep brown, an elegant red, a yellow, a sky-blue, a bright white, and many other tincts; and this in so surprising a manner, that it is almost impossible to describe it: God, the author of all miracles, producing these alterations, in the nature of things, by rules which, at the same time that they are most firmly established, infinitely surpass the strongest efforts our imagination can make to comprehend them.

*The anatomy of a Chrysalis, of this species, of sixteen or seventeen days old; at which time it is very near undergoing its last change, in order to become a perfect Butterfly.*

ON examining the Chrysalis at this period, we find, that its gold colour is become much paler; and it is so transparent withal, as to let us perceive distinctly through it all the colours of the upper pair of the future Butterfly's wings. If we strip off the skin, and other thin membranes that sheath the wings, these last sometimes appear perfectly dry. But this principally happens in autumn, when these Chrysalides are generally suffocated within their skins; the solar heat, at this season, being too weak to strengthen them sufficiently for the struggles which the bursting of their prison requires, otherwise the wings always retain some moisture. The forky particles, which I have before described in the Chrysalis, now shew themselves hollow; and the eyes, which, like those of Bees, are surrounded with hair, appear under them very plainly. The trunk has acquired its due strength, firmness, and

form, so that it presently curls and coils itself up, on taking off the case that covers it. Under the trunk are to be seen the true forks, between which the Butterfly hides that curious organ, as will appear in the design I shall give of that insect. The horns also are now perfect, and are covered with their little elegant scales, which resemble feathers. The legs, with their little feathers, joints, and claws, are in the same state of perfection; so that, on stripping off the coats and membranes in which they are bound up, they will begin to play, and move themselves very sensibly. Those legs, which, in the Chrysalis, lie most exposed to the air, and which I have already represented in one of these designs, as they appear upon the insect at that period, have in proportion a stronger skin to defend them. The same wise disposition is also remarkable in the skin that defends the upper and lower pair of wings.

wings. When we examine the internal parts, it appears that the eyes are perfectly formed, being replete with thin pyramidal filaments, in the same manner as those of the common Bee, as already mentioned. There are in the trunk two channels, which, uniting, form only one in the thorax, and constitute the gullet, which ends at the stomach. The muscles of the thorax have acquired their due firmness, and consist of three kinds of fibres; some running lengthways, others transversely, and the third kind obliquely. Near the gullet appear the three little particles, which I took for the Caterpillar's silk-bags. They are at this time curled into one, and are inserted near the end of the gullet, to which they are united on each side. A bladder full of wrinkles, and endued with a peristaltick motion, is now seen on the upper part of the stomach; and it communicates with the gullet, by means of a slender tube. This bladder, the stomach, and some part of the gullet, are full of a deep purple moist substance; but the upper part of the gullet has nothing beside air in it. The stomach, being gathered up into one mass, in a surprising manner, looks as if quite covered with tubercles. The back-part of it, like a little gut, is now become much more slender and shorter, and is wrinkled withal, so as to deserve the name only of an intestine. The *vascula cœca*, varicosa, or crocea, which were dropped from the stomach, appear now in the same place. Next were to be seen the *intestina crassa*, or large guts, which, from being very short in the Caterpillar, are now become very long and slender, and appear as if they had been stretched out to give them such an extraordinary length. They then dilate into a nodule, or knot, full of the purple matter already mentioned; and that dilatation is followed by another, greater than the first; but its contents are the same. The Chrysalis, on casting its

skin, discharges this liquid from the anus; by which means the nodule, or knot, next to it comes to be smaller than the other. This excrementitious substance, laid upon paper, looks like real blood. The stomach, of the *Aurelia* I am describing, is much more firm, and of a much better consistency, than that of the *Aurelia* of two days already spoken of; insomuch that it may be now handled with the forceps, and drawn out of the body with the intestines that are joined to it, without any damage or danger.

The heart and spinal marrow are now quite contracted, and considerably diminished. The fat is surprisingly wasted away, and wrinkled up by evaporation, so as to resemble a bunch of yellow oblong grapes, which are so firmly fastened to the pulmonary tubes, that the greatest care and patience is requisite to part them. There appeared no other alteration in the pulmonary tubes but this, that they were grown more membranaceous, and shew more distinctly their muscles, and other parts, which had now acquired their proper degree of perfection. The kidney-like particles are now no longer to be seen: perhaps they have been expanded by a slow growth into the organs of generation, which now shew themselves very distinctly; but are so intimately united with the fat and pulmonary tubes, that it is almost impossible to separate them, unbroken and entire. This makes it necessary to attempt the dissection of the genital parts in the *Butterfly* itself: I therefore hope, that, when I shall have proceeded so far, I shall be able to give a satisfactory description of these parts, with figures to illustrate the accounts; provided my health does not fail me, and I do not want proper subjects to work upon. I shall likewise describe at the same time, and in the same manner, the gullet, stomach, and intestines, with figures of them.

*In what manner the Aurelia assumes the form of a Butterfly.*

WHEN this, as I may justly say, surprising alteration of the insect, by the growth, and removal of the limbs, and other parts, happens in the month of June or July; it requires only about eighteen days to perfect it in this species: whereas late in autumn, it requires ten days more; sometimes indeed a great number of Caterpillars, by not beginning to change till the season is thus far advanced, perish for want of strength to cast their skins; so that, on this occasion, these little creatures are liable to the common calamities of nature, and very often come to an untimely end.

Nothing is more remarkable about the time when the *Aurelia* begins to cast its skin, than the perfection to which the wings, which have grown under it, are arrived. The colours that adorn them are chiefly black, red, and a sky-blue; and these, as well as the trunk, legs, and

horns, may be very easily discerned through the skin that covers them, even without the help of a microscope, Tab. XXXV. Fig. 1X.

On examining, with a microscope, the Chrysalis at this period, the extremities of its legs are observed to move very distinctly: a circumstance which I have often remarked in the *Aurelia* of *Silk-worms*, with the greatest astonishment.

The colours of the under pair of wings cannot be seen, because they are altogether covered by the upper pair; nor are the colours of the other parts, just now mentioned, very discernible, because there is not so great a variety of tincts in those parts. For though the colour of all Chrysalides appear through their skins, at the time they are going to cast them off; nevertheless, it is impossible to tell exactly what those colours are, where there does not happen a considerable distinction between them and the stain itself.

While

While the little creature remains in this condition, there is a violent agitation in its blood, and a motion in all its internal parts. The blood, in a hasty fermentation, is driven through the vessels from the heart into the wings, which are likewise supplied with air from the lungs. The insect, besides, labours violently with its legs: and all these motions concurring with the growth of the wings, it is impossible the tender skin that covers it, should not at length give way; and this it accordingly does, by bursting into four distinct and regular pieces.

First, That part of the skin which covers the trunk, the two fore-pair of wings, the horns, and the furcillæ or forks \*, falls off from those parts; but the several portions of it, in which they were separately wrapped up, remain firmly united together, Fig. x. *a*. This is the first time the legs appear without any covering, and they then help greatly to free the body, and the other parts that remain yet bound up. At the same time, the skin on the back flies open, and dividing itself into two regular portions, *b b*, disengages the back and the wings. Then there likewise happens another rupture in that portion of the skin, which covered the rings of the back of the Aurelia, *c*. After this the Butterfly remains very quiet for some time, with its wings pointed downwards, and its legs fixed in the skin which it has just cast off.

But it must be observed, that the wings, legs, horns, trunk, and other external parts of the Butterfly, do by no means rise from the body in the manner exhibited in the *II* Figure of the Table XXXV. where I have laid down all those parts, as they appear very distinct and conspicuous in the Caterpillar itself. Many of these parts remain as has been already said, firmly united to each other, the reason of which is, that they are all moist and wet in the Caterpillar, at the time when it is about throwing off its skin, and becoming a Chrysalis; and this moisture being of a clammy or glutinous nature, serves, on its being dried by the air and heat of the weather, as a real glue, to unite the parts it lies between so firmly together, that they never separate for the future. Now, as the skin, which lines all these parts, or covers them on the inside, is extremely delicate and tender, which it well may be, as it is not exposed to the air, it all breaks and flies off without any certain order; nor is any order necessary upon the occasion. Hence it arises, that so many broken and ragged little membranes, almost as thin as a cobweb, appear on the inner surface of the skin that has been thrown off. One of these little films is to be seen between the conglutinated coats or skins of the trunk, horns, and other parts, Tab. XXXV. Fig. x. *d*.

There likewise appear within the skin certain white filaments, *ee*. These are the cast coats of

the pulmonary tubes; for now these tubes cast their skins for the last time. The greatest part of the eighteen pulmonary tubes, of which I have represented nine on one of the sides of the Caterpillar, in the second figure of the XXXIV. Table, remain in the Aurelia, which breathes by them, until by casting this skin it becomes a perfect Butterfly; and this is the reason, why the pulmonary tubes are much more slender in the Butterfly, than they were either in the Caterpillar, or the Chrysalis: this circumstance also affords the Butterfly the means of taking more air into its body, and thereby renders it the better able to fly, to give a due motion to the contents of its intestines, to suck in the juices on which it lives, to void its excrements, and to perform many other operations necessary in the animal oeconomy.

At the time when this change of skin happens, the wings expand so rapidly, that the naked eye cannot trace their unfolding, from reaching scarce half the length of the body, Tab. XXXV. Fig. xi. *a*, they acquire, O miracle of miracles, in the short space of about half a quarter of an hour, their full extent and bigness; so as to be each of them five times larger than they were before. Nor is it the wings alone that are thus increased: all their spots and colours heretofore so minute, as to be scarce discernible, *b b*, are proportionably extended; so that what but a few minutes ago, appeared but as a number of unmeaning confused points, are now become distinct and most beautiful ornaments. All this may be best conceived, by consulting the *xii* Figure, which represents the wings bigger than the body, and with all their colours, which are chiefly red and black. About the edges, however, here and there some yellow, sky-blue, and white spots, are seen most elegantly combined, which exhibit to us, though faintly, and as it were by shadows, the inexhaustible treasure of the Great Creator's treasures, his stupendous majesty, and his other incomprehensible perfections; for though no adequate representation can be given of the Supreme Being, he has thus been pleased to shew himself to us, distinctly and conspicuously enough to engage our love, our adoration, and our gratitude.

This little creature is found also to have four legs, Fig. xi. *cccc*, each armed with claws, and adorned with hairs, and a variety of colours. The two horns *dd*, lie just above the eyes: near the space between the eyes, are to be seen the forks or furcæ; from between which the insect darts *e* out a double trunk, the use of which is to pump out the sweet juices from flowers into its body, so that this organ may be considered as its tongue. When this curious part is not at work, it lies so closely curled and coiled up between the forks, that it cannot be seen. This beautiful contrivance is represented in the *xiii*th

\* These appendages to the trunks of Butterflies have been supposed by some to assist in the procuring, disposing, or forcing down the food: but the nature of the Butterflies food is a plain contradiction of that opinion; for it is only a liquid, and thin honey juice. Reaumer has therefore, with more justice, allotted them the office of preserving the trunk from injuries, and supporting it in its intended use. This is confirmed by the constant observation, that these pieces or forks are always stronger in proportion, as the trunk is more tender.

Figure, in which we likewise see, that the Butterfly's wings entirely cover its legs. The first pair of legs lie nearly under the thorax; but they are now so altered, as not to deserve that name; for the Butterfly makes no use of them as legs, nor have they claws like the others: nature, indeed, seems to have intended them for some other purpose.

As the wings extend themselves so suddenly, they accordingly appear at first like pieces of wet paper, soft, and full of wrinkles, cavities, and swellings, as I have represented them in Tab. XIII. Fig. ix. x. xi. But they are quite dry in half an hour, by which means all the inequalities in them entirely disappear, so as to leave them perfectly fit for the creature's service. The Butterfly's transmutation being thus perfectly finished, it discharges three or four pretty large drops of a bloody liquid, which are the last remains of the superfluous moisture, the rest of which has been evaporated by the *Aurelia* during the heat of summer, in the space of about ten days; for as the parts, which this moisture was intended to expand, no longer need any increase, what remains of it is no other than an useless encumbrance, and accordingly it is expelled from the body as an excrement.

Thus the Butterfly, in a little more than a quarter of an hour, acquires its full perfection. During the Caterpillar-state, it may be considered as a newly conceived embryo. In that of an *Aurelia*, it represents a child as yet shut up in the womb, but about to break the membranes in which it is bound up, in order to make its escape. Lastly, the insect, when employed in extricating itself from its integuments, resembles the infant just coming into the world. However, there is this considerable difference between them, which well deserves attention. The Butterfly does not produce itself like our wretched offspring, weak, tender, and in a manner but half perfected; but, almost from its first moment of appearance in this state, it is a complete creature of manly age, if I may be allowed the expression, and qualified in every respect to avoid such things as are hurtful, and look out for those that tend to secure its existence, for the space allotted by nature, and make it agreeable.

Whoever considers these particulars attentively, must observe, in this poor insect, a great and indeed immense degree of perfection, which man, the greatest work of the creation, entirely wants. And this prospect should fill us, miserable mortals, with sentiments of the most profound humility. We see a little insignificant insect, distinguished from its last birth, with qualifications, ornaments, and perfections, which, during our stay upon earth, however long it may be, we can never flatter ourselves with the hopes of enjoying.

This creature, to support life, needs no other food but the dews of heaven, and those limpid distilled juices, which it finds ready prepared for its use by the beneficent sun, and plentifully stored up in every flower. No theatrical scene can be imagined equal to the ornaments with which it is clothed; and that its wings, and the rich co-

lours that embellish them, were bestowed upon it merely for the sake of ornament, appears from its being able to fly with but two, as well as with four wings. The skies are the Butterfly's proper habitation, and the air its element; whilst man, miserable in every respect, is obliged to earn his bread with labour and cares: he comes into the world naked, and destitute of all external ornaments, to demand attention; and, born in this wretched condition, he roves about without habitation or shelter, exposed on the one hand to the heat of the sun, on the other, to the damps and exhalations of the earth, both enemies alike to his happiness and existence.

Indeed, upon mature thought, we have no cause to be surpris'd at this difference. We are at present exiles from heaven, our proper home; stripped of that beautiful cloathing which our first parents possessed. But this is not the only creature, from whence we may draw useful instructions. All other kinds of insects are generated in the same manner. Not one of them grows the value of a single line, after the half hour that immediately succeeds their extricating themselves from their skins for the last time. We admire with the greatest astonishment, how the bodies of the flying insects could be contained in the little skins and membranes, out of which they came to appear in this state; whereas the wonder consists entirely in their expanding so much, and acquiring such perfections in the first few minutes that succeed their enlargement.

How then can we avoid crying out, O God of miracles! how wonderful are all thy works! how beautiful are the ornaments! how well adapted the powers which thou hast so profusely bestowed upon thy creatures! They are all, notwithstanding, subject to decay and destruction; and, with all their perfections, scarce deserve to be considered as shadows of the Divine Nature. It is therefore, with the highest reason, that a certain writer has said, That all nature is over-run, and covered with a kind of leprosy. This is her old garment, which she is one day to throw off, and its heaviness alone is sufficient to weigh down our senses, and disturb our reason, in spite of all its efforts.

Goedaert describes the Caterpillar I have here been figuring, and the Butterfly arising from it, in the XXI. experiment of the first part of his natural metamorphoses; but he forgot in his figure the Caterpillar's prickles, instead of which, he gives it nothing but simple hairs. He has, besides, been guilty of another mistake, in bestowing breathing-holes on every one of the Caterpillar's rings. Mouffet also has favoured us with figures of the Caterpillar, and the Butterfly, and has described the Butterfly according to its colours. But Goedaert's drawing of it, deserves the preference by many degrees.

The beauties of the Butterfly now before us, Tab. XXXV. Fig. XII. is but of a middle rank, if compared with that of many others. Its head is covered with little black hairy and scaly feathers; the eyes, which take up the greatest part of the head, are thickly guarded also with hairs resembling bristles; and they consist of a substance

stance which looks like gold, on account of the brightness of the uvea, which is seen through. The thorax and abdomen, are black; but they are covered with hairs of a golden yellow. The legs and horns consist of a black, bony, or horny substance, and are adorned also with scales and hairs of a gold colour. The wings look as if they had been slightly washed over with a deep red blood-coloured paint; and they have, besides, four great and four small spots of different forms. Near the thorax, the upper wings appear most elegantly sprinkled and waved with glittering gold; and the lower wings near the belly, are covered with hair of a gold colour. The spaces

between the spots of the upper wings inclines to yellow; but near the third pair of those spots which lie towards the edges, are two other marks of a snowy white. The borders of the wings are elegantly indented, and set off with four principal colours, a black, a sky-blue, a peach-blossom colour, and a yellowish red. The sky-blue, by bending its course upon the black, which serves as a ground to the other colours, forms a beautiful crescent; whilst the other colours, making so many circles, separated by the black ground, heighten the elegance of the disposition in a very delicate manner:

### C H A P. III.

*Containing a description of the internal parts of the male and female Butterfly, described in the preceding chapters.*

**H**AVING described the external and internal parts of the Caterpillar, and of the Chrysalis, and also some of the Butterfly's external ornaments; my next task is to describe its internal structure; though I cannot say I have succeeded perfectly to my wishes, in examining and investigating them one by one, as I proposed to myself. For, as I did not begin to dissect the insect in this state, till towards the end of Autumn, and had such only to dissect as had been changed to Butterflies within doors, and under my inspection, and had not acquired their full perfection; for this kind of Butterfly outlives the year in which it makes its first appearance I could not therefore observe all its parts so accurately as I wished: besides, there was no bright weather during the time my examination lasted; but the air was continually darkened with rain and clouds. However, some things in my observations appeared worthy of notice, which I shall now briefly relate.

On opening the Butterfly's back, there immediately appear in the thorax, some little wrinkled vessels, Tab. XXXVI. Fig. 1. *a a*, which lie near the gullet, and have their insertions in the fore-part of the body. I take these little vessels to be the same with those already represented in the vth Figure of Table XXXIV. Their beginning is a slender little channel, *b*, which divides into two fine tubes; and these tubes again dilating themselves, *c*, terminate at last about the beginning of the stomach, *d*; and they are so firmly united and fastened to it, by means of the fat and muscles, that I have not yet by any means been able to loosen them from that part, or to trace them higher. What greatly increases the difficulty is, that the beginning of the stomach itself, is here very strongly connected. What the office of those vessels is, and whether they may not be the salival ducts, I cannot take upon me to determine; for I know not how they terminate in front, or whether or no they have a communication with the trunk, *e e*.

Amongst the curled vessels I have been treating of, appears the gullet, *f*, which dividing in

the upper part, near the root of the trunk, into two little tubes, conveys to the stomach the juices sucked in by that organ. From the lower part of the gullet near the stomach, there issues a short and small channel, *g*, which ends in a little slender bag, *b*. This bag is no other than an air-bladder, into which the air rushes, whilst the insect's food is making its way to the stomach. This bladder is endued with a very considerable peristaltick motion: it is almost always found in the Butterfly's back, placed over the stomach. In the Chrysalis, I found it full of a deep red liquid, as has been already observed.

The stomach itself, *ii*, is strangely altered in regard to shape, from what it was in the Caterpillar, as before represented in the 14th Figure of Tab. XXXVI. It is now entirely swollen and tuberosous, and it resembles an inflated large gut; so that, on account of its many folds, hollows, and wrinkles, it exhibits a very pleasing sight in the hinder part. It so much resembles one of the smaller intestines, *k*, full of most delicate folds, that I cannot take upon me to determine whether or not it ought to be considered as such, rather than as a portion of the stomach. Under the pylorus, appear six intestina cæca, or vasa varicosa, *lllll*, which are much more slender in this state, than they were in the Caterpillar, and of a perfectly different form. They are likewise separated here from the stomach, to which, in the Caterpillar, they always closely adhered by means of the pulmonary tubes. I have not as yet been able to find out where and how they terminate in the Butterfly, so that I shall only represent them here as they appeared to me on this dissection. Under these lie the smaller intestines, *mm*, which are transparent and full of a globular substance. A little lower the gut widens considerably, so as to form the cloaca, *n*; then it contracts again, to dilate a second time into a lesser sinus, *o*, in which it terminates. Next follows the straight gut, *p*, terminating in a ring, of a substance between bone and horn, which forms the anus, *q*, is covered with hair, and drawn up within the abdomen. At the sides of the anus appear its

F proper

proper muscles, *rr*: their tendons are black, and of a substance like that of the anus itself. The two dilatations of the intestines, which I have just now taken notice of, supply the place of a colon, which appears only in the Caterpillar; for in the Butterfly it is so transformed, as deservedly to be considered as a different part. Certainly the surprising and incomprehensible changes of parts which we here observe, should engage our utmost attention, though for many reasons, yet for none so much as for this, that they most evidently demonstrate to the whole universe, the excellency of the Great Creator. The contemplation of these wonders has often led me to consider, whether the entrails of Nebuchadnezzar, when deprived of his reason, and armed with talons, like a bird of prey, covered with hair, such as is found upon beasts, and condemned to eat grass in common with the cattle of the field, did not suffer a change in his internal parts, correspondent to that which appeared in his external form; and such a change as might suit them to digest the food, with which his life was to be supported, in the course of this his most exemplary penance. At least there appears an occasional alteration of this kind in the entrails of these insects; for, as long as they continue under the form of Caterpillars, and live upon a gross and earthy food, their entrails are also gross and earthy; whereas these creatures, assuming a more delicate form, and beginning to subsist on a more pure substance, the organs by which such substance is to be taken in, digested, and distributed to the several parts of the body, become likewise more delicate, and that indeed to such a degree, that the alteration would never be credited, if the eye did not trace its gradations from one day to another.

There is no part of the Butterfly that deserves our admiration more than the trunk\*. I have but rudely delineated this organ, because I proposed making many other figures of it, considerably bigger than the life, which, after all my pains, I have not been able yet to perform, on account of the badness of the weather, and the season's being now so considerably advanced. That extremity of it, with which the Butterfly sucks in its

food, is particularly curious in its construction: it consists of a double tube, divided, as it appears, into many articulations. This construction suits it to a great variety of motions, and in particular, makes it easy to stretch out, and curl up again. It appears, that when the Butterfly sips up the honey or liquid sugar upon which it lives, a portion of air mixes with and accompanies this through the trunk to the stomach. This may be seen by fastening the Butterfly by its wings, with a very fine pair of iron pincers, and uncurling the trunk with a very fine needle, so as to bring the tip of it to bear upon a blade of grass dipped in sugar water; for the Butterfly immediately sucks the nourishment that is thus offered; and, with the assistance of a microscope, both that and the air that goes along with it may be traced in their course into the body: and this is a very entertaining sight. Indeed Butterflies may be kept alive in this manner many days together: they will take so well to this way of feeding, that at last they will dart out of themselves, without any compulsion, their trunk into the moistened sugar, or honey water, thus offered them. Hence we may guess how fine and delicate the muscles, veins, arteries, and nerves must be, by which this little organ is supported and governed. The very extremity of it is of a most amazing structure. As for my part, I must ingenuously own, that neither my eyes, my hands, or my head, are equal to the task of inspecting, handling, or perfectly describing it: but even this weakness is an useful lesson, since I learn by it, that all our boasted knowledge and perfection in this life, is in the main but ignorance and misery. Let it therefore suffice, that the things we see, are capable of conducting us, as it were, by the hand, to the knowledge of a much sublimer being; and let this consideration engage us, to adore the Divine Majesty, according to the perfect rule he himself has been graciously pleased to prescribe to us, and to perform, with due reverence, the penance enjoined us for transgressing his commands. This is the one thing necessary; all else is vanity of vanities, and altogether unworthy of our attention.

### *The genital organs of the male Butterfly.*

**O**N dissecting a male Butterfly of this species, four days after its last change, the genitals appear perfect in every respect. The penis, Tab. XXXVI. Fig. II. *a*, placed near the extreme rings of the body, has on each side two horny little bones, *bb*, of a pale brown colour, which cover it behind and in the middle. These little particles have an articulation, with a bor-

der, *c*, of the same substance, which surrounds the penis like a belt. There is near the two little horny parts, already taken notice of, another that is hooked, *dd*, and behind, is divided in two; by the parts of the penis, *e*. On raising the two first little horny bones, there appear two crooked little claws, whose business it is to grapple, and firmly hold, during the act of co-

\* The trunk of the Butterfly is indeed an organ of most wonderful structure. It stands in the part of the head where a nose might be expected, but it really is of the nature of a mouth; for all the food goes through it. The substance of the trunk is horny: the creature may be said to unroll it, by squeezing the head; or it may be drawn out with a pin. After this, if any violence be used to the creature, the trunk will crack lengthways in the middle, and the slit will run presently through its whole length, and divide it into two. Bonani hence supposed the trunk was really double in the Butterfly, or originally composed of two. Riget thought he had shewn, from unquestionable experiment, that the trunk of this insect was single, and that this splitting was the effect of the violence offered to it, and its own tender structure. He had his followers, till Reaumer verified the first doctrine of Bonani by more accurate trials; and established the true structure of this part, which is, that it is composed of two delicate tubes, laid parallel by one another.



pulation, the lowest abdominal rings of the female Butterfly. This action is particularly observable in the common white Butterflies; for the female of this species very often flies about with the male fastened to her, his claws or hooks in this part grasping her genital parts close to him, his head hanging down, and his wings quite motionless. The muscles of these parts of the penis appear between, and have their insertions in, the little horny parts already taken notice of. On the inside, near the two little grappling claws, there appear some other parts belonging to the penis; but I could not examine them with the due exactness. The penis consists partly of a bony and partly of a nervous substance. The former resembles, in figure, the little bone we find in the penis of Dogs; and has at its extremity an opening, thro' which the soft and nervous portion of the penis is erected at the time of copulation. The root of the penis is likewise of a nervous substance, *f*, but more compact than that portion with which the erection is performed. Next we observe the base of the penis, *gg*, containing in one part a white sperm, and in another part a thick fluid, divided into very minute granules; which, on letting it out by wounding the penis, shines like a white or silver sand, *z*. I leave to others to inquire what this last substance may be. The penis appears, in this part, very elegantly folded and curled up into two branches, *k*, which afterwards form four others, whose origins are all very firm and strong. I am not disposed to affirm any thing as a certainty, concerning the nature of these last portions. The two slenderest branches, which appear most closely twisted one with another *ll*, look like seminal vesicles; for they contain a white spermatick liquid, consisting of very minute grains, connected together by a membrane. The two other branches may

pass for the vasa deferentia of the insect, *mm*; and the nodule, or knot, *n*, in which those branches terminate, for the testicle; so as to make it probable, that the Butterfly has only one testicle. But these are only conjectures on a subject, concerning which I dare not advance any thing as a certainty.

This globular portion, which I call the insect's testicle, is of a pale gray, with a tinge of a purplish colour, and it is surrounded by two coats. The outer coat is very fine, and is united with a great many pulmonary tubes. The inner coat is much thicker, and yields, on dissection, a soft, clammy, and glutinous substance, no way fluid. Through this there run a great number of pulmonary tubes, of a bright silvery whiteness, variegated with some purple streaks. Perhaps repeated dissections may enable us to determine, whether or not this portion is to be really considered as the Butterfly's testicle. These parts are so firmly connected on every side, by means of the fat, and of the numerous pulmonary tubes, as to make it a very difficult task to display them. The rectum, or straight-gut, opens under those particles belonging to the penis, which consist of a substance between bone and horn, already taken notice of. The pulmonary vesicle, that is situated forwards near the stomach, appeared to me full of air. The stomach itself looks like a bunch of grapes; and close to it lie the cœca, or closed guts. The small gut is considerably longer than the stomach, and ends in some dilated parts.

The preceding observations I made the sixth of September on a Butterfly, which appeared, for the first time, as such that very day, and had been changed from a Caterpillar into an Aurelia the 17th of the preceding August; so that its change, from a Caterpillar to a Butterfly, took up nineteen days.

*The anatomy of the ovary of this species.*

A Few days after, I opened a female Butterfly, resembling so exactly, in its internal appearance, the male before dissected, that at first I imagined I had again got a male under my hands, till the thickness of the body indicated the contrary; and soon after the discovery of the oviducts confirmed me in my last opinion of the insect's sex. There were, as yet, no eggs in these ducts, so that they appeared very like the genitals of the male; and, indeed, it was some time before I could be sure that they belonged to a female. Many of the insects, whose date of life is of some length, have no eggs in the beginning, or very imperfect ones. I have indeed observed, that almost all insects die very soon after they have prepared their sperm; unless when their sperm, though visibly formed, has not acquired its full growth; or when the insects are to survive the winter, in order to lay their eggs the ensuing spring; as is the case of the Butterflies which I am now describing. Nor does it appear pro-

bable to me, that either the eggs of insects, or the insects themselves, in the Caterpillar or Aurelia-state, can endure that rigorous season; for which reason the little creature, now perfect in the Butterfly-form, is doomed to the hardships of this severe trial. Hence it is, that at the approach of winter they take refuge in the hollows of trees, in store-houses, and summer-houses in gardens, where their blood is condensed by the succeeding colds, like olive-oil at the same season, and becomes, in a manner, quite caked; so that they neither move nor eat till the returning warmth enlivens them. This I have often observed. They even discharge no excrements all the time. I have made many curious experiments upon Butterflies in this condition; but it would take up too much room to give an account of them in this place.

There are six oviducts, Tab. XXXVI. Fig. III. *aaaaa*, in the female Butterfly now under our inspection, and these all terminate in one common passage, *bb*; so that, in this part, the

the oviducts resembles a single trunk, which is a hollow channel, ordained to receive the eggs in their descent from the others. On each side of the channel are five little tubes, *c c c c c*, with their extremities closed. These open into the passage, and discharge upon the eggs, in their course, a glutinous matter, which makes them stick to the nettles upon which they are dropped. The construction of these little receptacles of the viscous matter is extremely elegant: they consist of various dilated tubercles, with lateral ramifications, which are likewise dilated again, and serve, in my opinion, to secrete and elaborate the glutinous substance here spoken of. On the other side of these ducts there arises, from the ovary, a much more slender tube, *d*, terminating in an oblong bag, *e*. This contains, as it were, two different substances. The contents of the upper part, *f*, is yellowish; and, on endeavouring to extract it, the membrane, constituting the bag, shews itself to have some strength. As for the yellowish substance, sticking to the inside, it looks very like the fat of the Butterfly. The substance, enclosed in the lower portion of this bag, resembles a limpid humour, and appears as such through the transparent *g* membrane that forms the bag. The other end of the little tube, just taken notice of, opens at its extremity into the external parts of the ovary, or the vagina, *b*, which has a little elegant horny bone, of a bright red colour, that extends from the womb to a considerable height within the vagina, and has an opening, which I have marked with the letter *i*.

All these parts of the ovary adhere so firmly together, by means of the pulmonary tubes, Fig. iv. *aa*, and fat, *bbb*, that I have often lost my desire of endeavouring to display them,

together with the hopes of being able to effect it: but patience, in the end, got the better of those obstacles.

These little creatures are very readily killed, by dipping them into spirit of wine. They likewise die in a very short time, on putting them into a box containing Brazil-snuff. I have observed also, that other insects are subject to the same fate; though, at first, it was by meer chance that I discovered it.

I have thus briefly recounted what I have been able to discover, concerning this little creature, in the space of a few weeks. But if I had been master of more leisure, and the autumn had not come upon me so soon in the operations, I should be disposed to mention, more at large, many other things worthy of admiration, which fell in my way; though I have not yet examined them with the accuracy they merit. Such, for example, as the true manner of the Butterfly's wings acquiring their size with such an amazing celerity; as well as the art by which the tubercles, bladders, and pustules may be imprinted on the wings; how the Caterpillar may be delayed and hastened in the course of its change; by what means all the colours, which appear through the skin of the Aurelia, may, in that short time of their appearance, be so firmly fixed as never afterwards to grow and spread. I had besides proposed representing, a great deal larger than life, all the spots, lines, and colours of this little creature; as likewise its hairs, feathers or scales, and pulmonary tubes, the articulations of its legs, and many other mysterious works of nature observable in it; all which I have elsewhere promised that I would some time or another describe.

*The End of the wonderful History of the Diurnal or Day Butterfly.*

*An Animal in an Animal; or the Butterfly hidden in the Caterpillar; which is a third particular example, serving as an additional illustration to the second method of the third order or class of natural transmutations.*

T A B. XXXVII.

**T**HOUGH, by the particular experiments before advanced, it has been justly shewn what changes of the third order are peculiar to the first and second species or method of transformation; I shall here, by way of further proof describe and figure the manner in which I can find a Butterfly enclosed and hidden in a Caterpillar, and perfectly contained within its skin. This I demonstrated, in 1688, to those eminent persons Magalotti and Thevenot.

But before I proceed to this, it is necessary to observe, that the Caterpillar, Chrysalis, and diurnal Butterfly, which I exhibit in these figures, are the same species with those which the diligent Goedaert has figured Tab. XI. Part 1. And the often celebrated and learned Mr. Ray, in his treatise on the plants owing about Cambridge, Page 134, has

particularly described a Caterpillar of this kind.

Tab. XXXVII. N<sup>o</sup>. 1. I exhibit the egg of the said Butterfly in its natural size. This egg, as I have described in general before, is really the Caterpillar itself, enclosed in this condition, and invested with a membranaceous cover, or integument. Indeed, this Caterpillar lies hid in its membrane, in the very same manner as the Nymph or Chrysalis does in its integuments. I have before treated this matter at large; and the whole will be again more accurately debated under the account of the fourth order: therefore I shall not here exhibit a more ample explanation thereof. I am now only to demonstrate clearly, that the Caterpillar is the Butterfly itself, and that this Butterfly lies enclosed in the skin of that Caterpillar, in the same manner as the Caterpillar does in the cover or skin

skin of its egg. And all these things will appear plainly from what shall be said immediately.

## FIG. I.

The egg of that Butterfly, which is represented in N<sup>o</sup>. VI. is expressed in this first enlarged figure, in the exact manner wherein it appeared under the microscope. It is observed hence to be, as it were, constructed of fifteen small ribs; each of which manifestly throws a shade on the adjoining membrane, situated between those ribs: and hence it is, that, to a person looking at the egg, it appears, about the shady parts, to be divided by as many other smaller ribs. These ribs, and the membrane of the egg between them, are also divided crosswise by regular grooves or channels. It may be also seen how all these ribs concur, as it were, in a center toward the smaller extremity of the egg, and extend themselves beyond its surface. This egg, when arrived at its full increase, is of a yellowish colour; but it is white, when it is fresh in the oviduct. That is, I observe that those eggs in the oviduct, which are first to issue forth, are perfect; but those that possess an higher place are smaller, though they are of the same figure with the former. Those that are situated highest in the oviducts, appear square; and such as lie yet in the extremities of the oviducts are so wonderfully small, that at length they become entirely invisible. The same is likewise observed in the eggs of another Butterfly of this kind, but smaller in the body and wings. I saw those laying their eggs in the month of May, and fastening them to cabbage-leaves, in such a situation as I have herein delineated the egg of this larger Butterfly; that is, so that the ribs run upwards, but the globular basis possesses the lower parts: the same thing holds with respect to these eggs. As the Butterflies, issuing from these, are found all the year, it is probable they lay their eggs at various times. This, however, seems to be done chiefly in Autumn, when we observe their Caterpillars in much greater numbers than at any other season.

N<sup>o</sup>. II. I exhibit the cast and forsaken coat of what is called the egg, which a little before, I have observed, was the real Insect or Caterpillar of the Butterfly; since this Caterpillar, like the Chrysalis, is found enclosed in its skin, even within the egg.

No. III. The Caterpillar of the Butterfly, or the Butterfly lying concealed in the form of a Caterpillar, is here represented as it appears at the full term of its growth. In order to demonstrate clearly and distinctly, that this Caterpillar is the real Butterfly, and the latter again is the Caterpillar itself; I shall first describe the external figure of that Caterpillar, which conceals the Butterfly within its skin. As the celebrated and learned Mr. Ray has, before me, very clearly and perspicuously performed this task, I shall therefore make use of his words, describing the Caterpillar in this manner. "If we consider the bigness of the Ca-

terpillar that feeds on cabbage, it is of a middle size, between the largest and smallest kinds; and is covered with whitish, thin, short hairs, no where clustered together or entangled. The colour of the body is variegated, and composed of black, yellow, and blue; whereof the yellow describes three lines as long as the body, that is, one in the middle of the back, and the two others on the sides opposite to each other. Between these lie the black and blue: the former painted in spots, the latter more diffused. These black spots also are protuberant above the rest of the body; and out of each of their centers, where they appear blacker than elsewhere, they emit the hairs before mentioned. The head likewise has the three aforesaid colours mixed together, and it is covered with the like hairs. The legs, being sixteen in number, are orderly disposed into three classes: the first of which class is composed of six, annexed to the head, near the breast: the second consists of eight, on the belly; and the third of only two, joined to the extremity of the body. The first six legs have each a claw; the other ten have each many crooked ones." This is enough, as to the outward form.

In order to discover plainly that a Butterfly is enclosed and hidden in the skin of this Caterpillar, the following operation must be used; One must choose a full-grown Caterpillar: tie to its body a small thread, and then put it into boiling water, and take it out soon after. Thus its external skin will separate; because the fluids, between the two skins, are by this means rarefied and dilated, and therefore they break and separate both the vessels and the fibres, wherewith they were united together. By this means the external skin of the Caterpillar, being spontaneously separated, may be easily drawn off from the Butterfly, which is contained and folded up in it. This done, it is clearly and distinctly seen, that, within this skin of the Caterpillar, a perfect and real Butterfly was hidden. Therefore the skin of the Caterpillar must be considered only as an outer garment, containing in it parts belonging to the nature of a Butterfly, which have grown under its defence by slow degrees, in like manner as in all other sensitive bodies that increase by accretion.

But as these limbs of the Butterfly, which lie under the skin of the Caterpillar, cannot, without very great difficulty, be discovered in the full-grown Caterpillar, unless by a person accustomed to such experiments, because they are very soft, tender, and small, and are moreover complicated or folded together, and enclosed in some membranaceous integuments; it is therefore necessary to defer the execution of the operation, just now proposed, until the several parts of the Butterfly become somewhat more conspicuous than at first, and are more increased and swelled under the skin, by force of the intruded blood and aqueous humour. This is known to be the case, when

the Caterpillar ceases to eat, and its skin on each side of the thorax, near under the head, is then observed to be more and more elevated by the increasing and swelling limbs, and shews the appearance of two pair of prominent tubercles.

That it may be known at what time the changes in the Caterpillar comes on, exactly and regularly, I shall proceed to explain the fourth figure, N<sup>o</sup>. IV. This design exhibits the Caterpillar swollen, *a b*, all about the second and third rings of the body; whilst, in the mean time, the rest, that is, the lower part of the body and the tail, are considerably diminished and contracted, *c*. This is the best state in which to skin the Caterpillar, which I would have well observed; for it is for this reason only I have said before, that, in order to make the intended experiments, one must chuse a Caterpillar when near the time of changing its skin: such is that which I delineate in this figure.

To explain in a clearer method this fundamental proposition, that the Butterfly is contained in the Caterpillar; or, otherwise, that the Caterpillar is the Butterfly itself; we must carefully observe, that after all the limbs of the Butterfly are sufficiently increased within the external skin of the Caterpillar, wherewith they are yet kept invested, the Caterpillar at length, when about to undergo its change, betakes itself to some retired place, in which it may securely cast off its outward skin. With this design the Caterpillar first fixes itself, by only a thin and slight web, to a board, tree, plant, wall, beam, N<sup>o</sup>. IV. *dd*, or any other solid substance; and after this, fixing the claws of its two hinder legs in this web, *e*, it immediately spins very carefully a strong double thread, or ligament, which it draws across its back, and fastens it with the former superficial web against the beam or wall in two distinct places, *ff*: so that the fore-part of the Caterpillar's body hangs in this ligament as in a wreath; whilst, in the mean time, the hinder part lies fixed in the superficial web, fastened to the beam.

In considering this Caterpillar, it must be carefully observed, that it lays the said wreath somewhat obliquely, and about the fore-part of its body. And hence it happens, that when the skin of this Caterpillar, lying under this wreath, is turned back and cast off, the wreath itself is not thrust more towards the hinder parts than to the middle of the body; it being there fastened a little to the soft skin, and dried. Hence this remarkable advantage arises to the Caterpillar, when stript of its skin, that it hangs, as it were, in equilibrio. The Caterpillar, having thus disposed all these matters with this appearance of judgment and discretion, is observed to cease all action and motion of its limbs, and to compose itself in the most profound rest.

Immediately afterwards, or within the space of twenty-four hours, about the fore-part of the head, it may be observed, that its limbs, being now fully enlarged under the skin, begin,

by the very slow and gentle transportation and appulse of the blood and humours, to be distended, extended, and inflated in such a manner, as to swell even beyond the level of the skin, and, by thus raising the skin, it stretches it, and makes it shine. On the other hand, it is observed, that, at the same time, the hinder parts of the Caterpillar's body decrease in size in their turn, in the same measure, and exactly in equal proportion, and become regularly so much smaller. Hence all power of motion is immediately taken away from the sixteen legs of the Caterpillar, so that it can afterwards neither creep nor stand.

At length this inflation or swelling of the limbs, and other parts, which are at this time forming themselves, and, as it were, budding out into a Chrysalis, proceeds so far, that the external skin opens on the back, and afterwards in three distinct places in the head, and begins to be drawn off, and rolled away from the fore towards the hinder end of the body: and, by this means, all the limbs enclosed within present themselves to view. These limbs and parts, being then disposed, according to a certain necessary order, and unchangeable rule of nature, the creature assumes the form of a Chrysalis, represented under No. V. This Chrysalis is an insect without motion; and indeed it cannot be otherwise, for its limbs are all incapable of motion: this is necessarily occasioned by the impelled blood, and other humours, distending them: add to this, that the limbs are drawn downwards by the separating skin, and a great part of them likewise are extended. Nor indeed is this skin drawn off easily; nay, not without great labour and difficulty: for all the complications of fibres, by which the upper is joined to the under skin, are then broken. For this reason also, the Caterpillar draws itself at that time one way and another, with an undulatory motion, and by the tremulous palpitation of the rings of its body. By this violence, at length, a limpid kind of ichor or humour is diffused between these two skins, and the Caterpillar then, at length, casts off the old one. This process is perfected very expeditiously, after the opening is made in the skull. Thus I have briefly, but exactly, described how this Caterpillar assumes the form of a Chrysalis; the several parts of which are however seen with greater difficulty, than those of the Nymph.

On the other hand, when this Chrysalis, or rather, to speak properly, the involved Butterfly, is drawn out of its skin, by means of hot water, it has a quite different form, as may be seen in Figure II. where it is represented laid on its belly: and this is yet more perfectly illustrated in Fig. III. which presents it lying on its back, shewing thus all its limbs. But because these delicate parts cannot be so well distinguished by those who are unaccustomed to such researches, in order to represent them the more plainly, I have delineated them, and marked them with distinct letters in Fig. IV. It may easily be observed there, how that Butterfly, which I have drawn out from the skin of the Caterpillar, is provided with all those members,

members, which are seen in the Butterfly, delineated in No. VI. As the two horns on the head, *aa*; the double curled proboscis or trunk, placed in the lower part of the head, between the horns, *b*; and four wings situated on the two sides of the thorax, *cc*; between which are likewise seen six legs; and lastly, the abdomen divided by its annular sections, *dd*. All these things appear so clearly and distinctly to the eye, in a natural example, that there is not the least room to doubt the truth of the fact. This is the very creature intimated in No. V. and called in that state an *Aurelia*, or a *Chrysalis*; tho' it scarce exposes to our view any parts, which agree with the creature of the fourth Figure: yet it has no other than the same limbs and parts, only they are disposed in a different manner, as I shall explain hereafter. It will then likewise appear that those, which I represent severally in this Tab. XXXVII. are all but one and the same creature, only hidden, as it were, under different forms; and this is likewise the case in man, if we consider the original egg, with its coverings, the navel string, and its several changes; as I shall explain at large hereafter.

To shew most distinctly the difference between the Butterfly drawn out of the skin of the Caterpillar, and represented in Fig. III. and the same Butterfly, when called a *Chrysalis*, or *Aurelia*, as delineated in No. V. It must be observed, that the real difference consists only in this, that the limbs, that is the legs, wings, &c. are ranged and disposed in the *Chrysalis*, according to a certain order and necessary rule; and, on the other hand, that these parts are by art rudely unfolded, and turned out in the Butterfly, drawn from the skin of the Caterpillar, and removed from their natural situation, which they obtain first under the skin of the Caterpillar, and afterwards in the *Chrysalis*.

Hence the *Chrysalis*, No. V. is nothing else but the Butterfly expressed in Fig. III. the expanded parts of which are folded, and disposed among one another in a different form and order.

It must be at the same time carefully observed, that these limbs, and other parts, are found to be of three distinct magnitudes: for, in the Caterpillar, No. IV. the limbs are still small, and concealed entirely under the skin; and then in the Caterpillar, or Butterfly, stripped of its outer skin, Fig. III. they are extended much larger; and lastly, in the Butterfly, under No. VI. they are larger. Yet this observation must be particularly attended to, because the three creatures, just now mentioned, are one and the same, and their limbs and parts also are the same. But as to the larger or smaller size of them, that depends only on the blood and humours, which being moved in the limbs, has at length extended them as much as possible. In the creeping Caterpillar, it was not possible for these members to increase much: and in the full-grown Caterpillar, they could not be produced further than the skin was capable of being distended: but under the form of a *Chrysalis*, there has been a considerably greater extension; since the external skin is

there cast off, and these parts have acquired another form. However, they are not yet arrived to their full size; since the last skin, which the *Chrysalis* must throw off, could not be extended further than the folds and wrinkles, into which it was contracted, could give way by unfolding or displaying themselves. It happens in this state, that the creature necessarily wants all that motion, which it had before under the form of a Caterpillar, and must rest for some days, until the blood and humours, with which its limbs were filled and distended, are dissipated sufficiently by means of an insensible evaporation, and then the faculty of moving is restored to it.

Hence, therefore, it is certainly and clearly evident, that one animal is here, as it were, hidden or enclosed in another: nay, that the Caterpillar and *Chrysalis* are the Butterfly itself, but enclosed or covered by an hairy and cutaneous coat; and so altered by the different disposition of the parts, that it cannot yet be known. This is the fact which I proposed to demonstrate. And nothing further now remains, but to describe the disposition of the limbs under the skin of the Caterpillar, No. IV. for which purpose, I must compare those parts one with another, as they are constituted in the *Chrysalis*, under No. V. for thus it will be evident, how the members of the Butterfly, drawn out of its skin, are disposed as well in the Caterpillar, as in its *Chrysalis*.

As therefore the disposition and arrangement of the parts in the Butterfly-*Chrysalis*, is found, in No. V. to be worthy of the greatest admiration, I shall observe, that these same parts are not less admirably disposed in the Butterfly, when drawn out of its skin, Fig. IV. this perfect animal being at all times hidden and enclosed in the Caterpillar, No. IV. The legs, which in the Butterfly, at the time it lies in the *Chrysalis*-state, are stretched between the horns, and placed on either side in the breast near the trunk, are in the Caterpillar somewhat curled and complicated under the skin of the six fore-feet of that creature: for, as the impelled blood could not equally extend them in that part; they therefore appear there somewhat wrinkled and inflected: that continues until the skins are at length cast off, and they are again extended as much as possible, in the Butterfly-*Chrysalis*; and whilst the skin is outwardly drying, they are joined one with another.

The wings, which in the *Chrysalis*-Butterfly, are evidently extended in each side of the breast near the horns, are placed under the skin of the Caterpillar, near the under legs of the first class; nay, their ends are enclosed in the skin of the same legs. This ought to be carefully observed; since this is the only reason why, when the Caterpillar is changed into a *Chrysalis*, the limbs are necessarily thus, and not otherwise, disposed: for these legs and wings are, at the time the old skin is casting off, drawn downwards, together with the skin in which they lie, and are then regularly disposed on the breast, near to and between each other: and this is performed with such great art, and in a manner so singular, that  
this

this subject only, might supply matter for a whole treatise.

The horns, which in the stripped Butterfly, that is already changed into a Chrysalis, are extended and situated between the legs and wings on each side on the breast, so as to touch at the same time the trunk with their extremities, are, in the Caterpillar, hidden under that part of the head which constitutes the skull; and these thrusting themselves up out of the head, are very closely folded together, and, by a particular convolution afterwards, represent a serpentine winding. Their extremities are likewise closely twisted into one. Hence the horns in the Chrysalis could be extended above the breast, on the casting of the skin. This I have already, with respect to the Chrysalis of the coloured Butterfly, more accurately demonstrated, magnified in the explanation of Tab. XXXV. It will be proper to compare this history with that, and to read them together, because the one throws great light upon the other.

The trunk, which, in the Butterfly stripped of its skin, and changed to a Chrysalis, is stretched along, and situated on the middle of the breast between the legs, horns, and wings, is found to lie wonderfully complicated, under the skin of the creeping Caterpillar, between some bristly and articulated hairs, situated near the lower part of the mouth. These very bristly hairs, and the trunk, are also found regularly disposed in their respective places in the Aurelia, after changing the skin.

Lastly, the belly and tail, which in the Butterfly, when it represents, Tab. XXXVII. No. V. a Chrysalis, are found shortly contracted and drawn together, are in the Caterpillar, No. IV. extended through the greatest part of the skin of the body. In the hidden Butterfly, or creeping Caterpillar, No. III. all that part of the body chiefly, which is extended from the fore-legs to the hinder extremity, must be accounted the belly and tail; and at the time this creature is changed into a Chrysalis, it loses all its ten hinder legs, without exception.

But, as it is not enough for me to have exhibited and described the most profound mysteries of nature, as I have done hitherto; so, at the same time, I think myself obliged to communicate to the reader, the management by which I was enabled to find out in the hidden Butterfly, the disposition of its limbs under the skin of the Caterpillar: since these limbs are there soft, tender, and almost fluid like water; and therefore, when any one draws off the skin from them, they are most easily removed from their natural situation.

In order therefore to provide against this, and that the parts of the Butterfly, Fig. IV. hitherto described, which lies under the skin of the Caterpillar, No. IV. may be viewed to satisfaction, and seen as they are naturally disposed, we must take care, that these parts be first hardened under the skin, to such a degree, as that they will not lose their natural situation afterwards, when the skin is taken therefrom. This is done very conveniently, if a Caterpillar, which is going

immediately to cast its skin, be put into a bottle full of a liquor composed of equal quantities of spirit of wine and vinegar; for, as the Caterpillar is very easily killed by this liquor, its limbs also will harden therewith, in the space of fifteen or sixteen hours. Therefore, if the Caterpillar be afterwards carefully skinned, the disposition, and several foldings of the limbs of the enclosed Butterfly, may be very beautifully seen, as they lie under the skin of the Caterpillar.

I shall now proceed; and, in order to set this matter in the clearest light, I shall exhibit also, by distinct letters in Fig. v. all those limbs and parts of the Butterfly which I have demonstrated in Fig. iv. or those that are already described in the Chrysalis under N<sup>o</sup>. V. That is, I shall now likewise shew, in the Chrysalis or Butterfly, which hath spontaneously changed its skin, all the parts which I have before shewn in the Butterfly, drawn out of the skin of the Caterpillar by art: for the creature, which I represent in Tab. XXXVII. Fig. v. is the same which I have already delineated under N<sup>o</sup>. III. In this are first seen the horns, Fig. v. *a a a a*, distorted from their natural situation: then are observed the two parts of the trunk, which, arising below out of the head, and running over the breast, are terminated, *b*, on the lower part of the body; where they are likewise, but not much, deflected or bent out of their natural situation. Next are discovered, on each side, two legs, which, being removed out of their natural situation, I have placed on each side of the upper wings, *c c*. The other two legs are not here represented, since they may be plainly and more easily exhibited lying under the trunk and wings in the insect itself, than they can in this figure. Under these two pair of legs the upper and lower pair of wings come likewise in sight, though only a part of the lower appears to the eye, *d d*, because they are covered in great part by the upper pair. All these four wings are likewise drawn out of their situation. The head and eyes, *e*, are seen above, and the tail and the annular divisions of the belly below, *f*. However, one can see all these things but obscurely, for two reasons: first, because these limbs, being placed in this manner in the Chrysalis, are disposed in a peculiar order; and because they are, in that state also, grown stiff and hard, by the power of the air. But it is easy to discover the same limbs of the Butterfly in all the Aureliæ, and to separate them from each other; provided one has first steeped them for a little time in hot water.

I shall now likewise exhibit, in Fig. vi. all the limbs and parts hitherto enumerated, as well of this as of the creatures represented above, since they are all but one and the same creature. There is this difference shewn in the present figure, that I have stript the limbs, which I now present to view, of their last skin, wherein they were kept still rolled up: so that we here now view this insect clad, as it were, in its perfect outside, which is never cast off, and is abolished only by death. But as in cast-  
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ing the last skin, there is as much art observed as in the drawing off of the external skin of the Caterpillar; I shall here briefly explain the whole order of this last change, or the sudden swelling out of the limbs.

In the VII Figure I exhibit the Butterfly, the limbs of which were before represented in the IV Figure, and as having put on the form of a Chrysalis, delineated under No. V. And this Chrysalis being very near its metamorphosis, is in that state every moment ready to cast its last skin. If any one desires to know, by what means it can be known, that this change is very near; let him observe, that this may be certainly known beforehand by those black spots, which are observed to appear through the skin of the Chrysalis, at the ends of the two upper wings; and therefore I delineate one of those pellucid spots in the left wing of this Butterfly-Chrysalis.

In order to understand the method, whereby this last change of the skin is performed, it is necessary to know, that after the enclosed limbs of the Butterfly, have by degrees acquired their full strength, by the help of an insensible perspiration, it at length, by agitating and moving itself, and by drawing its breath with greater force, breaks open the external skin with which it is surrounded, in three or four different places, and displays loose and free its hitherto united parts.

When the investing skin just begins to open, it is observed, that the strength of the enclosed Butterfly is likewise increased. And hence it then immediately thrusts its horny trunk and legs out the skin, and fixing the claws of its feet to the adjacent objects, or to its own cast skin, it thus, as it were, by force, disengages itself from this last covering. Thus at length it creeps out of its skin, formed in the manner exhibited in the ninth Figure. Nor does its appearance then differ much from that which it had, when drawn out of the skin of the Caterpillar by art, as may be seen by the Figure.

I desire leave to observe here, that the creature scarce retains this form a moment; for as soon as the skin is regularly broke open, and the Butterfly just begins to creep out of it, immediately its wings begin to increase, and they grow wonderfully fast. Before I treat this matter more fully, I must observe what I have hinted at in the preceding sheets; that is, that the limbs, and especially the wings of the Butterfly, are of three distinct sizes: they are smallest when they lie in the Caterpillar, delineated under No. III. and then in the Butterfly, drawn out of the skin of the Caterpillar, as in Fig. IV. they were observed somewhat larger; and lastly, they have acquired their third and full magnitude, when, by the impelled blood and humours, they have been orderly situated in the Chrysalis, delineated

No. V. But even then, they could not extend themselves further; because the last skin that remained to be cast off, did not permit it.

Therefore, when these last skins are cast off, it is at length seen, how these wings increase, swell, and are expanded in a most wonderful manner, by the force of the blood, humours, and impelled air: this is exhibited in the X Figure. When any one has for some time considered this matter in the Butterfly itself, he will say that it is like a drop of water, which, when it falls on dry paper, dilates the paper, and makes it unequal, thick, and full of holes. In the same manner, indeed, these wings, which are in the beginning rough and full of wrinkles, and unequal, fold and expand themselves, until at length they become smooth, and they are then twelve time times as large as they were in the beginning. This may be seen in No. VI. where I represent the wings fully and perfectly expanded, and in their natural size.

What deserves most admiration is, that all this accretion of the wings, great as it is, does not take up the space of a quarter of an hour. And besides, what is very considerable is, that if at this time a part of the growing wings be cut off with scissors, they manifestly discharge blood more or less copious, according as the wing is wounded at a less or greater distance from the body. This blood, which is yellowish, distils in small globules out of the wounded vessels, and the wing never afterwards expands itself properly. But these wings, being once wholly extended and dried, will never afterwards discharge any blood, though they be wounded ever so often. Hence it is evident, that this creature, in the space of a quarter of an hour, is sent forth from the Chrysalis in every respect perfect\*, so that it never afterwards wants a further accretion, nor is subject to the mischances of infancy.

In what manner these wings are in reality expanded, and how their black spots are diffused from small into large ones, and how all the colours of these wings are increased, and are all together equally changed by the same motion; these, with other innumerable curious and wonderful mysteries of nature, I shall, if it please God, explain hereafter in a treatise expressly on that subject: and I shall then shew how one may view, as clear as the light at noon, the resurrection of the dead, and the happy state of those that are brought to life again, in this little insect.

I shall finally in this place briefly lay before the eye, the limbs of the Butterfly, and the increasing wings in a rough draught, and afterwards conclude this history. First, in the head are seen two reticulated eyes. Over these are observed two horns, Fig. XI. *aa*, divided into their joints, and adorned with white, yellow and

\* The whole operation in the disclosure of the Butterfly from its Chrysalis, is full of wonder; but in no part so much as in the expansion of the wings. From the folded and complicated state wherein they lay in the Chrysalis, they display themselves so suddenly, that the first observers thought they were small at that time, and grew thus suddenly. The substance of these wings is membranaceous, and the dust which covers them is composed of regular little parts, called by some feathers, and by others scales; but neither properly. They have footstalks, and they are of various figures, oval, round, oblong, and indented. On these depend the colours of the wings. The vessels which support the filmy substance of the wing, contract as soon as the wing is expanded; for, till then, they are tubular. They are like the navel-string in the human body; at first vascular, but afterwards solid. The edges of the wings are supported by a strong rib, and fringed with these feathery substances.

blackish scaly feathers. Between these, one may perceive how the Butterfly rolls its trunk, *b*, which it some time afterwards hides between the forks. In the thorax, the two upper wings *c c* present themselves, which are almost every where covered with white little feathers, and in several places are variegated with thinner, feather-like yellow scales: even the black spots, which adorn their extremities, are composed of similar small feathers. The same likewise is the condition of the two under wings, *d d*. Six legs likewise appear, *e e e e*, which are increased to a much greater length than they had either in the Caterpillar, or in the Butterfly, drawn out of that skin: but in this last change of the skin, the legs are increased no more; since they have already acquired their full bigness in the Chrysalis. Lastly, the tail and abdomen are seen covered with their rings, hairs and feathers, *f*. It is likewise observable,

that all these colours may be wiped off the wings in such a manner, that only a thin, delicate, and transparent membrane remains. And now, can any person, who rightly considers these divine miracles, help admiring them, and agreeing, that they are most truly such? Indeed this remarkable history very strongly evinces, that the most wise and merciful God, is manifestly known from his visible works: since those instances of this power which are remote from our sight, become evident from those we see; that the eternal nature of God is therein displayed clearer than the meridian sun. Their offence therefore is inexcusable, who have either lived instructed by the law of nature only, or have known the law of Moses, and the gospel of Christ; for, according to these, all men shall be judged, and shall be either absolved or condemned.

## The F O U R T H O R D E R.

### *Of natural changes, or slow accretions of the limbs.*

**H**A V I N G now explained the more simple and intelligible modes or methods of these changes, I shall proceed to the compound, and more obscure, which seem indeed wholly incomprehensible; but in reality, all the insects of this fourth order, of which I am now to treat, the changes of which I have hitherto observed, are changed into real Nymphs, entirely like those of the first species or method of the third order. Therefore we may refer all the Nymphs belonging to this fourth order, to the Nymphs of the first mode of the third order: for though the Nymph of the fourth order, does not so clearly exhibit its limbs to view, as that of the first and second order; yet they are more distinctly visible, than in the Chrysalis belonging to the latter mode of the third order. Hence this Nymph must be rightly and properly reckoned among those, which I have delineated and described under the first method of the third order; since the former exhibits its limbs as clearly as the latter.

To those who examine this Nymph more accurately, there likewise occurs a considerable and important difference, which consists in this, that this creature does not cast its skin, but is changed within it, and without parting with it, into a Nymph. Hence it is, that on account of this difficulty of distinguishing the parts of this Nymph, I am obliged to add a fourth order, to comprehend this peculiar kind; though in reality the intrinsic Nymph of this fourth order, is exactly like the external Nymph of the third order, and is of the same nature and disposition with the latter, without any difference.

In order to place this matter in as a clear light as possible, it is necessary to observe carefully, that even in the worms, which undergo the changes of this fourth order, the limbs increase slowly under the skin, in the same manner as in the already mentioned Nymphs of the

third order; and are there disposed in like manner and order under the skin, as they are found arranged under it, in the Vermicles or Worms of the third order; but there is, however, a considerable difference, by which, as by a criterion, or certain sign, one may distinguish these two Nymphs of the different orders from each other. It consists in this, that the Nymphs of the fourth order do not at all exhibit to view their limbs, nor make them visible at any time: for, as the Vermicles, or Worms, which are changed into Nymphs of the third order, cast their skins, and afterwards present to outward view all their limbs and parts, which had been before hidden under them; on the other hand, the Vermicles or Worms belonging to this fourth order, do not cast, but retain the said skin. And hence, as the Nymphs of the third order, when they are afterwards about to put on the form of real Nymphs, cast only one skin; these interior Nymphs of our present fourth order, at the same time cast off two skins or membranes, whereof the outer is much thicker than the inner. This is what constitutes the essential difference I have named, between the Nymphs of the third and those of the fourth order, which are perfectly alike in all other respects.

It is very wonderful here, that some of the Vermicles, or Worms, which are referred to our fourth order of changes, preserve their original and external form entirely unaltered; whilst, on the other hand, others in great part lose it. But these, though they do thus far deviate from them, yet they never entirely lose all the marks of the former Vermicles, or Worms; for they retain, as it were, the figure of Vermicles, or Worms: and in this very figure, or, to speak more forcibly, in their proper skin, which they do not cast off, they become immoveable; and there shooting out new limbs, they at length put on the form of real Nymphs.



Nymphs, within their uncast skin. And this change is, therefore, almost like that undergone by the Vermicle, or Caterpillar, which is changed hidden within its web, and out of sight, as is properly and truly alledged by Mr. Ray. *Vid. Catalog. Plant. circa Cantabr. nascens, P. 137.*

Since, therefore, the Worm either retains its own proper figure entirely, or deviates a little from it; but which ever of the two forms it puts on, yet always increases into a Nymph within its uncast skin. Hence it is, that I think it very reasonable to denominate this change by the apposite appellation of a Nymph-Vermicle; for the Worm, having still retained its outer form, acquires the true nature of a Nymph in its uncast skin. Before I further explain in what manner these worms, which either retain their form or partly lose it, are constructed internally, I shall offer some general observations on the eggs, small animals, Worms, and Nymphs in each of the four orders, and compare all those proceedings of nature together. This, indeed, will contribute greatly to the understanding of this our fourth order.

With respect to the eggs of the Insects in the first order, it must be observed, that the small animals enclosed in them are like the Nymphs of the fourth order; and are surrounded or covered with their regular investing skin, in the same manner as the Nymphs of that order are involved in the skin of their Worms: so that, by reason of this integument, one can by no means distinguish the several parts. But the Insects of the first order, without any intermediate change, directly issue perfect out of the shells of their eggs; nor are they clothed like Worms first, nor do they attain the full term of their increase before they are hatched. And hence it is, that they are not afterwards changed into immoveable Nymphs, but only cast their last skin: and it is therefore for this reason I call this change, at that time, a Nymph-Animal.

Moreover, in regard to the eggs of the second order, it must be observed, that the Worms contained in them are likewise invested with such a skin as those of the first order, and that there are likewise properly Nymphs in it; but they issue from thence imperfect, in respect to all their limbs and parts, which afterwards insensibly increase externally in their body: and, for this reason, the Worm precedes that change of them, which I call the Nymph-Animal. And hence this second order considerably differs from the first, in which the animal issues perfect out of its egg. But these two orders agree also in this, that, in both of them, the animal increases into a Nymph, whilst it is moving and walking about; and this Nymph also is, without losing its motion, at last changed, and it casts a skin.

The eggs of Insects of the third order are likewise invisible Nymphs, which are placed there without food: so that, in this respect, all these three species of eggs agree. But the Worms, which, in this third order, creep out

of the eggs, differ still more, in regard to the perfection of their parts, from the Worms of the second, than those of the second order do from the small Animals of the first. For all the limbs of the small Animals of the third order do not grow out of the skin, but, in a concealed manner, under the skin; for which reason they are removed from our sight, until at length the creatures, having cast their skin, and changed their original form, present all these things to view externally. Besides, about this time, these Insects entirely lose all motion; and then put on a-new the same habit which they had before in the egg. This change I call the Nymph and Chrysalis, as being a third species, different from the first and second order. However, all these three orders resemble each other in this, that the eggs of each are Nymphs at first: and the second order yet specifically answers to the third in this, that, in each of them, the change into a Nymph is preceded by a Worm or Caterpillar.

Lastly, the Worms of the fourth order are, in their eggs, likewise plainly Nymphs, whose limbs and other parts are so involved in the shells of the egg, that they can by no means be distinguished: wherefore those Worms thus far agree with the eggs of the first, second, and third order. But these differ from the little creatures which issue from the eggs of the first order, in that they break, as imperfect Vermicles or Worms, out of their eggs. They likewise deviate from the Worms of the second order, in that their limbs do not grow externally, but within their skin: and, in this respect, they again exactly answer to the Worms and Caterpillars of the third order. However, they differ also from those of the third order, in that they never present their limbs, in this state, to outward view; but are changed into Nymphs within their skin, which they never cast off, but become immoveable therein. By this means they, in reality, assume a second time that form which they before had in their eggs; and therefore I call this change the Nymph-Vermiform, as being entirely different from that of the walking Nymphs in the first and second order: though, with respect to all the parts, it answers to the Nymph of the third order, only that it is invisible. It agrees likewise with the second and third order, in that the Worm precedes the final change: whereas, on the contrary, there issue out of the eggs of the first order of Insects creatures like their parents, nor does the Worm-state precede their Nymphs.

This matter being understood, it is clearer than the light at noon, how far those eggs, small Animals, Worms, and Nymphs of the first, second, third, and fourth orders agree, and in what they disagree one from another; and also what is accidental, as it is called, in each, and what is essential to their several natures. Indeed, when these things are rightly observed, there is nothing in our fourth order of transmutations which may not be clearly and easily understood; since the whole consists in

in this, that the Nymph remains hidden under its skin, which it never casts; nor does it even, at any time, present itself externally to view: that is, this Nymph lies hid in its Nymph, in the same manner as the little creature of the first order does in its egg, in which it is likewise an invisible Nymph; or as the Worms of the second and third order, which are likewise invisible Nymphs in their eggs; or, lastly, as the Worm of this fourth order, which is likewise an invisible Nymph, while in its egg. The eggs of all the four orders entirely agree, in general and in particular, with the change of the Worm of our fourth order into a Vermiform Nymph.

Having considered sufficiently what has been said, I shall proceed to explain how it happens that the Worms, belonging to this fourth order of changes, do more or less deviate from the original form of the Worms, though they do not by any means cast their skin. In order to explain this clearly and distinctly, I must first observe, that some of the Worms which belong to the fourth order of changes, are provided with hard, tenacious, and strong skins; and others, on the contrary, have thin, soft, and flexible skins. This diversity of skin not only makes the transmutation of form more or less remarkable, but renders it so obscured in the Worms invested with a soft skin, that it becomes entirely incomprehensible and inextricable. On the other hand, when the Worms are covered with a hard skin, we see nothing of this kind happens; for as their external tenacious skin cannot form and accommodate itself to the internal change, which the body of the enclosed Nymph undergoes, that skin necessarily retains the figure of a Worm, and resembles it as exactly as if it were still alive.

When the Worms, which I have referred to the first species or method of the fourth order of changes, have eaten sufficiently, and their limbs are increased to the proper degree under the skin, they seek a proper place for themselves, wherein they may safely and quietly issue into a Nymph. After this they rest for some time, until they insensibly lose all their former motion. But they are not even then considerably contracted, nor do they become smaller, or are they changed in form; though, in the mean time, they put on the form of a real Nymph within their uncast skin.

Hence, therefore, we draw this important conclusion, that the insensible perspiration, which I have asserted to obtain universally in the Nymph, may, in this example, be seen, as it were, with our eyes: for, in the Worms of this first species, it is observed, that the Nymph fills the whole skin of the Worm. But this Nymph afterwards, changing colour in a manner not perceivable by the senses, and contracting itself by degrees, inwardly recedes on each side from the extreme ends of the skin, and consequently then fills only a part of it. And this process continues, until the Nymph, being more and more contracted, by reason of the evaporation of the superfluous

humours, manifestly forms in the uncast skin of the Worm two very conspicuous cavities, one towards the head, and the other towards the tail and belly of the said Nymph; and these cavities become afterwards larger and larger, until the creature has acquired its perfect strength. The very experienced Dr. Harvey has observed something like this, concerning the little cavity in hens new-laid eggs; for this also is insensibly enlarged afterwards, by the evaporation of the fluids.

Wherefore, when the skin is hard and tough in these Worms, or when it grows somewhat hard at the time the Worm is inwardly obtaining the form of a Nymph, the former figure of the Worm must necessarily remain entire: whilst, in the mean time, the little creature puts on the form of the Nymph within the hardened skin, from which it is more and more insensibly separating; as I shall afterwards very clearly demonstrate, in the figures of my fourth order. The several observations which I shall subjoin to these, will indeed render this matter yet more clear and intelligible; for I presume boldly to appeal to those observations particularly, since I have employed thereon all the industry I was capable of.

As to the second method of the changes in this fourth order, it comprehends those Worms which are covered with a soft skin; and it offers one thing to be considered particularly, which is, that the external skin accommodates itself to the body of the Nymph which is inwardly changed. But because this internal transmutation of the little Body or Nymph becomes of the shape of an egg, in many species of these Vermiform-Nymphs, therefore the external skin also, which is not cast off, then necessarily acquires an egg-like figure. By this means these Worms also are changed into such Nymphs as do not cast their skin. The Nymphs, which are subject to this method, are very complicated and difficult to be known, beyond all the rest of the fourth order, as their Worms have a very delicate and tender skin. These Nymphs, for that reason, recede less from the form of their Worms than those in which their skin is somewhat thicker; so that the hardness or thickness of the skin makes the change plainer, or more obscure to us.

However widely these Nymphs differ from the prior form of their Worms, they all preserve various traces of that form. In the first place, they retain the skin uncast; and the annular incisions, the head, tail, and the rest, are preserved or altered, according as they more or less deviate from the form of Worms. Some also have appearances like legs, horns, and other marks. For these important reasons, I give them all promiscuously the name of Vermiform-Nymphs; though I very well know that they have been called eggs by some industrious searchers into nature, as Mouffet, Goedaert, the illustrious Mr. Ray, and lately by the very learned Francis Redi, as if no distinct limbs could be observed in them. But are not these the very Worms themselves, which have

within that skin sprung up, or budded into Nymphs, by means of the accretion of the limbs? For what reason then, or with what right, can we call them eggs? But, besides all this, the gentlemen now mentioned do not consider these eggs as real animals, but only as shells filled with a liquid, out of which the animals are at length to be generated by a strange and miraculous transformation. Hence we also observe, that Mr. Ray also, in his catalogue of the Cambridge plants, with great reason doubts, whether the Chrysalis be hidden in the egg which they speak of; at the same time confessing, that they want a proper word to express this transformation. As this author asserts a little before, that these eggs have the same relation to the Flies as the Aurelia have to Butterflies, he certainly commits a great error: for the Aurelia is the insect itself; but these eggs, as they are called, are only the Worm's skins unseparated, in which is contained not a Chrysalis, but a real Nymph; which clearly and distinctly represents to the life all its limbs, as may at any time be demonstrated by us. To this we are to add, that there is no total transformation in this egg, as they imagine to be the case in the Chrysalides. However, it is sufficient for me to have set forth the matter as it is: for I would by no means enter into disputes about words, but would give each its natural signification, provided the eggs, as they are called, be referred to the fourth order of disagreeing transmutations, which is the most worthy of notice in all nature; for in this proper distribution of things consists the great utility of the present work.

In proceeding to elucidate this obscure order of changes somewhat more, I must repeat, that these Worms, which undergo this particular change, do not put off, but absolutely retain, their skin, under which their limbs are insensibly increased and brought to perfection; and therefore, if that skin be tender, it accommodates and contracts itself to the figure of the enclosed Nymph. For the same reason also, as the old skin is preserved, the original rings, which, like so many small joints, divide the body of the Worm, may be then still seen therein; though, in the mean time, these incisions or rings, in some cases, appear to be obliterated, or nearly so, in the skin. This holds chiefly, when the incisions either have not been very distinct in the Worm itself, or when a very thin skin, every where entirely obedient to the inwardly hidden Nymph, is so extended therewith, that the incisions or inflexions of the body cannot be any longer known. This I have exemplified in Tab. XLV. Fig. xxvii. and xxviii.

I have observed also, that the skin, which is not cast off, in some of these eggs, as they are called, has been so accurately fitted and accommodated, all about the body of the Nymphs contained within, that it distinctly and externally represented the three principal

divisions of the body; that is, the head, thorax, and belly. And hence it is, that some of these Nymphs are observed to be, as it were, annulated; and others are without rings. This has likewise been partly observed by the before celebrated sagacious gentleman. Thus I have briefly explained all those things which I thought necessary to be taken notice of, before I undertook to define this fourth order.

I now therefore proceed, and shall direct all my labour to make manifest, as clearly as I can, the stupendous works of the most adored and all-wise Creator, which have been hitherto, to our shame, but little known; that we may therefore love God, our Creator, with the greater and more ardent zeal, and behold him with higher veneration. We can neither justly love or reverence God, so long as we are darkened with our ignorance. Let us, therefore, give praise and thanks to the Supreme Architect for his unmerited favour, since he alone has lighted, and laid before us, the clearest fire in all nature: a light, which has not only easily discovered his most wise providence and infinite power, in those wonderful means which he makes use of to defend and preserve those things which he created; but has also produced those things so openly to the view of all men, that its splendour cannot be obscured by any laboured arguments of human origin. We thus see, indeed, no more than the surface, or, as it were, the shadow of the wonderful works of God delineated here, or by any other. And this ought, indeed, to be the greatest encouragement to us, that we may indefatigably exert ourselves in these researches, and rather seek for the causes and effects of things in nature herself than in our studies. Indeed, most people are at this time so blind, that they imagine no truth arises from any other source than out of their reasonings; to which they contend, place should be given as to matters which surpass even nature. Indeed, we cannot know natural things but by their effects, being incapable of comprehending their causes.

Let us return now to what we proposed; and let it be observed, that our fourth order of changes consists only in this, that the Worm, having quitted its first form, which it had in its egg, wherein it lay, like a Nymph, without food, insensibly acquires, by force of the aliment it is afterwards supplied with, other limbs and parts, arising by accretion under its skin; and afterwards, at length, in this its skin, which is never cast off by it, as it is by other creatures that are changed into Nymphs, it assumes the form of a second Nymph, and for the first time loses, as it were, all its motion. This, however, is in a few days restored to it, by the evaporation of the superfluous humours: so that the Worm, then lastly disengaging itself from these skins, cast two skins together; and now displaying itself with pride, in a more elegant garb, and become mature, as it were, for propagation, it immediately shews itself ready to perform this, the great business of its life.

*A catalogue of the insects referred to the fourth order or class of natural changes, which we call the Vermiform Nymph.*

**A**FTER having set forth, with all the perspicuity and distinction I have been able, the four orders of changes which I have established, and before enumerated the insects of the second and third order, I now proceed to recount those creatures which I observe to belong to the fourth. A great number of these I have preserved in my Museum.

First, I refer to this fourth order the eggs of insects in general: not only those, which produce a perfect creature according to the first order, and those which, in the second order, contain a Worm; but also those which, in the third and fourth orders, produce a Worm or Caterpillar. For I observe, that all these creatures and the Worms are disposed in their eggs and skins, nearly in the same manner as I have said the Nymph of the fourth order, a little before described, is in its uncast skin. Even those little creatures, which issue perfect or imperfect out of their eggs or shells, cast two skins at the same time: and this has appeared to me very evidently in some; nay, I can separate even the external from the internal in some of them, as I shall shew hereafter in my figures. From this the reason is evident, why I say that these insects lie in their eggs like Nymphs, and are as much removed from our view as the Nymphs of our fourth order, just now described; that is, as I have already observed, the external skin, in each case, prevents the Nymph from being seen and known.

Of those eggs, which, in my first order or class of changes, I called Oviform-Nymph-Animals, and, in the second, third, and fourth orders, Oviform-Nymph Vermicles; I preserve a great many species, vastly different from each other, not only in shape, size, and colour, but in their origin likewise, being, as I have already observed, the produce of different insects. Particularly, there are in my collection some very minute Flies, immediately sprung from the eggs, which the Moths fasten with a kind of glue round the branches of trees, in form of a ring. Hence it plainly appears, that the eggs of such insects belong to the first mode or method of the fourth order.

Having said thus much of eggs in general, I now, in the second place, and in a more particular manner, refer the Worms found in our privies, or necessary-houses, to the same order, and the same mode of change, as, on their alteration to Vermiform-Nymphs, they lose nothing of their original shape; but are only covered with a hard and stubborn skin. I can produce that species of those Worms, and of their Vermiform-Nymphs, from which the common Flies of necessary-houses proceed;

and have therefore given, in the XXXVIIIth Table, drawings of this insect in the Worm, Nymph, and Fly-state, besides one of its eggs, which are very remarkable, drawn from a specimen I keep amongst my other curiosities of this kind.

Thirdly, I place in this order the Vermiform-Nymph of the Gadfly, as it perfectly retains the form it wore in the Worm-state. The XXXIXth, XLth, XLIst, and XLIIId Tables, with their explanations, give a satisfactory account of every thing for which this insect is particularly remarkable, in disposition, shape, and changes from a Worm to a Fly; including the figures of the apparent Nymph, and that of the real Nymph, which the apparent Nymph includes. This Fly, as Aristotle rightly observes, proceeds from a kind of broad and flat water Worm; the same with those insects which Aldrovandus, without knowing that they produced the Gadfly, has described by the name of Water-worms, or Intestines. I preserve four species of this Worm, with the Flies to which they change; as likewise an apparent Vermiform, or worm-like Nymph, of a very singular shape, and the real Nymph, extracted by dissection from the insect in that motionless condition. I have frequently met with this kind of Fly, about the end of summer, in the flowers of the garden-parsnep; though, at the time when I formerly made my select observations, I could not discover what their food was.

I likewise reckon of this order the Vermiform, or worm-like Nymph of the Tabanus, or Breezefly; though I am, as yet, at a loss for its\* origin: but I have great reason to believe, that the manner of its becoming a Fly is the same with that of the Asilus, or Gadfly. It is very remarkable, that nature has given these insects an aculeus, or sting, as well as a trunk; so that they may either make use of the trunk to procure the honey, dew, and other juices which spontaneously offer themselves upon plants and flowers; or of the aculeus, or sting, to suck blood of such creatures as they are obliged to kill or wound to feed upon. How admirable the mercy of their Great Parent, in having supplied them with this double resource in their necessities! Gnats seem to partake also of this advantage; but as to other insects, which feed upon blood, such as Bugs and Fleas, I must refer, for the shifts they can make, to future experiments. Another thing remarkable in these insects is, that the honey-juices they suck up with the proboscis, or trunk, are always accompanied by a quantity of air, which may be very easily seen, especially in the trunk of the Butterfly.

\* The origin of this Fly is, indeed, very strange. The parent lays its egg in the fundament of a horse, watching the opportunity of the creature's voiding its excrements for this purpose. From this egg are produced the Worms which farriers call Bots, in the intestines of horses. Having lived their time in the creature, they are voided with its dung, and take their chance for passing the Nymph-state upon or just under the surface of the ground; after which they appear Flies, like the parent.



the form of eggs, or whether they proceed from them as from an internal principle? A great deal may be said in favour of either system; it is therefore necessary, that I should defer, for some time, the discussion of this important question, as I cannot yet produce any ocular demonstration to support either opinions. Nevertheless, I must observe to such as are fond of natural history, that it is impossible for them to gain a competent knowledge of the dispositions and changes of Caterpillars, without feeding on purpose a great number of those insects of the same species, in order to have an opportunity of tracing them through all their changes: nor will this care alone be sufficient, for nothing but repeated dissections can give any satisfactory idea of their internal parts. The naturalist, who should think of succeeding in any other manner, would lose his pains, and remain in perpetual ignorance.

Ninthly, I reckon, among the creatures of my fourth order, those Vermi-form Nymphs, or, as they are otherwise called Eggs of Worms, which are produced by those contracted Worms, which, it is pretended, issue from the putrified bodies of Aureliæ. We see great numbers of different kinds of Flies, issuing from such Worms, in a few days after they become motionless, within their skins, and thereby assume the appearance of these Vermi-form nymphs we have been dissecting. Mouffet was the first who took notice of these kinds of mutation. After him Goadaert treated of them; and since him Redi, and many other authors. I have given by itself, Tab. XXXVIII. Fig. x. a drawing of one of these Worms, and likewise of one of the Vermi-form Nymphs, whose resemblance to an egg is merely superficial.

I place also in this my fourth order, the Vermiform Nymphs proceeding from Worms, which, contracting themselves within the bodies of Aureliæ, without casting their external skin, thus acquire the shape of an egg; this is a thing which I very seldom have had an opportunity of seeing; for these Worms generally open themselves a passage out of the Aurelia, as soon as they have acquired their full growth, as I have shewn already. There is sufficient reason why they should do this. The Chrysalides are generally somewhat moist, which makes it necessary for the Worms contained in them, to leave their bodies, and find out a more convenient situation for their external skin to harden, in order to their becoming Nymphs. But whenever it happens, that when all the moisture of the Chrysalis is exhausted by these Worms as their food, so as to permit the skin of the Chrysalis itself to harden and grow dry, then the enclosed Worms remain within it till they become Nymphs, and from Nymphs, Flies, to appear abroad; in which form they must also make their way through three different skins, as well as the Flies generated in the bodies of Caterpillars, whose labours on the like occasion, have already been taken notice of.

All those Nymphs of our fourth order, hitherto taken notice of, change in the end to different kinds of Flies, as has been already observed, and I preserve a great variety of the Flies pro-

duced from them, among my other natural curiosities.

Having thus enumerated the insects that properly belong to my fourth order, I shall finally add to it all the Nymphs of those Worms of the first, second, third, and fourth orders, which are changed into the said form of Nymphs, within the bodies or skins of other Worms, of Caterpillars, Nymphs, or Chrysalides, as likewise those changed within the several excrescences of trees and their leaves, in form of warts, galls, and the like. However, I must observe, that I do not rank such Nymphs in the fourth order, as having any further right to it, than that of becoming Nymphs, like the Worms which really belong to it, in an obscure, hidden, and mysterious manner. A person must have great experience in these little creatures, to be able to speak of them with certainty in their whole history.

In the eleventh place, I likewise reckon of this order, all those genuine Nymphs which are to be found within the body or skin of any Worm or Caterpillar, and are the offspring of Worms, which have preyed upon the flesh of that Worm or Caterpillar in which they are found. Thus it now and then happens, that a Worm or Caterpillar, not having strength enough to cast its skin, becomes hard and firm, without losing any thing of its external form; in which case, the worms that have hid themselves in it, devour all its flesh, and being freed in this manner from any necessity of altering their situation, they change there to genuine Nymphs, and afterwards to Flies. Sometimes a single Worm of an extraordinary size possesses himself in this manner, of the whole body of another larger Worm, and without ever leaving it, becomes therein a Nymph, and afterwards a Fly. But if the Caterpillar should retain vigour enough, notwithstanding such cruel treatment, to throw off its external skin, and reach the state of a Chrysalis, then the body of such Chrysalis becomes the scene of all the foregoing mutations.

What ought to be considered as a greater paradox than all, is, that these Worms sometimes desert the body or skin of the Caterpillar, upon which they had hitherto preyed, and upon deserting it, enclose themselves in an oviform web, within which, they at length change to real Nymphs, and afterwards into Flies. I shall have an opportunity of treating this subject more at large, when, if it please God, I come to publish my select observations; so that at present, I do not pretend to treat of this change in a particular manner.

Twelfthly, I refer to this fourth order those genuine Nymphs, which become such from Worms, within the skins or bodies of Chrysalides, in the same manner with the Worms of our third order, and first method; but I mean only such Nymphs as are found single in the Chrysalides corroded by them.

I have observed, that those Nymphs are of many and various kinds, and indeed so different one from another, that it would be a difficult task to describe them so as to be distinguished

each from the rest, without the help of particular figures. There is one thing remarkable in such Nymphs, which is, that we may easily obtain a full and satisfactory view of their change from the Worm to this state, and of the admirable order observed by nature, in affecting this transmutation, so as to trace with our eyes the mutation hitherto considered as a metamorphosis of the creature, from a Worm to a flying Insect.

I cannot therefore sufficiently wonder, that none of the authors, whose works I have read, have taken any notice of the Worms now under our consideration, or given us any drawings of the Nymphs of such Worms. Goedaert, it is true, was acquainted with the Flies, to which they at last change, and has given us pretty good figures of them. To describe these Flies in a few words, I need only remark, that I have already taken sufficient notice of them under the name of the Pseudo-sphæca in the detail of my third order, to which they properly belong: in that place too, I observed, that Goedaert's devourer or destroyer of Spiders, should be looked upon as a Fly of the same tribe.

I shall now deliver the method of viewing these most singular and interesting changes. Care must be taken to observe when the Chrysalides harden, and change colour; just at that time they are to be broke open, and the enclosed Worm taken out, and put into a little box, where you may very distinctly and conspicuously behold its gradual change to a Nymph, and from a Nymph to a Fly. I shall, at another time, with God's permission, and with a view of promoting the glory of the wise and powerful Creator, endeavour to set in the clearest light, among my select observations, the manner of such mutation; and likewise to shew what a great quantity of excrements this Worm voids in the mean while; and how it sometimes is obliged to spin a web, with many other particulars very well worth the attention of the curious. At present, I have not opportunity to dwell any longer upon this subject.

In the thirteenth place, I count of this order those Nymphs which become such, and afterwards Flies, from fifty to two hundred together, in the same manner with the Nymphs last mentioned, within the body, or skin of a single Chrysalis, and proceed originally from a great number of little Worms that have preyed upon this Chrysalis. These Flies also were known to Goedaert, though he was altogether ignorant of the true manner of their generation, or the real nature of the Nymph, by which alone these hitherto so perplexing appearances can be solved. Nor should I have succeeded any better than those who have gone before me in this province of Natural History, had I not, pursuant to the advice of the immortal Harvey, called anatomy to my assistance, upon every occasion, and laboured with insuperable patience to discover, and distinctly comprehend, the true principles of those

surprising changes, as often as there was a possibility of discovering and comprehending them. Without experiments, we cannot expect any clear and certain knowledge in matters of this kind, whether our conclusions are drawn immediately from our own reasonings concerning the things before us, or from inductions built upon their resemblance to others, we are equally liable to go astray, and mistake the productions of our own imagination for the representations of nature, as subsequent experiments generally prove. Descartes therefore had great reason to say, that he set more value upon the solid experiments of mechanicks, than the barren and fine-spun contemplations of philosophers. The creatures just taken notice of, as appearing in great numbers within the skin or body of a single Chrysalis, may be traced through all their mutations, in the same manner with those that require each of them an intire Chrysalis for this purpose; and certainly a favourable opportunity of viewing, though but once, so great a miracle in the works of nature, must afford the highest pleasure to those who are desirous of being acquainted with such wonders: but now they may easily procure themselves this satisfaction, as I have, I flatter myself, removed, though not without great pains, the many obstacles which hitherto opposed their desires.

I place also in the fourth order, those genuine Nymphs, which become such from Worms of a particular kind, found within the bodies of larger Vermiform Nymphs, in the same manner with the Worms of the first mode of the third order. This I had an opportunity of observing in the Vermiform Nymph of the common Fly of our necessary-houses; and the same is to be observed also in the insects of the first order.

In the fourteenth place, I must add also to this order, all those genuine Nymphs which we find in the middle of fruit, in the warts of shrubs\*, and the leaves of plants, in rotten parts of wood, and in other obscure and secret places. I have collected some of these Nymphs, and the Flies into which they change; as also the several substances in which the worms are found; all which the curious are welcome to examine, that the adorable Author of such wonders may receive an additional tribute of praise and glory. I preserve likewise some of those Flies which proceed from the little Worm, that Redi found within the excrescencies of willows, without being ever able to discover their changes. On opening the bodies of these Flies, we meet with eggs, which perfectly resemble those found in the same excrescencies; from whence, as well as from many other observations, we may fairly conclude, that all the Worms found in vegetable substances, are originally deposited there by the parent insects in the form of eggs. For a particular illustration of these things, I must refer to the explanations of the XLIV. and XLV. Tables.

\* These all owe their origin to eggs of Flies, and principally to the several species of Ichneumon-fly, which this author calls Pseudo-sphæca. All insects are directed by instinct to deposit their eggs where the young will find food. Butterflies do this on the surfaces of leaves. These Flies lodge them in the substance. They have for this purpose a hard and sharp instrument at the hinder part of the body, and with this they bore a hole in the leaf or rind, and lay their eggs. The wound and juices thrown into it by the animal, alter the course of the fibres, and hence arise galls on the oak; in each of which, there always is a worm originally, the burrs upon the Dogrose, and innumerable other vegetable excrescencies.

In the fifteenth place, I must insert in this order, all those insects that change, as it were, into a kind of web. To this class or order, more particularly belong those little Worms, whose web is so fine, tender, and delicate, that a person must have great practice in things of this kind, to open it without breaking. Within this web, the Worms change to very small Nymphs. I therefore refer to this order Goedaert's Flies, produced from the genuine Nymphs of Worms, which the said author tells us in his xth Experiment, Part I. crept out of the body of a Caterpillar that fed upon cabbages, and then made themselves each a nest of a yellow silk, in which they afterwards shut themselves up. But Goedaert knew nothing of the Nymphs of those Worms, as appears by all that he says in the place already cited. Nor was accurate Mr. Ray, Catalog. Plant. page 137, already mentioned, happier upon this occasion than Goedaert, whose observations he was acquainted with. This gentleman imagined, that the Worms here spoken of, lay hid within their webs in the form of Worms: he even went further, and committed another mistake, in thinking that the eggs of these insects, distinguished by annular incisions, were real Nymphs, and not their oblong transparent eggs: for those alone are Vermiform-Nymphs, though both in reality certain genuine Nymphs not as yet visible. I have sometimes also observed Worms, which form for themselves under ground an oviform case or sheath, which a person, not acquainted with things of this nature, might easily mistake for a Vermiform-Nymph.

Moreover, I give a place in this order to such Nymphs of Worms or Caterpillars, as are found upon the leaves of willows, enclosed in a very fine and delicate covering, or web of the same kind. These Nymphs are changed in time to a very delicate Fly, which the curious may see together, with its web or covering, among my other curiosities.

Lastly, I refer to this order the genuine Nymphs of a kind of Worms, which having made their way through the Caterpillar's skin,

upon the flesh of which they had fed, not only spin themselves a covering of white silk, but fortify it with a kind of cottony substance, which the parent Caterpillar had formed for its own use; and in a few days after this operation, force a passage through both these enclosures in the form of Flies. I preserve in my collection almost all the different kinds of Flies hitherto mentioned, with their coverings or webs, so that I can give, in a manner, an ocular demonstration to those who desire it, of every thing that I have advanced concerning them. I have, besides these, many other kinds of webs, which my desire of making a speedy end of this subject, hinders me from enumerating at present.

I may include, in this order, in the sixteenth place, all the genuine Nymphs which have arisen from Worms, which undergo their changes within very slender and delicate habitations of their own forming, and which they constantly carry about them, as snails do their shells, till at last they change to Flies, and again betake themselves to the open air. I preserve, in my Museum, a great variety of such Flies, and their Nymphs and Worms, together with the surprising cases of the latter, in which they lie hid, and wherein they walk about with, some in the earth, and some in the water. Some of these Worms are mentioned by Aldrovandus, who describes them by the name of Xylophthori, or Worms that destroy timber. I have likewise some Flies which are produced from these Worms, a few of which have been already described under the name of Ephemeri. Lastly, it must be remarked here, that all the Nymphs of the fourth order, may truly be reckoned of the third, if we consider them in themselves alone, and without paying regard to their skins, which they do not cast, or the webs and hidden cases, in which they conceal themselves.

Thus I shall finish this enumeration, and general description of the insects of the fourth order, which I shall hereafter more particularly treat of, and illustrate by just and careful histories, and convincing examples.

*A singular example of the fourth order of mutations, exhibited in a Fly; whose metamorphosis, or natural accretion into the first form of its limbs, and other parts, I call a Vermiform-Nymph.*

T A B. XXXVIII.

N<sup>o</sup>. I. **T**HE Worm of the common Fly of our privies or boghouses, represented of its natural size, and as it appears under its first coat or skin, in which form it is called an egg. This first figure exhibits the egg, as viewed with the assistance of the microscope.

N<sup>o</sup>. II. The double coat or skin of the egg, which skin or coat the Worm leaves behind it, when it is hatched; or, in other words, creeps out of it. This coat is represented as magnified by the microscope, to twice its natural size.

N<sup>o</sup>. III. The Worm itself, somewhat bigger than it really is, when it has just crawled out of the membrane, in which it was concealed under the form and name of an egg.

N<sup>o</sup>. IV. The same Worm, arrived at its full growth, and crawling about. As the feet of this Worm are very short, and narrow withal, it always moves, and, as it were, draws itself forward by the help of its head or beak: therefore, if you put it on a smooth piece of glass, it walks with great difficulty; whereas, upon a coarse cloth, it will advance pretty briskly; for it thrusts its head into the little hollows and cavities of the cloth, and very nimbly draws  
up



up to the head, where thus anchored as it were, the rest of its body, which has only very short feet about the hinder part of the belly. In this respect, therefore, the Worm, of which I am speaking, agrees very remarkably with the water Worm, from which the Asilus or Gadfly proceeds. The Worm of that Fly carries its feet, as it were, in its mouth; but I cannot pretend to say the same thing of the boghouse Worm, as I have not as yet examined it sufficiently; though I think it very probable, that its principal feet are situated in that part. The third figure exhibits this Worm increased by the microscope, to a considerable magnitude.

N<sup>o</sup>. V. I exhibit in this place the Worm already represented under the form it has, after losing all motion, without casting its skin; within which, notwithstanding, it becomes a genuine Nymph: and its becoming a Nymph, in this manner, must, I think, be looked upon as a sufficient reason for my giving it this new name of the Vermiform-Nymph, since, at the same time that it retains the appearance of a Worm, it really changes, under such appearance, to a genuine Nymph. This species of Nymph, with the Worm's skin upon it, in the fourth figure, as it appears when magnified by a microscope, and the Nymph itself stripped of its skin, is exhibited in the fifth figure, somewhat larger also than nature: but the sixth and seventh figures, next following, represent it magnified to much larger dimensions.

N<sup>o</sup>. VI. Exhibits the boghouse Fly in its perfect state, as it appears when it has cast its two skins together; namely, the external hard skin, in which it had the shape of a Worm, and under which it continued when changed to a Nymph; and the internal and more delicate skin, proper to it as a Nymph; for this insect throws off both these skins at the same time. We may observe here, with what extraordinary elegance it is clothed, when the time is come for it to appear abroad, and attend to the great work of propagating its species! The eighth figure exhibits the Fly, as it appears when greatly magnified by the microscope. I shall hereafter explain this figure at large, when I come to describe the insect's external ornaments. There is, it appears, a remarkable difference between this order of changes and the first; as, in the first, the creature issues perfect from its egg, without passing through any intermediate state. This order differs also from the second, as the insects of that order acquire certain membranaceous cases or coverings of the parts within, which rise above the rest of the surface of their bodies. And, finally, it differs from the third order, in which the creatures cast, at different times, the skins wherein they appear as Caterpillars, and the covering they afterwards wear in the form of Nymphs; for, in the fourth order, both these coats come off together. On the other hand, the insects of all these orders have thus much in common: they are Nymphs un-

der all these states, and in every order; and they so long and so often change their skins, till they are become perfect and ready for the work of generation. The Nymph, therefore, having its place in all the four orders, is the true, the only, and immutable foundation; upon which the changes of all these insects depend, as I have attentively and at large demonstrated in the beginning of this work. I make only a cursory mention of it in this place, the better to fix so important a truth in the memory of my readers.

TAB. XXXVIII. FIG. I.

By this figure, which represents the boghouse Fly's egg bigger than nature, we observe that it is of an oblong and angular construction, so as to form, in a manner, an elegant, chequered, and reticulated representation of that kind of cake known in Holland by the name of Woffel. These eggs are of a delicate whiteness, and they have two integuments, which are easily distinguished one from the other. The outer integument is the real shell; and this is, in every respect, like the shell of a hen's egg, as appears by its breaking to small pieces in the fingers. By this means it is an easy matter to separate this outer crust from the internal covering, which properly contains the embryo of the boghouse Worm. As these eggs are moist when just laid, and are deposited by the parent Fly upon the walls of boghouses, and sometimes even in the skins shed by former Nymphs, they stick together, when the air has dried the intervening humidity; so that, on endeavouring afterwards to separate them, part of the external shell of one egg comes off, with the inner substance sticking to it. By this means the angular form of the latter acquires a kind of projecting border. This was the case with the egg here represented, which I thought proper to exhibit in that form, in which alone I could procure it single, on account of its firm cohesion with the adjacent eggs.

FIG. II.

I here represent the delicate internal membrane which covers the egg, as it appears about the fore-end of it. This membrane has been broken by the boghouse Worm, when it crept out of the egg; so that we may see in what manner the external crust or shell has been cracked upon this occasion, and how it has crumbled off from the internal membranes. It is very surprising how these eggs are covered with so hard a substance, resembling plaister of Paris; though it seems probable that Nature ordained it so, the better to shelter the enclosed embryo Worm from the putrid and sharp effluvia arising from boghouses, in which places it is often deposited. This led me to an experiment, by which I have found, that the saline acrimony of urine makes no impression upon these eggs. But it is not in boghouses alone these eggs are to be found: we meet with them in several other places, particularly where fruits, herbs, and other succulent vegetables, lie and rot. But they appear no where so beautifully,





appearance.\* Its body is divided into several rings, which sometimes appear much rounder than at others. The colour is of a sky gray, approaching a little to brown. It is a mistake to think, this Worm proceeds from putrefaction, as Goedaert, or rather his commentators have advanced. It is produced from an egg deposited in bog-houses by a Fly like that, to which it is itself one day to be changed. I have sometimes also found these Worms crawling in vast numbers, and in a strange manner amongst one another, in meadows, in barns, and among very moist cow-dung. These insects are of a very slow growth; so that they do not change till the month of August. I have hitherto taken but a very cursory survey of their internal parts; their pulmonary vessels appeared to me to be those that best deserved further observation.

## B.

When these Worms are about to assume the appearance of Vermiform Nymphs, as is represented in the ninth figure, under the letter B, they remove themselves out of the excrements wherein they have hitherto lived, to some dry place, where they draw all their parts together. I have even sometimes observed these Worms fixed to the walls of country cottages, where they had climbed up to twice a man's height, in order quietly to go through their mutations. This important business is executed in the following manner. First, the Worm's tail is wrinkled up, and contracted by drying, and sometimes it curls itself up, sometimes not; sometimes even it grows quite flat by drying, as it hardens to a greater or less degree, or as it has taken up more or less time in hardening; then the rest of the body becomes wrinkled up, and so contracted, that its rings are in a manner forced together into one. But as the skin of this Worm is somewhat soft, it conforms to all the shapes that the hidden Nymph assumes in its progress towards the Fly-state; and this is the true reason why this Vermiform-nymph deviates a little from the appearance of the former Worm. I say a little, because we may still perceive in it, the skin of the Worm, its tail and legs: but above all, the antennæ, or horns differ; which in this Vermiform-nymph project more from the head, than they did in the Worm itself; besides this, from being soft and pliable, they become hard and stiff at this time. By dexterously opening the external skin at this period, we may obtain the true Nymph it conceals in such great forwardness towards the Fly-state, that it exhibits distinctly the parts peculiar to that creature, the horns or antennæ especially, which are disposed, as in a case, within those of the former Worm.

## C.

When the Nymph we are treating of, has thus lain hid for about sixteen or seventeen days

in the unaltered skin of its Worm; it is sufficiently grown and changed to appear abroad, and so at once forces its way in the form of a perfect and very handsome Fly thro' the said skin, and the internal membrane immediately investing it; as is common to the insects of this fourth order. This Fly is beautifully divided into the head, thorax, and abdomen; it has two eyes, two little antennæ or horns, six legs, a pair of wings, and its body is covered with hair. Its back and tail are yellow and red, delicately interspersed with black spots: it is represented in the ninth figure, under the letter C.

Some authors have fancied, that this insect ought to be ranked amongst Bees, as appears in Clutius's treatise on Bees, where he cautions the unexperienced against so gross a mistake. However, Dr. J. de Mey, regardless of such notice, falls into this error in his notes upon Goedaert, where he prodigiously magnifies the history of this insect as a real Bee. In this he gives evident proof of his little acquaintance with either the Bee or the Fly-kind. Thus the vain temerity of our corrupt nature makes us attempt to pass our judgment upon things of which we know nothing; with a view of passing for persons of knowledge and wisdom upon others as ignorant.

## FIG. X.

I here represent a Worm, that has pierced the skin of a Chrysalis, like that exhibited in Tab. XXXVII. N°. V. and has deserted it afterwards in search of a more proper place in which to perform its changes.

## D.

This Worm is divided by a great many annular sections. Its colour is white; its skin is soft and tender. It moves itself by the annular contraction and extension of its rings, and it continues this motion in its present state, till being quite spent, it quietly lies down to give way to the secret operations of nature, in the change of its condition.

## E.

While this is preparing, we may observe, that the head and tail of the Worm are drawn up, as it were, into its body, though as yet no change happens in the old skin, except its assuming the shape of an egg, in which, soon after, there appears a variety of colours; first, the body then shrivelled up grows white, then yellow, next red, after this of a purple colour, which then acquires a fiery brightness, like that, as it were, of a sparkling red, shining like amber; and, lastly, it turns to a deep brown, which it retains for some days without any further alteration.

On laying open and removing the skin of the Worm at this period, we find in it a true perfect Nymph, which exhibits most distinctly all the limbs of the future Fly: so that this is a real Vermiform Nymph, only that it yet represents the parts of the former Worm, though in a some-

\* We have in England three distinct species of these Worms; the French also have them as common, they call them *Vers a que de Rat*. They are the offspring of three distinct species of Flies, all resembling Bees, but with only two wings. The species here described, is the largest; and it changes into a large Fly, which our observers of Insects call the *Drone Fly*, from its great resemblance of the male Bee, which is also called the *DRONE*.

what obscure and confused manner: this is owing entirely to the softness and delicacy of its skin, which sticks close to the surface, and accommodates itself to the shape and figure of the enclosed Nymph.

By duly attending to the preceding observations, we may for the future easily understand, for what reason some of these Nymphs retain the figure of their former Worms more than others; for, it will plainly appear, that this difference arises solely from the skins of the former Worms, being more or less hard or pliable. For those Worms, that have a very dry and hard skin, as the Worms of the common bog-house Fly, and the *Musca Afilus*, or Gad-fly, cannot but retain their former appearance; whilst other Worms of a soft and delicate skin, cannot but lose a great deal of it; all which is made evident, by a remarkable example in the tenth figure, under the letter E.

Such being the nature of these things, we may plainly perceive how much those naturalists were mistaken, who called the foregoing condition of the limbs, and other parts, a true egg, as may be seen in Mouffet, and Goedaert, in the commentators of this last, and many other authors. But let no one imagine, that I mention this mistake, in order either to expose the writers, who have committed it, or to deserve glory from their ignorance: my sole intention is to publish truth, and excite those who love it, to search after it in the works of nature themselves; for they are capable of teaching us more in a single moment, than all the written accounts of them could do in a thousand years: but then we should prepare ourselves for such an inquiry, particularly by lay-

ing aside all manner of prejudice, as it plainly appears, that observations attempted upon a wrong foundation, have only served to produce a great number of pernicious errors.

F.

To conclude, I present the reader, under the letter F. of the same figure x. a representation of the Fly produced from the Nymph I have been last describing. It is like the common Fly, divided into the head, the thorax, and the belly. Between the eyes, which are seated in the head, and are of a deep purple colour, are two silver borders or zones; and between these borders are placed a pair of antennæ, or horns. From the shoulder-blades arise two grayish membranaceous wings, and from the fore-part of the thorax, six hairy legs. The abdomen is covered with hair, like bristles, and is divided by several rings, parted from each other by black rolls or bandages. This Fly, like the preceding, on its quitting the Nymph-state, leaves two skins behind it.

As to the manner in which this species deposits the eggs within the Caterpillar, represented in No. III. of the xxxviii<sup>th</sup> Table, and the course in which the Worms arising from those eggs, are changed into Chrysalides with the Caterpillar, upon which they feed; or, to speak more properly the manner in which these smaller Worms come to be enclosed in the Caterpillars Chrysalis, and their management in forcing their way thro' this Chrysalis, I shall give a general account of in the progress of my survey of this fourth order, and hope I may some time, or another, have an opportunity of handling this subject more particularly, and solving the gordian knot which it contains.

*The surprising history of the insect called the Musca Tabanus, or, more properly, the Afilus or Gad-fly* \*.

#### THE INTRODUCTION.

THE Insect, whose history I am about to give under the name of the Gad-fly, is so wonderful in all its parts, that it may be well ranked amongst the most masterly works of nature; for, the particulars which industrious observers have discovered in it, are most singular, and unheard-of in other kinds. The learned Mouffet inveighs severely against those authors, who confound this Fly with the *Tabanus* or Breeze-fly, as he affirms there is an essential difference between them, which I have myself also found to be very true; for, as the said Mouffet very pertinently alledges after Aristotle, the *Afilus* or Gad-fly, proceeds from a certain little, broad and water insect. This author remarks also, with equal propriety, that the *Afili* or Gad-flies are much more scarce than the *Tabani* or Breeze-flies, and they are not to be found except in the neighbourhood of rivers, and they have a much larger proboscis or trunk than the *Tabani* or

Breezes. This being settled, the Fly that I am here now about to describe, is a true *Afilus* or Gad-fly, and ought, by no means, to be called a *Tabanus*, or Breeze-fly; for, agreeable to the description given of the *Afilus*, or Gad-fly, it proceeds from a little flat water Worm; it flies about fields near waters; and, in fine, it has a larger trunk than the *Tabanus* or Breeze-fly. Mouffet has given us a true figure of the *Tabanus* or Breeze; and at the same time, has assigned the real difference between that and the common Horse-fly; for there are many species of Horse-flies, and the *Tabanus* or Breeze ought to be accounted one of them. But Mouffet is greatly mistaken in giving the *Afilus* a hard snout, with a strong sting or aculeus fixed to the fore-part of it, these particulars being observable in the *Tabanus* or Breeze-fly only. He errs as much in saying, that the *Tabanus* grows at the end of honey-combs. But it was impossible, that this author should not

\* The common writers have been very confused in their accounts of the two species of insects known by the names of the Gad-fly and the Breeze-fly, and have applied the names at random, to one or the other. The Latin denominations of the same insects, *Tabanus* and *Afilus*, have been as ill defined. The creatures are perfectly distinct, both in the Worm and Fly-state, and, 'tis to be hoped, that, for the future, they will be so understood and considered, this author having perfectly distinguished the words, and ascertained their meaning by his figures.

commit mistakes; for, as he had no experience of his own to go by, he was obliged to take things upon trust from other writers, and consequently was liable to adopt their errors.

I must, on this occasion, desire my readers to take notice, that in my general history of insects, I forgot myself so far as to describe the Asilus, under the name of Tabanus; nor can I account for this oversight, as I then made use of the words of Aristotle just now cited. After this preface and remark, I shall briefly describe the little creature, from which our Asilus or Gadfly proceeds. It is represented in Figure I. of Tab. XXXIX. its Nymph in the II and III Figure of Tab. XLI. and lastly, the Asilus Fly itself, in the II Figure, Tab. XLII.

There are several very uncommon particulars in these states of the same insects in the Worm condition; it lives in the water, breathes by its tail, and carries its legs within a little snout near its mouth. When it becomes a Nymph, it performs the change without casting its skin; and when it becomes a Fly, it can no longer live in the water; so that the element, which hitherto supplied it with life and motion, would now be its immediate destruction.

These are all no more than the external wonders; and they appear insignificant, when compared with the hidden changes and transpositions of parts, performed within the skin, sto-

mach and intestines, but above all, in the spinal marrow, which it is impossible to see, without being lost in astonishment.

There occur besides in this treble, though at the same time single, little creature, other particulars, surpassing, in a manner, all human imagination; such as its most uncommon alterations of colour, indurations of parts, losses of limbs, and acquisitions of internal organs.

Thus I shall close this short introduction, but I cannot too often remind my readers, that they will here meet with a collection of wonders, any single one of which, is worth their most perfect attention. Nor are they the lines only of an Apelles, that I describe in this place, but inimitable pictures, and the very handy-work of the great Creator, God himself, to whom we are indebted also for all that we have, or are, and whom we ought to acknowledge in the humblest manner, as our Creator, Preserver, and constant Benefactor. Hence, judge, O man, how incomparable must be the elegance of those miracles of his, which shall never perish, when so much art and contrivance is to be seen, even in the corrupt nature of creatures, that are buried, as it were, under darkness, by his great ordinations. Therefore to this all-good, all-wise, and all-powerful Being, and to him only, be all the honour and glory of the present discovery.

## C H A P. I.

*The external figure of the Worm, from which the Musca Asilus, or Gadfly, is produced, represented in its natural bigness; and also as it appears when magnified by the microscope; with the manner of its carrying its legs, by a most wonderful contrivance, in its mouth; and of its breathing by the tail.*

### TAB. XXXIX. FIG. I. a.

**T**HIS Worm, viewed with the naked eye, appears to consist of twelve annular divisions, *a*, by which it is separated into a head, thorax, and belly; but as the stomach and intestines lie equally in the two, the thorax and belly, their bounds are scarce perceivable, until the insect, still clothed in the Worm's skin, approaches the Nymph-state.

The parts most worthy of notice, that the naked eye can discern in this Worm, are its tail and its snout. The tail is furnished with an elegant crown *b* or circle of hair, disposed quite round it in an almost annular form; by means of which, while the Worm moves itself in the water, this tail can support itself on the surface, the body all the time hanging down towards the bottom; and sometimes it remains thus a long while, without the least sensible motion. The snout is divided, as it were, into the three parts, *c*, of which that in the middle is altogether immoveable; whereas the two others, which grow at the sides of the former, vibrate in a very singular manner, and, in appearance, are very like the tongues of Lizards and Serpents. The greatest strength of the

Worm is likewise seated in these lateral parts of its snout: it is by means of these it crawls, when out of the water, so that one would imagine it walked with its mouth. Parrots, whose upper and under jaws are both moveable, enjoy, in the same manner, the privilege of using their beaks with such force, in climbing, that they have the greatest advantage from it. In the same manner this Worm, as often as it can lay hold of any thing with those parts that I have been speaking of, appears to move, as it were, entirely by the help of its snout. These parts, however, do not constitute its mouth, as I shall presently shew.

When the Worm, being thus supported on the surface of the Water by means of its tail, has a mind to sink to the bottom, it generally bends the hairs of that part a little towards each other in the middle, and much more forcibly at the extremities, without disturbing them in the least about the roots. By this means a hollow is formed; and the air, pent up in it, looks like a pearl, Tab. XXXIX. Fig. II. *a*. It is by the help of this bubble that the insect can again gently raise itself to the surface of the water, and there remain sus-  
pended.

pended. The same thing has been observed in those Worms that produce Gnats. If at any time the air should happen to escape from between the hairs forming this bubble, the insect has the power of immediately replacing it, by a new supply from its pulmonary tubes; and sometimes even large quantities of air are seen to arise in bubbles from the tail of this Worm, *b*, to the surface of the water, and mix with the incumbent atmosphere. This is owing to the water's being so much heavier than air; it being natural for things, though heavy in themselves, to ascend, in order to make way for those that are more so.

This extraordinary operation may be easily seen at any time, by putting the Worm into a glass full of water, and it affords a very entertaining spectacle; for the air-bubble, enclosed in the tail, looks like a little transparent silver bladder. I have four species of this Worm, and of the Fly that is produced from it, all differing in size and colour; but without any other considerable distinction.

As all I have as yet said concerning this Worm, which produces the *Aphilus*-fly, can give but an imperfect idea of it, I shall exhibit it also as it appears through the microscope; and, at the same time, describe its external and internal parts. Thus the reader will be enabled clearly to comprehend the design and use of those little parts, which are situated near the tail and the mouth; as also, after what manner its lungs receive the air, which is both admitted and discharged by the tail. Finally, I shall make it evident, that those are really the insect's legs which are seen moving near its mouth, like the tongues of Serpents.

FIG. III.

On examining the external figure of this Worm with a microscope, it appears to be a little pointed forwards about the head; and its thorax, or that part of it which we may consider as such, is somewhat broader. The body again grows smaller, and converges at the abdomen; till at last it ends in a sharp tail, elegantly surrounded with hairs, in the form of the rays of a star.

This Worm, the head and tail included, has twelve annular divisions, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12. Its skin resembles the covering of those animals which Nature has provided with a crustaceous habit, much more than it does that of Worms, or of the naked Caterpillars. It is moderately hard, and, like that rough skin called chagreen, it is thick set with an infinite number of small grains, pretty evenly distributed. These grains lie so close together, that there is not to be found the least vacant space between them; and they are smaller in those parts, where the rings of the abdomen are pointed to each other, than upon the middle of the rings. This disposition renders the skin more flexible, and consequently facilitates the turnings, and other motions, of the Worm's body. The true construction of these grains is seen, on viewing them with the greatest magnifier, Fig. IV. and I give a sepa-

rate drawing of them upon a small portion of the skin. This figure also shews us how the skin, *a*, looks in the interstices of those grains. Those grains are very thick, and convex in the middle, *b*: near their edges they appear as consisting of many rings, *c*, which join each other; and form a great many irregular points, *d*, so as to add great strength and firmness to the grains themselves. The substance of those grains is a very firm horny bone; and I make no doubt but the skin of this Worm might be made use of, in turning, to polish the harder woods, as ebony and box, in the same manner that the skin called chagreen, just now taken notice of, is successfully applied to the same purpose.

There are also nine puncta respiratoria, breathing-holes, or points of respiration, on each side of this Worm's body; but I here represent only twelve of them, nine at one side, and three at the other. There are no such holes visible on the outside of the tail, Fig. III. *a*; nor in the third ring, counting from the head: for the tail has, at its extremity, openings for the admission and expulsion of air, as already taken notice; and in the third ring the breathing-holes only appear under the skin, and are very small, as it is hereabouts the embryo wings of the future Fly lie concealed. It is very remarkable, that this Worm should have but one ring without those breathing-holes; whereas Caterpillars always have two without them. The reason of this difference seems to be, that most Caterpillars change to Flies with two pairs of wings; whereas the Worm, under our consideration, changes to a Fly that has but a single pair.

Above these pulmonary openings, there besides appear a great many black spots; but they are much smaller than those formed by the breathing-holes. These lesser spots seem intended merely for ornament. They shed a skin, so that they are still seen in the insect, when arrived at the Nymph-state.

The skin has only three colours: it is adorned with oblong black furrows, spots of a little lighter colour, and orbicular rings; from the middle of which there generally springs a hair. In the figure before us, only the hairs that grow on the insect's sides are represented, Tab. XXXIX. Fig. III. *bb*; for to exhibit them all, would require too large a drawing. Besides the hairs already mentioned, there are here and there some other larger hairs, *cc*. All the variety of colours perceivable in this insect, proceeds from this; that the colour of the grains is somewhat deeper or paler in some places than in others; for there is no material difference between them, in point of size. According, therefore, as the number of grains is greater or less, or the colour of them is darker or lighter, the furrows and rings are of a deeper or paler colour.

The head of this Worm, *d*, is, as it were, divided into three parts, and covered with a skin, the grains on which are hardly discernible. The eyes, *ee*, lie forwards near the snout,

snout, and are somewhat protuberant. It has likewise two little horns, *ii*, on the fore-part of its head. The snout itself is somewhat crooked, and ends in a very sharp point, *f*; but what is altogether singular and surprising, and no doubt, if I may say so, is most wisely contrived by the Great and Almighty Architect, is, that this insect's legs are placed near the snout, between the sinuses in which the eyes *gg* are fixed: so that, at first sight, I imagined this Worm made use of its snout, as Parrots do of their bill, to fasten upon whatever it pleased, and move itself from one place to another; but I have since learned by experience, that those parts are real legs, which is altogether as surprising as if a small pair of hands, one on each side, should be seen growing in a man from the inside of his jaw-bones\*.

Each of those legs consists of three joints; the outermost of which is covered with hard and stiff hairs, like bristles. From the next joint there springs a little horny bone, *bb*, which serves the insect for a kind of thumb: the joint itself is likewise of a black substance, between bone and horn in hardness; and so is the third joint. But these particulars cannot be so well distinguished on the outside; for which reason the parts that form the upper sides of the mouth, and the eyes, must first be displaced with a very fine small knife. This done, we may plainly perceive, by the help of a microscope, that the leg is articulated by means of some singular ligaments, with that portion of the insect's mouth, which answers to the lower jaw in the human structure. We may also, by this method, discover the muscles which serve to move the legs, and draw them quite up into the cavity that lies between the snout and those parts of the mouth, near which the horns, *ii*, are situated.

I have taken the pains to draw five of those muscles administering to the insect's leg, which are very distinct. Three of them, Fig. v. *a*, are continued by their tendons, in form of a black substance between bone and horn; and after this, growing softer, are inserted *b* into the inside of the greatest joint of the leg, which is of the same kind of substance with the tendon. The other two muscles, *c*, had their insertions on the opposite side of the same joint. The muscles which move the other joint, *d*, are inserted into that large horny joint already mentioned; and in this joint also are to be seen the latent muscles, which move the extreme joint of the leg, *e*, with its bristles, and its thumb, which I here likewise represent, *f*. This figure shews, at the same time, in what manner the foot is surrounded with hair. This insect not only walks with the legs I have been describing, at the bottom of the water, but even moves itself on land by means of them. It likewise makes use of them to swim with, while it keeps its tail on the surface contiguous to the

air, and hangs downwards, with the rest of its body in the water. In this situation, no motion can be perceived in it, but what arises from its legs. At this time also it plies them so elegantly, that, to the naked eye, they appear like the vibrating tongues of Serpents. Hence we may conclude, that the greatest strength of this Worm lies in these parts; and we may be likewise convinced, that it exhibits in a singular manner, and more fully than many other animals, the wonderful contrivance and execution of the Divine Power and Wisdom.

The snout itself, Tab. XXXIX. Fig. vi. *a*, is very black, and of a substance between bone and horn. This may best be seen by turning the insect on its back: in this situation also we can discover the crooked point of the snout, *b*, near which the jaws open themselves, *c*, and offer to our sight the gullet or throat, and all the other parts of the mouth. Here likewise we may observe three membranaceous divisions in the snout, two of them running transversely, one at each side, *dd*; and the third stretched lengthwise between both: by means of these divisions, assisted by the muscles contained in the snout, the Worm can at pleasure expand or contract that part. But the back-part of the snout, *e*, is quite solid, and made up of a black substance between bone and horn, and of a rounded and somewhat globular form; whereas the sharp part that lies forward, which I have before represented on the fore-part of the head, Fig. iii. *f*, is hollow.

The tail is most artfully imagined and constructed. Its extreme verge, or border, is surrounded by thirty hairs, and the sides of them are adorned with others that are smaller. Here and there also, some of the bigger hairs branch out into others, each of which I reckon as a single hair. These hairs are all rooted in the extreme skin of the tail, which, in this place, is also covered with rough grains; as may be seen by cutting it off, and holding it up, when dry, against the light, upon a thin plate of glass. It appears likewise, by the same means, that the hairs of this part have, at their very extremities, grains also, like those upon the skin; though I could never yet get a distinct sight of them through the best microscopes. In the middle of the tail is a little opening, within which there are two small holes; by which the insect takes in and lets out the air it breathes. It seldom happens, that the hairs of the tail are so regularly disposed on the surface of the water, as I have here represented them, unless when the Worm but just floats with its body in the water, and the tail with the hairs belonging to it are a little lower than the surface; for then these hairs display their extremities, in the distinct manner that I have here represented them: and the least motion downwards of the tail, at this time, occasions

\* These singular and amazing Worms are very common with us in shallow standing waters. I found millions of them this year in a pond, in a field across the road on the right hand of Liffon-Green, near Paddington. They will live many weeks in a glass of water, and shew all their amazing qualities; confirming, in every instance, the accuracy and truth of this author's accounts. A microscope shews very beautifully the motion of their intestines; and few insects afford a more beautiful object.



a considerable pit or hollow in the water; whilst the tail itself assumes the figure of a glass, wide at top, and ending at the bottom in a point. Hence it is manifest, that this tail serves the Worm for both the purposes of swimming and breathing. Thus then, O wonder of wonders! this creature receives by its tail the universal principle of life and motion in animals. And the better to answer such an

important use, those hairs are so mysteriously constructed, that, let them lie under water ever so long, they never contract any moisture, the water running off of them the very moment they reach the surface. Another advantage the Worm has in these hairs, is, that, when swimming, it can by means of them immediately stop itself, and so remain quietly suspended in the water as long as it pleases.

## C H A P. II.

*Of the actions or motions of this Worm; the places where it is found, its food, and the manner of killing it for dissection.*

THE motions which this Worm makes in swimming are extremely beautiful, especially when it advances with its whole body floating on the surface of the water, after filling itself with air by the tail. To set out in this posture, it first bends its body to the right or left; then contracts it in form of the letter (S); and lastly, or lying flat upon its belly, it stretches out the body again to a straight line. By these alternate bendings, contractions, and extensions, it moves along upon the surface of the water; and as its motions are very slow, it will hold out for a long time in this manner.

These Worms are no way disturbed on being handled in the water; though they cannot suffer the touch of other Worms, even those of their own species, without agitation, when swimming amongst each other. From this circumstance we may conjecture, that they are provided with a ready instinct to discover whether what comes in their way is likely to do them any harm. Be that as it will, I drew great advantages from this quiet disposition of the insect, as it afforded me the better opportunities of examining it by the microscope, and making a satisfactory figure of it.

At the time when these Worms float on the surface of the water, it is impossible to drive them under it, so as to make them continue there, on account of the great quantity of air with which they are then swelled. But on expelling this air by the tail, they of themselves immediately sink to the bottom; nor can they again make themselves float on the surface of the water, till, having risen to it, they expand the hairs of their tail, and take in another draught of air.

On taking these Worms out of the water, all their motion seems confined to the head, because it is only by the help of their legs, which are situated there, that they can stir in this situation. But as it is necessary, for that purpose, that the head should bend at the same time, one would, at first, imagine they make use of their mouth to walk with; whereas, in reality, their progress is entirely effected by the feet only.

These Worms are to be found about the beginning of June, sooner or later, according

as the summer is more or less warm, both in salt and fresh waters. Sometimes great numbers of them offer themselves, as it were, of their own accord to our inquiry; whilst in other years, it is no easy matter to meet with them. They are common enough in the ditches of grazing grounds, especially in such parts of those ditches as here and there contain little patches, or islands, covered with grass and other plants, through which, and upon it, these Worms love to crawl. They are often too, to be seen in the cracks of our ditch-banks, where they float upon the surface of the water, by means of their tail, with head and thorax hanging down: and in this situation they will turn over the clay and dirt with their feet and their snouts, as those parts are so near each other, in search of food.

It is thus these Worms look out for their nourishment, which is principally a kind of viscous matter, to be met with in little pools, and about the sides of ditches; for these insects are never seen in large and deep waters, so that, whenever it happens that the ditches are quite full, the Worms, to come at their food, either betake themselves to the bottom, or venture on shore, in quest of something to live upon. It is very remarkable in these insects, that, when they lie under water, they very often drive air into the cavity formed by the hairs of their tail; which cavity, on being thus blown up, looks like a transparent pearl moving in the waters; at the same time that, by becoming the lightest part of the insect, it keeps uppermost, and thereby affords the feet and the snout a better opportunity of providing for the insect's support.

This little insect is exceeding harmless; it neither bites or wounds, or otherwise does any mischief; contrary to the opinion, one might at first sight be apt to form of it, on account of the surprising vibrations of the legs, placed in its head, which so much resemble the brandishings of an envenomed tongue or sting: but such notions appear altogether wrong on further examination; for the opening of the insect's mouth, at which it sucks in its food, is seated within the bending of its sharp pointed and crooked snout.

I find that clay and soft earth are the food of this insect; though I have likewise sometimes found

found in it, on dissection, little red stones, and small grains of sand intermixed: I am not able to explain, on account of the narrowness of this insect's mouth, how it could possibly take in such large and hard substances. This induces me to think, that it only sucks in the subtiler viscous particles of earth, mud, and clay, which afterwards undergo various mutations in the stomach, as I shall hereafter endeavour to shew, in the anatomy of this Worm, and the Nymph produced by it, where I shall also relate the manner how the very intestines of this insect cast their skins.

I have tried many methods of killing these Worms, in order to examine them anatomically. Spirit of wine does not so well answer this purpose; for they live in it a day and night, or perhaps longer; but I cannot affirm any thing positively on this head, as I grew tired of wasting my time, that I could otherwise so well employ, in watching them. Some of them that I threw into rain water, after taking them out of the spirit of wine, together with others, continued alive several days, till I had opened them all, while living, in order to view their parts, and found myself under a necessity of looking out for a fresh supply. In vinegar also these insects held out a long time, and they moved more briskly in it, than in water; they would sometimes also crawl

out of it. Some of them endured this trial for two days and a night, and some a longer time, whilst others expired sooner. But hardy as their constitution may be, they die in spirit of turpentine in less than a quarter of an hour. It is very curious to observe, at this time, how the air contained in them remains, in appearance, fixed between their hairs, and the divisions of their body, so as perfectly to imitate the appearance, as it were, of transparent silver.

The industrious Goedaert, as far as I can guess by his drawings, give us one of this Worm; as also a description of it in the first part, and seventieth experiment of his natural metamorphosis; but he forgets to tell us whether it belongs to land or water: nor is there among all his observations concerning it, any thing remarkable, except its being able to live for nine months without food. On this account he calls it the Chameleon, imposed upon by the vulgar opinions of the land-animal of that name, living entirely upon air.

We have likewise, in the learned Aldrovandus, a figure and a description of this Worm, under the name of the Water Intestine. But this author knew nothing of its changing to a Fly, or of the other surprising particularities, which I have observed in it.

### C H A P. III.

*The anatomy of this Worm, giving an account of its teeth, stomach, intestines, salivary vessels, pulmonary tubes, fat, heart, brain and muscles.*

THE internal parts of the Worm, which produces the Asilus or Gad-fly, are the teeth, gullet, stomach, thick and slender intestines, salivary vessels, pulmonary tubes, fat, heart, brain, spinal marrow, nerves and muscles; each of which I shall now separately describe. The teeth are seated in the back part of the mouth, as in many fishes, so as to enable the insect, after it has taken in any food, to grind it properly before it gets down into the stomach. I have by me specimens of Hermit-fish, and large Crabs, which have teeth in the very cavity of the stomach. The teeth of the insect now under consideration, are of a substance between bone and horn, and their surface is in many places rough and unequal; but these asperities are not considerable enough to be taken notice of in the figure. The gullet is a very slender channel, running from the jaws and mouth to the stomach, through a fissure or opening in the spinal marrow, contrived on purpose to give it free passage: this is likewise the case in many other insects. For this reason, the brain of this Worm lies, as it were, upon the fore-region of the stomach. The stomach itself appears as a small membranaceous particle, and is found full of the half-digested food, on killing the Worm, in spirit of turpentine, as soon as it is caught, and then dissecting it. The slender intestines also appear, on this occasion, filled with the same substance. In this species of Worms, the stomach and slender in-

testines are about five Dutch inches in length; or to use Mr. Thevenot's method, they are equal to five rows of regular cells of Bees, built one against another, five in a row. Mr. Thevenot imagined, that by means of such cells, an universal measure for all nations might be discovered, supposing such cells were every where equally regular, and of an equal bigness. I must here observe, that there is very little difference between the stomach and intestines of this insect.

Towards the extremity of the slender intestines are four vascula varicosa, or cæca, or little guts or appendages closed at the end: these are situated equally in the abdomen and thorax, which sometimes contain an aqueous fluid, and sometimes a bright white substance, like coagulated milk or new cheese, when beginning to crumble to peices. These four little intestines are full twice as long as the real guts of the creature, and they form a great many uncommon turnings and windings in the thorax and abdomen, so that it requires no small pains and attention to discover and separate them. In the next place are the large intestines, which here and there swell out into nodules, as it were, and are filled with clay, red particles of stone, grains of sand of different sizes, and other similar substances. All these particulars will appear to greater advantage in the figure which I propose to give of the Nymph's intestines, accompanied with

with a description of the nature of the sand or gravel which are found in those parts.

The salival vessels, Tab. XXXIX. Fig. VII. *a*. are two channels, closed at their ends. They are of a membranaceous transparent substance, and are seated in the thorax, where they make a great many windings and turnings. In colour they resemble fresh curds, on account of their contents which appear through them; and accordingly, on their being cut, nothing freely flows from them, the matter they contain being quite coagulated. The salival vessels unite at last, so as to form only one, *b*, which terminates at the mouth, to which it is inserted upon in the back part of it. Near this insertion appear two small particles, *cc*, which very much resemble little muscles. As I never met with any fluid matter in the vessels I have been last describing, I cannot take upon me to say any thing positively, concerning the use which the Worm may make of them, though I called them salival vessels, because such channels are very remarkable in other Worms, and also in snails. They appear even in the Nymph of the Worm now before us, and afterwards in the Fly, in which they are stretched out to their full length, and after pervading the thorax, they terminate in the abdomen, being remarkably broad at their extremities, if compared with their condition, as they were in the original Worms; this makes me believe, that these vessels do really, at last, perform in the Fly, the office of salival ducts. The mouth, Fig. VII. *d*, at the bottom of which those salival ducts terminate, is here represented without the eyes, because, in dissecting this Worm, both the eyes, and those parts which constitute the sides of the head, very easily separate from the mouth.

There is no part of this Worm without its pulmonary tubes\*. They consist of two very conspicuous and considerable tubes, Tab. XL. Fig. I. *aa*, which are composed, as it were, of flat-tish rings, and are much wider in the middle than at the back or fore extremity, which runs towards the tail. These tubes are seated on the sides of the insect's body, where they unite with the puncta respiratoria, or breathing holes. It is probable, however, that the insect does not make use of them for breathing, till it is arrived at the Fly-state, when it lives in the air; so that these channels remain closed, till the insect comes to live in another manner, just as the aspera arteria of a foetus continues closed, as long as it lies in the amnion, and surrounding waters. The pulmonary tubes are distributed all over the body; they even penetrate the bowels, brains and nerves, in order to supply every part with this vivifying fluid. Great multitudes of them are to be seen in the same place with the optic nerves, and the increasing membranes of the eyes, *b*, and they gradually enlarge, in order to contribute to the formation of eyes in the Nymph, and afterwards answer all the purposes of such parts in the Fly.

Here and there these tubes meet, and unite together from the parts, *cc*, especially about the sides of the body, *dddd*, where one may perceive a general anastomosis of them one with another, by means of their common intermediate branches, stretching from one breathing hole to another; from hence spring an infinite number of ramifications, administering to the membranes and muscles of the skin, which I here mark with points, *eee*, and likewise to the internal parts. At last, the principal channels end at the feet, *f*, by two distinct tubes opening into one passage, where they serve to take in air for the creature's use, and alternately expel it, as has been already shewn in the external survey of that part, as the said tubes appear very plainly through the transparent skin of the insect.

The largest of these pulmonary tubes are sufficiently conspicuous; and they are composed of crooked rings, and are also somewhat flat, as I already mentioned, Tab. XL. Fig. II. *aa*. On stretching a piece of these tubes, those rings which compose them, separate very readily, so as to roll out to the length of two or three spans, and then they look very pretty, being like an extended screw, or an untwisted spiral, or a silver wire that had been wound up upon a needle, *b*. This silver-like thread, of which the rings are formed, is almost as strong as the thread spun by the Silkworm, on breaking, it snaps with a crack that is very perceptible.

The fat, Fig. III. *a*, is distributed all over the Worm's body, so as to be met with in the head, as well as in the abdomen and thorax. It is as white as the purest snow, except at the tail, where it generally inclines to be a little green. As to its texture, I don't well know how to describe it, on account of the strange variety, in point of configuration of the particles that compose it; for they are round, *b*, oblong, *c*, broad, *d*, angular, *e*, pyriform, or in the shape of a pear, *f*, and of almost every other imaginable shape. This fat is most firmly united with the pulmonary tubes that run through it, *g*; so that I believe it serves, in the same manner with the Omentum or Cawl in man, to bind together the blood-vessels, and convey them in safety to their several destinations. This fat, if laid on a piece of glass, and held to a candle, melts like oil, and immediately flames; this proves, that it is really what I have called it. These particles, in regard to the vessels contained in them, might be called vasa adiposa, or fat vessels; but such a name would be improper for them. This fat in the Nymph and Fly, retains nothing of its original form, as may be seen by examining it in the Worm where it exhibits so entertaining a sight, that it is impossible for words to give a just idea of it.

Not only the form of the heart, Fig. IV. *a*. in this Worm, but its pulsations also may be seen through the skin, under the third ring, counting from the head; but this is a great deal more perceptible in the Nymph, when

\* The number of these pulmonary vessels in the generality of insects is astonishing, and it is so also in plants. They not only appear conspicuous in all parts of them, but the greater part of the stalk in May is composed of them; this is particularly observable in the stalks of bulbous plants: and in the same manner we see it in the insect-tribe most plain, and the tubes most numerous, and divided in the softest species.

stripped of its outer covering; for at that time the motion of the heart appeared to me so plain, and was withal so considerable, that I saw it displace a particle of fat in one of its vibrations. The end of this powerful organ, when it is fastened to the tail, is a little sharp and narrow, but here and there it dilates itself, Tab. XL. Fig. iv. *aa*. Towards the head it gradually widens *bb*, and then closes again into a narrow channel *c*, in which form, after passing through the abdomen and thorax, it pursues its course towards the head, where it is intimately united with the membranes of the brain. Thus, in regard of figure, the heart of this Worm nearly represents the Worm itself, except the part next the head, being a great deal narrower, and that next the tail, dilating itself here and there, as in Silkworms.

On opening either the Worm or Nymph, the motion of the heart presently ceases; and if it did not, the particles of fat with which it is surrounded, would hinder us from seeing it. For this reason, the best time for examining the heart of this insect, is when it has attained the Fly-state: or if we choose to do it in the Worm, we ought first to leave it for some time in spirit of wine, that the fat may gradually dissolve and waste away; but at this time, the heart is so delicate as not to suffer any air to get into it. In the beginning, I really thought I should never be able to discover or disclose this part; and I must own, that human ignorance and weakness never appeared so evident to me, as during my survey of this little insect; for with all my attention and diligence, I found it impossible to examine it as minutely as I proposed, tho' I spared no time to get the better of all the difficulties that opposed my inquiry; the wonders I discovered in it, being but a small part of those accumulated miracles I have here related. This my insufficiency has made me very often, in the course of my inquiries, break out within myself into the following words:--- O God, thy works infinitely surpass the reach of our feeble understandings; all that we actually know of them, or ever can know, is but a faint and lifeless shadow of thy adorable perfections. The brightest understandings fail in the contemplation of them, and are obliged to confess, that all this boasted penetration is but short-sightedness, when employed in fathoming the depths of that power, goodness, and wisdom it has pleased thee to exert in the lowest parts of thy creation!

The truth of these words evidently appears by the construction of the brain, spinal marrow, and nerves of the Worm here under consideration, which I am now going to describe; for this construction is so wonderful, that I doubt very much, whether any thing equal to it was ever before observed in any animal. The brain consists of two globular lobes, Tab. XL. Fig. v. *aa*. These lie upon the gullet;

and for this purpose nature has contrived a slit *b* in the spinal marrow for the gullet to pass through. On the forepart of the head appear the membranaceous parts of the eyes *cc*, which gradually expand themselves along with the optic nerves that are to serve the succeeding Fly, and grow till they are arrived at their just period of increase. In the mean time, these membranaceous rudiments of the Fly's eyes are curled and folded up, and cannot be seen but very imperfectly, because the insect has not as yet attained its Nymph-state, in which at last all these parts unfold themselves, and become very discernible.

The spinal marrow consists of eleven nodules *dd*, which form the most elegant spectacle that nature ever exhibited; for it is bent so as to resemble a swine's tail, and runs as it were in curls from one end to another. This curling may be still considerably increased by cutting the nerves. The figure I give of this part does not express all the windings of the original, the better to exhibit the eleven nodules, from whence all the other nerves take their rise; for all the nerves of the insect arise from the brain, the spinal marrow, and these nodules. In the first place we are to name those nerves which tend to the forepart of the head, and running under the membranaceous rudiments of the future eyes *ee*, are distributed to the gullet, the jaws, the mouth, and palate, to the Worm's eyes, the muscles of the legs, and parts thereabouts. Next are the nerves *f* which extend to the sides of the insect's body. Lastly, there appears a considerable number of them *gg*, that spring on each side from the eleven nodules of the spinal marrow. To avoid confusion, I have omitted some of them in the figure; the last mentioned ramifications go to the stomach, intestines, muscles of the skin, and all the other internal parts, which they supply with motion, sense, and life. But how is it possible to describe the spirits contained in those nerves, and the manner in which the secretion of such spirits is performed? For my part, I freely acknowledge, that as yet I have not been able to discover for what purpose the medulla spinalis is curled up in this insect, while a Worm, in so strange, but elegant a manner;\* whereas in the Nymph, and afterwards in the Fly, though neither of them are so long as the original Worm, it appears stretched out to its full length. It is in the eleven nodules that the alteration is most considerable, for these in the Nymph and Fly (O incomprehensible wonder!) are found at a greater distance from each other, than they were in the Worm. The nerves, on the contrary, from lying at full length in the Worm, are curled up and folded in the Nymph and Fly, and are otherwise altered in a most surprising manner, as I shall hereafter explain by a figure of the Fly's spinal marrow. The transmutation, there-

\* As important as the spinal marrow is to the animal œconomy, we find that it does not observe the same course in all creatures. In the generality of animals it runs through the middle of the back-bone; but in fishes in general, it is carried through certain peculiar apophyses situated on the upper part of the vertebræ: we see in how strange a manner it is disposed in insects. There cannot be a better subject of inquiry for the naturalists, than into the reasons of this various cause, and the purposes it answers.

fore, from a Worm to a Fly, observable in this insect, presents us with a real miracle, and may justly be considered as a laying down of old worn-out parts, and an acquisition of new perfect ones instead of them: in fine, as a total change of an old to a new, and of an imperfect to a perfect body, infinitely surpassing the utmost stretch of human understanding, as on reading and attentively considering the history now before us plainly appears. As for my part, I dare boldly affirm, that the incomprehensible greatness of the Deity manifests itself in these mysterious operations in a particular manner, and affords us an opportunity of examining, as it were, with our senses, the Divine nature.

If those authors, who invented a metamorphosis, in order to solve the difficulties that occur in the history of insects, had seen the wonders I have been just relating, it is probable, that they would have made arguments of them to support their erroneous opinions; tho' the insect itself, notwithstanding all its changes, constantly continues one and the same, and like a chicken, attains to a greater perfection, by a mere gradual increase of its parts, and no otherwise; for even the parts themselves always remain the same, whatever alterations we may observe in their figure. What I here affirm of the parts, holds true even at the time when they fall off or disappear, in order to make room for others which sprout out to supply their places.

Job, in like manner, speaking of the resurrection of his body, says, "with these eyes I shall see God."

Nevertheless, I should be sorry, that any one were weak enough to imagine, that these our mortal eyes, which are but dust and ashes, and as such are condemned to putrefaction and decay, are ever to appear in the sight of God. By no means; the body we now carry, is but the seed or egg, as it were, in which another

more noble body lies concealed; and of this mystery the Worm we are treating of affords a most satisfactory example; as it might very justly speak of its eyes, as it were, in the following manner: With these, my eyes, I shall raise myself on high, soar up to the skies, look down upon the fields, and dart with rapidity through the air, in praise of my maker. Thus, I say, this Worm might boast of its eyes in words, which however are far from being true, except in respect of that perfection which the eyes are afterwards to attain; on the insect's changing to a Fly; for then they are to be increased in number, otherwise ennobled, and shall enjoy a sight more perfect than the former, as I have already sufficiently demonstrated in the eyes of bees.

The most considerable muscles of the Worm here treated of, are in general placed in the head: of them I have described and delineated only those which serve to move the feet. Moreover, in the thorax also, the belly and tail, are seen a great number of muscles, which being extended from one of the annular incisions to another, move the body various ways, by means of fibres formed and disposed in a variety of manners. But as these muscles do not remarkably differ from those which I have described in other insects, and which have been represented in the preceding figures, I need say nothing of them farther, until I come to the Fly itself. I shall therefore close here the present chapter; adding only, that the limbs are sometimes distorted in this Worm; so that its body is found really crooked and bent: and hence we are taught, that these insects are liable to the same calamities that other animals are subject to by the law of nature. It is, however, worthy of notice, that when I viewed a distorted or deformed Worm, of this species, when changed into a Fly, it was no way deformed; its body being then perfect after its change, or rather its resurrection.

#### C H A P. IV.

*The wonderful manner wherein this Worm passes into a Nymph; and of the parts that are seen in the Worm, when it is stript of its skin; and the same parts afterwards clearly shewn in the Nymph.*

THE Worms here described, are at length changed into Nymphs of the fourth order, when their limbs and other parts are sufficiently grown under the skin. When they are about to change, they betake themselves to the herbs that float on the surface of the water, and creep gently thereon; until at length they lie at rest, partly on the dry surface, and partly on the water: if they are about that time driven off into the water by force of the wind, or if they be kept in a little vessel filled with water only, yet their change is not on that account impeded. But when they afterwards, under the form of a Fly, issue out of the habit

of a Nymph, then indeed they are very easily suffocated in the water; as long as these little insects are Worms, they can conveniently live in water, but by no means when they are changed into Flies. Indeed, man also, whilst in the uterus, lives in the water of the amnion; but he can by no means do this afterwards, when, by breaking open the membranes, he is brought into the world. Therefore these Worms, lying in their natural situation, always seek after the floating herbs, wherein at length they lie at rest; and then they, by degrees, contract themselves, and in a manner scarce perceivable, lose all power of moving.

Then

Then the inward parts of the Worm's tail insensibly separate from the outmost skin, and become greatly contracted: and this perhaps does not happen without pain to the creature: for this external skin is then commonly gathered into three, and sometimes into four windings, Tab. XLI. Fig. 1. *a a a*, and its extremity is left like an empty space, into which the air penetrates, and soon fills the place which the body had before occupied, but has now left vacant by contracting itself. If this void space be not filled up by the succeeding air, the skin of the tail becomes curled into itself: but this I observed only once.

Thus this insect is by degrees changed within its own skin, nor does it before this time cast it, or is it outwardly altered into a conspicuous Nymph; so that this order of transmutations is entirely different from that observed in silk Worms, and other innumerable species of insects.

I have often seen this Worm, in the space of twelve hours, that is from six in the evening to seven in the morning changed, into a Nymph. And all these things are performed in a hidden, obscure, and unknown manner, inwardly within the skin, which lock them up, as it were, from our view. For this reason, this species of metamorphosis has been tortured, as a thing so monstrous and incomprehensible by those, who, like the dog in Egypt, look only in a slight and cursory manner into nature\*.

When the Worm, which is thus to be changed, has a soft skin; that skin necessarily accommodates itself to the changes and contractions of the internal and invisible body of the Nymph. And hence it happened, that even the most learned, who have wrote on this subject, have not scrupled to give these insects the name of eggs: in which indeed they have committed a very great error, and corrupted the natural miracles and truths of God. Thus they think and insert, that one insect is changed in this instance into another; nay, that it again becomes an egg; and that the egg is afterwards changed into a Fly, by a rashly imagined absolute metamorphosis: others add, that all these things are produced by chance, and from putrefaction: and this indeed is the short path to atheism. For, if the generations of things be so subject to chance, what prevents man from being thus as easily produced in the same manner? This also some have not scrupled to declare in their writings. God is certainly as admirable in the structure of insects, as in that of man. The body of a beast deserves as great admiration as the human body, if we consider both in their kind and nature. Both far surpass the sphere of our inquiry: both are incomprehensible and impenetrable; since innumerable divine miracles are contained therein.

Whilst this Worm therefore is changing within its skin, the body, head and tail insensibly se-

parate from the outmost investing skin. The legs also about that time, and their cartilaginous bones, are, by reason of the joints, drawn back from them, left intirely empty within; and hence they are drawn backward or inward to the orifice of the mouth, and there they lie unmoved. The Worm at that time also loses all its skull, and the beak, together with the horny bones belonging thereto; for all these remain fixed in the skin of the head. From thence it afterwards draws its horns, its trunk, and other parts, which are there inwardly increased, and are afterwards to be seen in the Nymph.

A matter worthy of great notice here, is this: the optic nerves separate also from the eyes, and no more perform their former office. The muscles of the rings also in like manner, and a great part of the pulmonary points of respiration are separated from the external skin. Thus the whole body contracts itself by degrees, into a small compact mass.

But the greatest change is observed in the hinder part about the tail: for there the body, having quitted, Tab. XLI. Fig. *b, c, d*, its three extreme rings together, rises up into the fourth, *e*, and sometimes even to the fifth ring. Therefore, if you view, in the light, the Worm, which hath been for some time changed; you will very distinctly, and without the aid of dissection perceive, that its hindmost rings are empty, or are only filled with air: this is likewise, though more obscurely, observed between the head, and the second ring *f*. But the place which the Nymph, enclosed within possesses, then appears black, *g*; because it does not transmit a sufficient quantity of the rays of light.

At this time the gullet too, the intestines, and the pulmonary tubes in a manner cast a coat within the skin: this indeed is also very singular, and amazingly shews the miracles of God; teaching at the same time, how the former body is entirely cast off and renewed. In order to make this evident, it is necessary to open the skin of the abdomen: after this the Nymph, Fig. II. *a*, and its parts, together with the cast, pulmonary pipes, *bb*, will manifestly present themselves to view: nay, it will likewise be seen, how the Worm hath cast off, *c*, all the parts of its head and beak, and is became entirely immoveable, except in the tail; by means of which it strongly moves, agitates, and draws itself back even to the fifth ring of the body.

The whole *Aspera arteria* about that time casts its skin on each side. For, as this consists of two remarkable tubes; therefore they are first turned out of the body, whilst the Worm is contracting its tail, and are left sticking in the empty skin, as I shall more clearly describe, when I come to explain the method whereby the Worm, when changed into a Fly, breaks forth out of its skin; for it then draws the exuvia from the other pulmonary pipes.

\* The hardness of the exterior skin, in this and many of the other Worms which change into Nymphs, under a covering of their own outer skin, which forms a kind of shell, makes it appear strange, that so feeble a creature as the young Fly can get out. But nature has provided for this. There is always a weak part of this shell, where the head of the Fly lies: there are certain futures, at which it may easily be burst open: and the means ordained for these, are the swelling and subsiding of the creature's head. This becomes inflated like a blown bladder, and then shrinks down again at repeated intervals; and these motions burst the shell.

In order to place these truths the more evidently before our eyes, we must very cautiously draw the Worm out of its skin, at the time when it begins to harden or grow stiff; for, since this Worm is not yet in reality become a Nymph, but has all its parts disposed in a different manner than in the Nymph; we may see each of them in its place, and where they are respectively situated in this state in the head and tail. Thus I exhibit, Tab. XLI. Fig. III. *aa*, the antennæ or horns, the head, *b*, which I have delineated somewhat too large; under the latter is seen the proboscis or trunk, and on each side the first pair of legs, *cc*; beneath these appear the wings, *dd*, and then the second, *ee*, and third pair *ff* of legs. Then follows the abdomen, *g*, with its rings, and then the tail, *h*. In the abdomen are very distinctly seen transparent particles of fat; and in the tail, the pulmonary tubes come in view, displaying, or rolling out themselves, *ii*. It further appears how even the intestines, *k*, cast a skin; for they remain fixed to the orifice of the fundament, which opens in the utmost part, and is here cut off from the separated skin, *l*; for the Worm does not discharge its excrements through the extremity of the tail, but somewhat higher, where we may likewise see the fundament.

What I have hitherto advanced, may be seen more evidently in the Nymph; in which these parts are disposed in their natural order, and ranged beautifully and artificially among themselves. Here then occur the antennæ, Fig. IV. *aa*, with their joints: the eyes, *bb*, which are now arrived at their full size: the proboscis, *c*, and its appendages, situated under the eyes on the breast: the first pair of legs beautifully folded, *dd*; behind these are likewise seen another pair, *ee*: under the latter, again appear the wings, and their artificial convolutions and beautiful foldings, *ff*. The body likewise exhibits its annular divisions to view, *g*. Under the second pair of legs, the third pair likewise exhibits itself, *h*. Those black spots also that are seen on the body, and which we shew to be situated in

the Worm, above or over the points; the pulmonary pipes, are here likewise very distinct *ii*. But near them are also presented to our view four apertures of the pulmonary tubes, *kkkk*, and also the annular inflexions of the body, with some small prominences, there standing above the surface of the body, which have also cast their skin. The claws are transparent in the extremities of the feet; and make a beautiful figure, when the Nymph, being some days old, has lost the greatest part of the superfluous humours by evaporation, and in the integuments or covers of the membrane, wherein it is invested, and in its outmost skin in which it is involved, like a tender birth newly brought to light, becomes by degrees stronger and more firm; so that at length it is able to creep abroad, and break open and cast off both its coats at the same time: that is, this Nymph is covered with two integuments; whereof the interior is a thin membrane, which very closely invests the Nymph: the other, or exterior, is constituted by the outmost hard skin, within which the little insect has performed its change in an invisible manner. This is the skin which makes this insect look like a Worm at this time; and it is this same skin which made me give this order of changes, the name of a Vermiform-Nymph.

Whoever therefore desires to have a thorough knowledge of these creatures, must treat them in all these ways. I have observed, that in those Worms, which I had newly drawn out of the skin, one might distinguish plainly the mouth and the points of respiration; even more clearly than in the Worm that is still, creeping, swimming, and is no way changed. Indeed, had I not resolved to be succinct in this place, I should describe what has been hitherto said much more at large, and should have delineated all the parts, and at the same shewn their situation in the Worm; as also what pellucid little parts are observable therein, what their structure is, their motion, how the pulmonary tubes are inserted, and much more; but I am obliged to be sparing of my leisure hours.

## C H A P. V.

*The anatomy of the Nymph, the fat, the pulmonary tubes, the stomach and intestines: the wonderful changes observable in the ovary, muscles, spinal marrow, and other internal parts which insensibly come in sight.*

THE Nymph I examined being fresh stript of its integuments, was of a bright green colour, with white transparent, and some greenish particles of fat: and indeed it made a beautiful appearance; especially as the pulmonary tubes were at the same time observed to glitter like pearls. The head, the legs and wings were soft and fluid like water, and when but very lightly touched, they immediately discharged an aqueous humour. The pulmonary tubes had become considerably smaller, narrower and more contracted. From the tail unto the place, next below the wings, I counted seven apertures of the

lungs; all which, as well as the rings of the body being closely gathered up above each other, differed very much from the points of respiration in the Worm; so that therefore the Nymph was now only one third as big as the Worm had appeared to be before.

If this Nymph be laid on its belly, the heart is immediately seen beating in its back, without any previous dissection: this indeed appears very rarely so after the incision of the skin; because the heart then, by reason of the gushing out of the blood, which is aqueous, and like an ichor, presently ceases its palpitation. Immedi-

ately

ately under the skin are seen also the muscles appointed for moving the rings of the abdomen. The next thing that comes in sight is the fat: this was not much changed here; but, upon viewing it in a more adult Nymph, I found it so wonderfully altered, diminished, and extenuated, that I thought I saw not fat, but a parcel of eggs: that is, its former oblong, angulated, broad particles, were now become almost round and globular, Tab. XLI. Fig. v. *a*. Besides, also, it lost so much by the evaporation, and contracted itself in such a manner, that its diminution indeed was very considerable. Hence it must necessarily follow, that the body, on account of the great plenty of the wasted fat, must become more contracted, and possess a smaller space than before. The colour of this fat inclined to purple; but in the hinder part of the belly it was entirely green. Those particles of fat adhered to each other, and also to the pulmonary pipes, *bb*; so that, when I touched them with a fine sharp-pointed knife, made like a lancet, they parted from each other with the least motion. In the Nymph that was very newly changed, the fat became more green.

In the stomach and intestines also is observed a very great and wonderful change. This, however, is more or less observable, in proportion to the quantity of the Nymph's superfluous fluids which have exhaled, and as the internal humours have been more or less dissipated. Hence it cannot, indeed, be described how much the intestines are, by reason of their habit and figure, altered, dilated, or contracted; that is, according as the superfluous moisture is more or less expelled by perspiration. Among all the remarkable changes which I have observed in these parts, I shall exhibit that which, in my opinion, is the most beautiful, and shall begin a description of it from the gullet, Tab. XLI. Fig. vi. *a*. The gullet is here observed to be placed out of the horny parts of the head, *b*, back, and contracted legs. It appears also how this gullet passes *c* through the aperture of the spinal marrow, under the brain, and extends itself *a* unto the stomach. The superior or upper part of the stomach is also found to be contracted, as it were, into five annular small rugæ, or folds, through which the pulmonary tubes run very beautifully: and hence, on account of that contraction, it cannot be there seen how the stomach is circumstanced on the inside. A little lower, it exhibits quite another face; for it is divided by oblong grooves or furrows, which, in the figure, I have marked *e* with points. But as the stomach is there likewise inflated, and filled with a limpid humour, it is therefore observed *f* to be like an open transparent tube in this part; and it is the more conspicuous, as it is in colour somewhat red. But it is necessary to observe, that the part of the stomach, just now described, easily separates from the next intestine. The beginning of this small intestine is very beautifully sinuated, or bent, in like manner as the superior or upper

part of the stomach, with six foldings, or, as it were, corrugated convolutions, *g*. Afterwards, within this intestine, is discovered another smaller intestine, *b*, which, being contained in its cavity, and curled with many windings, wonderfully twisted, descends, *ii*, and again terminates underneath, in an open extremity.

This little intestine is of a bright yellow colour, and appears very plainly through the larger intestine; because the fluid, which is in that part of this intestine that comprehends it, is limpid and perspicuous. If that small intestine be wounded, the little intestine, contained in it, may be drawn out almost twice as large as it appeared in the cavity of the larger. Then it is manifest, that the yellow colour, wherewith its surface is distinguished, proceeds from the yellow fluid contained in it. What the use of this little intestine is, is impossible for me to explain: in this respect, the works of God are impenetrable. Nor shall I, indeed, scruple to assert here, that not even one truth, in respect to the actions of the parts of animals, or even of the human body, is hitherto fully and clearly known to us. Indeed, those who think the contrary, acquiesce in imaginations, taking them for facts. From my own observations I shall here add one thing, that is, that I have found this little intestine in the gut of the Worm now preparing to undergo a change: and this is the reason which induced me to attempt delineating the head of the Worm to the gullet, though I there represent the parts of the Nymph. I once found that inward little intestine in an old Nymph: it was there very brittle, and at the same time somewhat more red, and in a condition as if it began to waste away. And hence it likewise seems evident, why I have not afterwards found it in the Fly. Indeed, in those Flies, which are very just excluded, I have seen that this little intestine has been absolutely consumed. Wherefore one may probably conceive, that this little intestine is the inward coat of the small intestine in the Worm; and that this coat, not being cast out whole and entire, is by degrees consumed in the body. But these are only my own conjectures. I remember I have seen such little parts in Spiders too. I likewise find, that Thomas Willis, that celebrated member of the British Society, observed one intestine in another in the Earth-Worms. And since I here treat of the intestines, I cannot help taking this opportunity of complaining of the ingratitude of Casparus Bartholinus, junior, towards me: for he, though I had, out of good-nature, shewn him all the more uncommon preparations and specimens, which I had procured by the help of different anatomical contrivances; yet, in revenge that he did not so far succeed as to make me communicate the several methods to him, and being full of indignation, he has not scrupled to object to my proposition, whereby I affirmed that I would sometime restore the certainty of the office of sanguification to the liver. With what eyes has this lyncæan author, who, in the front of his book, assumes the  
bombast



bombast title, *Aut Cæsar, aut nihil*, i. e. a man, or a mouse, discovered my thoughts so far as to know, that I had only one experiment for this purpose? Indeed, my anatomical preparations, which he so much admired, could and ought sufficiently to have taught him, that I have not advanced that thesis rashly, or without important experiments. I would therefore advise him to contain himself yet, and temper his gall with water, until I have leisure, and a more convenient opportunity, to treat this subject, and solve the several doubts which I have said hitherto occurred to me. I shall then shew the experiments, and assign the reasons, which confirm me in this opinion. And these are the very words, wherein I proposed to the public the said thesis, in my notes on the Pro-dromus of the famous Hornius. But he that is bent on revenge, has in view only the monstrous images of his own thoughts. In the mean time, however, as I have there mentioned experiments and reasons, this rash young man might have concluded from thence, that I was provided with more experiments, to demonstrate this thesis, than that trifling one, which I really do not acknowledge to be mine, in the place above cited. Nay, I join with this good-natured Bartholinus, who, like a Butterfly, has yet scarce crept out of his Chrysalis, that the experiment, considered by itself, contributes nothing to strengthen my thesis: so that it therefore appears, that he would refute what he himself does not understand, and perhaps is not capable of understanding. But I return to my history, which I hope will be more useful than a controversy of this nature. In treating this subject hereafter, I shall only explain what is pertinent to the matter itself, leaving altercations to those who love them.

Below the place where the little intestine, before described, is seen within the intestine of the Worm, the small gut is again distended, equal, smooth, and moderately large; but then a kind of small tube, Tab. XLI. Fig. VI. *k*, is inserted therein, which is divided into vessels, either *vafa varicosa*, or rather the *cæca*, or closed guts. These vessels, like so many small intestines, discharge themselves into the beginning of the great guts, where the latter are united with this dilatation of the small. These blind or closed guts are of a wonderfully elegant construction, and two of them are found commonly filled with a whitish humour; which in the more adult Nymph, I observe, is by degrees sent also to the great guts.

This substance is sometimes beautifully divided, as it were, into knots; and is likewise inwardly separated, *mm*, by a more limpid substance, which seems mixed among it, like whey; that nothing can scarce be exhibited to the eye more artificially and beautifully disposed, or more conspicuous. The figure, I have given, exhibits only a small part of this elegance, and that is but rudely drawn or delineated; because, to express it accurately, there would be need of a much larger figure. These closed vessels cannot, but with very great diffi-

culty, be separated from the fat that is annexed to them; and this difficulty is the greater, because that white substance is not found in every part of them. Hence it is, that they are very easily broken. But this happens still easier in the Worm, because the blind vessels are more strongly connected in it; so that it requires more labour to discover them there. They disperse themselves, *nn*, with various and wonderful windings and convolutions, through the whole belly; for they are seen no more in the thorax of the Nymph, which is all filled up there with the muscles of the legs, and other parts. We at length observe, that the two superior or uppermost of these intestines unite, *o*; and one of them is likewise divided twice on the inside, and twisted into admirable windings, *pp*: this goes towards the great gut, into which it discharges its contents. The other lower pair, wherein the above mentioned division of the white substance is expressed, *mm*, are likewise twisted into various windings, *qq*, and at length terminate *r* in the closed tube. The fourth of these intestines is circumstanced in the same manner, *ss*; for after various convolutions, it terminates at last also in the blind annular duct, *t*.

The colon is also every where uneven, with many knotty dilatations, *u*. These are produced by the white substance found in its cavity, whilst the little intestine hath been contracting itself in those parts, where it contains a less quantity of that substance. A little lower is seen a larger knot *x* in this intestine, filled with a black substance. And at length two more dilatations occur *yy* in it, which possess those places of the intestine, which, by the help of the humours that flow into them, swell into very large bags. But as the little insect, after putting on the form of a Fly, secretes and discharges that colluvies of humours; hence these windings may be properly called the cloaca, or sewer. Lastly, one may see the rectum, or straight gut; and underneath, in the tail, the podex, or orifice through which the intestines discharge themselves, *z*, in the last ring of the abdomen. I have also judged it proper to delineate this ring, as it coheres with the anus, in order to represent more clearly all the things which I have mentioned.

When the Nymph is older, I have sometimes found its stomach filled with a green fluid: but when it approaches to the change of its skin, in order to acquire in a short time the form of a Fly, its stomach and intestines are found so considerably contracted, and by degrees become so much shorter, that one would affirm one had dissected another animal, unless one had observed all these changes, according as they gently succeed each other from the beginning.

In the lower region of the belly the cæcum and rectum, or blind and straight guts, are expanded at that time very wide; and are found to be swollen, glittering, and smooth, on account of the white moitures or humours which are mixed with a chalky matter. These hu-

mours,

mours, flowing out of the wounded cloaca, or liver, render every thing muddy; and, when thrown into the water, they likewise foul and destroy its clearness.

The double ovary \*, which appears of a whitish aqueous colour in the young Nymph, is, in the more advanced state, of a pale yellow colour. But if the Nymph is to change its skin immediately, it appears to be a beautiful green. In the region of the abdomen, where the ovary extends itself to the thorax, are seen two empty curled bags. They are the two pneumatic vesicles, as I shall shew more at large in the history of the parts of the perfect Fly. In the extremity of the body, between the last rings, appear three very beautiful transparent knots; each of which, being supported by its own footstalk, casts a skin, and discloses itself, when wounded. What these little parts are, I cannot determine: I have discovered only, that they belong to the genital organs of the female; for I never saw them in the males, and therefore I shall delineate them in the figure of the latter.

The male part, at the same period of maturity, became by degrees conspicuous; and, from a thin aqueous humour, having acquired sufficient firmness, they had obtained a limpid and pellucid whiteness. The muscles in the breast are at this time much more compact, and, from a pale white, become of a purplish colour. In the young Nymph they were soft, mucous, and like veal-jelly, and had no firmness.

But much more remarkable than these are those changes, which, by a slow accretion of parts, are seen in the head, eyes, pulmonary tubes, and fat, which may be seen there in a very abundant quantity; and also in the horny little bones, which first consisted only of humours, as it were, and membranes. But I now pass these things by, without further notice, because I shall hereafter make mention of some of them in the Fly itself. Above the brain are situated two white, soft, little parts, somewhat like knots, which rise like two horns: they are annexed to the sides of the thorax, and rest on the stomach, as on a basis or foundation. But what these little parts are, as also their use, I am likewise hitherto ignorant.

I afterwards likewise observed in a Nymph, which I found dead in its skin, that the purple fat was there variegated with white spots. The little intestine, which I before described to be contained within one of the intestines, lay loose therein, without adhering any where, and was curled; but that part of the intestine, which enclosed it, seemed to be very considerably dilated. The uvea of the eyes was of a very beautiful bright purple. Here and there, in the abdomen, were several small Worms; some of which were already changed into Nymphs, and appeared to me as if they were to

be transformed into Flies very soon. It would require a large treatise to describe how such things are produced in the bodies of other insects, and what strange and unheard-of things may be here further observed. So admirably does God shew himself before our eyes! and probably the relation would not be believed, if I described and delineated that a Nymph issues out of one species of Caterpillars, which belongs to the second mode of the third order; and that out of this Nymph the Butterfly is afterwards produced; and that out of the same species comes a Worm also, which is again changed into a Nymph, according to the first mode of the third order, and at last assumes the form of a Fly. And further, that out of the same species of Caterpillars, arise two or three Worms, which are again changed into Nymphs of the fourth order, and these afterwards into so many Flies. Lastly, that thirty, eighty, nay one hundred Worms have issued thereout, which have been likewise first changed into Nymphs, and afterwards into Flies. I have seen these twelve changes, which are very worthy of notice, distinctly in only one species of Caterpillars. And now, at length, I have learned that all these wonderful effects of Nature obtain likewise in water-insects; but this I have not yet sufficiently traced.

Though the changes of the intestines, a little before enumerated, are very singular in the Worm and Nymph of which I treat, those which the spinal marrow undergoes deserves yet the greatest notice, and that preferably to the rest. For as this marrow in the Worm was twisted, as it were, into a curled lock; so, on the other hand, we find it extended very straight in the Nymph, and almost all its eleven knots, Tab. XLI. Fig. VII. 1, 2, 3, &c. dragged or separated from each other. This is chiefly seen about the last knots; but not about the foremost knots, or those next to the brain, *a*; near or on the upper part of which I have delineated the cornea of the eyes. The first knot, *b*, preserved its former situation; but the four subsequent knots, *c*, having suffered a quite different change, were pressed closer to each other than before, and expanded to a considerable bump or swelling; and therefore the nerves, springing from thence, were now conveyed in a very different manner. Nay, further, the origination of the spinal marrow is also seen, stretched and extended between the first and second knot: and this, indeed, may be perceived still more plainly about the sixth, seventh, and eighth knot; and therefore only the three lowest knots, *d*, remain in their former situation; though the last of them is likewise more conspicuous than the two next above. If we would here follow Reason as our guide, she would certainly have rather dictated, that the convolution of the marrow in the Nymph is extended in the

\* This double construction of the ovary is almost universal in flying insects, and it is the same in almost all the kinds of fishes; and the vast number of eggs bears likewise an analogy. In many fish the body of the female is filled with this ovary, as entirely as in insects. The intent of Nature seems to be the providing, from the abundant eggs and young of some kinds, food for the others; for it never could be the intent, that all the eggs contained in these ovaries should yield perfect insects.

Worm, since the Worm is two thirds longer than the Nymph: and hence it should seem necessary, that the marrow in the Nymph must be thus twisted, by reason of the contraction of the body, which, as it were, accommodates itself thereto spontaneously. But experience teaches, that all our reasonings here are of no consequence.

Wherefore, if any one well considers these changes and extensions of the nerves, and the knots of the spinal marrow, he will clearly see, that the change of the Worm into a Nymph, and of the Nymph into a Fly, the insect, in the mean time, being one and the same, is, in reality, very miraculous, and may be called, as it were, a new creation, or rather generation; the true causes of which we are at as great a loss to investigate, as the nature of God, who is the author of this work. This should certainly excite us to acknowledge the offensive cloud of our own blind ignorance in every thing, and afterwards to cease from pride and arrogance. It teaches us also, how largely the miracles of God are expressed in these small creatures: they are, as it were, spontaneously

evident to any one, with the least pains, in the investigation. However, one may observe, that such changes are likewise observed in the larger animals; for the spinal marrow of the embryo, which, in the beginning, is hardly larger than a pea, is also insensibly expanded as it grows larger: yet one cannot, on the other hand, deny that this is only a simple augmentation of the parts, which produces such changes in the larger animals. But in the insects there is observed a remarkable transposition of the parts, and an admirable accretion of the viscera; which, as it is performed in a small space of time, deserves to be called miraculous, nor can it by any means be distinctly explained: for our eyes never discover, nor can they ever discover, how these things are really executed. Add to this, that the adult animal here grows young as it were again, and must receive other additions, until it is at length clothed in a more noble body: all which tend to the honour and glory of God, the Supreme Deity, the Author of all these miracles.

## C H A P. VI.

*Of the true manner in which the Nymph breaks out of its outer and inner coats; so that, by a kind of visible resurrection, the creature afterwards assumes the form of a Fly. Also of the pulmonary tubes and intestines, the coats of which are drawn off, and left in the exuviae.*

WHEN the time approaches, in which the hidden insect, now changed into a Nymph, in its outmost uncast coat, is to attain the form of a Fly, which change it performs in the space of eleven days, the superfluous humours, wherewith its members are swollen, are first insensibly expelled by perspiration. The little body of the Nymph also, as hath been observed before, is contracted unto the fifth ring of the skin: and hence the four last rings of the abdomen and tail become empty and hollow, or are all filled with air, through the aperture of the respiratory orifice in the tail. The Nymph likewise yet draws its breath through the same aperture.

If you desire to see this, expose the Nymph a little to the rays of the sun, and afterwards put its tail into water. Thus you will find, that it will breathe stronger than it did before, and, by expressing an air-bubble out of its body, and again sucking it in, will manifestly perform the action of inspiration and expiration.

The anterior part of the Nymph's body likewise draws back from the skin, and having partly deserted the beak, head, and first ring of the breast, the little insect afterwards lies at rest within its skin; until its exhaling members have acquired due strength and firmness to break open those two membranes, wherewith it is now surrounded, and hindered from

coming into light. All these things must be here remembered, that what I shall say hereafter may be properly understood.

If, however, the outer skin be opened about this time, very wonderful varieties of colours, such as one can scarce imagine, present themselves through the inner skin, with which the Nymph is covered. Some of the parts are changed from white into black; others are of a yellow, purple, brown, or very black colour, like pitch; others, from aqueous, have become membranous; and, from this latter state, again become hard: some become fleshy; others again acquire an horny or bony hardness, so that, when pressed, they crack and break asunder.

It is likewise observed at this time, that the whole body becomes insensibly shaggy, and the feet and claws begin to move. All these things may be distinctly seen, provided one opens one of those Nymphs constantly every day, until the time of change. But, for this purpose, it is necessary to lay them on white paper in an earthen dish, or glass saucer, and then to make them somewhat moist with water, and keep them under a glass. In this case, the paper serves the Nymphs to fix their claws in, when they come forth under the form of a Fly; and I pour in a little water, to preserve them from drying and suffocation.

When the creature is at length to come in  
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fight, the outmost skin of the Worm begins to move about the third and fourth anterior ring, Tab. XLII. Fig. 1. *a*. This motion arises from hence, that the insect, now hidden within the skin, uses all its efforts to promote its exclusion, and to quit its innermost coat as well as its exterior skin together, at one and the same time. This is constantly the course of nature, in our fourth order of changes. It is observed, on this occasion, that the skin is divided into four parts: hence it happens, that the third *b* of the foremost rings, and also the fifth, *c*, are partly separated; and even these, as well as the fourth above, open very regularly and orderly in the breast. After this, the insect immediately breaks open its inner coat, with which it is immediately invested, and casts it off, together with the skin, breaking forth from thence under the beautiful form of a Fly, Fig. II. *a*.

But I would have it here observed, that the breaking open of the outmost skin, as now explained, is not at all casual or accidental; but is perfectly ordained by a constant order, since it always proceeds in the same manner in all these changes. The skin also is in those places, where it is broke open, so circumstanced by the all-wise Author of Nature, that it easily opens, as if joined together by sutures.

When the Fly is thus produced, its wings are not immediately obvious, or distinctly visible; but are curled up, and wrinkled into folds, in the same manner as I have exhibited in the Nymph. However, in the space of a quarter of an hour, which is well worth observing, we see that they are displayed and extended, and become smooth. The causes of this sudden effect are the blood and air, which are then impelled forcibly into the vessels of the wings and pulmonary tubes: therefore, if the wings about this time be wounded, they shed some small drops of the creature's blood, like clear flowing water; and this never happens afterwards, when the wings are once expanded and dried, though you wound them never so often.

When the wings are expanded, the little insect discharges three or four small drops of muddy water, and immediately enters into another state of life: for the creature, that lived before in water and mud, now wanders thro' the air, carried by very swift wings, and visiting the grassy fields and meadows, enjoys a more noble and happy kind of life.

In the same quarter of an hour, wherein this creature is produced, it hath also acquired the knowledge of every thing necessary to do what it ought, and to avoid what may prejudice it; wherefore it never afterwards has occasion of a tutor, or director for any thing. Hence the birth of this insect by far excels the unfortunate condition of man, after he is born. He for some years increases or grows up, as it were, in disagreeable circumstances, before he has reason, or a knowledge of those things which he ought to do, or avoid: but, on the contrary, this insect is of full maturity when

born; nor does it increase any more after the quarter of an hour, in which its birth is completed; but it feeds itself with a most distinguished kind of pleasure, and lives on dew and sugared liquors, which it finds in the meadows and flowers: indeed, it sometimes nourishes itself with blood, to the just punishment of the sins of Man, who is more miserable than the Worm fixed to the earth, and thrown into this world as into exile. This Fly naturally torments cows and cattle, that serve for the use of man, in such a manner, that they run through the fields mad, as it were, with pain.

Relying with just reason on these things, I can at length affirm, that the aforesaid metamorphosis of the Worm into a Nymph, under which change the Nymph is for some time, as it were, dead, and destitute of motion, and, after the short space of eleven days, increases into a Fly, by the wonderful alterations of the internal parts; may be justly compared to the true resurrection from the dead, or, as it were, to a new generation. The human understanding is, indeed, amazed at this; but at the same time we are taught thereby, as with a visible example, how near our resurrection and reformation is, when we love God above all things, and our neighbour as ourselves; in which consists, indeed, the real metamorphosis of the human mind. This, having then cast off the ancient dirt of avarice, pride, and envy, and changing those vile passions for the most sweet and gentle love of Christ, lives afterwards eternally in a more perfect body.

The Fly, thus produced from the Nymph, exhibits two antennæ, or horns, Tab. XLII. Fig. II. *a*, on the head. The four anterior legs are jointed to the lower part of the thorax. The two last are seen *bbbb* under the posterior part of the body, and shew very distinctly their joints, and the two claws, with which their extremities are fortified. Two little apertures are seen in the upper part of the thorax; but its posterior region is girded round with a beautiful margin, near which, on each side, are seen two little parts, with globular extremities, designed for making a noise or sound. The two wings are affixed *cc* to the shoulder-blades. The body, *d*, is divided by some yellow spots, with black horny or bony rings, which are beautifully adorned above and about the sides with fine hairs. I had once intended to delineate these things magnified; but I am now so stinted in time, that I cannot execute this design.

The other miracles of God, shewn in this insect, must be now exhibited to view; I mean, those which occur in the skin, and in the inner integuments, which have been forsaken by this Fly. I shall now shew these exuvizæ, or cast parts, dissected and magnified by a microscope. In the hinder part of the outer skin, the cast off pulmonary tubes, *aa*, which, upon the Worm's being changed into a Nymph, and contracting its body into the fourth annular incision, had separated from its interior parts, still adhere to the second, third, and fourth rings:

rings: and as the body was wrinkled at that time, it happened that these pulmonary tubes were turned out of it, through the posterior apertures of the tail, and remained fixed to the respiratory points or breathing-holes of the outer skin. From considering therefore this position of the exuvia, it is easy to understand how the insect has at that time, besides other changes, suffered so great a contraction of its body. The extended extremities, or ends of these pulmonary pipes, being protended forwards, are curled and twisted, *bb*; which proceeds from hence, that when the Worm contracts its body upwards, from the tail to the thorax, these pulmonary tubes are, by their own infertions, and this force, thrown out of the body: and hence it happens, that these being afterwards left to themselves, they fly back, as it were, and from straight run into curled strings or cords. This I once plainly saw, when I opened the skin about that time.

The like operation has place also, with respect to the inner *c* coat of the intestines; which then likewise separates from the body, and remains fixed to the skin, very beautifully representing the complicated web of a Spider. Within, in this little intestine, which is of a beautiful white colour, are found some particles, like grains of sand, clear as alum, and consisting of many points and divisions. I first thought these were sand; but I afterwards saw that when they were mixed with spirit of vitriol, they fermented very strongly, which is not a property of sand. And, therefore, as I am unable to explain the nature of many other parts, so I do not know what this substance is; whether it be of any use in the body, or whether it probably contains the calcarious, chalky, and alkaline particles of excrements? I therefore, here again, candidly confess my own great ignorance. If we invert this part of the intestines, and the tail, we may likewise see how the separating intestine, Tab. XLII. Fig. iv. *a*, inwardly detaches itself from the inner cavity of the straight gut or rectum, *b*; and, when separated, remains fixed to the external orifice of the fundament, which opens *c* within the outer skin. This I have roughly delineated, the better to explain it.

\* It is universal among insects, that the creature which has put off its exuvia, or cast its skin, immediately appears much larger than it was before. This is indeed true in fact, as well as in appearance. The body has by degrees grown under the skin, till it is too large for it; and this is the very reason of the throwing it off. As the increase has been gradual, and the parts are soft, the skin has pressed them together, and they lie close; but as soon as this skin is cast off, they distend themselves, so as to appear in their proper form.

In the anterior or fore-part of the Worm's exuvia, are seen the legs, beak, eyes, Fig. III. *d*, and skull, *e*, left and cast off together\*. There is likewise seen the coat, which parted *f* from the internal surface of the gullet and stomach. But it is necessary to take notice here, that every thing, hitherto mentioned, happens when the creature first assumes the form of a Nymph.

When it afterwards, upon breaking forth under the form of a Fly, quits this outmost skin and the inward pellicle together, there are again other remarkable things observed, which I shall now describe. In the first place, I exhibit, as now cast off, *gg*, the hitherto hidden inward coat, which had invested all the Nymph's limbs and parts, and which is now irregularly broke open in the fore-part, together with its outmost skin. This may, indeed, be easily done, on account of its thinness. In its hinder part, one may see where the tail, *b*, or the extremity of the Fly's body, was before situated within it. In each side of this skin are seen the pulmonary tubes, rolled out, and all terminating *ii* in a pointed extremity, like so many small tops or points of needles, tho' each of them may be very easily separated into many branches.

But it must be here again observed, that these pulmonary tubes do not separate or go off, when the Worm is changed into a Nymph: for, otherwise, the Worm must have crept out of its external skin; as, indeed, is always the case in some other orders of transmutations. But since that does not hold here, therefore the most wise Creator has ordained that these changes shall happen, when the Worm, on forsaking both its skins together at the same time, and being cloathed in more noble ornaments, and under this form afterwards dignified with the name of a Fly, is to come to light. These things, indeed, afford us matter very worthy of consideration. We are excited to industry not only by the small Ant, but may draw knowledge and learning from the contemptible Fly. And thus all things tend, at length, to the honour and love of the Supreme Architect, whose works are evidently the open books of Nature.

## C H A P. VII.

*Treating very particularly of the Afilus, or Gadfly, and its external and internal parts, as well male as female.*

NOW that we have seen the order in which the Worm grows or increases into a Nymph, and how this latter is at length changed into a Fly, and consequently appears under three different forms, though it always remains one and the same insect; it is necessary, for my purpose, to exhibit particularly the parts of the Fly. This I shall now attempt to do, and I shall begin with the male; and afterwards describe those parts in the female, which cannot be seen in that sex.

The male Gadfly, considered externally, shews itself divided into the head, the thorax or breast, and the abdomen or body. These three parts are joined together, as it were, by a small filament; and this makes a most beautiful figure in Wasps. This is the reason why these creatures are called insects.

In the head the eyes, horns, and proboscis or trunk, are very conspicuous. The eyes are smooth, of a dark brownish-green colour; and they seem spotted, upon a transparent gold-coloured ground. Their structure is like that of the Bee's eyes; for each consists of a collection of many lesser eyes, between the hexagonal divisions of which some hairs are scattered up and down. A small, black, horny margin divides these eyes one from the other. The hinder part of this margin, which lies upwards towards the thorax, is likewise adorned with three larger eyes; the two hindmost of which are somewhat smaller, and the two fore ones as large again. In the neck, or where the beginning of the medullary substance is joined to the cerebellum in us, there are observed two yellow spots.

In the foremost region of the head, where the margin just mentioned reaches towards the mouth, two very beautiful horns, of an obscure blackish colour, are placed in the middle. These are divided each into eight joints, whereof the lower are longest, and are set with fine hairs. About the mouth are likewise seen a considerable number of hairs, of a glittering deep gold colour. The mouth has no opening, as in other insects; for the proboscis or trunk, like an hollow little tongue, is here placed in the mouth; and through it, as through an hollow tube, the Fly, when eating, conveys its food into the stomach.

By pressing the thorax with the fingers, this proboscis will come in sight out of the mouth: in its fore part appear two oval bubbles, Tab. XLII. Fig. v. *a*; the middle parts of which are applied to each other lengthwise, and between these the food passes to the stomach. Their upper part is beautifully divided with various pulmonary tubes, which, like so many semi-circles, run from one side to the other. The proboscis also has bristly hairs *bb* on each

side of it, which, arising out of the outer skin of the mouth or lips, hide the trunk itself, when drawn back by the Fly. The inferior or lower part of the proboscis has two small *cc* appendages; out of the ends of which, consisting of a black horny bone, likewise arise some hairs. They are jointed into a singular kind of black *d* horny triangular bone, which gives considerable strength to the membranous parts of the tube, which supports the proboscis. Beneath this is afterwards seen another horny bone, which is of a different figure, *e*. I have not yet been able to discover the aculeus or sting in this Fly, though it shews itself very visibly in the Horsefly, which carries it enclosed in a small sheath. Whether the great tenderness and fineness of the sting prevented my finding it, or whether I missed discovering it, I cannot say. Neither can I explain in what manner this little insect sucks the blood, since I have never learned this from observation. I have said, indeed, in my general history of insects, that these little creatures had a sting or point in their mouth; which, I believe, to this time is the general construction, tho' I cannot at present demonstrate it.

The shape of the thorax on the upper side, or in the back, is oblong, and it is moderately hard like a horny bone. It is in some of these Flies, covered very thick with fine hairs. Its upper part is bent a little inwardly at each side: and hence it happens, that two holes, as it were, are there formed; besides, each side of it is set with thin hairs. In the lowest region of the thorax are seen six legs; they are articulated to the thorax. Each of these legs consists of five joints; the last of which is again subdivided into five single joints, and is armed with two redish claws, having their extremities as black as pitch. All these joints have also bristly hairs, and are constructed or formed of a horny or bony matter, somewhat hard like lobster-shells: within this the muscles, vessels and nerves are placed. On the upper and hinder part of the thorax are two wings, of an even and generally smooth surface; though they have some few hairs dispersed over them. A considerable number of pulmonary pipes is also distributed through these wings, and these divide them as so many small nerves. The membranous parts of the wings are somewhat wrinkled, or plaited with small folds, and they are of a colour approaching to a pale red. The wings are, by the help of their joints, connected with the back; where the muscles, which move them, are inserted therein. Four small folds of the wings are likewise seen there; whereof the lower are beautifully surrounded with hairs; and where the contracted wing rests, they are received by a kind of hole or pit, conspicuous in each side of the thorax; and

and this likewise has some setaceous hairs, but not placed so regularly. Near these appear two globules, each of which is supported by a bent or crooked small foot or peduncle, and these resemble the iron head of a hammer. All the little parts, just now enumerated, serve for modulating the air; for, as this is driven out of the thorax into these cavities, hence is produced that crashing noise in the sides of the body, made by the Fly when it displays its wings in flying. The malleoli, or little hammers, in particular, are very beautiful, and such are found almost in all Flies: but I never saw them in any species of Bees; that is, the Bees have four wings: and therefore they produce their sound or noise in a quite different manner. The same may be also observed in Locusts and Grasshoppers. Indeed every kind of insect has particular instruments to vibrate and modulate the air. The part of the back opposite to the abdomen, is adorned with a yellow margin; out of which arise two sharp-pointed little parts, like sharp needles, terminated by black points. However, you may more easily discover these little parts by the touch than by the sight, because they are surrounded with a great number of hairs.

The abdomen, in like manner, consists of a horny or bony substance, and being set all round with hairs, has five yellow spots on each side, which flare here and there as if folded up, and laid smooth, and without hairs. It is moreover divided into several rings, which are disposed in the same manner in the male as in the female: though, in respect to the particular structure, there is some difference between them, as far as they constitute the Fly's tail; but this difference cannot be seen, unless when these parts are pressed backwards.

As to the external parts, there is no difference between the male and female, except with regard to the bigness of the body: the male is a full third part less than the female, which is likewise the case in the Worm also, and the Nymph; for those which are to produce males, are less than those which are to yield females. The female must carry in it an ovary, which, as it contains so great a number of eggs, that it cannot be comprehended in a narrower compass, it is therefore necessary that she should have a larger body. To make this the more evident, I shall now describe the inward parts of the Fly, and their difference in the male and female. Let it be here observed, that it is a female I have delineated here, and described in general.

Before I proceed to the internal parts, I must observe, that all the Flies which belong to this species, do not exactly agree with one another, in regard to their spots, colours and hairs, which is also the case in their Worms; between which there is great difference in regard to their paler or fuller colour.

Now, if, in order to settle the dissection of these Flies, you desire to kill them in such a manner as not to hurt any of the parts, there is nothing so proper for this purpose as spirit of wine, in which they die immediately: however, I could not entirely kill the Worm in this liquor.

I have killed a young Fly in the space of three hours, by the smell of Brasil tobacco, put near it in a flask: and this indeed I have often done since.

In the head of a male Fly of this species, two days old, I observed that little particles of fat became considerably smaller than I before described them in the Nymph. When I had afterwards removed the cornea from the eyes, the colour of the uvea, which still lay within that, appeared of a bright red. I observe also, that the colour of the uvea is very different in proportion to the age of the Flies: for those that have very recently cast their skin, sometimes shew the uvea of a very beautiful and full orange colour.

All the muscles of the legs and wings, which are inserted in the horny or bony investing coats of these parts, were in this Fly entirely perfect. I found little fat here. But the belly, when opened, appeared to be very full of it. This fat was of a purple colour, and its particles globular; so that at first sight I took them for eggs. These fat particles very easily separate at this time from the pulmonary pipes. These tubes were become much less, and more contracted, on account of the great loss of the considerable coats which they had cast off; but I could not find any tube among them dilated into vesicles, as is the case in many other insects. I further observed also, that the largest branches of the pulmonary tubes, which I have before described in the Worm, were here in the Fly compressed, and insensibly worn away, as it were, or abolished: and the same thing is true with respect to the bags, out of which the Silkworms spun their silken threads.

I observed also two considerable pneumatic bladders of a pear-like shape; one of which I here delineate, Tab. XLVII. Fig. vi. *a*. They were large, and very much dilated, and were somewhat curled in the curvature of their tops, in the manner of those little purses, in which the earth Spiders carry their eggs about them: this happens probably, because these bladders have not been extended as much as they might. Each of these was terminated by a closer tube, *b*, composed of orbicular rings; out of the sides of this other small branches, *cc*, issued here and there; two of which I here exhibit magnified. These pulmonary tubes are principally conveyed towards the sides of the body, under the wings, and there forming small orifices, they afford the air by which the Fly makes or produces its noise.

The stomach and intestines were in this Fly very much contracted. I found a little air in the stomach, and in its hinder part near the pylorus, a brownish yellow fluid. The little intestine found in the other intestine, was wanting in this subject, having been wasted away. The four convolutions of the four closed or blind intestines, were here found forced out of the breast into the belly. The rectum shewed itself dilated to a considerable width, and filled with a white moist substance like chalk.

Below, in the abdomen, were seen the genital parts; the penis, the testicles, and the seminal bladders. The penis is situated underneath, within the last ring of the abdomen, thro' which

it erects and stretches itself. Its forepart is divided into three horny or bony points, Tab. XLVII. Fig. VII. *a*, variegated with a palish yellow colour, somewhat approaching to red: the middle one of these is properly the penis, which can erect itself internally, and push through the horny little bone, wherewith its hinder parts are invested. It is connected as by two joints, *bb*, with black horny little bones, twisted into serpentine windings, which I here represent, joined to the hinder part of its horny sheath. Moreover, this can bend itself in some degree about the middle, *c*; its case, or sheath, being there a little more membranous: hence the penis seems to exhibit a joint in that part. The last or extreme ring of the belly, wherewith the penis is articulated, is likewise adorned with two margins or verges, which are small, horny, or bony, black, and considerably strong, *dd*; and in the forepart, are, as it were, jointed with the horny little bones, which are bent in a serpentine manner *ee*. I have here delineated that ring open: for all these horny little bones are closely joined together, and cover, as it were, the penis.

The soft and nervous part of the penis, twisted in a serpentine *f* manner, runs inwardly into the cavity of the abdomen, and is there at length dilated into a considerable knot, *g*; into which the testicles, *bb*, and seminal vesicles, *ii*, discharge their sperm through four orifices, and thus convey it to the penis. The testicles, when dissected, shew themselves to be composed of very numerous, small, very short and tender *kk* tubes, with their ends closed; all which threw their sperm into the vas deferens, *l*, by which it is conveyed on further. The seminal vesicles are not so considerable; but they deserve notice, on account of some bendings and curlings, *mm*; they terminate in dilated extremities. Their sperm, as well as that of the testicles, is white; though the testicles are not so white as the seminal vesicles.

The spinal marrow is here disposed in the same manner as it is in the Nymph.

I find the same parts in the female as in the male; only that an ovary is found in that sex, instead of the male genital organs. This ovary is divided into two parts, Tab. XLII. Fig. VIII. *aa*, and being *b* fastened to the last rings of the abdomen, it opens there by a large orifice, and discharges its eggs; these the Fly always drops into the water: this is likewise the practice of the Perla or Dragon-fly. These hinder rings of the body, are here and there very beautifully variegated with black, horny, or bony spots of different figures, *ccc*, and are likewise beautifully adorned all round with hairs *d*.

The eggs in the ovary seem to be exactly spherical, and to exhibit each an opening in the middle of it, *eee*: but this is only a false appearance, produced from their too obscure colour. In reality these eggs, are oblong; and they become the longer and more acute, *f*, as also larger and more conspicuous, the longer time has passed since the Fly's change; so that they insensibly

fill the body more and more. But if these eggs be laid before a microscope, that magnifies in a great degree; then their real figure is discovered, together with the pulmonary tubes, *g*, which connect them every where, and which furnishing many shoots, *b*, diffuse *ii* themselves through the whole ovary in several beautiful branches. No veins or arteries are seen here; because these little creatures have white blood, as also on account of their great smallness.

In the young Fly these eggs are very tender, and of a beautiful colour; which becomes the stronger or fuller, in proportion to its age. In one ovary of this kind, I have distinctly counted about four hundred and forty eggs: hence it is evident, what a great number of Worms one Fly may produce.

I have placed water, sweetened with sugar, before some of these Worms; but they did not touch it, and died the fourth day. Others lived much longer, and the more so, the more they were exposed to the cold and rain; for then almost all insects abstain from eating. I have neglected to offer them blood.

In one of these Flies, which I opened alive, all the fat was consumed, so that no part of it remained, but those purple little membranes, with which I had observed it before surrounded.

Lastly, near the orifice of the ovary, which discharges, Tab. XLII. Fig. VIII. *k*, itself, thro' two ducts, I have discovered those three very beautiful little knots, whereof I have before made mention in the Nymph. The extremities of those Nymphs are twisted, *l*, or turned like a snail-shell: and they are then inflected or bent, *m*, in a singular manner, then curled, *n*, and run towards the last ring of the belly, and are placed *o* near the ovary. Where these knots form *m* their bending, something like a common membrane joins them together. But if they be dissected, there are as many pulmonary tubes seen enclosed therein, as they are in number. The coat or membrane, which invests these pulmonary tubes, entirely dries away and perishes, if these are put on a glass, and leaves the tubes bare with open cavities. By opening the said knots also, one may turn the air-tubes out of them unhurt.

The use of these little parts is utterly unknown to me; I cannot even conjecture for what purpose they are formed. There are also many other parts of this insect, concerning which I am as much at a loss. Wherefore, all who read these matters, as well as myself, being convinced of our ignorance therein, are obliged submit to before God; who hath shewn himself so incomprehensible and adorable in this insect. We are obliged to extol him with praises, for that he hath been graciously pleased to discover to us so many, and such great things in this creature. If we cultivate and exercise together these two duties under such researches, the visible things will serve to excite and encourage us to know and see God, from those objects which he created, and to love him cordially, and like children, as the supreme venerable Deity.



*A Letter written by the author to Mr. Thevenot, on the nature and anatomy of the Worm bred in rotten cheefe, or the Acarus, and called by us the Mite, and of the Fly produced from it.\**

SIR,

I Doubt not, but at the time when you held weekly conferences at your house in Paris, and thereby made it a general place of meeting for the learned, some of your inquiries turned on the nature of Mites, their singular disposition, and surprising manner of their springing up into the air. I therefore take the liberty of submitting this little treatise to your judgment, which I respect and value infinitely more, than the opinions of many of the professed litterati of the present age, whose inquiries into natural things, seldom go deeper than the surface.

I am not ignorant, that the illustrious Redi has wrote with great knowledge and accuracy concerning Worms, which are bred in cheefe; but I know also, that he could not possibly be thoroughly acquainted with all the circumstances remarkable in those insects; and that the great number of uncommon experiments

which he proposes, could not but hinder him from applying himself thoroughly to all parts of the subject, especially as he, at the same time, paid his attendance at the court of the great duke of Tuscany.

I have therefore taken upon me to lay before you, most illustrious philosopher, a full account of this little Worm, and its Fly, their external appearance, their dispositions, and their internal structure; for I can take upon me to affirm, that the limbs, and other parts of this Worm are so uncommon and elegant, and contrived with so much art and design, that it is impossible not to acknowledge them the work of infinite power and wisdom, to which nothing is hid, nothing impossible. You will see these minute creatures have, as well as the greatest, a brain, nerves, muscles, lungs, salival ducts, a stomach, small and large intestines, cæca, or blind guts, pinguiferous or fat membranes, and the several other viscera.

### *The external parts of the Mite.*

Although this Worm is very common, I have thought it not amiss to give a figure of it at its full growth, and of its natural size, Tab. XLIII. Fig. 1. as names are equivocal, and there are many who know but little of it. These small creatures being generally held in detestation, though some eat them voluptuously with the rest of the cheefe, from a vulgar notion, that they are formed out of the best parts of it; whereas in reality, they proceed solely from the eggs of a common Fly, as I shall presently demonstrate. But before I undertake to explain the disposition of this Worm, and give some account of its internal parts, as they appear on dissection; I shall describe its external parts, as well as such internal ones, as the transparency of the outer ones affords us an opportunity of examining, without being obliged to dissect, it.

The Mite, when viewed with the microscope, appears divided into twelve sections or rings, Fig. II. 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12. The first of these rings, properly speaking, forms the head *a*, the skin of which, as likewise that of every other part, is tough and firm like a piece of parchment; so that it is no easy matter to break or wound it, though the Worm leaps with a surprising violence, on being ever so gently touched. The forepart of the head is, in a manner, divided or separated into two tubercles, from which arise two very short

antennæ, or horns. Between these two divisions of the head, there constantly appears, through the transparent skin that covers it, a small particle, which, like the head, consists also of two divisions. This little particle really contains the organs constituting the mouth, which are of a substance between bone and horn, and produce on their forepart two little black claws, which serve the Worm not only as such, but likewise for feet, and in the place of teeth. We may also clearly perceive thro' the insect's transparent skin, that it can move these claws in and out, together with the already-mentioned parts of the mouth, in the same manner as the Snail thrusts out, or draws in, its head and horns.

The next ring is very remarkable on this account, that the pulmonary tubes of the insect scarcely open any where else, except in the hindermost ring of the body, where there are two more: I could never discover any other breathing-holes, or apertures, in this insect. Those in the front ring next to the head, are very large. These extremities, or rather the beginnings of the lungs, Tab. XLIII. Fig. II. *b*. are curiously contrived, and elegantly constructed. On the forepart, where they are thrust out beyond the skin, they are of a membranaceous substance, somewhat white, and very delicate; a little lower they swell, as it were, into a small belly, and grow yellowish, and in some mea-

\* It has been a custom to call any small creature found in cheefe, in Latin, Acarus, and in English, Mite. This author takes the accustomed liberty of speech, and gives, in the present account, the name Mite to the Maggot of a small Fly; but the creature we commonly call Mite in England, and which is most universally called Acarus in Latin, is of a different kind; it is made smaller than this Maggot, and appears like a moving particle of dust. This is the Acaris of the antients, which Aristotle observed in decayed Bee-wax, and was called the least object of the human sight. This Mite has six legs, an oval or rounded body, with a hard skin, and very distinguishable eyes. The Maggot here treated of under the same name, is a creature altogether distinct.

sure to appear of a golden brightness. After this, they grow narrower towards the third ring, where we may plainly perceive, through the insect's clear skin, that after acquiring a silver whiteness, like mother of pearl, they unite with the branches of the trachea, serving as larynxes. One great advantage the insect draws from these openings, being placed forwards, near the beginning of the third ring, is, that when it draws in its head and legs, as it burrows in the moist cheese, these larynxes are covered by the folding of the skin. A contrivance worthy of its great Author, the sole fountain of every thing good and wonderful. Within the third ring there plainly appears, through the transparent skin, the two great branches of the wind-pipe, which communicate about the beginning of the fourth ring, by a very conspicuous anastomosis or inosculation. There are also many other smaller branches of the trachea issuing from the two great branches, which are placed within the third ring; and these small branches ascend towards the second ring, and toward the head. I have omitted these ramifications in the drawing, for fear of rendering it confused. There appear besides, tho' somewhat obscurely, some other internal parts, through these rings. In the fourth ring there are seen two more branches of the trachea, issuing on each side of the breast from the two main trunks *cc*. Of the two small branches last mentioned, one goes to the fourth, and the other to the fifth ring, where they join the branches springing from the trachea in this place by a double inosculation, or anastomosis, that is easily discernible.

I do not find, that the greater branches of the wind-pipe form a mutual inosculation, or anastomosis with each other, any where, except about the beginning of the fourth ring; but the smaller branches arising from the sides of the greater, and which appear very distinctly on each side of the body extended all over the annular divisions, communicate with each other in a very obvious and conspicuous manner. This may be best seen on the declivity of the breast and belly, above the borders visible in those places, as also in the rings of the left side, marked in the figure with the numbers

5, 6, 7, 8, 9, 10, 11, 12, and the letters, Tab. XLIII. Fig. II. *ddd*, &c. There appear, besides many other, smaller branches in the same places, which spring from the greater, and extend to the viscera within.

All the other rings, from the fifth to the eleventh, are constructed alike; and the ramifications of the pulmonary tubes, which shew themselves thro' these rings, are nearly of the same form: the principal difference, and that too is only accidental, as it is called, is, that the other internal parts of the Worm shew themselves a great deal more plainly thro' some of the rings, than they do thro' others. In the fifth ring some particles of fat may be discerned thro' the skin *e*, and some more, tho' very faintly, in the sixth. In the seventh and eighth, I could perceive some of the *cæca*, or blind guts, or closed intestines *ff*. These, on account of their contents, appear of a very pale colour, in some degree approaching to green; the same also I could sometimes perceive, pretty distinctly, thro' the ninth ring, tho' at other times very little or not at all. In the tenth ring, and between the principal trunks or branches of the wind-pipe, which extend themselves along the back of the Worm from one end of its body to another, there generally appears a considerable branch of the trachea *g*, running to the internal parts. In the eleventh ring, there is seen a very remarkable particle of fat *h*, resting upon two branches of the wind-pipe; but it has been only in some Worms that I could perceive this: it is not universal.

The twelfth ring differs in construction from all the others; for the two greater branches of the trachea terminate there, projecting at their extremities in the same manner as the lesser branches of the trachea do beyond the surface of the body. The projecting parts are, like the other breathing holes near the head: they are of a pale colour, but formed in a different manner, as may be seen by looking over the figure.

To conclude: the surface of this twelfth ring, is covered with a variety of prominent tubercles, and little cavities like wrinkles; the use of which I shall hereafter describe.

### *Of the disposition of the Mite.*

**T**HUS, Sir, I have described, in a few words, the external parts of this Worm, and such of the internal ones as appear thro' its transparent skin. But all these particulars will appear of little consequence, when compared with the wonderful contrivance that is seen in every part; when more minutely examined: such a contrivance, as the great Architect of nature alone can thoroughly understand, or could form; the most ingenious inventions of man being, in comparison with it, lame and defective.

The figure I here give of this Worm, which is surprisngly strong, and has a most vigorous

constitution, represents it lying on its back, and seizing its tail with its teeth or claws; but this posture is not, as you may guess, the natural condition of this Worm, nor is it ever found lying on its back, when alive; so that my only design in giving it thus, is to be better able to explain the manner of its leaping, in the most satisfactory terms. By turning the figure, you will have a most exact and natural representation of the little insect, preparing to make a spring.

When this creature intends to take a leap, it first erects itself upon its anus; in doing which, it is greatly assisted by the prominent tubercles

tubercles of the twelfth ring, which enable it to maintain an equilibrium, by projecting more or less at its pleasure, from the body. Immediately after this, the creature bends itself into a circle, and having brought its head, Tab. XLIII. Fig. III. towards its tail, it presently stretches out its two black crooked claws, and directs them to the cavities formed between the two last or hindmost tubercles of the body, where it fixes them in the skin; as the second figure, done from nature by the help of a microscope, accurately represents.

The Mite having thus made itself ready, contracts its body with such force, that from a circular, it becomes of an oblong form, Fig. IV. the contraction extending in a manner to every part of the body. This done, it again reduces itself with so prodigious a force to a straight line, that its claws, which are seated in the mouth, make a very perceivable noise on parting from the skin of the last ring of the body: and thus the Mite, by first violently bending, and afterwards stretching out its body, leaps to a most extraordinary height, if compared with the smallness of the creature, in consequence of the stroke the body gives in recovering its place on the cheese, or wood, or any other substance upon which it was before lodged.

I have indeed seen a Mite, whose length did not exceed the fourth part of an inch, leap out of a box six inches deep, that is, to a height twenty-four times greater than the length of its own body\*; others leap a great deal higher. But this Worm does not always erect itself per-

pendicularly to take a leap; it very often prepares for this when lying on its side, though the first is the commonest method; but whether it erects itself, or lies on its side when about to leap, it never fails to bend its body into a circle, and afterwards to reduce it to a straight line.

If, Sir, you should be desirous of examining with your own eyes, these surprising miracles of God's power and wisdom in this abject creature, you need only place the Mite in a drop of water, upon any white surface, and adapt it to the microscope in this situation; for, though it cannot leap in the water, you may distinctly perceive it endeavouring to do so, by seizing its anus with its claws, and making every other posture, exhibited in the second, third, and fourth figures.

This may also be seen in another manner, by fastening the Mite with a little paste, made of stiff starch, on the point of a very small needle made for the microscope, as it cannot loosen itself, so as to perform its leap in this situation. Another method is, to roll the Mite about a little upon a table, and handle it till it has lost a great deal of its strength; for, in this condition, it takes hold of its anus very irregularly, and sometimes fixes its feet into the pulmonary tubes placed about that part; you may then very conveniently see in what manner it extends its claws upon this occasion. Our common friend, Dr. Matthew Slade, will confirm all these particulars, he having had the pleasure of admiring, together with me, all these prodigies of nature.

*An anatomical description of the internal parts.*

**T**O kill some of these Worms for dissection, I threw them into rain water, where they died, but not till after six or seven days: they are fittest, however, for anatomical dissections, at the end of two or three days, lying in water; for though still alive, they are benumbed. On being taken out of the water, at the end even of five days, they will crawl, however, and sometimes leap about as briskly, in a manner, as ever, and sometimes live after this to become Nymphs, and afterwards Flies.

I could discover no eyes in the Mite's head; but the first things that presented themselves in that part, on dissection, were the claws, which I before mentioned by the names of teeth and legs, as indeed I have found by experiment, that they will answer the several purposes of all those parts. The insect makes use of them as teeth, in scraping off the cheese, and afterwards swallowing it, so that it is but reasonable to call them by that name: next the Mite employs them to walk with, so that one would imagine it walked upon its nose. This may be seen, by placing it upon a piece of fine linen, or paper; for it fixes these two parts into the pores of the linen, or paper,

and then draws after them the rest of its body. Thus they deserve the name of feet: but this is not the only manner in which this creature crawls; it can likewise move itself by an undulation, or waving motion, of its body. Finally, these parts, may be justly considered as claws, not only upon account of their resemblance to those parts in other animals, but also, because it is with them that the Worm takes hold of the last ring of its body, so as to bring its mouth and anus to meet together.

These teeth or claws are very sharp on their fore part, and they are moderately crooked, almost like those of hawks and eagles, Tab. XLIII. Fig. v. *aa*. Nearer the root they grow broader, and they have two apophyses or swellings, wherein the muscles, that serve to move them, are inserted. These teeth are articulated with the mouth and palate, which are two little black, oblong, hollow, horny bones, with which the pharynx is also connected. These little bones, from a slender beginning, *bb*, afterwards become broad, and at last terminate in four appendages, *cc*, which are in a manner of a membranaceous substance: but in the fore

\* We may admire in this instance the powers nature has given to different creatures, and their limitations, to answer necessary purposes, and not for mischief to mankind. If nature had given this power to the serpent kind, how terrible would it have been! A Viper would have thrown itself from a concealed place, seventy-two foot at the traveller; a Rattlesnake an hundred and fifty: this being the proportion to the length of their bodies.

part, they are connected in the middle, with two other horny, and very singular bones, *d*, which serve to keep them in their places, and at a proper distance from each other.

The gullet, which lies between these appendages of those little bones I have been describing, and in their hollow part, becomes considerably wider in the Worm's thorax, *e*, where it, in a manner, forms an ingluvies or large hollow.

Under this are seen four appendages, closed at their ends, *ff*, which are, as it were, clustered about and surrounded by little globular particles of a fatty matter, but of a peculiar nature. They are indeed properly made up of these. As yet I cannot determine what these particles should be called, or the use of them may be, unless, perhaps, they may serve to moisten the food of the Worm, in its passage through the œsophagus or gullet, and thereby render it of easy digestion.

The stomach, *ggg*, offers itself next to our consideration. It is very long, as is the case in all other insects, while they continue in the Worm or Caterpillar state. It is supplied with a great number of ramifications from the wind-pipe; but I have omitted them all in the figure, except two principal, and some other smaller, ramifications distributed over the surface, *bbb*. The length of this stomach is so very considerable, that one might easily mistake it for a gut, and describe it as such; and no doubt, I should have been myself of that opinion, had I not had an opportunity of comparing together the construction of this, and of the stomachs of other insects. This stomach is of a membranaceous substance, in which there appear some muscular fibres through its transparent coats. All the contents of the stomach were white: I have endeavoured to represent them in the figure by some dots, as seen through the coats of the stomach, *i*. The stomach appeared also invested with numerous particles of fat; but I did not discover this last circumstance in the stomach, till after I had dried it on a thin piece of glass.

Lower down, towards the end of this channel, there rise from it two little slender intestines, *kk*, like those found in all other Worms or Caterpillars, that I have yet dissected, and even in the Loufe. I call these cæca, or blind intestines. In the Mite, these two intestines divided, each into two others; two of these contained a greenish yellow substance, *ll*; and the two others, a matter that was partly green, and partly white, and looked as if it was coagulated, *mm*; but what was very surprising, the motion of this substance through the intestines was so quick, that my eyes could not keep up with it; and, on my cutting one of the intestines in two, it flowed from it with great rapidity. This I observed in a live Worm, that I dissected; but in another, which began to putrify, I found the coat of this intestine dissolved into an infinite number of little fatty lumps. In both, these intestines were of a prodigious smallness; but from the motions of the matter contained in them, we may reasonably conclude they are furnished with muscular fibres, though I could by no means obtain a sight of them, as they evade by their extreme

delicacy, the sharpness of both our eyes and instruments, which are at best only fit to examine visible and sensible objects, and even these very imperfectly. How much therefore are we bound to humiliate our hearts, when, on account of our great weakness, we cannot thoroughly search into any one of God's creatures! These intestines had also their pulmonary tubes, *n*. And who can tell how many more wonders may yet remain hid in them!

The pylorus, *o*, or opening of the stomach, appears below the insertion of the four intestines I have been just describing, and near to this is the gut colon, *pp*, which is followed by the rectum, *q*. I could discern the very extremity of the rectum, *r*: it was of a somewhat different form from that which I have given it in the figure; for I there represented it as it appeared on my squeezing it at the fundament out of the Mite's body.

It is extremely remarkable also, that two of the cæca or blind guts, were so united with particles of fat, *ss*, that their closed extremities appeared firmly fixed in them, and connected with them by means of a great number of pulmonary tubes. In the figure I have only represented this circumstance in one of the intestines. There are in this creature a great number of these particles of fat. They are of an oblong oval form, sometimes double, and sometimes hung about with appendages, round, hollowish, and flat, as may be seen in the two little portions of this fat, which I have here represented, *ss*.

On examining this fat with a powerful magnifier, every division or lobe of it appears wrapped up in its own particular membrane. We may, even by this means perceive, that every single particle of this kind, contains an infinite number of globules of fat, Fig. vi. *aaa*, which flow out of the lobe as soon as it is opened, and mix confusedly together; so that, a variety of branches, composing, as it were, a little tree, are formed by the combinations of the concurrent lobes. The particles of this fat are of a dusky white, and, by this means, they exhibit in the Worm a spectacle, whose beauty no words can properly describe; but we need not think this extraordinary, as it is effected by the Omnipotent Being, who, with a word, produced all things.

It is very entertaining also, to consider in what manner the pulmonary tubes, which are of a bright silver whiteness, Fig. vi. *b*, run every where, and in every possible direction, through these pinguiferous or fat vessels, so as to distribute themselves principally over the particles of the fat, where this substance is laid up in little round lumps; at the same time, that in the interstices of these lumps, they run into one another without any apparent order.

On one side of the gullet, there lay a very delicate and small tube, stretching to the jaws, and the horny bones constituting the palate and mouth; but I have not as yet been able to trace this tube perfectly to its origin. I found that it divided itself, in the breast, into two small channels, each of which widened again into an oblong globular bladder, Fig. v. *tt*, and then became

came again contracted into a narrow tube, which reassumed once again the form of a bladder, beautifully adorned with a great number of pulmonary tubes running over the whole surface, *uu*. Some particles of fat very regularly placed, and most curiously contrived, surrounded one side of these glandular vessels, *xx*, and underneath, extended into a kind of blind or closed appendages, *yy*, such as I had never observed before in the fat of any creature.

Nor can I tell the use of the particles last described, though I have reason to think they perform the office of salival glands and ducts. For, as the Mite spins no web, and these baggs are closed behind, I do not think any other service can be so properly attributed to them.

The pulmonary tubes, which are distributed through all the parts we have been surveying, are constructed in the Mite after the same manner as they are in other insects. That great anatomist Malpighi, has given an instance of this in his account of Silkworms; and I have, myself, frequently done the like in this work. But the rings composing these tubes, are not so very numerous; for which reason, they are of a more membranaceous and flexible structure.

The motion of these pulmonary tubes is seen very evidently through the skin, on examining with a microscope the Mite, held on the point of a pin run through its head; for, as the insect in this condition turns and twists itself a great many ways, the pulmonary tubes assume, in consequence of its motions, a variety of appearances. Sometimes they are stretched out to their length, at other times they are bent in a serpentine manner, or coiled up in form of a circle; but notwithstanding so many distortions, the rings composing them always retain their form, and never collapse. Thus has the Omnipotent Architect given us the specimen of a tube, so perfectly flexible, that the most violent contortions cannot do it the least injury.

The brain is situated in the neck, near the horny bones, that form the mouth and palate of the insect. This situation of the brain makes it fall lower in the neck, on the Worm's pulling its feet into its mouth; and, on the contrary, it is drawn forward, as often as that creature thrusts out its snout: this is very much the case also in Snails. What atheist is there, who would not be confounded and struck dumb, on examining attentively the wonderful contrivance in the viscera of animals? For my part, I dare challenge mankind to describe properly the smallest portion of the meanest creature that crawls upon the earth. Whoever should undertake so bold a task, would lose his eyes in the attempt. For, there is no doubt but any one, who, in this vale of tears and ignorance, should fully and immediately behold the divine sun of these truths, which God has treasured up in his creatures, would forfeit sight for his presumption. Such has been the unhappy, though deserved fate of all those, who have attempted to disprove and overturn by human reasonings, and sensible experiments, the divinity of the Creator, so clearly shining forth in the whole nature of things.

Whatever is a sensible object, must lie within the sphere of the senses; but our senses are coarse, and cannot of themselves teach us any truth, unless prior ideas of it have been impressed upon us by him, from whom we derive our existence. This, father Malabranche has most incontestably proved in his inquiry after truth.

The brain in the Mite consists of two globular parts, which in a manner constitutes its right and left portions, Tab. XLIII. Fig. VII. *aa*. Near the brain is situated the beginning of the spinal marrow, which in this place is always opened, so as to give a passage to the gullet. From the fore region of the brain there issue some considerable nerves, which dilate a little, at the distance of half their length from their origin, *bb*. But this particular is not observable in every Mite. These nerves at length swell into two distinct and very conspicuous nodules, *c*, from which arise two smaller and very delicate nerves, *dd*. I could not trace these far enough to know what parts they run to: I believe it is to the muscular parts of the mouth, palate, and feet. Next under the brain, and from the beginning of the spinal marrow, there arise two pair of very slender nerves, *ee*, which administer to the viscera in the abdomen, and to the muscles moving the rings of the body. Under these appear two considerable nerves, which, after dilating into two oblong globes, *ff*, close again, and then form two other globes, smaller than the former; from which there arise again two nerves: but what these nerves are, or what purposes they serve in this insect, I cannot tell. I believe, indeed, they exist uselessly in the Worm, and are to work the muscles of the wings, when it becomes a Fly. From each side of the spinal marrow there issue a great many other delicate and small nerves, *gg*, which are all distributed to the inner parts of the creature, and to the muscles of its body; and many of these nerves subdivide into various ramifications, *bbb*.

The spinal marrow will appear very short, if we compare its length with that of the entire insect; and the same may be said of the body of the Fly into which the Mite turns. It is therefore necessary, that the nerves, which are extended to so great a length, should contract themselves, and become shorter, at the time that the Worm begins to change to a Nymph. In animals, whose blood is of a red colour, such as Dogs and Calves, I have often observed, that the nerves shrink up, as Serpents do, into rings, or like a spiral, as often as the part to which they are fixed undergoes any contraction: and this is chiefly observable in the nerves of the mesentery; whereas in the Worm now before us, the nerves are in every part equally contracted. This likewise happens in the Coccus, or Worm of the Beetle, where this contraction affords a very uncommon and very entertaining sight.

The spinal marrow of the Mite consists of twelve divisions, or, as it were, nodular sections. These, however, are scarce discernible,

on account of their smallness, being no larger than grains of sand. This part is invested with a most delicate coat, through which are spread a great many pulmonary tubes: it is besides covered with particles of fat, which I have endeavoured to represent by dots on the figure of the marrow. All the nerves issuing from the spinal marrow are covered with a continuation of the same coat, which invests the marrow itself; and they are likewise furnished with pulmonary tubes, which accompany them in their most delicate ramifications.

The spinal marrow, viewed sideways, has quite a different appearance from that which the figure here given of it represents; for, on looking at it in this manner, it appears situated lower than the brain, Tab. XLIII. Fig. VIII. *a*, and looks somewhat crooked, *b*. This form, I am inclined to think, was purposely contrived to allow a freer passage to the gullet, where it runs down, like an intestine, from the jaws to the ingluviæ, or swallow. This is the reason why the brain is placed above the gullet, and the gullet, together with the stomach, rests upon the spinal marrow, and its nervous ramifications: so that, properly speaking, the spinal marrow rests upon the muscles of the rings of the body in the under part, and is cushioned up with particles of fat on every side.

The construction of the muscles, which in this insect move the rings of the body, is very singular and surprising. I discovered three different kinds of them, without examining farther than the foremost part of the thorax; some descending obliquely with two bellies, Tab. XLIII. Fig. IX. *aaa*; some broad ones run

crossways, *bb*; and others again ascend obliquely, *cc*. All these muscles are so elegantly situated, that the greatest adepts in designing and painting, I am certain, must confess their inability, were they to go about representing them as they deserve to be figured. To exhibit exactly every thing worthy of notice contained in these parts, we should be obliged to make use of figures twenty times larger than these now before us. And, after all, the muscles which I have called the obliquely descending, and which have two bellies, do not, properly speaking, deserve that name; for they appear to have five tendons, of which one is inserted into the muscle that lies next to it, and the other four into the tough rings of the body, which they serve to move, as I have endeavoured to represent, if the unspeakable magnificence of God's works can at all be represented by human art. An infinite number of pulmonary tubes are distributed all over these muscles; but, as yet, I have not been able to discover in them any insertions of the nerves: so that I must, in this point, own myself as much at a loss, as I have upon many other occasions.

As to the heart, which sends the white or aqueous blood of this little creature, in a due circulation, through the body, I could by no means discover it; and this I attribute to its smallness, and to its being of a thin and delicate structure. But I am persuaded, that it lies in the upper part of the back, like that of Silkworms; for I could plainly discern pulsations in that part.

*An account of the manner in which Mites get into cheese, and cause it to rot, instead of being caused by or formed themselves out of rottenness; with many other uncommon observations.*

**T**HE parts I have hitherto mentioned and described, are all I have been as yet able to discover in this minute insect. And now let the sharpest geniuses, and men of greatest penetration and learning, judge if a creature, in the fabrick of which there plainly appears so much art, order, contrivance, and wisdom; nay, in which is seen the hand itself of the Omnipotent God; could possibly be the production of chance or rottenness! Is not the light of human understanding alone, unassisted by divine revelation, sufficient to convince us, that it cannot be so? Certainly it is sufficient. The illustrious Redi as evidently proves, that this system of the production of animals from putrefaction, assisted, as they would have it, by heat and moisture, is a mere idle imagination, founded on the erroneous maxims of heathen philosophers, unacquainted with any superior origin of existence.

That ingenious naturalist most accurately explains in what manner Mites proceed from Flies, which have deposited their eggs in the cracks and holes of cheeses\*: and I can add to his account, that the body of these Flies terminates in so fine a point, that they are able to thrust it into, and penetrate very deep in, the smallest openings. I cannot but also take notice, that the rottenness of cheese is really occasioned by these Worms; for they crumble the substance of it into small particles, and void their excrements in it, and foul it with their saliva, or the moisture of their mouths; so that the smallest spot of rottenness, produced by these insects, cannot but immediately spread itself. I once observed a cheese, which I had purposely exposed to this kind of Flies, in order that they should lay their eggs in it, grow moist in a short time, in those parts of it where these eggs had been deposited, and had afterwards

\* This species of Maggot, though altogether different from what we call the Mite, is not uncommon in large cheeses, particularly in such as have not been well made, and have fermented. In such cheese, where it is moderately soft and damp near the surface, these Maggots are frequent; and if they fall off, on being disturbed, they will leap about, upon a dish or table, in a surprising manner.

been hatched into Worms, though before the cheese was perfectly sound and entire. I have likewise observed, that this putrefaction in cheese is considerably augmented by the carcasses of the Worms that happen to die in it; for there always die some of them: and it is impossible there should not, as it is a certain death to them not to be able to harden into Nymphs, and all of them cannot escape out of the moist part of cheese to a drier situation, which is necessary to such a change. Further, I have observed, that some of these Worms contained other Worms within their bodies, but so minute as to be scarce discernible. But, on extracting these smaller Worms from their places, I found they were almost of the same form with the larger Worms, though they move themselves from place to place in quite a different manner. I could even discover, in the transparent bodies of these smaller Worms, that, by examining with the microscope, notwithstanding their almost incredible minuteness, they were furnished with pulmonary tubes, and other parts in common with the greater.

It is certainly very difficult to explain in what manner Worms are bred in living animals; as, for instance, in the livers of Oxen, in the kidneys of Dogs, and even in the blood-vessels, as is observed by that celebrated anatomist and professor of surgery at Amsterdam, Ruysch. For my part, I freely own, that I want sufficient experiments to form any solution of this surprising phenomenon; though I have met with great numbers of different kinds of Worms, in the living and healthy bodies both of land and water animals, and even of fowls and flying insects. However, on this occasion, I cannot as yet advance any thing certain, or satisfactory.

I must not omit a circumstance which I heard from Otto Marsilius, the late famous painter of flowers and insects. It was this, that he had seen, at the time when Caterpillars were busy in divesting themselves of their skins, or when they had just performed the operation, and were grown faint and weak with the fatigue of it, a great many Flies, some bigger and others less, piercing the bodies of such Caterpillars, and depositing in the wounds, so made, quantities of little eggs; from which proceeded the Worms, that are every year so commonly found in Caterpillars. As yet, I must own, I never saw myself this strange operation: but allowing it to be fact, it would perhaps greatly help us in explaining the generation of Worms found in the viscera, or bowels, of larger animals; provided especially such Worms were found afterwards to turn to Flies, or other winged insects, which as yet I have not been able to determine experimentally, notwithstanding the pains and attention I

have bestowed on the observations of changes in this kind. Admitting Marsilius's account to be true, and that some of the perforations he observed were made into veins and arteries, and eggs were deposited in such perforations, there can be no difficulty in conceiving how the circulating blood might have dispersed these seeds of animals all over the body. It must however be owned, after all, that these things are as yet buried in a cloud of darkness, which obscurity, nothing but the brightest light of experiments can ever dispel. In the mean time, we may see, by the manner in which we are affected by the stinging of a Bee, how an animal, without getting into our bodies, may convey a matter into it, capable of producing great alterations; for the Bee, at the same time that it gives the wound, insinuates by it into the body a drop of poison. This is not a place for explaining how eggs come to be found in the substance of plants; besides, that I have already sufficiently treated of that subject.

As to the opinion of some people, that the Worms found in our intestines proceed from the eggs of animals which we have swallowed, it only deserves contempt, being altogether contrary to sound reason; unless the favourers of that system would at the same time allow, that the eggs so swallowed are those of Worms bred in the intestines of other animals. This opinion cannot by any other means be admitted, as it is quite inconsistent with the nature of things, that an animal should live for any time in a situation so different from that in which it naturally should live, and on so different a food. Besides, for this to be true, it is requisite that such Worms, intended for living in other places, should also be able to endure the heat of the intestines, and of the fluids passing thro' them. A thing which no man in his senses can admit.

The generation of animals, or the laying and hatching of their eggs, is by no means a thing which requires little care or attention. Every creature has its own season, its own haunts and element, its own manner of living, and its own food. Every year we observe the same renewals of the several species, performed in a manner limited by a constant and inviolable law and order of Nature; as the illustrious Redi, before mentioned, has, on another occasion, likewise observed. For this reason we always see, that Worms of the same kind, found in the intestines of animals, have constantly their blood of the same colour, be it red, yellow, green, or white.

In regard to Caterpillars, indeed, I have observed four different ways in which Worms lie hid within their bodies, and afterwards creep out of them\*. The first is, when one or more Worms make their way into the Cater-

\* The case in those Flies, which we see hatched out of *Chrysalis's*, from which we expected Butterflies, is exactly the same with those produced from galls, and the other excrescences of vegetables. The parent Fly is guided by instinct to lodge her eggs in the body of the Caterpillar, piercing its skin, for that purpose, with a sharp instrument at its tail. I have seen the operation; and the misery of the Caterpillar, which can no way escape from its winged enemy, is terrible. All the variation in number of the young, and other accidents, is owing to the different species of the Flies.

pillar, kill it by their corroding, and afterwards make their way out again through, the skin. The second way is, when two or three Worms lay hold of a Chrysalis, and, after killing the enclosed animal, escape in the same manner. In the third way, the Worms, after depriving the Caterpillar of life and motion, eat up all its inside; and, this done, they bore or gnaw themselves holes to creep out at in its hardened skin. Fourthly, when one or many Worms treat a Chrysalis in the same manner exactly, in which the Caterpillar is treated in the third way.

There are several other things to be considered in this place. First, when the Caterpillar happens to be killed by a single Worm, which afterwards fixes its residence between that creature's body and its web, then the Worm spins itself another white oval web, in which it changes to a Nymph, and afterwards to a Fly. But if the Caterpillar is destroyed, and perforated by a number of Worms, then these Worms settle themselves under the belly of the dead Caterpillar; where each of them makes itself a gold-coloured web, in which they cast their skins, then become Nymphs, and at last assume the form of Flies.

Secondly, when two or three Worms eat into a Chrysalis, and afterwards creep out of it, they do not, immediately after so doing, cast their skins, but only contract their bodies: and while they are in this state, they assume, in an orderly manner, and with a constant regular succession, thirteen different colours; the last of which, alone, they finally retain. At last, they turn to Nymphs within their old skins, and then to two or three common Flies.

Thirdly, the Worm which singly takes possession of a Caterpillar, and, after having eat up all its inside, remains within the skin; sometimes makes itself a web within this skin, and then becomes a Nymph, and at last changes to a Fly like the bastard Wasp, Pseudo-sphæca, or Ichneumon-fly. In this case, we always find some excrements within the Caterpillar's skin; as likewise the two skins which the enclosed Worm has severally thrown off, on turning to a Nymph, and then to a Fly. But the minute Worms, which remain in the Caterpillar they have destroyed, make no web in it; though they grow to Flies, in the same manner with the Worms producing that kind of bastard Wasp just spoke of, and then gnaw themselves holes to make their escape.

In the fourth place, the Worm, which remains singly in a Chrysalis, makes also a web within it, voids its excrements there, and then changes to a kind of bastard Wasp, in the same manner with the Worm just now mentioned, as living singly within a Caterpillar. If you open the side of this emptied Chrysalis, before the enclosed Worm changes to a Nymph, it immediately spins a patch against the broken part. But when many Worms are placed together in a Chrysalis, they neither make themselves webs, nor do they even contract themselves, but only change to a great number of

small Nymphs, which afterwards turn to as many Flies. These Flies, which are of a most elegant structure, sometimes gnaw themselves one, and sometimes more holes, for their escape, in the dried skin of the Chrysalis.

All these things proceed every year in so constant, certain, and regular a manner, that no accident whatsoever can alter the course of the operation. One very singular instance of this unchangeable order in nature, is, that even the Caterpillars and Chrysalides, which are to become the scenes of the last mentioned changes, may be easily distinguished from the other insects of the same kind. In the first mode of these mutations, when the Worms, which have lodged, many together, in a Caterpillar, place themselves under its belly, the Caterpillar raises that part, to make way for them; and though, by this time, it has received its death's wound from those cruel invaders, it notwithstanding, with the greatest care and attention, encloses and connects all their particular webs, within one of its own spinning, for fear they should be scattered abroad and lost, and after this expires.

From hence we may reasonably conclude, that if the Worms had thus lodged in the Caterpillar, and killed it, merely by accident, instead of doing both, in consequence of an immutable decree of the All-governing Power, the Caterpillar, when it found itself so roughly treated by them, would by no means take this regular care to secure them from rain and winds, and thereby insure the renewal of that particular species of insects; for they generally turn to Flies the year following.

The same order is observable in all the other perforations, destructions, and excavations of Caterpillars and Chrysalides, which I have already taken notice of, so that we can only ascribe to our own rashness and ignorance that erroneous notion, of putrefaction being able to perform wonders worthy of the Deity, and to which the power of the Deity alone can be rationally deemed equal. It is therefore in the highest degree surprising, that all mankind, the learned as well as the ignorant, should have so readily adopted, and so long entertained, so gross an error; especially as the least degree of reflexion must have convinced them, it arose from prejudice; at the same time that the smallest diligence, in examining the works of Nature in themselves, would have put them in the way of obtaining more just ideas on this subject.

Let us then be wiser than those who have gone before us, and accurately survey and examine the sensible wonders of the Deity, with all their conditions and circumstances, if we intend to obtain a true and solid knowledge of them. Let us not servilely submit our judgments to the doctrine of Aristotle, and the rest of the heathen philosophers, who ascribe to putrefaction, works that contain visible marks of an all-perfect Contriver and Maker; tho' at the same time we are, as men, convinced by daily experience, and, as christians, are



taught to believe, that all the things we see are liable to decay and destruction. God's power and wisdom is not to be separated from his justice, since, according to the unerring testimony of his holy spirit, he has entered into a covenant with his creatures; and these, under their corruption, groan and sigh after liberty.

That vulgar opinion, more worthy of brutes than of rational beings, which ascribes the birth and growth of animals to putrefaction and chance, is diametrically opposite to sound reason, and favours rankly of atheism. It has not even the least shadow of experiment or observation to support its truth; but is founded altogether upon sloth, prejudice, stupidity, and error; all which is the more obvious, as in the smallest animals we constantly every where find as much order, contrivance, beauty, wisdom, and omnipotence in the Great Architect, as are shewn in the viscera or bowels of the largest animals. For to these greater animals all others, however contemptibly minute, if their minuteness can make them contemptible, are similar in the great respects of brain, nerves, muscles, heart, stomach, intestines, and parts subservient to generation, and to every other useful purpose; so that one might in a manner affirm, that God has created but one animal, though divided into an infinite number of kinds or species, differing from each other in the figures and inflexions, and extensions of their limbs; as likewise in their dispositions, food, and manner of living.

As Caterpillars, which turn to Butterflies, often contain in them Worms which change

to common Flies; so the Worms, which change to Beetles, very often contain in their viscera also certain Worms, that turn to Beetles of a smaller kind: and, in these changes, Nature observes the same constant order and method, as in the first. From hence I again conclude, that nothing is produced by putrefaction; but that the business of generation unalterably proceeds in a certain and regular manner. And certainly, if our little philosophers would attentively examine what is the nature of putrefaction, when it breaks out in an animal, or in any part of one, which thereby rots, and is resolved into its constituent principles; and would withal consider that species of putrefaction which Worms occasion, and which they cannot but occasion, in other bodies, or in some parts of their own; they would soon free themselves from the yoke of so absurd and slavish an opinion.

As yet, I cannot by any observation determine, whether the Mites, which are found to contain other Worms, are perforated by them, while they remain in the cheese, or after they forsake it, and turn to Nymphs. It is only within these six or seven weeks, that I have made the experiments concerning these insects, which I have just now related, having never expressly examined them before that time. However, in this time I could discover in the cheese a great number of dead and rotten Worms, of a red, purple, and livid colour, whose carcases not a little contributed to increase the stench and putrefaction of the cheese in which they lay, and likewise the acrid and peculiar taste found in such parts.

*The manner in which Mites are changed into Nymphs\*.*

THESE Mites, when they are about to become Nymphs, generally desert the cheese in which they had hitherto lived, by leaping up and down, till they find, if possible, a more favourable situation. In three or four days after this they loose all motion, grow stiff, and harden. I have remarked also, that the change of these Worms may be forwarded by enclosing them, when well grown, in a dry box, without any thing to feed upon. In trying this experiment I have observed, that some smaller Mites remained alive in this confinement, without any food, for two or three weeks together; when they at length died, without turning to Nymphs; the embryo member hid under their skin not having attained the growth and firmness requisite for that state, which is obtained by the rest in the following manner.

First, the Mite draws up together the rings of its body, so as to make the interstices appear full of wrinkles; and this contraction is so great, that the Worm becomes twice as short

as it was before, Tab. XLIII. Fig. x. This also renders the rings less discernible: however, the fore part of the head, Fig. xi. *a*, may be still distinctly perceived, as well as the tubercles, *b*, at the other extremity of the body. As to the form of the little animal at this period, it scarce affords any thing worth particular mention; for the skin loses its transparency. In this state the Worm gradually changes its colour, till from white it becomes red, and in the end resembles pure red lead.

The most experienced naturalist signior Redi, who has favoured the world with a short history of the Mite, tells us, that its mutation agrees in nothing with that of Chrysalides, and other Nymphs, but he does not acquaint us wherein they really differ. Other authors consider Mites at this period as eggs, though they have no other reason for thinking so, than a bare supposed resemblance. This indeed, is so far from being even a superficial one, in proper terms, that it can only be found in their own extravagant imaginations.

\* Let the reader be cautious not to extend what is here said of the Nymph of the Mite, and its change into a Fly, to the common little insect, usually called a Mite by us; that is, an insect which is hatched perfect from the egg of its parent, and undergoes no change, but only grows larger. This state of change belongs to the offspring of all winged insects, and to no others. Therefore it is necessary, according to the universal law of Nature, that this Maggot should undergo such a change, and that the Mite should not.

They pretend to see things, which never existed, and they well deserve to be compared to those persons, who, sometimes, with equal truth, think they discover armies in the clouds, which were never formed but in their own disturbed imaginations.

For my part, I call this change, by the name of the Vermiform-Nymph; because, in this state, the creature externally resembles a Worm, and is at the same time really a true Nymph, and not a Chrysalis, under the former Worm's skin, which it still retains together with the internal figure of a Worm. And accordingly, the limbs of a latent Nymph, appear, in some measure through, to a careful examiner, this skin. But I have already sufficiently explained this fourth order of mutations in its proper place.

The Nymph, thus concealed under the skin of the Mite, is of a most elegant form. But to have a distinct view of it, 'tis necessary to break this skin, and then strip it off from the Nymph. This must be done with great dexterity and circumspection. By this means, we at last obtain a sight, and a beautiful one it is, of the head, thorax, and abdomen of the future Fly, as I have represented them of their natural size, Tab. XLIII. Fig. XII. But to perceive them distinctly, we must use a microscope; with the assistance of that useful instrument, we discern its two little horns, Fig. XIII. *a*, growing out of the forepart of its head, and under them its two eyes,

*bb*, which take up the greatest part of the head. Under the eyes lies the proboscis or trunk, *c*, with all its parts. Near the proboscis appear the first pair of legs, *dd*, and under the first pair the second, *ee*, disposed in a very beautiful order. The rings neatly folded up, *ff*, present themselves next, and under them, we may see in what manner the hinder pair of legs, *gg*, lie stretched against the abdominal rings of the body, *b*: these, with the extremity of the anus, are very distinctly to be seen. In fine, all these parts are arranged together, with so much art and beauty, that it is impossible to give a just description of them. They will be seen yet a great deal more distinctly, by divesting the Nymph of the skin that immediately encloses it.

At first all these parts are of the colour of coagulated milk, but as fluid as water, which makes it very difficult to separate them; nor can they, after all, be accurately distinguished one from another, because they are at this period, all of the same colour. In ten or twelve days, they acquire so much consistency, and so much of their peculiar colouring, as to assume the form of a complete Fly, on throwing off the internal membranes that cover them, within the former Worm's skin, which they still retain for twelve days longer; when the new insect, having acquired sufficient strength to appear abroad, breaks this external enclosure likewise, and launches into the air, in the following manner.

*The manner in which the Nymph of the Mite breaks from its membranes, and assumes the form of a Fly.*

THE first thing observable in this change is, that the Vermiform-Nymph loses its deep red colour, and grows much darker; then the Nymph itself breaks that part of the skin, which covers its head into two parts, Tab. XLIII. Fig. XVI. *a*, *b*, and at the same time throws off from every part of its body a very slight membrane, which it leaves within the old skin. When this is done, there breaks out from under this skin, a little insect like a gray Fly, without wings, but so nimble, that it runs immediately about as if it were several weeks old.

Sometimes after this, the new born Fly rubs with its forefeet, that part of its head which lies immediately over its horns; for, on this spot, there arises a considerable swelling, with a violent pulsation in it. The Fly never gives over rubbing, till it has dispersed the swelling, and made it entirely disappear. 'Tis probable, that it was in this part, the fore-legs lay while the insect remained in the Nymph-state. The next thing the Fly does, is to rub very gently with its hinder-legs, the surface of its two short little wings, which are as yet folded up, till it thoroughly expands, and displays them. This operation may be very distinctly seen, and I have represented the great folds, Tab. XLIII. Fig. XIII. *ff*, which the insect thus expands. The Fly, after this labour, takes a little rest, remaining quiet until the wings fully display themselves,

which is performed very suddenly, for their vessels are no other than ramifications of the wind-pipe, which run up and down through them; so that we may easily conceive how they may be so suddenly expanded by an injection of blood and air from the main trunk. The insect, however, cannot as yet fly; its wings yield some blood if they be wounded at this time; whereas, when they are once perfectly dried, which is done in a quarter of an hour, it is impossible to obtain the least drop of blood from them, even by cutting them off, the vessels being in that time perfectly dried up and closed; for my part, I firmly believe that all the membranes of animal bodies are no other than a kind of webs, consisting of vessels consolidated in this manner, as may be seen in the blood-vessels of the epidermis, which dry up as soon as the foetus comes from the womb, and ceases to draw nourishment from that part of its covering.

The Fly produced from the Mite is one of the common kind; and it affords very few things worth our notice: this may be seen by the two figures, in which I have represented it of its natural size, Fig. XIV. The wings, when they lie on the body, extend beyond the extremity of it. I give also a figure of the male, after a drawing taken with the microscope, in which the head, thorax, and abdomen are seen very distinctly. On the forepart of the head, there arise two short horns,



root of the penis is bent in a very wonderful manner, and grows broader at its extremity, *e*, where it unites with several other parts, amongst which the testicles *ff* deserve our particular notice, on account of their singular figure and construction. They are of a pale brown colour, variegated with red; but the sperm contained in them is white, and that, as well as the coat of the testicles, appears thro' the microscope, as if made up of little globules. The vasa differentia, *gg*, next present themselves. These vessels widen considerably at a little distance from their union with the testicles, and resemble, as it were, the two globose appendages of these parts, *bb*. There is so little difference between the other parts, that I cannot distinguish them from one another, though I take the longest of them, as appears by my drawing, *ii*; for the feminal vessels, and the others, which are more globose for the prostata, *kk*. All these parts are of a delicate whiteness, and they convey a feminal matter of the same colour to the cavity of the penis. These are all the parts I have examined in the male Fly, as it was the Worm alone, of which I proposed to take a full and accurate survey.

The female, on the other hand, is furnished with a double ovary, constructed nearly in the same manner with that of Herrings. But I shall defer speaking of these organs, till the external parts of the uterus are described. The female hides its vulva, and the extremity of its uterus, under the two last rings of its body, Fig. XVIII. *aa*. The vulva consists of three joints, the first of which is oblong, and hairy at its extremity, *bb*, and is furnished in the middle with two little black horny bones, which help greatly in the protruding of this organ out of the body. The second joint lies entirely within the first, as within its prepuce. It is naked, or free from hairs, and it ends in a horny bone, *cc*. The last joint, which, properly speaking, constitutes both the vulva and anus, is perfectly black, and is composed of a horny bone, and a membranaceous substance, with here and there a few hairs, *d*. These parts of the Fly generally hang out of its body, on its quitting the Nymph-state, in order that they may dry to a proper consistency; they then void a drop or two of a fluid, which looks like water mixed with chalk. The excrements afterwards, thrown out from these parts, look little balls with tails to them, and consisting of a substance that very much resembles plaister of Paris.

In dissecting this Fly, I found it contained an ovary divided into two partitions, each consisting of thirty-two oviducts, with four eggs in each, one pretty large, Fig. XIX. *a*. and three imperfect ones *b*; so that the ovary of this single little creature contained no less than 256 eggs. These eggs were white, oblong, and crooked; the colour of the smallest was wa-

tery. When viewed with a microscope, they appeared to consist, as it were, of little globules, and the oviducts shewed themselves in the same manner. All these oviducts discharged their eggs into the uterus by two common passages, and the uterus conveyed them out of the body by a single channel. I surveyed the other viscera, or entrails lying thereabouts, but very slightly; so that I could only see that the fat that had existed in the Mite, was now almost totally wasted away, and that the intestines formed a great many more folds than they had formerly done, though they were grown considerably shorter, and lay now entirely on the abdomen. Nor were the eggs yet perfect, tho' the Fly I dissected was four days old.

Flies are by nature of a very warm and lustful constitution; so that the female, immediately after its first appearance in this form, and before it has changed its gray colour, invites the male to copulation. In this act, which lasts for a considerable time, the male always gets upon the female; and in this situation he is carried by her up and down like a man on horseback. All this time the female keeps her wings expanded, and extending her vulva to that part of the male's body, where the penis lies, thrusts it into the cavity of this organ, which does not, upon this occasion, suffer any erection. And this manner of copulation obtains in many other kinds of Flies, and likewise in some kinds of Hornets. It is very singular to observe how the male gently pats the female during this operation with his body, and presses himself upon her just as a Cock does with the Hen, tho' the copulation of those fowls is very speedily performed, and that without any absolute corporal conjunction.

The Flies under our consideration, are very stout and vigorous; so that it is no easy matter to destroy them by drowning: after lying in the water a considerable time, so as to appear quite destitute of life and motion, they will immediately recover on being exposed to the sun, and fly off as briskly as if nothing had happened to them. They have two methods of flying; in the one their motion is slow and regular, and in the other it is rapid and disorderly. I fed some of these Flies with new milk-cheese steeped in water, which they sucked up thro' their trunk, or proboscis. This useful and curious organ is placed on the lower part of the head, a little below the horns, or antennæ, and it consists of three hairy joints. I likewise had the pleasure of seeing them lay their eggs in a piece of cheese, and I found in a few days afterwards a number of Worms which had sprung from those eggs, perfectly resembling those of the first brood that had produced the parent-fly.

*The manner in which these Flies lay their eggs; with an account of the membranes they throw off on leaving the Nymph-state.*

IT appears, at length clearly, by what I have observed concerning these insects, how readily the females can lay their eggs in the smallest cracks of a cheese; and I have seen them myself thrust out their tails for this purpose, to an amazing length, and by that method bury the eggs in the deepest cavities. These eggs in time produce Worms, which afterwards turn to Nymphs, and then to Flies: and this business constantly proceeds according to the immutable decrees of providence, in one uniform circle of production, without the least variation in time or place, unless it be when the Flies cannot find cheese to receive their eggs, for then they look out for some other kind of food, as much resembling cheese as possible, in its nature and qualities. Thus has this species of little creatures been kept up from the time of Adam to our days, thro' a succession of many thousand generations.

After having made the observations already related, I thought it worth my while to examine the skin which is shed by this insect, on its appearing abroad in the Fly-state; and upon inspection, I found that it contained a very delicate transparent membrane thrown off at the same time. In this membrane I could discern a great many of the pulmonary tubes

which had likewise peeled off from the body; and what was still more surprising, the snout of the Worm, with its teeth or claws, remained entirely with it. These unseemly organs, with which they heretofore used to crumble and take in their unfavourable food, and to run about and burrow in their putrified habitations, are no longer necessary in the Fly-state. These creatures have, instead of them, a trunk or proboscis, by means of which they suck up the sweetest juices, and a pair of swift and beautiful wings, wherewith they ramble at pleasure thro' the untainted air, and raise themselves far out of the reach of stench and putrefaction.

I heartily wish you, illustrious friend, a similar change and resurrection, of which that now we have been considering, seems to be an earnest; for I am firmly persuaded, that by treading courageously to the end of this mortal life, in the footsteps of our Divine Master, we shall then change it for a better; and lay down this corrupt body, to which we are now confined, in order to assume a far more perfect one. God, the giver of all good things, grant us this necessary perseverance, thro' the infinite merits of his only Son, our Lord and Saviour. Amen.

*The End of the surprising history of the Acarus, or Mite, and the Fly produced from it.*

*The history of the Worms found in the tubercles and swellings of the leaves of the Willow.*

P A R T I.

AS in enumerating the Insects which belong to my fourth order of changes, I have assigned there the place for all those Nymphs which are found enclosed in fruits, tubercles of plants, trees, and their leaves; I shall now propose some of those Nymphs, by way of a particular example. In treating of the Worms found in the tubercles of Willow leaves, I shall describe the Tubercle itself, the Egg, the Worm, its Web, the Nymph, and the Fly.

The warts or tubercles of the leaves of the Willow, Tab. XLIV. Fig. 1. are so obvious to the view, that there would be no necessity to describe them, provided each of us had the same ardent desire, and equal curiosity. But as all men are not delighted with the same thing, the most common objects in nature sometimes remain unknown, and affect the ignorant with a rapturous admiration. For this reason, I shall briefly, in this place, explain the construction, figure, colour, situation, bigness, tenderness, hardness, and smallness of these tubercles.

That the construction of the several swellings that are observed in the leaves of the Wil-

low trees may be distinctly known, we must first consider particularly the leaf itself on which they are found. The leaf of the common Willow consists of three coats; the internal as well as external, are very thin, and are set with light hairs, or a kind of down; but the middle coat is nervous and fleshy, if I may be allowed the expression; since the nerves, or rather the vessels which convey the nutritious juice to the leaf, are placed in that part. These vessels are, indeed, extremely numerous, and are divided into so many scarce visible branches in this coat, that they may be properly called the parenchyma, and compared to the fleshy substances in the viscera of animals: this may be seen most distinctly in those kinds the leaves of which are thick and spongy.

The outward coat, or external side of the leaf, I call that part wherein the nerves or ribs are prominent, Tab. XLIV. Fig. 1. *a.* beyond the rest of the surface: the external or outer coat, and the inner coat, or inward side, I call that part of the leaf which exhibits these nerves, not so distinctly conspicuous *bb.* Between these two coats the tubercles of the leaves, whereof we are treating, are situated, and



the other more acute. It appeared tinged with a watery colour, and had an extended smooth surface. These eggs lay loose and disengaged in these tender tubercles. There was no particular little cell; but they were every where equally surrounded with the inner substance of the tubercle. But when the wart afterwards becomes larger and harder, and by degrees loses its stiffness and tenderness by accretion, then it is observed, that it insensibly opens on the inside; and in process of time is divided, as it were, into two distinct parts: in one of which only an egg is placed, Fig. I. *o*, and is gradually increased and augmented.

About that time one may very distinctly see, that the egg is no where fixed or annexed to any thing, nor has any vessels, filaments, fibres, or any other ties, by the help of which it may cohere with the wart, and receive nourishment from it. Indeed, it never has any certain place in the tubercle; for it is sometimes fixed in this, sometimes in that side: it is sometimes in the middle: it is sometimes at a greater or less distance from the chink, which is naturally observed in the body of the tubercle. There are as yet no excrements found in the wart; but all things appear pure and clean.

It is very certain, that this egg is then in a state of nourishing; for one may plainly see, that it is considerably increased, from time to time, and augmented. But the most obvious signs of this are observed chiefly in those Worms which are a little older; for in such the fore part of the egg is considerably swollen, so that even the head and two eyes of the Worm or Caterpillar, enclosed in it, are gradually seen through its integuments, and are observed, Tab. XLIV. Fig. II. *p*, to grow continually blacker.

If therefore it be asked, how this egg is nourished? I answer, it may conveniently have all necessary food from the effluvia and transmitting liquids, which perspire into the cavity of the divided and broken excrescence, and likewise may easily penetrate the coat whereby the egg is invested; so that they may be sucked in, and swallowed by the Worm that lies within. All membranes serve to illustrate what I have here asserted; for these being put into a damp place, are likewise affected by the moisture: but when they are suspended wet in the air, or are expanded, again they exhale, by a contrary action, all the moist humours which they contain. Nay, it is plainly seen that gum tragacanth, though tied up in a membrane, is notwithstanding considerably swollen, when put in a moist place. But here it deserves particular notice, how powerfully salt of tartar attracts water to it. In the roots of trees and herbs, wherein open pores are not yet demonstrated, no other mode of nutrition can indeed obtain or prevail. However this matter be, I think the juice, perspiring from the substance of the warts, feeds the Worm that is thus contained within it.

Now, as an egg is nothing else but a Nymph enclosed in the pellicle, not yet having the firm-

ness and strength necessary to break open this coat with which it is surrounded, one may easily comprehend how the Worm, still contained in the shell of its egg, may suck the nutritious juice which penetrates into the cavity of the egg. And indeed this observation, by which it is evident that the egg is nourished, and becomes bigger, whilst it is and remains an egg, most strongly proves, that the egg is really the insect itself; nor is there any other difference between this and that, only in respect of the investing coat, which prevents our seeing the contained insect; though, in some cases, one may distinctly enough observe it transparently through the skin of the egg. The egg, of which we treat in this place, is, in this respect, different from those of many other insects, because the latter never increase, but for some time only cover the contained little insects; just as the membranes of the Nymphs surround or environ the enclosed insects for a time.

When this little creature afterwards has broken out of its egg, it has the form of a thin and small Caterpillar, and is twice as long as the egg wherein it had been hid a little before. It is then always found within the tubercle, that the skin cast off by the little insect lies near to it. This little Caterpillar is at this time so small, that, if it were delineated according to its natural size, it would scarce be as big as a point: wherefore I represent, Tab. XLIV. Fig. I. *q*, it rather at its full maturity, as it appears when it hath bored its way through the tubercle, and crept out through the hole *r* it made.

This little Caterpillar properly belongs to what are called the Bind-weed kind. If you view it with a microscope, you will see it composed of fifteen annular incisions, which constitute the head, thorax, abdomen, and tail. The head is of a raven-black colour, and exhibits, Fig. III. *s*, the eyes placed on each side. In the fore part, in the lower region of the head, are seen two hard horny or bony jaws; the extremities of which are divided into many small sharp-pointed teeth. With these the insect, when provoked, is not afraid to bite even at a steel-needle. These teeth are of a brownish red colour, and transparent substance. The six first legs, *tt*, each of which consisted of five joints and one claw, were articulated with the three foremost rings of the thorax. The two rings immediately following had no legs affixed to them. But twelve other legs, Tab. XLIV. Fig. III. *u*, adhered to the lower part of the six rings of the body. Finally, the tail was also furnished *x* with two: so that this insect has in all twenty legs. In the posterior part of the head, and in the neck, as also about its tail, there are some black spots. This Caterpillar, like the *Cossus*, or Worm of the Beetle, had a wrinkled skin, here and there set with hairs. It twisted and gathered together the posterior part of its body, like the Bindweed Caterpillar. It did not frequently make use of its middle, or last feet, except

when it endeavoured to wind and twist the posterior part of its body about the extremities of leaves; for then it fastened itself in the place with its feet, making no use of its fore legs at the same time. When it walks, it uses only the fore legs, and then draws after them the hinder part of its body. This is likewise the case in regard to the Caterpillars, before mentioned, which have many legs; and which likewise change into Butterflies so constantly, that I have hitherto observed no example to the contrary. The points of respiration were seen to open in the surface of the body, and the pulmonary tubes were transparent through the skin. In the hinder part of the body, the heart shewed itself also, beating.

While these little Caterpillars are small, they are of a colour mixed of a yellowish white and pellucid green, which by degrees improves and grows stronger. Even while they are, as it were, still in their cradles, a narrow line of a deep green colour, which denotes the aliment contained in the stomach, is seen through their skin; and this becomes of a more and more dusky green, the more the Caterpillar approaches to maturity; and the Caterpillar itself then also gets a much greener colour all over, only that it continues of a yellowish white about the belly. These little creatures several times change the skin within these warts, and grow whitish for a time, on casting it.

The inner substance of the wart is their food, which they immediately begin to eat, as soon as they come out of their eggs. About that time their excrements also are found in the tubercles; and there is the greater quantity of them accumulated, the more the Caterpillar is grown. I have sometimes found so great a quantity of these excrements in the tubercles, that it was three times bigger than the body of the insect. This principally proceeds from rain, which swells these feces, and sometimes kills the little Caterpillar. This most commonly happens, when it has already bitten through and perforated the coats of its wart, or tubercle. These habitations are commonly pierced through by the Caterpillars, when these insects are arrived to their full size; for then they always eat a hole through their tubercle, and then thrust the hinder parts of their body through the hole, so that they may cast out their excrements, Tab. XLIV. Fig. 1. y. The Caterpillars behave in this manner chiefly in rainy weather; for then their excrements swell vastly by the force of the wet, and would occupy too large a space, being otherwise not bigger than small grains of sand.

In process of time the whole substance of the wart is so cleanly eaten out by the Caterpillar, that absolutely nothing remains of it but the two outmost coats of the leaf. After this the creature ceases to eat, though it sometimes also abstains sooner. It is indeed very worthy of consideration, that the Worm in this excrescence finds its aliment in such plenty, that it is never in want. On June 29, I observed that many of these Caterpillars had crept

out of the mouths or orifices of the verrucles, or little warts; nor could I, notwithstanding, find any of them either on the tree, or under it on the ground. In another tubercle, which I then opened, I found a dead Caterpillar. In another, the little creature had been entirely consumed, its remains resembling only a thin skin; and near it lay a Worm without legs, which had probably consumed the entrails of the Caterpillar, and afterwards had crept out of the tubercle, in order to undergo its proper change. As I had unluckily given this Worm a little wound, I could not further prosecute its changes. I shall not presume to affirm, as a certainty, that the viscera of the dead Worm were consumed, or had been pierced, by this creature.

In order to investigate further what is done by these little Worms, I brought some leaves and little branches of Willow-trees into my chamber, and there put them in moist sand. But so it happened, that the Worms of these, having quitted their tubercles, got into the sand out of my sight. As I imagined it was the want of food that made them leave their abode so quickly, I put some leaves and entire warts of them upon the sand: nay, I likewise offered some of them a mass or lump, prepared of some bruised tubercles, in order to invite them to eat; but all was to no purpose. I therefore finally enclosed some of them in a dry box, into which I had before put some rotten wood, that I might see whether they would make their webs there. All these died likewise, pining away, some sooner, some later: wherefore I at length learned, that they could not live naked or uncovered in the air.

On the 5th of July I observed, that some of these little Worms had dug into the sand, and there began to weave webs; and this was the first opportunity I had of discovering any approach toward their change. For, when I diligently examined the sand on the inside, I found a great number of them in it, some of which lay much deeper than others. And thus I at length discovered, that these little creatures, after they have eaten sufficiently, quit the Willow-leaves, and fall; and then dig into the earth, in order to weave their webs there, and suffer other changes.

Out of this sand likewise I took some perfect webs. They were of an oval figure, Tab. XLIV. Fig. iv. a; so that if they were exposed on the surface of the earth, the moisture or rain could not do them great harm. I have likewise observed some Spiders woven up in webs. These webs were of a bright purple, approaching to scarlet. I afterwards opened one of these webs, woven by the insects; but found that the Caterpillar, in the inside, was not yet changed. On the 6th of July I cut open such another web; and in this also there the insect still lived, in full vigour. In the third web which I opened, I found the creature just on the point of suffering its change.

Its green colour began by degrees to disappear. The body became a faint yellow, and decreased.



decreased very much in bulk, becoming at the same time clear and perspicuous; as is likewise the case in Silkworms. The little line on the back, produced by the contents of the stomach, became likewise obliterated by degrees; since the Worm had now cleared its intestines of all their gross contents, afterwards lying in its web without any remarkable motion.

July 13, I found some dead in their webs; but others had by that time assumed the habit of real Nymphs. Therefore it is evident, that these insects strictly belong to the first mode of the third order of natural changes; though I shall not here refer them to it, because they weave their webs, and are changed in a very obscure manner under the earth.

Some days after, that is July 18, I observed many little black Flies issuing, Tab. XLIV. Fig. iv. *b*, out of those webs which I had taken out of the sand, and put into a dry box. This little Fly, being viewed with a microscope, shews itself divided as usual into a head, thorax, and belly. Out of the fore part of the head arise two black horns, Fig. v. *c*. These are placed before the eyes. The thorax is elegantly divided, and shews four membranaceous wings fixed to its scapulæ, whereof the lower pair are covered by the upper, and all together cover the body. The upper wings are provided with many pulmonary tubes, passing through them, and near their extremities are marked *dd* with two blackish spots. Six legs adhere to the lowest region of the thorax, *ee*, that are divided by joints and two claws: they are of a colour approaching to black. The abdomen also is black, and is divided into rings. Some of these Flies also had a tail, others not.

The males I found had tails, but the females none. If the last rings of the females abdomens were pressed out, Fig. vi. *ff*, towards the hinder extremity, a sharp-pointed part was forced from thence; which being carefully examined with a microscope, exhibited an instrument like a saw, *g* situated *bb* between two pointed horny or bony little parts, and consequently fit for piercing the coats of leaves; as I shall relate hereafter. On viewing the under part of the female's body, I observed that it grew white about the breast, but that the legs were ruddy there.

*In what manner the eggs of these little creatures come into the leaves of the Willow-tree.*

MANY who call themselves searchers into nature's secrets, agree, that all obscurer modes of generation must be attributed to putrefaction as their cause, which is the effect of moisture joined with heat. And this opinion extends even to stones; for they observe, that some insects issue from them. It is however very remarkable, that they cannot prove or illustrate that assertion by any one solid argument, or fair experiment. They rely only on their own erroneous opinion, occasioned by an

But when I afterwards opened the female's abdomen, I found perfect eggs there, exactly like those, which I before described to be found in the tubercles of the leaves: so that doubtless, they are eggs of this Fly, which are found in the tubercles. This Fly is of the same disposition with those which proceed from consumed Chrysalides. Nor did Flies break out of those webs only, which I had put into the box: they likewise issued out of the webs, which were yet buried in the moist sand. Hence I saw some such little Flies lying dead in the sand, and others that had grown faint and weak with the moisture.

In some other webs I found living Flies which issued from thence so quickly, that I could not catch them. I likewise opened some males of this kind, and therein found the male organs of generation: however, I cannot now say much of them; because I did not commit my observations thereon to writing. These little insects are changed in a double manner: for when it happens, that their Worms, at the end of the year, creep into the ground, and there form webs; Flies do not proceed from them before the spring of the following year.

I cut open also the webs that were forsaken by these Flies; which indeed, they break in a very singular manner: they make a round hole *i*, Tab. XLIV. Fig. iv. in each, like that in a barrel. In those webs I found a skin, which the little creature cast off, when it became a Nymph, and also a tender skin, which the Nymph, on being changed into a Fly, had afterwards cast.

After the creatures forsake the tubercles; these latter grow dry entirely, and in some days become contracted together. But as my curiosity had proceeded so far as to keep all these little insects, as they are circumstanced in all their changes; hence I learned, that these tubercles could not be otherwise kept in the Willow leaves, than by filling them with a sufficient quantity of dry sand, and then leaving them to themselves, until they grow dry: after this, the sand may again be easily taken out of their cavity. Let this short description of this great and unheard-of natural miracle suffice; in which the wisdom and providence of God are clearer than the meridian sun.

universally prevailing error. I except only Dr. Francis Redi, who has pointed out a very different and much better way: for he, having first, by irrefragible arguments and reasonings, destroyed the system of generation by putrefaction; yet not improbably infers, that these little insects, which are found in leaves, fruits, and the like substances, are generated there from the very soul and natural vigour of the vegetable which produces the fruits and plants. I say, the opinion of this gentleman is not altogether

together improbable ; for the experiments that may be made concerning the matter, are involved in so many difficulties, obscured by such thick darkness, and are so inextricable, that one may be easily induced to think these little creatures are really generated from the plants themselves.

This induced me to investigate, with much labour and difficulty, the origin of the Worm in the tubercles of Willow-trees. Dr. Redi says, he could never see that the Worm itself is changed ; and, I confess, I should easily have concurred in opinion with this gentleman, if I had not, though he did not succeed, discovered the absolute change of this Worm into a Fly, and had not observed the eggs in the Fly's body to be like those which are found in the tubercles. I cannot agree with this very learned author, that the Worm has only six feet, as it is represented by him ; for I find, on the contrary, that it is provided with twenty.

These are errors into which each of us may easily fall. And, indeed, I have not advanced what I have hitherto said with design to confute a gentleman who is my friend ; for I think none ought to be censured with the rod of correction, but those petulant persons, who, swollen with vain-glory, bark like Dogs at all writings whatsoever, and seek laurels for themselves by defaming others, which Bartholinus endeavours to do on every occasion ; and hence even his theses are debased by railings. Indeed, all our writings out to be directed to find out the truth with our best strength : I say, the truth, to which we all ought to adhere, whether it favours or opposes our own opinions, since there is nothing really amiable but its beauty only. Therefore, though the opinion has an air of probability, I shall not agree with the celebrated Redi, that any creatures are ever produced from vegetables, in the same manner that leaves and fruits issue therefrom.

I know indeed some learned men, and some of very eminent rank also have been brought into this opinion. But I know too, that it will never be proved by experiments, however fair it may appear. For I am really obliged to confess, that opinion seems to be so consonant to truth, that, unless these Worms had increased into winged and stinged animals before my face, I could scarce have said any thing to the contrary. Finally, in order to give my own opinion, with which I observe the very excellent physician Dr. Francis Redi formerly concurred, I think, indeed, that all those tubercles of plants, leaves, fruits, and excrescences in the which insects are found, are of no other use, nor do they grow for any other end or purpose, but to give a safe habitation to the animals in them, in order to preserve them, and likewise to serve for food \*. Indeed, extreme necessity, in this case, required such provision ; for many of these Vermicles have no feet, by the help of which they might move

about, and get food for themselves. This is particularly remarkable with respect to the Worms of Bees and Ants, which have no feet ; since the former are, for this reason, very carefully nourished by the Bees themselves ; and the latter are, for that reason, continually removed into different places, in which they can get food without assistance. Tho' the Worms which we have above described have feet, they make most use of them when they seek for the habitation, wherein they weave their webs ; but they by no means serve them to find out their food. Therefore, both in the constitution of the parts, and in the food, which the Worms found in the tubercles, there seem to appear reasons of great moment, why these tubercles are produced. These are perhaps, however, mere conjectures ; while Nature herself never intended, in her works, any thing to verify them. God shews himself every where equally adorable and immense.

I think these Worms, which are found yearly within the same kind of tubercles, and are peculiar and natural to them, are produced only from eggs of insects of the same nature, or congenial with them ; that is, such insects as deposit their eggs on the plants, leaves, or fruit, and convey them thither from without. This is indeed evident from what I have before observed, with respect to the eggs that lie in the tubercles of Willows, and those that are found in the bodies of Flies produced from thence : for these two kind of eggs do not in the least differ from each other.

Now, then nothing further remains but to explain the method whereby these eggs are conveyed into the leaves of the Willows. Nor do I see much difficulty in this matter : for, since the mother Fly is armed with one or two weapons, proper to pierce such substances, and with another instrument, which is fitted for directing and guiding the eggs issuing out of her body ; she may very easily pierce the tender leaves, when recently springing out, and may cast her small, and almost invisible eggs, into the little holes that are thus made : that this really happens, and in this manner, is the more manifest ; because, in the new leaves that have just appeared, the little egg is found every where loose and disengaged ; and only a part of it is situated between or under the coat of the leaf : nay, I have sometimes thought I saw the little holes, thro' which the eggs were conveyed into the substance of the leaf.

I own, this history would at length be completely perfect, if I could see all I have advanced, as my opinion, which, I think, I shall hereafter be able to do. But though I have not hitherto done that, the experiments which I have now proposed, to confirm my opinion, seem to me so strong, that no body can desire more convincing. I willingly confess, I have not accurately and distinctly seen the perforation of the leaf in all its circumstances : but I should think, that it is not possible for it to come within the

\* Reaumer, indefatigable in his searches into the insect-world, has given us an account of a peculiar race of creatures, which he calls *Mineurs des Feuilles*, miners of leaves. These burrow between the outer rind and substance of the leaf, feeding as they go, and leave a tract of white behind them, so that the leaf seems variegated.

cognizance of the eye-sight. For, who can see the wound in his skin, made by the stroke of a Gnat or Flea, immediately after it is inflicted? Surely no one. What one sees in the skin, is nothing else but a change of colour: and this is likewise observed in the leaf of Willows; that is, the place through which the egg is conveyed and joined to the leaf, is distinguishable in no other manner but by a small discolouring. To which we may add, that the little wound, given to the succulent leaf, by so small a creature, easily closes up again, and is stopped and filled up by the impelled humours.

It will be asked, why are tubercles produced in the Willow leaves, for the benefit of those eggs conveyed into them? And how are those rare and admirable excrescences generated in other plants and trees? I confess this question is very difficult to explain. Nor do I know what other answer to make to it, but that the first stroke, which the insect mother gave the plant, fruit or leaf, into which it endeavours to put the egg, is the real cause of the tubercles produced afterwards, whatever form or figure it may assume. Do not we thus on Pumpions, and other fruits, and even on trees, by the help of a knife, or bodkin, cut letters and characters; the vestiges whereof insensibly swelling with the humours, raise themselves up considerably beyond the common surface?

I do not think this is done by chance, but by a previous design of nature, which has ordered, that this generation of insects, and the tubercles which serve for nourishing them, should be produced in this, and in no other order. Therefore also, the generation of these insects is plainly regular, and is not subject to any fortuitous change. The great Harvey, in his book of generation, fully demonstrates, how much the strokes, struck with one and the same external instrument, differ from one another; when he says, from experience, 'That the flesh itself distinguishes the 'poisoned stroke of a sting, from that which is 'not poisoned:' and further proceeds: 'And 'therefore, from the poisoned wound, it is 'strained and condensed, and therefrom arise 'tumours and inflammations. I once, says he, 'for the sake of the experiment, pricked my 'hand with a needle, and immediately after, in 'another place, with the poisonous tooth of an 'African Spider; I could not discover any difference between these two little wounds in feeling; but there was a great difference shewn in 'the skin; for when the poisoned puncture had 'been made, it suddenly swelled.' Who can presume to deny, that plants have this kind of sense? I should indeed think they would exhibit manifest signs of sense, if they had muscles; the want of which seems to be only the cause, that prevents their being able to shew us their faculty of sensation. This is evident in the celebrated sensitive plant; which, in my opinion, has a certain species of muscles, by the help of which, it extends and contracts its little boughs, almost like arms.

As to the different figures of these tubercles, which are never found on plants, but they are

pregnant with little insects, to be nourished within them; I think they are caused principally by the variety of the stroke, whereby those creatures perforate plants, and fix, and, as it were, inoculate their eggs in them: this may be likewise seen in all inoculations. For the same reason, the Flea forms with its stroke in our skin, a swelling altogether different from that of the Bug: and the latter differs also from that of the Bee. All these things are far from being subject to chance; they proceed in a certain order, and they are observed to be always similar: except when the plants, or bodies of animals, have different figures; as the celebrated Redi hath accurately and clearly observed in regard to the bites of serpents.

I have often seen the legs of insects so strongly impressed upon the tender branches of trees, that they could not be taken off without injuring them. But, principally, the Dutch phalæna, which proceeds from the Worm, found chiefly in the bark of Willow-trees, and of the Maple, which it corrodes in some measure, and impresses its eggs outwardly on the bark: hence it follows, that the Worms produced therefrom, afterwards make a passage for themselves inwardly towards the wood. Nay, if you pull these Worms out of the tree, they first weave and cover themselves with a web; and then having afterwards broken it, they pierce the wood with their teeth; and, in so doing, rest upon the web on their backside, in order to get sufficient power and strength to penetrate.

This winter, I observed in turnips many warts and tubercles of various sizes, in which lay so many Worms without feet, but furnished with eyes and hard teeth. In the smallest of the warts or tubercles, I found a little egg; and in the larger sort, a tender and soft Worm. In regard to these Worms without feet, that are found in tubercles on plants; it is worthy of notice, that they can by no means be kept alive, when they are drawn out of the cells, which they have formed for themselves, in proportion to the bulk of their body within the excrescences, and in which they are nourished. The cavity, wherein that wonderful Worm is lodged, which lives enclosed in the young buds of Willow trees, as in a rose, which will be afterwards particularly described, exactly answers to the bulk of its body. The Worm that lies in Turnips, has a cavity somewhat larger than its body. I have observed also, that those little cells, which the Worms, without feet, form themselves with wonderful art in dry timber, are nicely fitted to their bodies; and they can therefore, with sufficient quickness, move through these cavities. They perform this motion by drawing in, and fixing their hinder parts to the wood, and stretching out their forepart: and thus they move forward with great swiftness in these burrows.

When these little insects are deprived of their cells or caverns, and the nourishment they have there ready; they cannot move any more; they stiffen with the heat and dryness of the air, and perish by innumerable other ways. Many feetless insects also, that live under the earth, and in

the water, are nourished and sustained in the same manner. For those that have no feet, and live in the water, change place by the help of their tails and certain appendages, which serve them instead of oars. But the Worms that live under the earth, advance forward almost in the same manner as the Worms of Beetles, and creep in this manner between the cracks and fissures of the mould. What happens to the feeble vermicles of Flies, Ants and Bees, may be seen in the histories I have already given of these insects. As to the Caterpillars, and other of the many-legged insects; the matter is clear, and without all difficulty. Nay, it is no way repugnant to my proposition, that some insects are observed to issue, after some years, out of rotten wood: for, we know, that these insects arise there also from Worms, and that these draw their origin from eggs; the females regularly betaking themselves yearly to such wood, and casting their eggs into it. It is often necessary, that such Worms should receive increase for some years before they arrive at their time of change; as is manifest in the Coccus, and in that Worm also, from which the Holland Cantharis, commonly called the Golden Beetle, is produced. The same thing likewise holds in the Aquatic Worms, that live in the tubular cells, as I have already remarked in the history of the Ephemerus.

We must further observe, that many creatures that are said to want feet, are really provided therewith. Thus the Earth-worms indeed have many feet, but they are constituted in another manner than feet commonly are. I have clearly seen the same thing in serpents: these I have indeed observed, have five sorts of feet. Some of them have a thorny or spinous excres-

cence in the middle of their body, with two heads, almost like the military Caltrops, and contain in the middle a little bone, which is articulated in the os pubis, and covered with a skin; by the help of this, they can move quickly over the rough surface of the earth; and in cracks of rocks, I have seen others again provided with two such machines for their greater swiftness. Two feet of a certain third species were presented to me, which being composed of distinct articulated bones, likewise carry claws on their extremities, which may be drawn out of them, like the hollow claws of hogs feet. I myself have examined a fourth species, which had four articulated, but very small feet; the foremost of which consisted of three joints, and two toes; the tops of which were armed with claws: another shorter joint also, or, as it were, small thumb, armed with a claw, projected also out of their inside. The hindfeet also were made in the same manner, only that they had one toe more than the forefeet. Lastly, D. Frederick Ruysch, professor of surgery in Amsterdam, made me a present of a fifth species, furnished with very tender feet; each of which consist of three joints, but they are not distinctly visible; because they are covered even to the extremities with the scales: at the extremity of them, is seen only a simple claw, without any division into toes. Therefore, that little serpent seems capable of making use of those feet, only on certain conditions or occasions; since, on account of their great tenderness, they are not able to support the body, tho' they may often contribute to move it with the greater speed. Behold, how admirable God shews himself in all his works! the smallest of which most clearly expose to view his Magnificence, Majesty, and infinite Wisdom.

*Of other insects found in the tubercles of Willows; and how they come there.*

**I**N the preceding pages I have observed, that when I opened the tubercles of the Willow tree, I found various other insects besides the Caterpillars there mentioned; and this may impose upon, or deceive, the unexperienced, who are accustomed to make experiments only slightly: since it may be possible, that one animal should be taken for another, and wrong conclusions drawn from thence. For this reason, I shall now explain that matter more fully. I have before observed, that in some animals not yet perforated, I found some other animals, from which the insect before described hath been suffocated and killed. But in order to make this understood, we must observe, that the leaves of Willows are frequented by various species of insects, which indeed lay their eggs either in or upon these leaves; and these eggs at length grow into vermicles, some with, others without feet. The unperforated tubercle, whereof I now treat, contained two kinds of animals; the Caterpillar, which I have described above, and a Worm without feet, both which lay together in the same cavity. But as both were nourished with the substance of the tubercle, and both discharged their excrements into it; it happened,

that the Caterpillar was suffocated, and so destroyed by its companion.

When I first saw some of these feeble Worms in the tubercle, I took them for the Caterpillars I described before, thinking, that those sprung from their eggs without feet; and afterwards, when they grew somewhat bigger, that their feet appeared. But at length I discovered, by repeated observations, that these feeble Worms are of a different species: though, notwithstanding I am very certain, that their eggs are thrust into the leaves of the Willow tree, in the same manner as the Caterpillar; and that the Vermicle that is to spring from thence, is there nourished, and undergoes a change. The feeble Worm here mentioned, had already grown a little more than the Caterpillar. It has a paler head, and discharges a great deal of excrements: But because, I never observed a considerable number of these Worms, in the warts or tubercles of Willow-leaves, which they only occasionally inhabit; therefore the opportunity of investigating their change to the Fly-state failed me. Perhaps I shall hereafter take farther pains in this inquiry.

In another excrescence, I found a third species of Worms, which were likewise without feet, and were twice as little as the former. Their head was formed almost in the same manner: but it was thicker, where it is joined to the thorax. I observed also, two black spots in the head, which probably were the eyes: these Vermicles changed their skin also, and crept pretty quick. Sometimes two of these are found in one tubercle; and they then live separated by their excrements, as by a wall between them: this very thing I have likewise sometimes observed, when their tubercles touched each other. These Vermicles or Worms, likewise seem to undergo their changes within the excrescences; but at this time, the excrescence assumes a rusty colour all over it. I have not yet distinctly seen their change; because they are not found to be very common. It must be good fortune, if any one should happen to discover the order, in which the limbs and parts of those animals increase. I made these observations on the 28th of June.

When these feetless Worms have undergone their transmutation, or the Caterpillars, which I have described, have left their tubercles; so that these are open and empty, then various other little Worms with feet, visit and hide themselves in them, or cast their eggs there, in order afterwards to nourish their young in those cells. The smaller Spiders also frequently betake themselves to these warts on leaves, that they may lie in wait, and catch the lesser insects that pass by, and when caught, feed on them. For the Willow-leaves feed an infinite number of very small insects; so that a whole treatise might be wrote on the different species of minute insects that are found about these trees.

*A particular description of certain insects, which live between the first and second coat of the Willow leaves, and are changed into Beetles.*

BESIDES the tubercles hitherto delineated, which contain the Caterpillar before described, there is likewise another species, Tab. XLIV. Fig. VIII. of Worms without feet, observed to lie between the outmost and inmost coat of the Willow leaves: these I shall now describe, and delineate them magnified, but I shall first treat of the leaf itself. The Willow leaf, as I have observed before, consists of three coats; whereof the inmost is the most succulent; and may therefore serve many insects which eat the entire leaf for their proper food: but the Vermicles whereof I now treat, eat only the inmost part of the leaf, leaving the inward and outward coat entirely untouched: they do not indeed devour the little nerves of the inward fleshy substance, but only the matter in their intestines. Since these Worms therefore consumed only the middle of the Willow leaf, hence it is, that they are always found lying immediately under the inmost coat of that leaf; for this they eat and consume by degrees on the inside, until they come to the external coat, which very strongly supports the nervous filaments of the leaf. Thus at length it happens, that the inside of the Willow leaf is

Among other insects, I found on these leaves a very small Cicada; which, as to its changes, and its manner of living, is altogether like the larger Cicadæ of France and Italy. Very small Caterpillars are likewise found there, affixing an oblong and gold-coloured web to the leaves; out of which some remarkable species of small Flies are usually afterwards produced. When those Flies issue out of their little cases, they likewise throw out of them an operculum or cover, which is exactly round, as I have related of the web of the Caterpillar, which I have described before and delineated.

Among the little insects which come from without, into the tubercles, I have observed a very small one, that was white, oblong, Tab. XLIV. VII. and has very great vital strength. It had two black eyes, situated in the lowest region of its head towards the thorax. Out of the forepart of its head projected two antennæ. It had six legs, over which were seen four wings, enclosed in little knots. The body appeared to be divided into rings. This little animal was changed afterwards in to a black oblong Fly, with wings as long as the body. But when this change happened, the insect was not at all deprived of its motion; therefore it belongs to the second order of changes. The reason why I describe it under the fourth order, consists in this, that its change is inwardly perfected in a concealed manner in the hollow tubercles of the Willows. It is so small, that it can hardly be delineated in its natural size. One must therefore first know those different modes of changes, and what insects visit the excrescences of the Willows, before one can, without error, make experiments on this matter.

hollow underneath, and becomes separated from the external: this is the reason also, why the two coats of this leaf grow dry in that part, and assume a rusty colour: and this shews plainly, that the little animal lies between these two coats.

I sometimes have found seventeen such Worms in one Willow leaf, which then indeed appeared to be divided into so many rusty coloured spots. In order to understand these matters more clearly, I have judged it proper to represent two of these spots in the natural size; whereof the one is closed, and the other open, Tab. XLIV. Fig. 1. 22. In the open spot, it may be observed, that the inmost coat of the leaf is entirely removed from the middle larger nerve. It likewise appears there, that the smaller nerves of the one side, are entirely naked, and the matter that had filled their interstices is consumed. In the opposite side, besides some excrements, there is seen the naked head of the Worm, together with the body, transparent through the elevated coat.

That what has been hitherto said, as well as the method whereby the Worms performs all these matters, may be more clearly comprehended; I shall now delineate the insect itself

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magnified, and shall describe its external parts. This Worm, or Vermicle, has no feet; but it consists of fourteen annular incisions, which constitute its head, breast, belly, and tail. In the forepart of the head are seen two teeth *a*. The thorax, in that here represented, was very much expanded in breadth *bb*, and shewed in its first ring two spots of a rusty colour, approaching to brown. The head also appeared to be of the like colour, but somewhat paler: there were also, very many transparent pulmonary tubes seen in the breast. The rest of the body was formed *cc* nearly like the thorax. Out of the sides of each ring of the thorax and belly there sprung hairs like flaxen threads. The last rings of the body also, were variegated with some black spots. This whole Worm was of a beautiful white colour, somewhat approaching to green. It moved a slow pace, going forward by the assistance of the rings of its body; which it sometimes contracted, and again expanded: and this it did more readily, whilst it lay between the coats of the leaf, than when drawn out of it. The exuvia, or skin which it casts, was left between the coats of the leaf; where likewise lay the excrements, which the Worm had even thrust into the hollow interstices of the little nerves.

I have not yet seen the egg of this Vermicle, though I have very diligently searched for it; but I had begun that observation on the 20th of August, when the Summer draws to an end. I afterwards observed, that the Vermicles were too far advanced for me to be able to find out their proper construction and history. The investigation of that matter must therefore be deferred to another opportunity. However, even at that late season of the year, I found, in a Willow-leaf, a very small kind of orbicular spot, which I have figured therein, near the former spots, Tab. XLIV. Fig. 1. *zz*. I expected to have found an egg in this; but when I opened it, I found a very small oblong, black Nymph; which, I found on examining it with a microscope, would at length change into a small Beetle. But I could not then discover either the worm or the egg of this Nymph. When I attempted, and was desirous to keep the Nymph, it was lost from my sight, on account of its extreme smallness. Consider, reader, therefore, how minute that egg must be; the Nymph of which was almost invisible. I began this observation on the 30th of August.

It is evident from what I have said of the teeth of these Worms, with what instruments they gnaw and break open the inmost coat of the leaf. For the Worm, in a very irregular manner, hollows the leaf, forming a sinus which runs into various angulated and serrated borders; by which means it widens its habitation by degrees, eating the substance of the leaf sometimes round it, sometimes lengthways, and at other times through the angulated curvatures. It is very admirable, that the Worm never eats even the smallest hole in the coats of the leaf. It separates the internal from the external coat so carefully, and without injury,

that the method whereby it is done would indeed be incomprehensible; unless we consider its fine teeth, by the help of which it consumes the middle substance of the leaf. Hence it is likewise evident, that the orifice must be very small, by which the egg of this Worm is first conveyed through the inward coat into the substance of the leaf, that it may live, be nourished, and perform its metamorphosis there.

On the 24th of August, I saw *a* Fig. x. one of these Vermicles put on the form of a Nymph in my chamber. This may be seen very exactly, by holding the leaf to the light of the sun or candle. I observe, that this Nymph properly belongs to the first mode of the third order; since it very clearly, and without impediment, exhibit its limbs to view. In the beginning of this change, the Nymph is white; but it afterwards becomes gray, and by degrees black. It very strongly moves its tail; by the help of which it can go between the coats of the leaf. On August the 26th, it became as black as pitch.

The head, thorax, abdomen, and all the other limbs of the future Beetle were now seen in it. In the forepart of the head were situated two crooked, Tab. XLIV. *a* bristly hairs. In the lower part of the head, its mouth or trunk lay hidden in an oblong case. On each side, near the head, appeared the horns *bb*, elegantly composed, as it were, of little joints or knots. Near these was seen the first pair of legs; and under the latter another pair, out of which projected *cc* two bristly hairs like two crooked prickles. Below these legs appeared the sheaths or cases of the wings; which proceeding from the back and bending, lay along upon the belly, and were beautifully divided with ribs *dd*. Underneath them lay the membranous wings themselves, enclosed in a membrane; immediately under the cases, the bending of the third pair of legs shewed itself: and this pair also was armed *ee* with rigid bristly hairs. Next followed the rings of the body, and some prickles *f* projecting out of the tail; by the help of these the Beetle probably pierces the leaves. But this is merely conjectural; nor have I observed it, being then engaged in other business.

On the 30th of August, one of these Nymphs was changed into a Beetle, Fig. xii. after it had some days worn the appearance of a beautiful Nymph. When at the same time, I opened some other spots of the Willow-leaves; a great number of Nymphs presented themselves on the inside; which when, after casting their skin, they were changed into Beetles, I observed, eat thro' the leaves, and made very conspicuous holes.

I have been informed by many travellers, that in hot climates, Worms are found in leaves an inch long: on these many fine experiments might have been made, if the inhabitants of those places had not laboured under the cursed thirst of gold, and prematurely broken the thread of life with intemperance. This Beetle is divided into a very beautiful head, thorax and tail. The eyes are very black, of a reticulated

lated construction, Tab. XLIV. Fig. XIII. *a*, and situated in the head at a very little distance from one another: under the eyes is seen a black, crooked snout, full of little cavities, and of a substance between bone and horn *b*, and on the forepart of the snout are placed the teeth of this Beetle. The little horns are very discernible, and are of the same colour with the skin of people who have been much exposed to the sun: they arise very gracefully from about the middle of the snout *cc*. They are each composed of eight joints, and are so thick at their ends, that they may very properly be called præpilata, or knobbed horns. The thorax consists of a very black horny bone, and is full of white hairs, and little cavities; from the lower part of it arise six legs *ddd*; they are of a moderate thickness, but slenderer at their extremities. These legs are covered with hairs, and with little irregular eminencies; in colour they resemble the horns. Each leg consists of six joints, and each foot of four, of which the last are armed with two nails. The second joints of the two hinder feet are some-

what blackish, and much thicker in proportion, than the same joints in the fore legs.

The reason of this difference seems to be, that the former contain some very strong muscles, by means of which this insect can spring on its hinder feet in the same manner as Flies, but somewhat slower. I saw one of them make a leap of three inches and a half, which is about twenty-eight times the length of the creature's body. The cases of the wings are likewise black *ee*, but covered with a fine white down, and are surrounded with a small border; they are also ribbed, and full of cavities; notwithstanding which, they shine like the best polished looking-glass. The wings are membranaceous, and twice as long as the cases, so that to defend them, they must be folded up, which they accordingly do in a most exquisite contrivance. Tho' I could easily procure insects enough of this kind, I could not find time to dissect them; for which reason I have nothing to say of their eggs, or of their genital, and other internal parts.

*An account of some small Worms that are bred within the new and tender leaves of Willows, and afterwards change to Flies.*

ON the twenty-eighth of June I observed, in looking over some Willows, that some of their young leaves, which had but just made their appearance about the tops of the branches, began already to dry up and wither, Tab. XLIV. Fig. XIV. *a*. This was enough to engage my curiosity; and accordingly, I immediately set myself to discover the reason of so sudden a decay. On separating these withered leaves from one another, I found between them many collections of living Worms, to the number of eighteen or twenty together *b*, and as it were, in the most friendly and sociable manner. These insects were of an oblong figure, but somewhat broader in the middle than at the extremities, and of a most delightful bright orange or saffron colour. Some of them had already begun to make their webs, and others were employed in preparing themselves for it.

On this discovery I searched some other new leaves, and found in them a great variety of Worms of the same species, some more grown than others. I found also in some of the leaves the eggs from which these Worms had been hatched; but they were lodged only between the folds of the leaves, and not within their substance, as was the case in the last observation.

These Worms lived merely upon the juices flowing from the leaves where I found them; but as this juice is very tough or viscous, it may naturally contain sufficient nourishment for them, and so render unnecessary their preying on the substance of the leaf itself. Whether this juice flowed spontaneously from the leaves, or whether they made incisions in them to extract it, is a thing which I cannot take upon

me to determine. I never saw any of these Worms stir from under the folds, and wrinkles of the leaves, but observed, that they constantly crawled under cover, from one cavity to another, till they had attained their full growth, and the embryo limbs contained under their skins, were arrived, by the due degrees, at a proper size, to prepare for their succeeding appearance.

When the leaves, whose greenness and growth is destroyed by these Worms, begin to harden and dry up, the Worms, without stirring from under cover, form themselves webs, in which they at length become Nymphs. They make their webs stronger and thicker about the head and thorax, than elsewhere, as these parts are to be the chief scene of the ensuing changes, and of the growth of new limbs; and therefore require an extraordinary bulwark to defend them, especially as the leaves about this time grow very hard and rugged, and therefore more apt to crush, and otherwise hurt the enclosed insects. As these communities of Worms live under one cover, and in a kind of brotherly state, on the same spot, they form their webs one close to another, without any disturbance and encroachment one on another.

The Nymph of this Worm is very small, but it exhibits, notwithstanding in its parts, the figure of the future Fly. It loses all manner of sensible motion, except in the tail, which it is still able to stir with great violence. On the fourth of July, I observed that these insects were turned to Flies, which appeared through the microscope, of a most delicate construction, Tab. XLIV. Fig. xv. The head resembling that of a pin, was joined to the thorax by a  
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very fine and slender neck. On the forepart of the head, were placed two oblong horns. It had six long black legs, and wings longer than the body, which glittered like mother of pearl. The body scarce differed in colour from that of the Worm. This Fly, when moving through the air, appears no bigger than an atom of dust. It is very surprising how ingenuous these little animals

are in depositing their eggs within the tender buds of such leaves as are fit to afford shelter and nourishment to the Worms that are to rise from them, that, by this means, they may be able, in obedience to the immutable laws of nature, to renew their species from year to year, and continue it even to the end of the world.

*Of Worms which are found enclosed in tubercles like Roses, that appear on the tops of Willow branches; and likewise in many of the dwarf Willows that grow upon heaths and commons.*

WE not unfrequently see a tubercle formed at the ends of Willow branches, in the shape of a Rose \*, and which the learned Mousset accordingly calls by that name, Fig. XVI. *a*. In some seasons, these tubercles appear in great numbers, and in others, they are scarce. I once observed, in company with Messieurs Thevenot and Henon, that there was hardly a single Willow branch in all the open country, that lies near a little sea-town called Egmont, which had not one of these tubercles at its extremity.

After breaking off the external leaves of this tubercle, there appears in the middle an assemblage of other tender leaves, in form of a pear, Fig. XVI. *b*; which lie one over another, in the same manner with the innermost leaves of the Cinara or Artichoke, so as to make it necessary to pull them off one by one, Fig. XVII. *c*. in order to obtain a sight of the Worm, *d*, which lies hid within them, wrapped up in a tender and delicate membrane, or kind of web, *e*. This Worm lies there in an inverted posture, with its head the lowest, and its tail the highest part of its body; and it is so narrowly confined within its web, and in the surrounding leaves, that it seems very probable, it cannot either move at all, or, at most, not without great difficulty: in this respect, it differs extremely from all the other Worms that have been before described. On extracting it from the place of its birth, *f*, its body appears composed of various rings, and is somewhat slenderer towards the tail, than the head. Its colour is of a florid red, and by no means unhandsome.

The food of this Worm is no other than the juices of the Willow, flowing to the extremities of the branches, where the insect is most conveniently placed to receive them. There is not the least excrement to be found with this Worm, nor indeed with those last described, which makes it probable, that, like the fœtus, while it lives in the mother's womb, and is there subsisted by nourishment, taken in after a peculiar manner, these insects retain their excrements till they appear in the Fly-state. I omitted unfortunately dissecting this insect, though, by doing so, I might have attained perhaps a satisfactory solution of this uncommon circumstance. I could not have found any difficulty in investigating the

matter that way, as I could easily have procured what number of these insects I pleased: but our negligence and inattention are so great, that we generally despise those things that are under our hands, to satisfy an inordinate curiosity of knowing and possessing those which lie at a greater distance, and are hard to be obtained. The best of us must own himself so far the slave of vanity, as to be more desirous of producing any thing foreign and unheard of, than that which is spontaneous in our own country. Though the Majesty and Wisdom of God, the fountain of all revealed wonders, most evidently shew themselves the objects of our love, praise, and adoration, equally in every creature.

A fault of the same inexcusable kind, made me forget myself so far, as to neglect examining the egg of this insect, though the little rose, which had first engaged my attention, is produced merely to cherish it. This is plain from the Willow branches never bearing any such excrescences, unless these Worms are in them; for, when the parent insects happen not to deposit their eggs at the extremities of the branches, they shoot into separate leaves of the common form. These Worms perform their changes for the Fly-state at two different periods, namely about mid-summer, and in spring, when the Willows begin to bud. Those which assume the Nymph-state, Tab. XLIV. Fig. XVII. *g*, in summer, without stirring from the place of their birth, in a few days after become Flies, *h*. But such as happen not to be changed to Nymphs till autumn, continue enclosed in their covertures till the ensuing spring; when, on the sun's nearer approach, they likewise become Flies: all these Flies immediately betake themselves to the Willows, where they may be sure their offspring will find convenient food and lodging.

The Fly is of a middle size, but of a very delicate construction. The extremity of its body is armed with an aculeus or sharp weapon, by means of which, it may open a passage for its eggs into the tender tops of the Willow branches. It has two horns on the forepart of its head, two membranaceous and considerably long wings, and six long slender legs, formed very like those of the common Gnat. As to its colour, I forgot to observe it particularly. Those Flies which I

\* This peculiar excrescence of the Willow, we have very common in the fenny counties in England. I have seen them on the edge of Lincolnshire, as large as a common red rose, and very double. In this state they make a very beautiful, as well as peculiar, appearance: and our old English botanists, who were not acquainted with this part of natural history, supposed the tree a distinct species, and called it *Salix Rosea*, the Rose-Willow.



dried, in order to keep by me, are of a dark gray. I have sometimes observed four Flies to proceed from one of those Willow roses, but they were four times less than those kinds, which require each a whole rose to itself. These smaller Flies were of a resplendent jetty black colour, had six legs, and shorter horns than the other kind. Their two wings were adorned with a black spot, each in the middle of its ex-

tremity: some of them also were provided with a sharp aculeus or weapon at the tail\*.

At present I can say no more of these Flies, being so much taken up with other business at the time of my writing these observations, that I have not leisure duly to revise them. I must therefore refer this task to another opportunity, if it should please God, the disposer of all things, to offer me the means of performing it.

*Of certain Worms without feet, found in the Hazel-nut.*

THESE Worms are so common, and so easily to be had, that a description of them may seem in some degrees superfluous. Their bodies are white, soft and hairy, their heads are red, and armed with two sharp teeth, with which, in autumn, they bore themselves a passage through those nuts in which they had hitherto resided; but which they then forsake. These Worms may be found sometimes lying in hundreds together, at the bottom of drawers and baskets, in which hazel nuts have been kept. I have often formed a resolution of examining accurately the nature and dispositions of these Worms, but have not as yet an opportunity of doing so. Nevertheless, I see no reason to doubt, but that they, as well as all other animals, derive their origin from an egg, thrust from abroad into the substance of the young nut, or perhaps into the bud or flower, out of which it is to be formed, as has been already observed, of many other little animals of this kind.

There is no keeping these Worms in dry boxes; for they will live in this confinement but a few weeks. But in pretty moist sand, some of them have survived with me the rigour of a whole winter, and lived to the 24th of March;

and all that time without any food. Some of them, after undergoing this severe treatment, were yet vigorous enough to set about their mutations: but, by digging continually into the sand, in order to satisfy my curiosity, in seeing what they were doing, I wounded so many of them, that as yet I have not been able to discover what kind of creature they finally become.

I observed besides, that some of them burrowed much deeper into the sand than others; and I even found some at three inches under the surface. I never could perceive any web about them, nor do I believe that they form any, as they always appeared lying in the sand entirely naked. Nevertheless, I do not think there is any reason to doubt, but when these Worms escape from the nuts, and leave the hazel shrub to live in or under the ground; they, in this last situation, change to Nymphs, and afterwards, in the ensuing spring, to a kind of Flies, which again deposit in the tender rudiments of young nuts, eggs, like those from which themselves originally were produced. It would be no difficult matter to ascertain, by experiment, the truth of this conjecture.

*Of Worms found between the two coats of the Alder-leaf.*

FIRST OBSERVATION.

ON examining some Alder-leaves on the 20th of August, I observed the substance lying under the surface, formed by the internal coat of the leaf, was in many of them irregularly gnawed away in little angular cavities, without any passage to the outside of the leaf, that I could discover; nor had the leaves, in which these cavities appeared, lost any thing of their greenness or fresh hue, as the Willow-leaf just spoke of had done. The internal coat, hollowed in this manner, rose considerably above each hollow, into a kind of little canopy, Tab. XLIV. Fig. XVIII. *a*, whereas, on the opposite parts, the other side of the leaf, which is covered by the external coat, was only a little altered by a few small wrinkles, *bb*; this no doubt was the true cause of the extraordinary roundness and convexity of the opposite tumor.

On opening one of these swellings, I discovered between the two coats of the leaf now spoken of, a perfect web, formed exactly like that of the Moth in its Worm-state; and, on opening this web, I discovered a Chrysalis, *c*, in

point of shape and construction, plainly belonging to the second mode of the third order of changes. The skins under which this insect had lived in the Worm-state, lay near it under the same web. I could also discern that it was, by means of this web, the Worm had reduced the surface of its cavity, formed by the external leaf, to the appearance already described. On each side of the web lay the Worm's excrements. The method used by this Worm, to form itself, between the two coats of a leaf, a cavern or nest in which it may conveniently perform its mutations, is certainly one of the most surprising objects that natural history offers to our consideration.

As to the Worms themselves, I could not discover any of them, or any of the eggs, out of which they must have been hatched. In all the leaves I examined for this purpose, there appeared nothing, only webs; so that the season, for finding eggs or Worms was certainly elapsed, at the time when I looked for them. The Chry-

\* The females have all of them this weapon at their tail; the males never. The reason is very plain, for its use is to bore a hole in which to lodge the eggs; therefore only the female has occasion for it. This author has observed the same on other occasions, in various species of Flies.

falis, viewed through a microscope, plainly exhibited the form of the Butterfly, to which it was thereafter to be changed. It was oblong, somewhat flattened and broad on the fore part, where it terminated in a point, Tab. XLIV. Fig. XIX. *a*, whilst its hinder part grew gradually narrower, so as to resemble a pyramid or cone, *b*. Each side of the body was covered with a few, very delicate hairs, *c c*. Its surface was of a pale brown colour. The eyes appeared on the head, *d d*, and under them a double trunk *e*. A little lower down, and just by this, the first and second pairs of legs were seen, *f f*. The antennæ or horns, which were of an extraordinary length, extended from the eyes to the very extremities of the two first pairs of legs, *g g g g*. Near these lay the wings, *b b*. The hinder pair of legs was placed between the antennæ, and stretched beyond the extremities of these parts, *i*. The body consisted of several rings, *k k*. This Chrysalis looked as if it had cast its skin but a few days, and it moved its tail very vigorously, making use of it to turn itself, and indeed to move from one place to another.

On the 26th of August, two of these Aureliæ yielded two very elegant Butterflies, less than Moths of cloaths; but like them in colouring and ornaments, as may be seen by the drawing I have given of them, where they are represented of their natural size, Fig. XX. It is hardly possible to conceive a more beautiful little animal, than what this Butterfly appeared to be, when viewed with a microscope, Fig. XXI. It consisted of a head, thorax, and abdomen. The head was furnished with two antennæ or horns, *a a*, and a short and crooked double proboscis or trunk, *b*. From the shoulder blades of the thorax spring four wings, and from the under part six legs. The wings were partly of a mere membranaceous substance, and partly composed of delicate feathers, or scaly hairs. The upper pair shone and glittered most gloriously with crescents of gold, silver, and brown, *c c*, surrounded by borders of a delicate black: besides this, they had a black spot at the extremity of each.

Moreover, these extremities were edged with little feathers, which made them look like a crest, when they lay close upon the body, one folded over the other. The lower wings are likewise in a great measure covered with feathers, *d d*, and are of a pale colour, and silvery brightness. Along the middle of the wings there runs a membranaceous little stem, from which issue the feathers that, in a manner, compose them; and even this stem has, as it were, its own scaly feathers to defend and adorn it.

All the ornaments bestowed with such profusion on the wings of this little insect, consist in reality of feathered scales of different lengths, and various diversified colours; and they are divided, more or less, into lateral branches, like the feathers of the larger winged animals. The colours are more lively or faint, according as the scales forming them lie together in greater or smaller quantities; and from the same construction, and contrivance alone, results all that striking variety in the wings of Butterflies: for, on rubbing of their feathers, they appear entirely even and plain, like the surfaces of all other membranes.

The legs of this Butterfly are entirely covered with the same kind of plumage, and they are divided into joints: every extreme or lowest joint is armed with two little claws. The hinder legs have, besides these, three little white prickles, or spurs, Tab. XLIV. Fig. XXI. *e e*. The body is divided into rings, and covered likewise with feathered scales of a bright silver whiteness. This little animal, being put in a box that had served to keep Brazil-snuff, began immediately to tremble, and in less than two minutes expired in a convulsion that seized every limb. As yet I have made no more observations of this insect. The surprising manner wherein the Worm, from which it is produced, nestles and feeds between the coats of the Alder-leaf, will, I hope, alone be judged sufficient to recommend to the curious what I have said upon this occasion.

## S E C O N D O B S E R V A T I O N .

**T**HE 30th day of August I found, between the same coats of Alder-leaves, a flattish Worm, of the size and form represented at the letter *d*, Fig. XVIII. as it appeared on removing from it a part of the coat belonging to the leaf on which it had fed. The body was oblong, and somewhat broader about the thorax than at the belly or tail. The head was large, of a pale brown colour, somewhat flattish or depressed; and on its fore part furnished with two eyes, and a pair of sharp teeth. From each side of the lower part of the thorax there arose three legs. In the transparent body there appeared a little green streak, produced by the Worm's food. Counting the head and tail, this Worm consisted of twelve rings.

I discovered also, that this insect had cast a skin, in the same place where I found it. The

internal substance of the leaves, where it resides, serves it for food; and it had accordingly gnawed this substance away, without offering to touch the adjacent coats, into a great many windings and turnings. As this parenchyma, or pulpy matter, had been but lately devoured, the leaf, even in the spot where the devastation had been made, still retained its verdure; but soon after it withered, and changed to the colour of the leaves of the Alder that fall in Autumn. The external coat of the leaf, in which the ribs appeared, was very strong and thick; but the other side, or internal coat, was very thin and delicate. The excrements, which were at first green, and then grew black, rolled freely backwards and forwards within these two coats. I could not discover in these leaves the smallest opening, by which the enclosed

Worm

Worm might be supposed to have insinuated itself into their substance. Some of the Worms within these coats were dead, which I attributed to the striking of the leaves against one another with the wind; or to their withering and wrinkling up, for want of nourishment; or, finally, on account of other external injuries. As yet I have had no opportunity of

tracing this insect through its changes, so that I have nothing more to say here concerning it; but that it was very delicate, and moved itself but weakly. On taking it from within the leaves, it died in a day or two. The Alder is not the only tree inhabited by these Worms: they are to be found also on the Pear and Apple, and many other kinds:

### THIRD OBSERVATION.

ON the 31st of August I found, within the same coats of certain Alder-leaves, a third species of Worms which had no feet, and were divided into twelve rings. This species had a much rounder body, Tab. XLIV. Fig. xviii. *e*, than the first, with a very small head and teeth. The back and belly were diversified with various white spots, which appeared through a yellowish green transparent substance, and seemed to me to be so many particles of fat. The nest which this Worm had gnawed itself within the coats of the leaf, was not so spacious as those of the two Worms last treated of; and sometimes one nest contained two Worms, which lived and fed together in common; but in this case, the nest was somewhat larger. In another leaf I found two of these Worms, that had each formed itself an oblong web, *f*. In the same place I also found their excrements, and the skins they had cast off.

These webs were red, as were also the shrivelled coats of the leaf that contained them. On opening one of these webs, in hopes of finding a Nymph, I met with a Worm, which as yet had suffered no change, except that of being grown a great deal smaller

than before; and it was impossible it should not have lost somewhat of its bulk, considering the great quantity of silk it had drawn from its body, to form itself a covering. Four weeks after this, I opened another web, little thinking that I should meet with a second disappointment, yet so it happened; for there was no Nymph even yet, but only the Worm lay there quite unaltered. I have therefore laid by some of these webs, in order to discover next year, if possible, what kind of an insect they produce, which is possessed of the surprising art or power, as a faculty of burying its eggs thus subtly within the two coats of leaves. When these Worms are very small, their nests, which they gnaw themselves, are very small likewise, Tab. XLIV. Fig. xviii. *g*; but they widen proportionably by degrees, *h*; as their inhabitants grow bigger and bigger. From whence I conclude, that the holes in which they have been originally deposited, in form of eggs, must have been of a minuteness almost beyond conception. But, as yet, I have no experiments or observations to enable me to say any thing certain on this head.

*The same subject continued. Histories of insects that are found in fruits, tubercles or warts, and leaves of plants. An observation on the common Thistle growing in the fields of Holland.*

WALKING about the middle of summer into the country, in order to find leaves for Caterpillars I was at that time feeding, I happened to observe on a common Thistle, not as yet arrived at its full growth, a yellowish slender Fly, Tab. XLV. Fig. 1. *a*, with a large head, red eyes, two short antennæ, and wings very elegantly coloured. This insect had thrust out, to a very great length, the extremity of its uterus or womb; and was employed in endeavouring to bore, by means of this part, a hole into the substance of the leaves, wherein it might deposit its eggs. This curious sight could not fail of engaging my attention, and accordingly I spent a long time in viewing it, equally astonished at its novelty, and overjoyed at having an opportunity of seeing, with my own eyes, the manner in which this kind of

insects attack the plants, which are proper to afford their Worm-offspring a never-failing food and shelter: as likewise to observe their method of conveying into these plants the eggs from which their Worms are to proceed. In that part of the plant where these eggs have been deposited, there afterwards grows a large globus, or round tumour, in substance not unlike the calix or cup of the Hazel-nut, which by degrees becomes ligneous, and hardens to a more compact substance, resembling wood. Within these swellings there appear, here and there, certain white Worms, which change first to Nymphs, and then to Flies. Some pretend this Worm, carried in a purse, along with its tubercle or swelling, is good against the piles.

*Of Worms found within the tubercles or swellings of the stinging Nettle.*

IT is very remarkable, that even in some stinging Nettles we meet with Worms, which are destitute of feet, and derive their origin from a very small but yet discernible egg. These excrescences are found on the Nettle, in a great variety of forms. Some are produced upon the stalk, Tab. XLV. Fig. II. *a*; others on the ribs of leaves, or the tender buds, *b*: some again lie confusedly, here and there, all over the surface of the leaves, *c*. The substance, of which these swellings are formed, is very hard and compact, which makes it an easy matter to crack them. In colour they are somewhat of a yellowish green. On the 28th of June I found a great many, both eggs and worms, in these swellings. The smallest of them contained each one egg; those somewhat larger, a worm; and the largest of all, which were composed of two or three of these swellings growing together, afforded shelter to two, three, or even four Worms of different sizes, and all this at one time.

The largest of the Worms I discovered at this period, were exactly of the same size with that, whose form, taken from the life, I exhibit in this figure, Fig. III. *d*. This Worm, viewed with a microscope, appeared somewhat broad, and depressed in the middle, *e*, and armed on its forepart with a delicate slender snout, *f*; its body was almost white, but a yellow streak appeared within it, which the Worm's transparency rendered very discernible. I found afterwards that this was an intestine, and that the colour of it was entirely owing to its contents. The skin of these Worms had some delicate hairs scattered loosely here and there over its surface, *g*.

On opening some more of the swellings on this plant on the third of July, I found some of the enclosed insects were changed into Nymphs. Such of them as had lately cast their skins were white, but the older Nymphs exhibited a variety of colours. These Nymphs belong to the first mode of the third order; for it was easy to discover in their limbs the form of the future Fly. They very plainly appeared to consist of a head, thorax, and belly. In the head, I could discern two remarkable eyes, Fig. IV. *b*, of a reticular form, which were beginning to look red; and on the sides of the head the horns, legs, and wings,

were curiously folded up, and might be seen springing from the thorax. The rings of the body were very conspicuous, and it had a little tail bent back, so as to lie over them in a very elegant manner, *i*. All these parts, the legs and wings excepted, were changed by degrees from white to yellow, which they afterwards lost, to assume a deep brown colour, and finally a perfect black.

On the ninth of July, many of these tubercles were burst open; and they no longer contained any insects, but only some of the cast-off skins. This gave me room to judge, that the Nymphs I had observed on the third of this month, had passed in the interval from that time, into the Fly-state, and my conjecture was confirmed by what happened in the tubercles I kept at home in boxes. To me it appears probable, that all these tubercles open of themselves\*, at the time when the enclosed insect has its wings, and is in readiness to launch out into the air; and this may serve to account for my finding Nymphs at this very time, in some other tubercles which remained unopened, which had not as yet acquired their proper colouring, nor strength enough to cast their skins.

The Fly thus produced *k*, is furnished on the forepart of its head, with two longish black horns. The head is of a dusky brown, with a fine tinge of blueish green: and the eyes are red: from the upper part of the thorax arise four membranaceous wings, and from the lower six legs of a colour between red and white. In the males the body ends in a little tail, divided into two stiff hairs, or in a forked manner; so that this Fly is to be referred to the order that takes its name from this circumstance, *Bifetæ*; but in the females, this part terminates in a pointed weapon. The breast and body of these Flies is of a very delicate and resplendent green, like that of Spanish Flies, or *Cantharides*, so as to afford, when viewed with the microscope, a most entertaining and elegant spectacle. I unfortunately omitted dissecting these insects. To preserve these Flies and their Nymphs, I extend their limbs on white paper, and there fasten them down with a little moist starch, for they are too delicate to be fixed upon pins.

\* So far as I have observed in these cases, the Fly, when perfect, gets out of the tubercle two ways, but both are by violence, not by the natural opening of the tubercle. Sometimes the substance is so hard, that the Fly is forced with great labour, to gnaw its way out: in other instances, the covering is by this time become nothing more than a thin, dry, and brittle membrane; and the successive swellings of the Fly's head, which have been mentioned on a former occasion, burst the rind and let it out.

*Of the Worms that are found in some downy excrescencies of Oak-trees.*

THE Oak-tree affords shelter and nourishment to as great a variety of insects as the Willow; of this, at present, I shall produce only two instances. The first I take from the insects which breed within a kind of downy or soft excrescence at the extremities of the branches; the second from certain other kinds which we find enclosed in a most remarkable and surprising manner, within the tubercles arising on the leaves. This woolly or downy excrescence, of which I now intend to speak, is found in the form of a ball, Tab. XLV. Fig. vi. *aaa*, and is made up of a soft thready matter, like wool or cotton: it is composed of very delicate hairs, running in every direction so as to form a very firm and substantial web; but the hairs are not very strong in themselves, for they are hollow, and look as if they consisted of small globules. They arise from the foot-stalk, or from tops of the Oak branches *b*, and sometimes from the leaf, which in many instances shoots, as it were, from the central part of the excrescence *c*, so as to appear entirely surrounded with this down. But the principal foundation of these hairs is no other than some little oblong hollow bags or tubes, Fig. vii. *d*, if I may give them that name, which are at first soft and tender like purses, but afterwards harden to the firmness, as it were, of wooden pipes.

Each of these cavities is constantly found to contain one Worm, which lies hid, and grows in them, till it changes in the Summer months to a Nymph, properly belonging to the first mode of our third order. Nevertheless, as I have already often hinted, I rank these insects in the fourth order, because they perform their changes in a dark and mysterious manner, which nothing but the indefatigable diligence and attention of the curious can bring to light. It is owing to this that these insects have been hitherto treated, not according to the laws common to other animals, in which the great Creator has been pleased more openly to manifest his glory, but according to false notions, suggested by our human ignorance and prejudice. I must here, however, do justice to the illustrious Redi, who has treated the works of nature in a very different manner, and thereby rescued the operations of that great but subordinate agent, from those thick clouds of darkness which human error and ignorance had raised about them: by what other name can we call that absurd opinion, which attributes every thing to chance and putrefaction. Certainly, whatever allowances we may make on this occasion, to the generality of mankind, those among them, who would be thought

people of sense and learning, are altogether inexcusable in countenancing such a thought. This gross error is the natural consequence of mens manner of proceeding, when contented with sitting quietly in their studies, and looking over books; they neglect to trace the ways of God, the great Author of all things, in his works, which surround us on every side, neglecting them, to follow the delusions of their own feeble imaginations.

The cavities now mentioned, are sometimes found to the number of ninety; or even a hundred, or more, growing through one another; and wrapped about in the woolly down, or cottony matter that is lodged in the same place. When the Worms, enclosed in them, have changed to Nymphs, and afterwards acquired their proper degree of strength, they each throw off a delicate skin, and are thus turned to very small Flies; then they bore with their teeth through both the little tubes in which they hitherto have lain concealed, and the down that surrounds them, and then issue forth at a great many openings, Tab. XLV. Fig. vi. *ee*, in a very entertaining manner. On this occasion, ignorant spectators are lost in wonder, and form to themselves variety of systems to explain so unusual an appearance; but when they come to relate their opinions, we generally find them void of reason, and altogether ridiculous.

The Fly produced from these Worms, is divided into a head, thorax, and body, Fig. viii. *f*. The head is furnished with eyes, and it has two long antennæ. From the upper part of the thorax spring four membranaceous wings, that shine like mother of pearl, and the upper pair are adorned also with two black spots, and with several very pretty ramifications of the nerves. To the under part of the thorax are fixed six transparent legs of a delicate reddish brown colour. The body consists of several rings, and is armed, at its extremity, with a weapon of an oblong form that is plainly discernible: no doubt, this is the instrument with which the insect pierces the Oak branches, in order to deposit its eggs within their substance. This Fly is altogether black in the body. I have not yet had the good fortune of discovering its eggs, either in the excrescencies wherein they are hatched, nor in the body of the female, as I never have dissected any of them. I made the foregoing observations on the 26th of June, when a great many of these surprising Flies issued from their nests, which they likewise continued to do, till the 8th of July. The males were smaller than the females.

*Of some little insects that are found concealed in the tubercles, or swellings of Oak-leaves, in so artful and wonderful a manner, that the foregoing relations must yield the preference to their history.*

THE observation I am now about to exhibit, is so uncommon in its kind, that nature perhaps cannot furnish any thing to excel it. On this occasion the infinite power and wisdom of the Great Sovereign of the universe strikes our eyes with its full lustre, and indeed so plainly shine forth in his creatures, that we must consider the meanest of them as so many voices engaged in publishing his praise; and thereby putting us in mind to yield him that tribute of love and adoration, which we owe on so many accounts: us, I say, on whom he has bestowed the inestimable faculties necessary to investigate and consider him in his works.

To proceed with due order in this relation, I shall first describe the excrescences of the Oak-leaves, in which these wonders are found\*, and add a figure to render the description more intelligible. I shall then, in the same manner, give a satisfactory account of the insect bred in these excrescences, as it appears in the Worm, Nymph, and Fly-state. As to the excrescences themselves, the particulars in them most worthy of our attention, are their situation, construction, figure, colour, and size. Their situation is irregular, and it is pretty like that of the excrescences on nettle-leaves already described. Some lie on the fore part of the leaf, upon or close along the sides of its nerves or ribs, Tab. XLV. Fig. XII. *aa*. Others appear in the middle of a leaf, seated upon the main rib, *b*. And some, in fine, are scattered confusedly about the edges, *cc*.

These tubercles consist of a hard, knotty, and compact, but brittle, substance, without the least toughness; so that, in this respect, they very much resemble a cartilage. But, upon the whole, I know nothing to which this substance may be more justly compared, than to the cup or covering of the hazel-nut or filbert, before it ripens, or has been pulled. These tubercles, or swellings, are formed between the two coats of the oak-leaf, and acquire their hardness when the delicate parent Fly has buried its eggs there. These tubercles are sometimes round, sometimes oval or oblong; and we often meet with two, three, or four of them growing into one, so as, in a manner, to compose but one continued body. Their colour is generally a deep green, sometimes a watery sky-blue, and in some inclining to white and yellow. In point of size they differ greatly, according to their age, or perfection of growth, and their joining two or more into one tubercle, *b*.

I have not as yet had the satisfaction of seeing the first rudiments of these tubercles, which first I took notice of by mere chance, in company with my much honoured friends, the principal magistrate of Niewenrode and his lady, in the Hague-wood, from whence I took many of them home to examine at my leisure. I shall, therefore, now describe those wonders I observed in them, in the course of a most diligent inquiry. In one of the largest of these tubercles, which I opened by paring off its upper part, Fig. XIII. *d*, I found a pretty large cavity, in which there again appeared three other peculiar or separate excrescences, *e*. As to the manner of their coming there, it is more than I can conceive. These smaller excrescences lay singly each within a kind of hollow, but without any partition between them. On taking out these three separate excrescences, *f*, I found that in figure they greatly resembled a kidney-bean, which has one side more convex than the other. On inspecting them with a microscope, they looked as if they had been connected by the middle to a kind of pod, by means of a petiolus, or little stalk.

These singularities served only to make my curiosity more eager, to examine attentively the other tubercles that I had taken home with me; and I found them all filled with the miracles of the Great Creator. On separating in the middle a tubercle, that wanted a great deal of being arrived at the size and perfection of that already described, I found no hollow or void space within it; but only two such pea-shaped substances as I have before taken notice of, and two little Worms, which I had cut in two, along with those substances. All this is plainly shewn in the figure I give of them, Tab. XLV. Fig. XIV. little larger than nature; in which may be seen the two dissected or cut substances, situated in the middle, and about them the substance of the tubercle, by which they are closely surrounded, like the seeds of an orange by its pulp. I could likewise observe, that the external coat or shell of the tubercle was much more compact, and of a greener colour, than the inside; which difference I have endeavoured to represent in the figure, as if there had been a separation between the differing substances, though, in reality, there is no separation in this state of the production.

On opening a third tubercle, that was somewhat more grown, I could discern that its internal substance was drying up by degrees, and

\* The Worms found in tubercles of leaves, and other parts of plants, are all owing to the eggs of winged insects. Their parents are of three kinds: 1. Butterflies. 2. Beetles. 3. Flies. We may know, at sight, to which of these kinds any Worm belongs by its form. If it have no feet or legs, it is the Maggot of a Fly. If it have six legs, and no more, it is produced from a Beetle, and will be changed to one. If it have more legs than this number, it is a Caterpillar in miniature, and will change to a Butterfly or Moth.

separating from the enclosed kidney-bean-like substance; by which means this came at last to lie in the tubercle as within a hollow, and to rest against one side or another of this hollow. In this manner I plainly discovered, that the three detached substances, in the tubercle I first opened, had obtained, by evaporation, that wonderfully elegant situation in which I found them. This discovery was afterwards confirmed by all the other tubercles, and their internal substances. On my first observing these surprising changes, without knowing the ends which Nature intended to answer by them, I looked upon the whole as a most inexplicable riddle; as did likewise the ingenious persons then in my company: for our walk was made merely with a view of regaling ourselves, together with a contemplation of the stupendous miracles of the Universal Parent.

We find in nature many other things, which agree and correspond with what I have been just now relating. The seeds of apples and pears, buried within the flesh of their respective fruits, fall off, little by little, from their coats and cups. The same thing is observable in the kernels of filberts when they grow dry, and even in the nut itself or filbert, which at last drops from its cup. But what is altogether singular and uncommon, in the tubercle now under consideration, is, that this substance, which separates from it, and lies loose within its body, should contain a living Worm.

When these substances, in consequence of the hollow occasioned in the tubercle by a large evaporation, have newly become loosed from it, their circumference is somewhat rough and uneven; but as it dries, it grows even and smooth to the naked eyes: but the microscope always discovers on the surface the remains of the former ruggedness, Tab. XLV. Fig. xv. *g*. In the same manner the spot, at which this substance received its nourishment, never entirely disappears; but remains discernible to the last, in the form of a little cicatrix or scar, *b*.

The substance of these internal nodules is at first soft and tender; but it afterwards hardens and dries up, and assumes a brownish red colour, which it never afterwards loses; so that, when viewed within the hollow of its green tubercle, it affords a most pleasing spectacle. When thoroughly dried, it is of a pretty compact and firm texture; and in respect to its coat or crust, it greatly resembles the rind of a chestnut, only this last is much thicker. But neither these substances, nor the Worms they contain, are all of the same size.

Likewise the number of these contained within the tubercles, varies greatly. In single tubercles, every one lies by itself in its own particular hollow; but it is the reverse in the double or more composed tubercles. Sometimes also, though three or four tubercles grow in one, all their inner substances have notwithstanding each its own little cell, separated by a

kind of diaphragm or division. The spots on which these substances grow within the tubercles, is generally a little moist or damp, which keeps them from rolling about. The cavities also of the tubercles differ in size, which I attribute to the tubercles themselves having been some bigger than others, or to their having been dried up in different degrees. But, in general, there is found only one detached substance in every tubercle.

On opening one of these substances, that I had taken out of its tubercle, I found in it a living Worm, composed of many rings, as I have represented it, larger than nature, on the middle of the Oak-leaf, Tab. XLV. Fig. XII. *m*. The figure of this Worm was oblong, and its colour white. On its back appeared a gray streak, approaching to black; which I afterwards, on dissecting the Worm, found to be no other than one of its intestines, which appeared through its transparent skin, and owed its colour to the half-digested food which it contained. In other Worms this streak was sometimes brown, sometimes red, yellow, or green, owing to the cause already assigned. This little Worm lay in its bean-like substance in the form of a crescent, quite free and loose on every side. I could not even discover in it any umbilical vessels, or other connecting filaments, by which, according to the vulgar opinion, it might have drawn in its food. It moved and turned itself about at pleasure in this little habitation, being very vigorous and lively. There appeared no excrements in the cell, nor yet the least opening by which it could empty them. The hollows of the tubercles were equally free from any foulness of that kind: every place was perfectly neat and clean.

Nevertheless I shall not deny that this little insect received nourishment within its covering, since the contrary is plainly seen from the altered food which appeared in its intestines, in the form of excrements. Hence I conclude, as a certainty, that this Worm subsisted on the juices of the Oak-leaf, which were conveyed into the cavity of the substance by its stalk, and that it took in these juices with its mouth. As this aliment, no doubt, is of the most refined kind, there is the less reason to wonder at the Worm's not voiding any excrements, in consequence of its using so fine a nourishment. On the contrary, retaining within its body the little that was secreted, till an opportunity offered of discharging it all together, when it should be turned to a Fly in due course of time, and freed from its confinement. It is common with several insects, produced from Nymphs and Chrysalides, to evacuate their excrements very copiously, within the first quarter of an hour after their appearing in the Fly-state. Nor is there any reason to wonder at a creature's being able to grow without discharging any excrements, since new-born Lambs and Calves furnish us daily instances of this kind. These animals  
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never void any excrements at the anus, till they are dropped from their mothers\*.

I think it probable that the substance of the tubercles does not begin to dry up, till the enclosed Worm, having attained the full term of its growth, becomes mature and ready for the Nymph-state; and even at this time, the lower part of the substance still continues moist, so that the enclosed insect may, at this period, also draw nourishment through it, from the ascending juices of the tree, in case it should happen to require any. Thus we have another instance of God's all-seeing providence, which, with so much goodness, watches incessantly over his creatures; and this instance is the more striking, as the lower part of the bean-like substance grows looser and drier by degrees, on the Worm's actually entering into the Nymph-state; so that the moisture I have been speaking of, begins little by little to dry away, when the time approaches for this Nymph to appear abroad in the Fly-form. Sometimes indeed the detached substances, at this period, are found quite loose in the cavities of their tubercles.

One of these Worms, which I had extracted from its bean-like substance, lived, notwithstanding, from the fifth of June to the fifth of July. When the Worm has received sufficient nourishment, it draws the rings of its body closer to each other, Tab. XLV. Fig. xvi. It after this casts a delicate skin, and at length assumes the form of a Nymph, which is at first white all over, but grows blacker and blacker by degrees, in the same proportion as the enclosed limbs of the future Fly acquire sufficient strength to expand and produce themselves. At this time, there very plainly appear on the Nymph's head, two reticulated or net-like eyes, Tab. XLV. Fig. xvii. *a a*, and underneath in the thorax, the two teeth, which were before discernible in the Worm. Along the body lie the antennæ, *b b*, and between them the six legs, and the wings neatly folded up. The rings of the body show themselves very distinctly in the lower part, *c*. I refer this Nymph to the first mode of the third order of natural mutations, as it clearly represents the limbs of the future Fly, in the same manner with the Nymph of the Ant.

The two figures I give of this Nymph represent it, one of its natural size, Fig. xviii. the other as it appeared through the microscope, Fig. xix. It is divided into the head, breast and body. The eyes are seated in the head, and before them are placed two moderately long antennæ, *a a*. The breast bears four wings, *b b*; the upper pair, which are the largest, are stretched over the body; to the under part of the breast, are articulated six red legs, each armed at its extremity with two claws, *c c*. The belly of the females is thick, swollen, or distended; but it ter-

minates in a sharp point, *d*, which perhaps the creature makes use of as a weapon, to bore the Oak leaf, and afterwards as a channel to convey the eggs into the hole made in that manner. The surface of the body is smooth all over, as if polished, and is of a shining deep black, which gives the Worm a pretty appearance. These Flies broke from their confinement the 28th of June; but I dissected none of them, so that I can say nothing of their eggs, or of their genital parts.

We are now to consider another wonder, equal to any of those I have yet related; and this is the singular and uncommon manner in which the all-wise, and all-powerful Architect has provided for the delivery of these Flies, without their meeting with any opposition. At the time the Worm has attained the Nymph-form, the enclosing tubercle begins to grow thinner and thinner by degrees, at a certain determinate and select spot. This circumstance I have endeavoured to represent in a tubercle, where I found two detached substances, Fig. xx. *i i*; nor is Nature content with only reducing the thickness of the tubercle in this manner; but she likewise ordains things, so that it dries up and hardens in the same place, in order to make the perforation of it, by the teeth of the Fly, easier than it otherwise would be. The little prisoner, on its becoming a Fly, first gnaws through the inner substance, and then through the tubercle itself, a round hole, Tab. XLV. Fig. xii. *k*, just large enough to afford it a free passage to its new element.

We may know of a certainty, when these insects are about to turn to Flies; for the dry spots at which the Flies are to make their way, appear very obviously on the surface of the tubercles, *ll*. On inspecting these tubercles again, a few days after the 28th of June, I found many of them perforated, and that the Flies bred in them had made their escape, so that nothing remained in them but the detached substances, which were likewise perforated. The tubercles wrinkle and wither away, for the most part, on their inhabitants quitting them. These wonders all return with the succeeding year, and thus call upon us without ceasing, to publish the praises of their Author, who has openly manifested Himself in all his creatures, and has given to man alone, amongst all sublunary beings, the faculty of knowing Him. In what a bad light therefore must those appear, who, unaccountably blinded by their ignorance, dare to oppose the existence of that all-watchful and adorable Providence, by foolish arguments! Behaving in this manner, and working their own destruction, they debase themselves below the rank even of beasts, and deserve to be considered as monsters in the nature of things.

\* Beside those Worms which proceed from eggs let into the substance of the leaf by the parent Fly, there are some, both of the Fly and Butterfly kind, which only drop their eggs upon the surface of the leaf, and fasten it on by a glutinous matter. The Worms and Caterpillars hatched from these, the moment they burst from the egg, make their way through the outer coat of the leaf, and get into the substance. They thus live under cover till they change.



*Of certain Worms that feed within the spongy excrescence of the Dog-rose.*

THE excrescence of the Dog-rose, as to its external appearance, is not altogether unlike that of the Oak represented in Fig. vi. of this plate, though it is not of a woolly, but on the contrary, of a spongy substance, in so much that it may, with great propriety, be called the sponge of this shrub. The colour, when dried, is a blackish gray; and in the same state, the surface of it is full of little cavities and prominencies, Fig. ix. *aa*. It grows as the other, at the extremities of the branches, where it stands upon the center, just as the bud of the Rose does upon its stalk *b*. On opening this excrescence, we find in it a great many cells, Fig. x. *c*, full of little white Worms of different sizes and ages. These Worms assume, by degrees, the Nymph-form, in the same manner with all the Worms living in excrescences, that I have hitherto mentioned; and under this form they most manifestly exhibit the limbs of the future Fly: this happens about the end of summer.

I had the pleasure of observing two species of Flies issue out of these sponges, thro' holes

they had made in them for that purpose. The first species was not unlike the Flies that had been produced, at my house, from the tubercles of the Oak, only, that they had somewhat thicker bodies, Tab. XLV. Fig. xi. *d*, with black eyes, and all the rest of them was of a redish brown colour. The other species *e* were of the Bisetæus kind, or had two hairs at the tail, though this character was peculiar to the males. They had likewise, in common with the first species, four wings and six red legs. Their bodies were oblong; and their heads, which hung to the thorax by a very slender neck, were furnished with a pair of redish eyes. Their bodies all over shone like those of the Cantharides, or Spanish Flies, with a gilded green, so as to afford a very entertaining spectacle. These Flies did not all appear abroad at the same time, but were employed for several days successively in making themselves openings in their habitations: this they effected by gnawing the spongy substance with their teeth, into a great variety of holes and cavities, Fig. ix. *f*.

*A careful and exact observation which I made on the tenth of July, 1674, on the black Poplar, in presence of the principal magistrate of Nieuwenrode, and his lady; both very curious in examining the natural wonders of the creation.*

THOUGH all the works of the Almighty are wonderful, we may observe, that some publish his praises more manifestly than others. This appears most eminently in the various organs of generations bestowed upon animals, and the different manner in which they use them; for some declare, by evident and intelligible characters, the power and contrivance of the great Architect, whereas others represent it by marks that are somewhat obscure and mysterious.

On the tenth of July, 1674, as we were going in a chariot to Scheveling, we saw some red fruit like Cherries hanging from the leaves of the Poplar-tree, in such numbers, that they could not but strike the eyes of all that passed by. When we viewed them near, it appeared to us, that they were so many rough tubercles, or extuberances, on the leaves of those trees, Tab. XLV. Fig. *xxi. a*, each of which, when opened, shewed a great number of living insects, to the amount of 60 or 70. Those warts, or protuberances, which projected above the surface of the external coat of the leaves, were situated exactly under the middle of the nerves or ribs; so that these nerves passed *b* over them; being sometimes a little higher, and sometimes lower, according as the warts themselves projected, more or less, without any order from the leaf. Two warts were likewise sometimes found, but very seldom, on the same leaf. Their size greatly differed; some of them, as if young, were smaller; others larger

and more swollen; a third kind also grew still larger and higher than all the others. When we first saw these tubercles, we thought they were every way shut up or inclosed: but upon a more accurate examination, we found, that each of them had, on the inside of the leaf, where they were smooth, an orifice *c* somewhat long, thro' which the insect passed at pleasure.

It is worth notice, that the leaf always swelled under its largest nerve, which it constantly elevated; and likewise, that this tumor was only found about the nerve, and in the middle of the leaf. The reason of these circumstances seemed to us to consist in this; that the eggs of the insect-inhabitants had been impressed on that place only, and that the nutritious juice of the leaf was for the most part conveyed thither. Thus it might easily happen, that the leaf might be there increased and inflated by the nutritious juice accumulated by the irritation which had been produced by the lodging of the eggs in the substance. And hence also we observed plainly, that the whole wart on the leaf was nothing else but a larger dilatation and expansion of the leaf itself; which caused the nerve, pushed out at the same time, to be twisted into various bendings and windings, which were very considerable *dd* in some of them.

It deserved great consideration to observe how regularly all these things are done. For when the leaf is newly struck and begins to swell,

swell, it first grows yellow, and thence insensibly red, and is at length expanded like a bag, or a hollowed Cherry. In the mean time, the two edges of this extuberance grow so exactly opposite to each other on the inside of the leaf, and are, as it were, so united together, that the opening, or chink can scarce be perceived. This is regularly appointed in that manner by the Almighty, in the nature of things, lest the eggs or the young Worms should fall out of this their cells, or lodgings, or should creep out before they have attained their full perfection, and are become able to fly. We have now said enough of the external form of these tubercles.

When we afterwards opened them, we found in the inside the following very observable circumstances: in some we saw Flies full grown; in others, Worms with six feet, which were real Nymphs of the second order; and also some Worms, which, not yet exhibiting the limbs of a Nymph, were only in their first growth. We also discovered there a downy white substance, and some tough fluids, which seemed to be enclosed in the membrane.

To treat of each of these in their order, I shall first observe, that we found the inner surface of these warts more smooth and flat, than the outward. We thought the reason of this difference was, that in the external surface of the warts, the smaller nerves, which are there distributed thro' the leaf, were dilated and extended with the rest. As to the paleness of the colour, we conceived, that the reason of it consisted in this, that the whole inner surface appeared sprinkled, as it were, with meal and small white grains of bran formed like down. From whence this downy matter draws its origin, we shall examine presently. We sometimes observed something, tho' but little, and that not frequently, of a roughness in the cavities of the warts: but whether the cause of this was, that the old Flies, remaining there for some time, had scratched the surface with the claws on their feet, we could not certainly affirm.

The smallest Worms we found within these warts, were each divided, like perfect Flies, into the head, thorax and belly, Tab. XLV. Fig. xxii. In the head were seen two eyes and two antennæ. To the lower part of the thorax six legs were articulated. The rest of the body was somewhat short. They appeared to the naked eye of an azure or fine blue, but greenish under the microscope. They cast a skin in like manner as the other species of Worms. They also moved very quick, and were much more vigorous than the larger Worms, or than those that were already changed into Flies.

What deserves most observation in these little insects, is a heap of floccs or down, which each very beautifully and admirably carries on the hinder extremity of its body. Whether that down grows out of the very body of the insect; which indeed is very likely, or whether it be produced from the tubercle or wart,

and afterwards is lodged in the hinder part of the body of the Worm, we could by no means discover; tho' we were most inclined to think, that the down grew from the body of the insect, because we no where saw it sticking to the bodies of the more mature ones.

In certain Worms, with soft bodies, that live exposed to the sun upon the leaves of the Lilies, I have observed, that they heap together all their excrements on the hinder-part of their body.

In others that lived among the leaves of Thistles, I have observed two stiff bristly hairs standing in the hinder-part of the body; on which was always fixed the skin which the insect had cast off, together with some excrements. Thus they lie under their skin, as under a pent-house, free from the sun's heat, and walk up and down with it among the leaves. The first species of these Worms, at length, changes into a Beetle, of an orange red colour, with black horns and legs; but the other into a large Tortoise-beetle, in like manner, with black legs and a black body. These two very extraordinary contrivances do not much differ, with respect to the down, from that which the insect, whereof we here treat, carries on the hinder part of the body. We may likewise see from hence what miseries all creatures are subject to in this vale of filth and calamities, finishing their lives continually under unhappiness and misfortunes.

The whole inner cavity of the wart, as I have already mentioned, is set as it were, or rather sprinkled over, with that farinaceous down. And this, doubtless proceeds from the exuvia, which the insect contained in it has cast off. At the time they cast the skin and this down together, they diffuse it every where about by running up and down. This downy substance is very elegantly divided into branches, and greatly resembles that species of nitre which rises out of walls newly built in some parts of Holland: when viewed with a microscope, it seems like the smaller or branched moss of trees.

As to the food of these Worms, it is very hard to demonstrate what it is: however, it is very certain, that they are nourished within the cavity of their warts. Probably, that white, tenacious, and glutinous moisture which I have before shewn to be secreted within the warts. Hence, that humour is so admirably ordered by the all-wise Creator, that it never flows away, nor does it wet, nor can it suffocate these little creatures. As it is ropy and clammy, the down immediately adheres to it, and performs the business of a membrane or bag, in which, as in a close vessel with a spout, it lies enclosed, and cannot run out of it.

I compare them to those close vessels, because there are some of these bags of that figure, Tab. XLV. Fig. xxiii. *f.* and by means of a hollow footstalk, are fixed to the surface of the wart, where the humours, just now described, probably flows out of that excrescence. Therefore, this is probably the real and only use the said down is of to these warts, and to  
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the little creatures, it serves to confine the moisture. When this moisture is consumed, the downy integuments, which surrounded it outwardly, become curled g into each other like pressed flocks of cotton; and therefore several such downy clusters are found gathered together in the warts.

The bags just now mentioned, containing a fluid, are all furnished with a petioli, or foot-stalk, by means of which they adhere to the inner surface of the tubercle: but whether that fluid be the real aliment with which the Worms are nourished, according to my opinion, or whether they are there fed with some other matter, has not hitherto appeared to us from experience. But this is certain, that these Worms have neither a trunk, nor any teeth. Nature hath given them only an acute and delicate converging beak, not unlike that of the Cicada, which sucks the dew: by this beak they can penetrate easily enough thro' the downy coat of their bags, and suck the moisture before described. But whether these creatures do really nourish themselves in this manner, or not, I cannot yet affirm, tho' it is very probable.

We poured a small drop of water into the cavity of these warts; and it was immediately covered round with that farinaceous down, and was deprived of its fluidity to such a degree, that when it was afterwards shaken on dry paper, it did not wet it, but slid and rolled over it, and did not stick to it: this was a very agreeable sight.

There is not such a great quantity of that down about the largest, as about the smallest Worms. On these indeed there grew four buds or rudiments of coverings of legs, on each side near the shoulder-blades. I have represented them *bb* on each side of the thorax, above the hinder legs. The principal cases, or first buds of the limbs are, in reality, a kind of covers, in which the wings lie folded up. Therefore, these creatures may then be properly called Nymphs belonging to our second order of natural transmutations; for in that order, the insects do not at all lose their motion during the time whilst they are changing into Nymphs; but on the contrary, walk, stand, eat, and move about, until they change their skin; and having at length cast their exuviae, they assume, as it were, another structure, and acquire only wings. This must be well observed. I would likewise have it remembered, that I have ranked these Nymphs

in the second order, because they perform their change in so obscure a manner, in the warts of the leaves.

These Nymphs, which are to change, cast a very fine skin or integument, which is left in the cavity of the wart\*. When this is cast, they acquire, Fig. xxv. the form of delicate small Flies, with four wings. These Flies are of a blackish colour, except the membranaceous wings, which have brown nerves, and elsewhere approach somewhat to red. The limbs, and other parts, that is, the head, thorax, abdomen, antennae, eyes, legs, and the rest, may be now seen much more distinctly in the insect, now perfectly mature, than when it appeared in the form of a six-footed Worm.

The horns appear to be divided into six joints; and are very beautiful; they are composed, as it were, of grape-stones, or are like a small piece of cinnamon, incrustated or rough-cast with sugar. The eyes are considerably large, and reticulated; they appear very distinctly when the creature lies on its back. The beak is closely applied to the lower part of the thorax, and is there seen extended downwards between the first pair of legs, just in the same manner as the Cicada. The wings, besides their nerves, and the vessels, wherewith they are elegantly distinguished, exhibit two oblong black spots, with which they are ornamented.

This creature flies very slow; indeed it does not move with so much swiftness as the small Worm, out of which it is produced. I have not yet discovered, by dissection, the difference between the male and female; nor have I ever seen the eggs of this Fly. I am inclined, however, to think, that they are lodged by the parent, on the inner coat of the Poplar-leaf: and that the wart or tubercle here described, is afterwards formed there by nature, in order to hatch and nourish them, and to keep them in safety. But how all these things are performed, we can yet only conjecture: since they must be known, not by reasoning, but from solid experiments. I shall here therefore furl my sails, and in amazement, celebrate the great Creator, who hath hidden so many, and such inexhaustible natural and important miracles, full of true knowledge and erudition, in his creatures; so that the air, the water, and the earth; the plants also, that vegetate therein, abound with them; and all vegetables and animals, however small, proclaim the glory of the Supreme Being.

\* The modern term for all Worms bred from the eggs of winged insects in tubercles, or parts of vegetables, is *Ascarides*. Reaumer is the author who established this. Some of them burrow deeper, others very slightly; all get under cover of the upper membrane. The manner of their getting through it, when their parent insects have lodged them on the surface, is various; the Caterpillar kind eat their way; the Worms of Beetles get in by breaking the surface with blows of their head.

*Of the footless Worm of Cabbage-leaves, which properly belongs to the fourth order or class of natural changes.*

ON the 15th of August, I found on Cabbage leaves several footless Worms, and some of their Nymphs. The body of the Worms, was in the fore part somewhat pointed, but in the hinder part a little thicker, Tab. XLV. Fig. xxvi. They were also divided into annular segments, which appeared in the skin like so many small incisions. They were of a pale green colour; but they appeared variegated, by means of certain white viscera, which were seen through the transparent skin. This creature was by nature very slow and heavy, though, when touched, it shewed greater agility and sprightliness. Whether it uses Cabbage leaves for food, or hunts there after some green little six-footed insects, which are at length changed into Nymphs of the second order, and from the latter into Flies; I have not accurately investigated: I know some are of this last opinion. This Worm usually stretches aloft the fore part of its body, in the same manner as an Elephant does its trunk, when it first begins to move and go forward. Therefore, I do not doubt, but it is the very creature which Goedaert described, Exper. XI. part II.

When this Worm hath at length fed enough, and its internal parts have acquired sufficient strength to put on the form of a Nymph, it is then changed, Tab. XLV. Fig. xxvii. and xxviii. into a real Nymph of the fourth order; which change is performed in the following manner: We first observe, that the Worm, before it casts any skin, becomes insensibly shorter; that its head is entirely contracted on the inside, and at the same time it becomes thicker; but the hinder part, by degrees, grows smaller, and more slender, the body thus loses its former figure. For the blood, and all the fluids, are propelled forward to the new parts, which are now increased, and swollen under the Worm's uncast skin, and appear divided into the head, eyes, thorax, legs, wings, and body: this may be clearly seen, if this Nymph be artificially stript of its yet uncast skin. One may likewise see the several particulars beforementioned through the skin itself; when the Nymph, being some days old, begins to acquire its proper colours.

As the colour of the Nymph, on the change is white, and is afterwards altered into a green, mixed with a pellucid white; the red eyes in the head appear, Fig. xxviii. *aa*, gradually through the transparent skin. The same thing holds, *b*, in regard to the thorax, which exhibits some pellucid hairs on its surface. In the hinder part of the body, the abdomen is seen through the skin, divided *ccc* into several rings, which are likewise set with small hairs. On one side of the body is seen a wing *d* somewhat pellucid. Towards the hinder parts, and near the tail a curled little vessel, Tab. XLV. Fig. xxviii. *e*, which indeed seemed to me to be a pulmonary tube rolled out.

When this Nymph is grown older, and at length becomes all coloured, then these parts appear most distinctly, if the skin be taken off: this will be evident from the magnified figure thereof, which I have given here. In this are discovered, Fig. xxix. *a*, the Nymph's reticulated eyes; above and between which are two short *b* horns. The proboscis or trunk is laid along the breast *c*, and near it, the first and second pair of the fore legs, are seen to be beautifully disposed. On each side of the breast lie the folded wings, *dd*, and under them the last pair of legs, *e*. What deserved the greatest notice in this creature was, that the extremities of the genital parts, were placed, *ff*, as it were, beyond the rings of the body, and terminated in shaggy points: which are at length drawn into the body, when the Nymph puts on the form of a Fly.

This Nymph is therefore a very uncommon one; and though properly referred to the fourth order, yet it undergoes considerable changes, and exhibits no more of its former shape than the skin only, which it does not cast, but retains. The reason why this Nymph so much differs from others, of the same order is, because it is invested with a tender and thin skin, which obsequiously accommodates itself to the growing and protuberant limbs within. All this I have explained in the preceding pages, where I treated expressly of the nature of the fourth order. We must further observe, that this Worm, when changing, is not disengaged from the Cabbage leaf, as is the case in regard to many other insects: on the contrary, it first glues itself thereto by a viscous matter, which appears Fig. xxviii. *ff*, like a thin membrane on the leaf.

The Worm having had this form sixteen or seventeen days, the hidden Nymph then breaks open, and casts off the outward skin, and at the same time draws a thin film off from the whole body, and from all the limbs, which is left on the inside in the old skin. Thus the Nymph appears, Fig. xxx. at length under the form of a Fly. The young Fly is much smaller at first, than in a quarter of an hour afterwards; for its parts are in that time insensibly extended, particularly about the head and belly, so that the Fly becomes almost twice as large, in so short a time after it is produced; after which it never increases any more. If any one would know the reason how the body of this Fly is so remarkably distended, it will appear, on examination, that it consists in respiration, which fills all the pulmonary tubes, and pneumatic bladders with air; and these, on the other hand, expand the hitherto soft body of the creature, and give it a firm and durable figure.

This Fly is beautifully divided into the head, thorax and abdomen, and has six legs and two wings. Behind these, two little parts are observed to be fixed to the thorax, supported, as it were, by two fine footstalks, with their extremities headed;

headed; so that they resemble two little hammers, which, the Fly striking against the wings, forms the noise peculiar to it. The eyes are ruddy, the thorax is greenish; the abdomen, on the contrary, is yellowish, and is variegated with blackish hairy wreaths.

I have often seen instead of the Fly, which is commonly produced from the Worm before described, eight other Flies issuing out of its Nymph, which had indeed drawn their ori-

gin from the Worms that feed on the internal parts of that Nymph, and were changed within it, into so many small Nymphs. When these little Nymphs had at length grown into Flies; they flew out, after piercing the skin of the larger Nymph. These Flies had each six red legs, four wings, and a body that glittered with a golden and very lively green, excelling the light of the sun's rays.

### *Of the Worms called Moths.*

**T**HOUGH the Moth is a very common creature, yet few know it; for it lies hid, and does not exhibit itself to open view; for that reason it is the more mischievous. Moths are in reality Vermicles, or Worms that live in woven cells, at all times, except when they build their nests, in wool, skins, or birds feathers: in those cases, they usually build themselves irregular cells, because they have both the habitation and food, which they then irregularly grind with their teeth, always ready.

They build their habitations very artificially, so that they are always larger in the middle, and narrower, Tab. XLV. Fig. xxxi. *a*, on each side, where the passage is: and that structure does this service to the Moth, that it can the more conveniently turn itself in the middle of its habitation, and go out through either orifice when necessary. It is also observed sometimes, that the Moth spins a fine thread, especially when it creeps near the walls and beams of houses, seeking its food there; for this is of various kinds. In that case it forms this thread, to prevent falling down, when it ceases working, and goes into its cell; for at that time only it hangs suspended, *b*, from the thread. I have likewise often seen, that the Moth spins this thread, when the anterior or forepart of its body has first crept *c* out of its little case, and endeavoured to fix itself somewhere by means of it: but when the creature was afterwards inclined to proceed further, it broke this thread, and going out of either opening of its cell, fixed it again in another place: and when this is done against a beam or wall, it forms a very beautiful sight.

In order to describe more particularly the little Moth, which I here exhibit in its natural size; I must observe, that with respect to its structure, it is not unlike a small Caterpillar. It has a glittering raven-black head, in which its eyes, and two sharp-pointed teeth are placed. The rest of the body is of a whitish or fleshy colour. Six legs are fixed to the breast, eight in the middle of the body; and two are situated in the extremity of the abdomen under the tail. The Moth, however, never creeps out of its habitation, but by the six fore feet; by the help of the other ten, it lies fixed in its little case: that is, when that Worm advances forward with its six fore feet, then it takes hold of its cell within, with the others: and this too is the reason, why it always carries its case with it, not differing much in this respect from tortoises.

But the Moth, while growing, always entirely forfakes its case, when it is become too little for its body, being on account of the increase of bulk, obliged to form itself an intire new cell, into which, as into a new habitation, it afterwards repairs, after leaving the old one. The Moth never undertakes that office, until compelled by necessity; that is, when the old habitation is not sufficient to cover its body. The instinct and prudence of this creature, are most evident from hence, that in preparing an habitation big enough for its body, it does not desire large and magnificent buildings, which the folly of mankind so much seeks after. Man, whom God created with an upright countenance, over-burthens himself with heavy labour, nay, he sometimes perishes under a multitude of houses and apartments; the tapestry and hangings of which are exposed to this Moth, only to be gnawed and eaten for food.

When the Moth leaves its former case, in order to form for itself an entire new cell, it does not get for that purpose beams of cedar, nor Italian marble: it prudently and ingeniously makes use of that matter which it finds near about it. When it lives in green cloth, it makes the outside of its whole cell of a green matter; that is, the wool which it bites off the cloth, and artificially interweaves with its web: it lives on the same substance, and uses it for food; and therefore its excrements are also green. It does the same when it rests or pitches on white, yellow, red, blue or black cloth; or when it finds in its way any coverlid, garment, or cap, that lies unused and neglected in a corner. If it can find none of these materials, it remains in old old houses, armories, repositories, and even in stone walls; it eats dust and Spiders-webs, whereof it makes an habitation in the same manner. I have, on these occasions, seen it interweave small bits of broken cement with its habitation, in order to make it stronger; so that this creature makes every foil its country, and yielding to necessity, leads a happy life amidst the miseries to which we are subject.

The Moth never brings any foreign matter into the inner surface of its cell, where its body lies; consequently nothing else is observed there, only the Moth's proper web, which being of a soft, smooth, and even texture, serves both for a habitation and bed. In this manner that Worm lives, till its parts are increased to their due perfection under the skin: and at that time, it

covers both the orifices of its little case, and casting of its old skin within, Tab. XLV. Fig. xxxi. *e*, is changed into a Chrysalis, which is properly referred to the second mode of our third order; because it does not very clearly exhibit the limbs of the insect to be produced from thence: this is a nocturnal Butterfly, or Moth. When this insect is first changed, all its parts are beautifully white, but they afterwards grow insensibly yellowish, and at length acquire a faint red, which they finally preserve. In the head, particularly the eyes, which are seen through the skin, first acquire their colour and perfection; afterwards the whole body finally appears through the skin, of the same colour with the nocturnal Butterfly, to be produced from thence.

July 13th, the Butterfly appeared, *f*, after it had lain twelve or thirteen days under the form of a Chrysalis, without food or motion, and its tender limbs had, by the evaporation of the superfluous humours, insensibly acquired sufficient strength to break open the outmost skin. This Butterfly was provided with four wings, six legs, two horns, and two black eyes. Its wings and body had many superb scaly feathers, which very beautifully adorned the creature with various and agreeable colours. These colours being viewed with a naked eye, resemble fine flour, and may be easily reduced to such a powder with the fingers:

and therefore, frail man, as mentioned in scripture, is very properly compared to a Moth.

This little creature, the Butterfly, is commonly called a Moth; though it is noxious on no other account, but that it lays those spheroidal eggs out of which the real Moths, or eating Worms, are at length produced, in hangings and cloaths, in like manner as the Flies producing Maggots lay theirs in meat, fish, cheese, and meal. When these creatures fly or flutter about, those who would preserve treasure from Moths, must be careful to keep them from it; for otherwise their neglect will be a great hurt to them, and cause much loss and concern. These are the consequences that commonly attend sloth and negligence.

When this Moth hath broken out of its woven cell, it is always observed, Tab. XLV. Fig. xxxi. *g*, to hang a little out of one extremity of the skin, which the Chrysalis had cast. But if the case itself be then opened, one may distinctly see how even and smooth it is woven, *b*. I should never finish, if I attempted to describe and delineate all the species of Moths, since there is a great number and variety of them. I should think, that what hath been hitherto said is sufficient, so that there is no need of more; for it is easy to know a Lion by his paw.

*Of certain Worms that, like the Moths, live in cells, feeding on the leaves of Pear-trees, Apple-trees, Plum-trees, and Cherry-trees.*

#### O B S E R V A T I O N I.

**I** Preserve, in my collection, various and particular species of these Worms, some of which form their cells of bits of wood, which they bite off; and hence are properly called Ligni perdaë: but of these I shall hereafter treat in another place. The first species of those, of which I am to treat here, was shewn me on the leaf of a Cherry-tree, by the very experienced and celebrated Dr. Luke Schaght, professor of the Materia Medica in the university of Leyden. I afterwards found it likewise on the leaves of the Willow and Alder-tree. The cell which this Worm inhabited was black as pitch, Fig. xxxiii. *a*; and consisted of a substance, as it were, of bark, and woven into wrinkles. Its hinder part was thicker than the fore part, and divided, as it were, into two lobes. Its foremost extremity terminated somewhat acutely, and out of it crept its inhabitant, carrying this little case entire, obliquely

on its body; but when the Worm rested, the case stood perpendicular on the leaf.

This Worm was, in regard to its structure, scarce different from the Moth. When it has eat enough, it fixes itself to the leaf, near the opening of its cell, and is changed within it into a Nymph of the first mode of our third order, which *b* grows at length into a very beautiful Fly. On the head of this Fly, which is black, are placed two redish horns. Its thorax and abdomen are partly red, and partly black. It has four beautiful membranaceous wings, which shine like very fine Mother of Pearl; and are likewise variegated, nearly in the middle, with two black spots. It has moreover six red legs, which are divided into joints, each having two claws at its extremity. This creature is alert and sprightly, and flies very swift.

#### O B S E R V A T I O N II.

**I** Found a second species of those Worms, which carry their cell with them, on the leaf of the Alder-tree. This creature fed on the inward coat of the leaf, and therefore consumed it all unto the nerves of that external coat. It does not differ much from the former, except in respect of its habitation, which it car-

ries every where on its body: but in this there is a considerable difference; that is, it is of the colour of the leaves that fall in autumn, tho' some of these cells are also found of a stronger colour. This cell is triangular, Tab. XLV. Fig. xxxiv. *c*, at the upper extremity: it swells a little in the middle; but the part that contains

tains the body of the creature, is again contracted, and therefore it is formed like a big-bellied cylinder.

I have seen three sorts of creatures produced from these Worms; for as one of these small creatures had, according to the second mode of the third order, been changed into a Nymph, which assumed the form of the future Butterfly, I at length observed a pretty little nocturnal Butterfly or Moth, not much different from the Cloaths-Moth, sprung *d* out of it. I saw a black Fly *e* with two horns, four wings, and six legs, produced from another similar Nymph, which however shewed before the form of a Fly, according to the first species of the third order. But the most singular event of all was, six or seven very small *f* Flies, which, from more tender Worms, had been first transformed into Nymphs, issued out of another Chrysalis of such a Vermicle as belonged to

the second mode of the third order. Whether this be common, and constantly happens annually, as is the case in other Caterpillars; or whether it be peculiar only to those that inhabit the bright brown cells, in which only I observed it, I have not indeed yet learned from experience. And, indeed, what man can perfectly investigate all the changes of parts which happen, even in one creature. I am, indeed, every moment taught by experience, that nature is, in regard to those real causes, by which animals and their parts increase, in many particulars, perfectly impenetrable to man. However, a firm and constant diligence hath, by degrees, discovered to me more than one could easily believe; though what we are ignorant of is, and will remain, much greater than all we know. Hence, indeed, we have knowledge of many things; but our ignorance still prevails and predominates.

*Of certain Vermicles or Worms, whose eggs are lodged in the bags wherein musk is brought to us.*

I should never make an end, if I attempted even to enumerate all the hidden changes of the Caterpillar and Worm kinds into winged insects; so fruitful and manifold is Nature in her genera and species! For this reason I shall only add the following observation, and afterwards finish this history of the fourth order with accounts of two Worms which live in tubes, one in the earth, and the other in the water; for the water abounds as much with these insects as the land.

On the 10th of July I found a great many small white Worms, Tab. XLV. Fig. xxxii. in a bag, wherein musk comes to us. All these had a reddish brown head, and black teeth. Six legs adhered to the breast. The body was covered with fine hairs, standing erect. This musk-bag was in a little box, not very closely shut, the bottom of which was covered with white paper, through which these Worms penetrated into the wood of the box, by various holes which they gnawed through it. And indeed those holes, which are as conspicuous in the paper as in the wood, moved the admiration of the persons who viewed *b* them. As they were bit regularly into a round, oblong, or oval circumference. I further observed, that many of these Worms made themselves in their caverns a pretty thick, oval, lemon-coloured web, whereon they had weaved many cotton-threads, after the bag of musk had been placed in the cotton.

When I opened these webs, I found real Nymphs in them, Tab. XLV. Fig. xxxii. *d*, which belonged to the first mode of the third order; for each very distinctly represented the limbs of a future Beetle. Some of these Nymphs were very white; but in others, which were older, the eyes were turned black, and the whole Nymph, from white, insensibly became tinged with various colours; and

was, at length, changed *e* into a very beautiful little Beetle, after casting its skin. When these Beetles have newly cast their skin, in which they appear like Nymphs, they are of a snowy white colour: they afterwards grow yellow by degrees, till at last they become of a dusky purplish hue, and afterwards always continue so: some of them, however, constantly preserved a colour between yellow and red.

They are distinctly divided into the head, thorax, and belly. They have two black eyes in the head, just over which project two reddish horns, thick set with fine hairs of the same colour. The thorax is likewise adorned with yellowish hairs, that glitter almost like gold, and exhibit six hairy legs of the same colour with the horns, affixed to its lower region. The cases or covers of the wings are divided with ribs; and the latter, together with several little depressions, are every where set, as it were, with fine hairs. This obtains chiefly about the shoulder-blades, and on the hinder part, where these cases or covers are bent, near the extremity of the abdomen; for they have a tuft of whitish hairs in the fore and hindermost parts. The under wings are membranaceous, and they very expeditiously fold themselves under the sheaths or cases with which they are covered, notwithstanding their being twice the length of the abdomen.

This species of Beetles may, on account of the construction of the horns, be referred to the flying Capricorn kind. I have seen Beetles produced from some other species of Worms, that live on rotten and hollow wood; the horns of which were formed in the same manner as the Silkworm Butterflies. The only difference was, that all their divisions or plates were severally jointed together. This structure formed a very beautiful sight, and clearly demonstrated the wisdom and art of the Creator. This is still

more evidently conspicuous in the Fullo-Beetle, whose female is delineated in Mouffet; but it wants those ornaments, which are found in many species of insects, peculiar to the males, wherein they are more beautiful than the females.

The Worms here described feed on birds

feathers, and therefore do a great deal of mischief. They are found in several places in Holland, and may be reckoned among the second species of Worms that gnaw flesh clean from bones; and therefore are very proper to prepare fine skeletons.

*Of certain Worms which lie in little tubes or cells.*

OBSERVATION I.

I Preserve several species of tubes in which Worms live\*; but I shall not, in this place, describe them all. The first which I here exhibit is formed by a Worm, resembling a Caterpillar; which makes, Tab. XLV. Fig. xxxv. a pyramidal tube or pipe for itself, to which it afterwards fastens, for greater firmness, various little parts, bitten off from plants and leaves

of trees; so that the surface of the tube resembles those chequered works, with which the doors of armories and castles were formerly adorned: and with this beautiful cell the Worm walks and goes about, till it is changed into a winged creature, being disengaged then from the burthen of its house and bed, which it was hitherto obliged to carry.

OBSERVATION II.

THE tube, whose figure I here add, Fig. xxxvi. to the former, is not less beautiful or artificial in its structure. I found it in the salt water, on the coast of the German sea. It is inhabited by a tender Worm without feet, having many gold-coloured bristly hairs in the fore part of its head; by the help of which it can gnaw innumerable grains of sand, and join them so accurately together, that even the most nice artists must be astonished at it. The inner surface of this tubulated and pyramidal cylinder is smooth and equal; but the external part is, on the contrary, uneven. This difference proceeds from hence, that the creature can turn all the plain and polished surfaces of the sand inward, and leave the angulated and rough surfaces on the outside. The figure, by which I represent this tube, exhibits only the third part of its natural size: it could not be all delineated otherwise, for want of room in the plate. I have not yet observed what kind of metamorphosis this insect undergoes.

It merits great consideration, what kind of saliva or glutinous moisture that is, by which this Worm can fasten the grains of sand together in such a manner, that the whole contexture dries and hardens in the salt water. I

must ingenuously confess, I am doubtful in this as well as many other matters; since I can by no means conceive how this piece of art is executed. I have observed, that many other aquatic insects also frame a web or covering, under the water; the thread whereof hardens in the midst of the fluid, in the same manner as the Silkworm-webs in the air.

In regard to the other aquatic insects, I have observed, that some of them form their cells of small fragments of stones; others of larger pieces joined together; some of snail-shells, which they have gathered up and fastened together; others again are made of pieces of rushes, various parts of plants, wood, and other materials: nay, I have seen some, which, when they were preparing for their change into the winged state, could weave very heavy stones into their cells, and fortify them, as it were, with a lattice-work of masonry. They dived to the bottom of the water by this means, and, being there free from all danger, they changed and renewed their bodies. God is therefore admirable, wherever he is manifested: he hath represented his omnipotence and wisdom in all his creatures; therefore, let him only be honoured and glorified to all eternity.

*The End of the History of Insects that inhabit fruits, tubercles, leaves, and the like.*

\* The name by which this kind of insect is generally called, at this time, is *Tinea Campestris*, the Field Moth. Reaumer, who gave them this name, observes, that their origin and manner of life are the same with those of the common Cloaths Moths; the only difference being, that these feed upon moist, the other upon dry food.



*A particular treatise on the Frog and its young, exhibiting its history, and comparing it with insects.*

## T A B. XLVI.

A Comparison of the metamorphosis, and, if I may be allowed the expression, a transfection of the parts, happening in young Frogs, with that observed in the Nymphs of insects.

As, in the preceding sheets, I have occasionally, though slightly, touched on the likeness of the change of limbs in the larger or sanguiferous animals, to that which insects undergo; I shall here delineate and explain this subject more at large, in order to make the knowledge of it distinct and clear. For this purpose\*,

Tab. XLVI. N<sup>o</sup>. i. exhibits the Frog's real egg, or the Worm of the young Frog, enclosed in its first coat. It represents a small *a* black globule, surrounded *bb* by another globe, consisting of a clear, clammy, and glutinous matter. This matter is the real food of the Worm of the Frog, which now lies within, covered as yet with its proper integuments: therefore the Frog's Vermicle or Worm may be considered as the yolk, and the food the white of this egg.

N<sup>o</sup>. ii. I lightly express the investing coat or integument before mentioned. It is here cast off *c*, and rolled back *d* to the hinder part of the Frog. It likewise appears, in this figure, how much the surrounding aliment is now dilated, *eee*. Hence the young Frog is circumstanced exactly in the same manner as all Worms and Caterpillars of each of the four orders are, when they have cast their first coat, or their egg-shell; in which I call them Ovi-form-Nymph-Animals, or Ovi-form-Nymph-Vermicles, as may be seen particularly in the fourth order, where the egg is considered.

N<sup>o</sup>. iii. It is delineated to the life how the young Frog, called a Tadpole by authors, swims in the middle of its food, and also in what manner that food appears in the water like a dispersed cloud, *fff*. The Vermicle or Worm itself is here delineated much larger than it was, when it first began to swim into its food, immediately after quitting its shell, or first membranaceous integument. Therefore one may now very distinctly see its head, breast, and body. But because the person, who I shall desire to distinguish these parts, ought to have a thorough knowledge of them, those who investigate nature but superficially, look into that globe only for the young Frog's head, though it really comprehends the whole body; as the incomparable Harvey has before just observed. At the extremity of this young Frog's body is seen a long continued tail, Tab. XLVI. N<sup>o</sup>. iii. *b*, by the help of which it swims;

since the Frog is, whilst it wears that form, a real footless Worm, and, in this respect, resembles the footless or apode Vermicles or Worms of the first mode in our third order.

Here it must be well observed, that the young Frogs never consume their food entirely; which, for that reason, is diluted by the imbibed fluid, and gradually attenuated; so that, at last, it resembles a little cloud floating in the water. Indeed, that gluy cloud is insensibly dilated to such a degree, that it seems designed for the young Frog as a place to rest in, when it shall think proper: for which reason it is likewise observed, that, when tired with swimming, it quickly penetrates into this cloud, and there remains without motion.

And here I shall beg leave to observe further, that as the insects which are found in cheese, putrified flesh, and many fruits, and in tubercles, lie surrounded with their nourishment; so, in like manner, the young Frog swallows its food, at this time, through its mouth, as they do. There is however this difference, that the young Frog is nourished while it yet lies in the integument or coat of its eggs; and this I could never observe with respect to any other insects. The insects, in general, lie in the coats of their eggs, in the same manner as Butterflies do in their Caterpillars, and only increase in strength. Therefore, I do not doubt but the young Frog is provided with umbilical vessels, of which matter I shall afterwards treat in its place.

N<sup>o</sup>. iv. I represent how the hinder legs *ii* are observed to increase in the Tadpole, or young Frog; that is, whilst they insensibly spring out of the body, as the cups of flowers from out of their footstalks, or as the cases wherein the wings of insects are at first deposited: so that the young Frog is, in this respect, very like those little creatures described under the second order; though it again differs from them, in that it is produced from the egg in form of a footless Worm.

I likewise observe, that about this time the young Frog's fore legs are insensibly increased and augmented, under the skin, in such manner as I have before explained, in regard to the Worms and Caterpillars of the third order. For this reason one may likewise plainly distinguish, with the naked eye, the rudiments of the legs, if the skin be then opened in that part. And this is likewise the case in all the Worms and Caterpillars just mentioned, as I have occasionally exhibited in the former tables.

Tab. XLVI. N<sup>o</sup>. v. I here represent, to the life, how all the limbs of the young Frog have

\* There is scarce any animal which has the principle of life so strong as the Frog. It will continue moving many hours after the guts are taken out. An Eel is celebrated for this strength of life; but the Frog exceeds it greatly. No creature is so truly amphibious; for it will live for a length of time equally well on land without water, and absolutely immersed in water. A Frog has been tied down under water many days, and received no hurt, nor suffered any seeming inconvenience.

at length arrived to perfection, by a slow increase. The two fore feet are seen *kk* still lying under the skin; but the two hinder legs project beyond the skin, *ll*, though they are, in reality, still invested with the skin of the Tadpole, which they afterwards are to cast off. This skin is dilated and stretched out with the growing feet, as is likewise the case in insects of the second and third order. Hence it is, that I really very properly give the young Frog, in this form, the appellation of the Frog's Nymph, which it seems may be likewise referred to the second or third order. But as the young Frog, while it is under this form of a Nymph, still seeks its food, and moves about, it therefore approaches much nearer to the insects of the second order, than to those of the third; for this reason, it likewise casts its skin in moving and swimming, and brings to view its fore legs, then resembling those of a perfect Frog; though it still, for a long time, keeps its tail, which afterwards shrivels up by degrees, and, finally, dries away.

N<sup>o</sup>. VI. I show how the Frog, having gradually gone through the forms of an Egg, Worm, and Nymph, at length has attained its

perfect maturity, and appears fit for propagating its species, in the same manner as insects and vegetables, and thus is able to continue its generation. It must be observed here, that the Frog is not absolutely perfect, or fit for generation, immediately after its metamorphosis. By no means; for, unless I am greatly mistaken, this creature does not acquire that degree of perfection until two or three years. The Frog, therefore, differs in this double respect from the sanguiferous animals, and from insects; most of which are perfect in one or two hours after their birth, or after their metamorphosis from Nymphs, and then likewise immediately obtain their full size and maturity, and at the same time become fit for the office of generation. The Frog which I here express, of full age, is the male; as one may very certainly know from those two vesicles, Tab. XLVI. N<sup>o</sup>. vi. *mm*, which are situated behind its eyes, and are never to be found in the female. There is moreover another certain sign, whereby the male may be distinguished from the female; but that I shall describe and delineate in a particular history, which I shall subjoin to this general account.

#### *Man himself compared with insects, and with the Frog.*

IT is evident from comparing the Frogs, as we have just now done, with the insect tribe, how the sanguiferous animals, or such as have red blood in their vessels, are, in respect to their changes, like these smaller creatures. Indeed this likeness proceeds so far, that it extends under many names, even to man himself: for all the works of God seem to proclaim, only one foundation of propagation and increase.

I first observe, that it is clearer than the light at noon, that man is, like insects, produced from a visible egg, which, after being impregnated, is brought forth: that is, it is by a local motion conveyed out of the ovary through a tube into the uterus, which is the place wherein man, that rational animal, finds his first nourishment, and represents, as it were, a Vermicle or Worm, or, to use Harvey's words, a Maggot lying in the egg.

Secondly, The membranes which then invest the Infant-Man, are there likewise dilated, in order to receive an aqueous humour conveyed from without to the Man-Vermicle. Therefore, the human egg likewise resembles the eggs of insects, in that the latter dilate, nay, break open their coats, in order to get elsewhere the nourishment which they do not find in their egg.

Thirdly, We observe, that the Vermicle or Maggot of Man, as well as the Vermicles or Worms of other insects, have not completely perfect limbs; therefore it is increased in size, even from the beginning, till its limbs project at length out of the skin, and its umbilical cord is divided into two arteries and one vein, which take root in the internal surface of the uterus, and constitute the placenta, or after-birth.

Fourthly, It is very clearly observed, that these parts of the Man-Vermicle grow by degrees into a head, thorax, belly, and limbs. In the head, the coloured eyes are very distinctly seen through the skin; but they are more conspicuous in the beginning than afterwards, when the skin becomes thicker; for then they can be no longer seen. But it is indeed very admirable to observe, how the limbs sprout about the shoulder-blades, and at the lower parts of the body: for, in the beginning, they resemble the small cups of flowers just budding, or the bags and cases of the parts of insects; the former enclosing the flowers, and the latter the wings; and then, by degrees, just as the legs of Frogs, they grow out of the body, and are divided into joints.

Fifthly, We observe further, that all the limbs of the Man-Vermicle, in time, acquire their due perfection, and are strengthened to such a degree, as to be able to break out of the uterus, and to disengage themselves from all their integuments. And hence this first state of man likewise resembles an insect, in that it hath, under the form of a Chrysalis or Nymph, acquired all the strength requisite to change its skin, and appear like a perfect creature. Man therefore, as on the point of his birth he does, like insects, throw off and lose several very considerable parts, may indeed be deservedly called, at that time, a Nymph; since he then is to cast off his umbilical vessels and placenta, together with the skin and the amnion.

Sixthly, This tender and new-born creature leaves the uterus, in the same manner as the Ephemerus and Libella, that have cast their skin, and leads a new life, and has a different nourishment.

ment. The infant-man, who lived before in the water of the amnion, now breathes the vital air, which rushes into his lungs, and dilates and extends them. But this miserable creature is very far from meeting with such good fortune, as the Ephemerus and Libella, which are in an instant brought forth absolutely perfect. On the other hand, his appendage of misfortunes and

trouble, like the tail of the Frog, yet adheres for a long time to him, for he is full of misery, and is born in tears; and it is very long before he comes to maturity of understanding, and full growth of body. It is now time to come to the singular history of the Frog; which is highly worthy of consideration.

*A particular treatise on the generation of Frogs.*

HAVING hitherto premised only general observations, and such as tended to explain the figures in Tab. XLVI. I shall here treat particularly of the generation of Frogs, and describe the genital parts of the male and female, and shall add some other observations, I hope, of some use. I would, on first setting out, inform the reader, that there is a much greater number of miracles, and natural secrets in the Frog, than any one hath ever before thought of or discovered; as I shall evidently demonstrate, when I shall have opportunities to describe particularly the whole history of that animal; and I am now here to explain a great part of it.

The genital organs of the male are the testicles, the vasa deferentia and seminal vesicles. The testicles, Tab. XLVII. Fig. 1. *aa* are placed in the loins, and being there situated over the kidneys themselves, *bbbb*, are furnished with arteries, veins, and spermatic vessels. Their figure is not constantly the same, but is sometimes observed to be more oblong, sometimes more round, and sometimes lunated. Some yellow appendages always adhere *c* to the upper part of the testicles; and these appendages are sometimes single, *d*, sometimes double, *e*, and at other times triple or quadruple. These little parts likewise have their blood vessels, and consist of several bags joined together, and containing an oily or fatty matter; and enclosed in so many oblong common membranes, produced like appendages. I have likewise sometimes observed, that this oily matter was joined to the coat investing the testicles, and diffused through half their surface. A kind of similar, but white fatty matter, is observed in Rats, and several other animals.

These appendages may be examined with great ease in Frogs, that are not bigger than the first joint of one's thumb; for, by the help of a microscope, we then distinctly perceive, that they consist of a congeries of minute spherical and membranaceous particles, full of a yellow, oily, or fatty substance; but these particles are too small to come under the cognizance of the naked eye, to which they only appear as a bright heap of transparent gold dust.

The testicles are generally yellow, with many blood vessels elegantly variegated with black, beautifully running through the coats that invest them, Tab. XLVII. Fig. 1. *f*. On stripping this coat from off the testicles, they appear to consist

entirely, as it were, of small globules, *gg*, but by making this separation slowly, and by careful degrees; we may clearly perceive, that these apparent globules are no other than the heads of so many feminal ducts; some of them double, *h*, or divided into branches, that rise all to the center of the testicle. In Frogs, therefore, the testicles is composed of seminal vessels; and I have discovered the same to be the case in many other animals, as the cuts I have occasionally given demonstrate.

Some pretty considerable seminal vessels, *ii*, rise from the internal side of the testicles; part of them single, and part divided into branches, which convey the sperm, as it were, by so many different streams from the testicles: this may be easily seen, on compressing or squeezing these last parts ever so little; for then the seminal vessels, first mentioned, fill with a pale white sperm. These seminal vessels, or natural divisions of the parastata, run by degrees towards the kidneys; upon which the testicles lie, and, after passing through the coats of the kidneys themselves, and forming a variety of divisions, *kk*, they at length discharge themselves into the vasa deferentia, which are seated near the internal edge of the kidneys, *llll*, and are there united with the feminal vessels already taken notice of.

We must here duly observe, that the kidneys discharge their urine by the vasa deferentia, thro' which the testicles, in copulation, eject their sperm: as in man, the sperm and urine are discharged through the same urethra. In man, indeed, there is but a single vas deferens, distinct from the ureters; nor has this urine any such passage; whereas, in Frogs, the great Architect has thought proper to make the same vessel serve both these purposes; and this, perhaps, he ordained, because it was proper to contract or abridge the number of parts that were to be placed in so small a body, and likewise because the Frog was to evacuate its sperm only once a year\*.

In the midst, between the two kidneys, are to be seen the arteries, and emulgent or kidney veins, Tab. XLVII. Fig. 1. *mm*; these I have but rudely designed. They are distributed all over the surface, and through the substance of the kidneys, by so many ramifications, that great circumspection is necessary, not to confound the seminal vessels, just described, with these blood

\* The animalcules in femine, are seen more easily and distinctly in the sperm of the male Frog, than any other way. They who doubt the existence of such animalcules, (for it is at present a fashion to doubt them) have not examined the male sperm of this creature. The proper season in England is the first week in April. The vessels are then full of the fluid, and these animals are innumerable in it.

vessels. Beneath the testicles, and under the skin of the kidneys, there lie two other singular, and strange bodies, *nn*, but I neglected duly examining them.

The vas deferens grows smaller by degrees, so as to form but one trunk, *oo*, but soon again it dilates considerably, and in this part we may distinctly see the seminal vesicles lying against it, *pp*. These vesicles do not differ in construction from the correspondent vessels in man, and other animals, except in regard to their being of a more membranaceous substance. They open into the vasa deferentia, and convey to them from a great many little cells, an aqueous seminal fluid, which is perhaps the vehicle of the true sperm. In fine, both these vesicles, and the vasa deferentia are inserted into the surface of the rectum, *qq*, directly under the bottom of the urinary bladder, where I have represented both their mouths, by two openings *r* that appear through the straight gut. Upon this last intestine lies a double urinary bladder, *ss*, into which the urine is conveyed by those ureters, which at the same time perform the office of the vasa deferentia. When first I discovered these vasa deferentia, I immediately searched for the ureters, with a great deal of attention, as I could hardly think, that a vessel of such importance could serve two such different purposes. But I afterwards found, that the ureters of the female Frog, were constructed in the same manner as these vesicles in the male; and by this discovery, I became thoroughly acquainted with all these parts. I have accordingly exhibit them, as they appeared in the smaller Frogs, as may be seen by inspecting the second figure.

It is now time to say something of the genital parts of the female: these are an ovary, uterine tubes, or horns of the uterus, and the uterus itself. The ovary lies upon the uterus, with which it is always united; and near the same place are the fatty appendages, which I described in the male Frog, when I treated of the genital parts. The ovary, which is always double, equally occupies the right and left region, and is constantly found subdivided into lobules. I have seen them, to the number of five, on a side in some Frogs. Nature, however, does not always observe the same order in this particular, except that the ovary never appears, but divided into more or less of these parts. The blood vessels are principally distributed through these divisions of the ovary, Tab. XLVII. Fig. III. *a*, and afterwards they diffuse themselves all over it. Each lobule is hollow, and wrapped up in its own particular coat; so that, by fixing in a little tube, *f*, it may be easily distended with air, and separated from the neighbouring lobules, *b*. This must be done very cautiously, because this coat is so tender, that anything of a rough blast would burst it. We may then plainly perceive, that all these lobules are confined, each to its own limits, and have not the least communication one with another.

As the coats investing the lobules of the ovary are so very delicate, the eggs may be seen thro' them distinctly, *cc*: a person that was not very cautious, by directing his eyes and hands to this

part, might easily fancy to himself, that the eggs lay on the outside of the ovary. These eggs are black, and perfectly round, and generally they have a white or yellow spot in the centre. They lie close to the internal surface of the coats or membranes that constitute the lobules of the ovary, and are fixed there by the blood vessels, as it were, by so many short little stalks. This circumstance is very visible, in cutting off one or two of the lobules of the ovary, *d*, for then the enclosed eggs shew themselves most distinctly.

But this experiment cannot be conveniently made, unless about the beginning of March, or a little afterwards, as it is chiefly at that season, that the ovaries abound with perfect eggs: this is moreover the properest time for examining the genital organs. On examining carefully the ovary at this period, we may likewise find in it a species of eggs different from those I have now described. These are smaller, white at first, and when pretty well grown, yellowish. These last eggs, however, are only the rudiments, not yet perfected; and therefore, they remain in the ovary, after it has disburthened itself of all the perfect eggs. But before I treat of this operation, I think proper to describe the uterine tubes or horns.

In Frogs, these tubes arise very high in the breast, from whence they stretch in the middle, from one end of the abdomen to the other, and terminate in the uterus, with which they lie concealed in the lower part of the belly, but so as to be able to move higher, according as the uterus dilates or contracts itself. Every Frog has two such tubes, which are placed, one at one side of its body, and the other at the other side.

Properly speaking, the superior part of the tube lies near the heart, and is connected on each side by the ligament, by which the liver also is suspended. In the same place, where part of the peritoneum passing freely over the heart and pericardium, forms with the liver a distinct cavity, in which the heart, wrapped up in its pericardium, lies under the breast bone, as in the hollow of the mediastinum or diaphragm. To see all these particulars distinctly, it is necessary to lay open the Frog's belly a little higher than the extremity of the breast-bone, where this bone degenerates into a cartilage; then cut off the membranaceous parts; and lastly, turn over the breast-bone upon the head, and secure it in that posture with a pin, Tab. XLVII. Fig. IV. *a*. Thus we discover a considerable cavity above and about the point of the heart, *b*, in which the heart lies hid with its pericardium, under the breast-bone, as within the diaphragm. At the same time, we may see on each side of the heart, the extreme ends or natural openings of the tubes, *cc*, which most firmly and immoveably grow there to the peritoneum, and to the ligament, by which the liver is suspended, so that they cannot reach to the ovary, which lies at too great a distance from them. Besides, these tubes are very slender and delicate. They bend a little, especially where they lie upon the lungs; for they stretch over the lungs and the liver, where they arise from very slender membranaceous beginnings. For this reason, they

always

always are ready to collapse, and are only discernible by those who have accustomed their eyes to such inquiries by frequent dissections. Such persons can readily demonstrate, or produce them, even without blowing them up.

The remainders of the tubes are most elegantly curled, and folded up, as it were, in a great many wonderful plaits, *dd*. And indeed, the shortness of the animal's body could not admit of any other construction, these tubes being so very long, that, on measuring a single one, seated on one side of the body, I found it to be upwards of two feet. All these beautiful foldings and windings of these tubes, are connected by means of a slight membrane, through which there run a great number of blood vessels, *e*, in a very orderly manner.

The extremities of these tubes open by wide mouths, *ff*, into the two sides of the uterus. These mouths appear circular when dissected, after they they have been inflated and dried; but they are oval when the parts are any ways moist, as they then collapse. The uterus itself is double, *gg*: it is of a membranaceous substance, and is elegantly overspread with blood vessels. When full of eggs, it wants very little of being spherical in shape; but when inflated, it is rather oblong, and shaped like a pear: the introduced air gives it a somewhat different figure. Finally, the uterus terminates at each side of the body, in the rectum, about half an inch from the place where the tubes are inserted into the uterus. In all Frogs, the straight gut *b* is placed between the right and left portions of the uterus, and shews on its forepart the bladder, which is likewise double in this place, *i*. I have here mentioned nothing, that I have not distinguished with my own senses in a Frog, which had discharged its eggs, about half an hour before I dissected it.

The same figure likewise represents the contracted ovary belonging to the left side, *k*, seated at a great distance from the mouth of the tube, with one imperfect egg, which had not as yet disengaged itself, but remained entangled with the ovary. One of the kidneys likewise may be here in part seen, *l*, together with the pinguiferous appendages of the ovary, *m*. I also exhibit two eggs which I found loose in the abdomen, *n*, on account of their straying from the mouth of the tube, in the act of copulation. The tube itself also still contained another egg, *o*, fallen into it, after all the others had been conveyed into the uterus. This was very plain from this egg's not as yet having any white. The stomach, *p*, and also the small guts appear in their natural situation; and a portion of the liver, *q*, and some of the finest blood vessels, are distributed over the surface of the stomach. On the side of the liver, I represent the gall bladder, *r*, and the lungs with their vessels, *ss*. I made an incision into one of the parts, to let the air in it escape, that I might the more clearly exhibit the course and opening of the tube; the other, on the contrary, being the right, I exhibit as it appeared distended with air. The auricle of the heart is represented, *tt*, divided by a membrane

not unlike a valve; it is transparent. I next shew, in the same place, the separated parts of the abdomen and breast, *uuu*, interspersed with some muscles, having endeavoured as much as possible to shew all these parts in one and the same figure, and of their natural bigness.

Here I cannot omit the opportunity of illustrating the account of Oligerus Jacobæus, who owns he could not discover the opening of the tube, and of shewing him at the same time how much he was mistaken in thinking, that the tube was inserted into the straight gut, which he has represented in an imperfect drawing. I shall transcribe his words, especially as he has thought proper to charge me with the error which himself committed, a proceeding to which he was perhaps prompted, by the flatteries bestowed on him by the younger Bartholin, who extols, in the most disgustful manner, this author, and his treatise on Frogs. But his panegerick serves only to prove, that he understands nothing of the most curious branches of anatomy; otherwise he would be more cautious, not to censure in so supercilious and dictatorial a manner, performances which he has not sufficient abilities to understand. For this reason also, he appears a great deal more solicitous about the external appearance, than about the real nature of the subjects he takes in hand. This may evidently appear by his treatise on the diaphragm, in which he has been at more pains to express neatly, his own face and hair, than to make the figures of the things he treats of plain and intelligible, as if the learned were in love with his countenance.

The words of the illustrious Jacobæus, in his observations upon Frogs, are as follow: "This tube, in the upper part, hides itself in the region of the heart, liver, and lungs; but where it afterwards stretches its course, I cannot tell, as I could not get the air I ejected for that purpose; to ascend any higher than this part. Below, where it runs under the ovary, it dilates into a pretty wide oval mouth, and branches into fibres that unite with the kidneys and ovary, whilst the rest of it is inserted into the straight gut, about a thumb's breadth from the oval mouth just now mentioned." He afterwards adds, "Swammerdam, though very clear sighted upon every other occasion, does not seem to have taken notice of this oval mouth, when in his treatise on the construction of the womb in women, he says, that in Frogs, the motion of the egg from the ovary, to the tubes and arteries, is more obscure, as he tells us, the orifice of the horns of the uterus, or of the tubes, are about two fingers breadth distant from the ovary, and that not only their orifice is very narrow, but the part also is unmoveable; and further, he denies that it lies close to the ovary, as in the females of the human and feathered species."

We may reasonably imagine, this learned author did not so much as think of any part of the uterus; for he does not, in his whole treatise, make the least mention of that part, and affirms, that the tube is inserted into the straight gut; whereas, on the contrary, it is the uterus itself that is inserted into that intestine, and by no

means

means the tube. Besides, the ovary of Frogs is never found to have naturally that figure, which Jacobæus very rashly gives it, though it is to be observed, that the uterus, when loaded with eggs, is found on dissection to have, in some degree, such an appearance. Therefore, the oval ostium, or mouth, which this author mentions, is, in my account, really the opening of the tube into the uterus, which, properly speaking, shews itself where the tube ends, and the uterus commences. See Tab. XLVII. Fig. iv. letters *ff*, where I have at large described all these parts.

Such being exactly the case, and it being at the same time certain, that the inferior extremity of the tube has no communication with the ovary; and that no eggs can enter there from the lobules of the ovary, which are perfectly closed; and as likewise M. Jacobæus could not discover the upper orifices of the tubes, I would be glad to know in what manner this author can explain the passage of the eggs from the ovary, into and through the tube. I really cannot conceive how he can acquit himself of this task; so that he has in good earnest made the motion of the egg, from the ovary more obscure, than he is pleased to fancy I had done. But I, by no means intend to enter the lists with this gentleman, or imprudently treat him with rough language; for it is not in search of glory to ourselves, but the great Creator, that we ought to survey and examine his works. For this reason, I rather look upon myself as under an obligation to this illustrious naturalist, for having condescended to criticize, and bring to the test my experiments concerning Frogs; and, in the same spirit, I must tell him, that he can never miss finding the opening of the tubes near the heart, provided he looks for it a little after the Frogs have deposited their eggs. At this time, even the whole uterus may be distended with air through the tube; and, on the other hand, from below, upwards, the tube thro' the uterus. What is still more, these openings of the tubes may be then discovered without any dissections, by only blowing slightly through a pipe in the adjoining part of the heart. But none of these experiments will succeed, whilst the eggs are only in their passage through the tube, at which time, perhaps Jacobæus surveyed these parts. Thus the natural opening of the tube becomes very discernible to those who take a right method to discover it. But is it not surprising, that the description given by me, and which Jacobæus must have seen, as he quotes it, did not open his eyes; for, though short, it is very plain and intelligible. Mankind is liable to error; but, to persist in it, after friendly admonition, shews a perverse arrogance, that will not submit to acknowledge its mistakes.

It is now time to speak of the egg's passage through the tube, from the ovary into the uterus, which is indeed not only difficult to express in words, but even to conceive, so that in the whole science of anatomy, equally abstruse and mysterious, I must own, that this is very ob-

scure in many other animals, but in Frogs, it is altogether incomprehensible; for the ovary, as I remarked above, and am ready to demonstrate in the Frog itself, does not in any way communicate either with the tube or with the uterus. The opening of the tube cannot by any means move itself towards the ovary. Besides, there are no other mouths at which the eggs can be received, than the narrow membranaceous orifices of the tubes, which above grow to the membranes of the heart; so that there does not appear in this place the least trace of any oval mouth, by which it is said, that the tube opens itself about the inferior region of the ovary; for it is very easy to separate the tube and ovary from one another: and the ovary afterwards extracted from the body, may by itself be distended with air, and dried, not having the least aperture to let the air escape, or the least mark of ever having had one.

I have sometimes distinctly observed in breeding Frogs, that whereas the ovary of one that I dissected, about the beginning of April, still contained all its eggs; that of another, opened a few days afterwards, had lost the greatest part of them, Tab. XLVII. Fig. v. *a*. I could likewise, at the same time, easily discover a great many of the eggs that had escaped out of the uterus, and were broken, lying here and there in the abdomen *bbb*, between the lungs, and under the sinuses of the stomach and intestines, among the membranaceous parts of the viscera, and elsewhere. Some also appeared near the opening of the tubes *c*. Others were still adhering to its inside *ddd*, part in its higher, and part in its lower region. I even discovered an egg lying at the very mouth of the tube *e*, and in what manner the eggs were leisurely forced thro' the extremity of the tube into the uterus *ff*. I observed also, that the greatest part of the eggs still adhered to the uterus; which I here represent two ways. First, I exhibit the uterus as it naturally appears *g*, with the contained eggs visible thro' it, but very faintly; and on the other side I represent it as it looks, after having been macerated in water, or on its beginning to dry, after being exposed to the open air for some time; in both which cases it very distinctly shews the eggs shut up in its cavity *b*. I represent besides, lower down, the extremity of the double uterus *i*, which is inserted into the straight gut, about half an inch from the opening of the tubes into the uterus. Near the heart appears the beginning of the great artery, with two smaller arteries springing from it *k*. On each side, near the heart, are openings of the tubes *ll*; and I have represented the lungs as bearing upon these openings *mm*, in order to render their situation next above the lungs more distinctly perceivable. It is very remarkable, that living Worms are almost always found in the lungs of Frogs; I have often met with six in one Frog.\*

\* Naturalists have been perplexed extremely to account for the Worms found in the intestines; but these are much more strangely situated. They cannot have been swallowed in food by the Frog, for this would not be their place. The opinion of Vallisneri is, that the Worms found in our intestines, were created with the human frame; and that the bowels are their natural and proper place of living: it is much more strongly probable here.

These Worms are, on their fore part, pretty like *Lumbrici terrestres*, or common Earth-worms, but on their hinder part they are somewhat thicker, and they generally lie in plaits and folds within the lungs. In size they differ but little from the Worm that gnaws or corrodes the shell of the common Wilk. Their colour is a yellowish white, except that they are black towards the tail, which variety in colour proceeds from that of the food they have taken into their bodies. They have their mouths constantly fixed to the internal membranes of the lungs, from which they suck the blood. On separating them cautiously from these membranes, we may discover in the membranes a little opening made by these insects, and even a small quantity of blood discharged from that aperture: the mouth also of the piratical Worm appears bloody, if immediately inspected. These Worms appear to have another aperture in their breast, which however I did not sufficiently examine. I omitted also taking a survey of their inside, except that I observed some great and small guts, and some distinct particles; but the insect's skin being transparent, these particulars could be seen without dissection.

Other kinds of Worms are often found also in the lungs of Frogs. These are like bristles, with sharp heads and tails, and they coil themselves up. In colour they differ little from the first kind, only that on the inside of their bodies they shew thro' their transparent skins, some of their intestines in the form of a little thread or line of a dusky brown. On opening both these species of Worms, immediately taken from the Frog, I found in them a great number of small particles wrapped up in an oblong membrane. On observing that these particles were not only all of the same size, but were likewise regularly placed as in an oviduct, my curiosity led me to examine them with a microscope, by which I at length convinced myself that this prodigious number of particles was no other than so many roundish, or oblong eggs, in which also there was a very discernible motion. This induced me to open some of them. But how great was my surprise on finding, that every egg contained a minute but perfect Worm lying folded up in it, like a young serpent in its egg! Even these little Worms, when extracted from their eggs, moved themselves exactly in the same manner with the parent-insect. This was an undeniable proof, that this Worm was both oviparous and viviparous; thus propagating its species in the most surprising manner. But I return to my proper task; for this little animal, tho' no longer than a young Frog ten days old, contained too many miracles to be published in a few pages.

To return therefore to the Frog itself, what I have said sufficiently shews, how the eggs are dispersed, when they break the ovary, and from thence roll into the cavity of the abdomen. But I would fain know, by what art, regular motion, or contrivance an egg lying

thus loosely in the body, can be conveyed into a narrow tube, whose opening is placed very high up near the heart? Certainly, the best thing we can do on this occasion, is to own such a conveyance utterly inconceivable by human understanding, and humbly to acknowledge the narrow limits of our faculties. It cannot be denied, that at this time, the ovary is distended very much towards the upper parts of the belly, by the great size and number of the eggs it contains; nevertheless, the eggs which possess the lower part of the ovary, never lie nearer than within two fingers breadth from the opening of the tube; and in the largest Frogs, they are at a greater distance. Let us suppose them ever so near the tube, who will tell us how they can get into the opening of it, which some of the best anatomists could not discover. The eggs have no motion of their own; nor are there any muscles in the way to move them. I therefore conclude, that this motion of the eggs of Frogs lies hid in a mysterious darkness, too thick for human understanding to penetrate.

But however incomprehensible this motion may be, we may derive from it great light into the motion of the eggs in women, in whom this tube is moveable; so that it can apply its mouth to the ovary, in order to receive the egg falling from this last part, a thing which that industrious anatomist Bidloo saw, and procured a drawing of. I have myself observed more than fifty times in Frogs, that the eggs which had broken loose from the lobules of the ovary, had insinuated themselves into the tube, and thro' the tube into the uterus; nor do I see any manner of difficulty in conceiving how in any animals the egg once got into the tube, should from thence pass to the uterus, the difficulty entirely lies in the passage of the egg from the ovary to the tube. In the Frog there is all the reason in the world to call this motion a miracle; indeed, there is nothing to hinder us from giving it the same appellation in all other animals. The causes of wonder are the same in all; and in general, the motions of eggs serve most manifestly to prove, that the human understanding is confined within very narrow bounds.

I have sometimes counted upwards of eleven hundred eggs in one Frog, all which are to pass thro' the narrow, immoveable mouths of these two tubes; nor can such passage be looked upon as an easy matter, as these tubes scarce deserve to be considered as simple channels, but rather as the horns of the uterus, which other animals exhibit. The white of the egg is formed in them, to surround the Frog's egg, or fœtus, and afford the young animal nourishment for some days in the same manner as the colliquamentum, or white, does the Chicken. On this account also, it is impossible to distend these tubes with air at this time; it is even a difficult matter to alter, even by squeezing with the fingers, the situation of the eggs at that time fastened within the tubes, the matter supplied by them, for the nourishment of the Frog's fœtus, which it most regularly

larly surrounds, being very clammy and glutinous. For this reason the eggs do not pass fast, or easy thro' the tubes, but very leisurely, and by slow degrees, and chiefly by the action of the muscular fibres administering to the tubes, which little by little push the egg and its nourishment into the uterus.

I find this white of eggs to be a very nourishing substance ; for which reason, when I had young Frogs to rear, I used, as often as I wanted, other food that was proper for them, to take a tube from the body of a female Frog, and give it to them cut into pieces, which they immediately fastened upon, sucking eagerly the juices that flowed from thence. This matter even dissolves, and diffuses itself in water, like the white of the Frog's egg, being of a similar composition and substance : hence the tube itself, on being just thrown into water, becomes by degrees eight times as thick as before : but this experiment must be made within a few weeks of the eggs passing thro' the tubes, as afterwards they contain no more of the white or albumen.

This tube, no doubt, is furnished with its glands ; tho' as yet I have not had the satisfaction of seeing them distinctly. I observed, however, that the tube on its inside is thoroughly lined with a regular reticulated glandulous coat ; from whose pores the albumen, or white is secreted. Behold what, and how many wonders appear in the Frog only ! But we ought not to content ourselves with a single experiment ; we ought to try every thing that appears, and in every manner in which it can be tried, to acquire a perfect knowledge of any thing we desire to be thoroughly acquainted with.

It is no easy matter to determine whether the uterus contributes also to the generation of the white of the egg, and the full perfection of the egg itself, or only serves to collect all the eggs, and eject them at one and the same time. To me it appears probable, that the uterus serves merely as a receptacle for the eggs. It differs greatly from the tubes, as it is membranaceous, and in part fibrous, or composed of, or furnished with many fibres ; but it is no ways glandular, for which reason it is always found in a contracted state, and never exhibits itself distinctly, but when naturally distended with eggs, blown up with air, or injected with some kind of liquid. It is even impossible to distend it by macerating it in water ; so that upon the whole, no two things can be more different than the tube and the uterus.

The eggs, as I said before, at the time that the Frog is to discharge them, break loose from the lobules of the ovary, to the insides of which they adhered, and are forced by I know not what motion thro' the cavity of the abdomen into the open mouths of the tubes ; but I cannot exactly determine how much time may be requisite for this passage, as the Frog is very far from being transparent like some other animals. It may not, perhaps, be impossible to observe this process in some other species : ne-

vertheless, the knowledge of this truth could then be only analogically obtained.

About the same time we find that the testicles and spermatic vessels in the male Frog fill with sperm. These animals become then so eagerly intent on the business of propagation, that they take no care in a manner of their own safety ; so that they may be easily caught with the hand. I believe that they eat nothing, or very little, during this fit of lust, which lasts more or less time, according to the heat of the weather.

To carry on the intercourse of the sexes, which this great work requires, the male Frog leaps upon the female, and when seated on her back, he fastens himself to her very firmly. For this reason, the Dutch country boors, with great propriety, tho' in their vulgar way, call this manner of copulation, the riding season of the Frogs, as the male is carried about, riding, as it were, by the female.

It is necessary, those who intend to dissect this insect, should know how to distinguish the male from the female. I have observed two marks by which this distinction may be made. In the first place, the male has two air bladders, which he expands in croaking ; and the mouths of these bladders are seated on the sides of his jaws. These bladders consist of two membranes, which may be easily parted, and separately distended with air, and so preserved. One of these membranes is a continuation of the external skin ; the other a continuation of the membrane of the palate ; and this last is furnished with blood vessels and muscular fibres, which serve to contract and dilate these bladders. Properly speaking, the orifices of these bladders lie in the upper region of the mouth, where the gums are seated in men ; and near them, within the mouth likewise, are to be seen the orifices of the organs of hearing, or of the animals ears. The tympanum, or drum of the ear, lies withoutside, immediately under the skin. The same construction obtains also in the Chameleon.

The other mark of the male Frog is furnished by the animal's thumb, which is very thick in the males, Tab. XLVII. Fig. VI. *a.* perfectly black in some kinds, and covered with a great number of papillæ, *b.* which are likewise of an extreme blackness, and constructed in the same manner with the papillæ on the tongues of oxen. These papillæ become rough in drying, and, like the rough skin called shagreen, feel very rugged ; their use I shall presently describe.

The males, at the time of copulation, leap on the females, and they continue sometimes on their backs, for forty days successively, according as the season of the year is more or less cold, and the eggs take up more or less time in their passage to the organ that is to shed them. Sometimes these animals continue together in this manner even for a much longer time ; as when the female is weak or sickly, and the eggs on that account descend more slowly through the tubes to the uterus, or when they meet with delays in the abdomen or uterus, as I observed in some Frogs, whose intercourse lasted a very long time.



The very moment the female has deposited her eggs, the male forsakes her, having performed the task, for which this lust was so wisely designed.

This wonderful copulation is performed in the following manner. As soon as the male has leapt upon the female, he throws his forelegs round her breast, Tab. XLVIII. Fig. 1 and 11. *aa*, and closes them so firmly, that I found it impossible to loosen them with my naked hands without wounding them; so that I found myself under a necessity of introducing an iron spatula, between the female's breast and the male's legs, the better to separate them. The male most beautifully joins his toes between one another, in the same manner as people do their fingers at prayers. His head rests on that of the female, *bb*, but in the hinder part, his body hangs a great deal lower than her's, as he lies so much more backwards than she does: this posture has its use, which I shall hereafter relate. The thumbs of the male's forefeet press with their thickest sides against the breast of the female, and the extreme joints of the thumbs are bent a little.

Let the female shake herself ever so much at this time, the male never lets go his hold, even tho' she should get out of the water, so that one may carry them any where in this posture; which is likewise the case of garden Snails, when engaged in the same business. Such is the male's eagerness to act his part, that he is not to be parted from his mate, even by pulling him forcibly from her by his hind legs. Thus these little animals swim, creep, and live together for many days successively, till the female has shed her eggs, which, at length, she does in a manner instantaneously. I observed, that when they breathed, during this intercourse, the external skin, which immediately covers the drum of the ear that lies under it, near the eyes, Tab. XLVIII. Fig. 1. *cc*, continually heaved up, and then fell again against that organ of hearing; and this alternate elevation and depression affords a pretty spectacle, when they both breathe, and open and shut their nostrils by turns.

It may be asked, at what time the male leaps upon the female? Whether it be before the eggs have passed through the tubes, or after this, when they are already heaped up in the uterus? But this circumstance I omitted to examine. However, I cannot help delivering it as my opinion, that the male ascends the female when the eggs have been taken up by the tubes, and some of them have begun to adhere to the uterus. My reason for thinking so is, that otherwise the male might defeat all his endeavours, by compressing and closing with his arms the mouths of the tubes. Perhaps, also, it is for this reason, that sometimes some of the eggs remain in the abdomen, after the others have been ejected. But a certainty, in these cases, might be easily obtained by dissection.

When, therefore, all the eggs of the female are got together in her uterus, the tubes are quite empty; and when every egg has received its coat of white in these tubes, or in the horns of the uterus, she throws them all out together by a single effort; and, while this is doing, it may be observed, that the male acts the part of a midwife, and promotes the expulsion of the eggs by working with his thumbs, and compressing the female's body harder with his fore legs. Thus, at last, the eggs are discharged at the female's fundament in a long stream, *d*; and the male, who has no penis, immediately fecundifies, fertilizes, or impregnates them, by an effusion of his sperm, which he likewise discharges at the anus, *e*, \*. But as the eggs, rendered very clammy and glutinous by the white that invested them, have grown together, had been compressed in the uterus, they immediately, on being cast into the water, expand themselves into their former round form, *f*. Hence appears the necessity of the hinder part of the male's body hanging more backwards than the female's. As soon as these eggs have escaped from the female's body, between her's and the male's hinder legs, and have been impregnated by the male's sperm, the two Frogs abandon each other. The male swims off, and works his fore feet as before, though they had continued so many days successively, without the least motion, in the most violent state of contraction.

The eggs thus dropt, immediately sink to the bottom of the water, unless hindered by weeds that grow in ditches, or the like; and in a few days they return to the surface again, if not stopped in the same manner. I opened a female about two hours after she had discharged her eggs in a glass vessel, where I had kept her for that purpose, and found the ovary perfectly contracted, as I have represented it in the fourth figure of the forty-seventh plate, under the letter *k*. Besides, there still remained some eggs in the abdomen, one in the ovary, and one likewise in the tube.

Upon my proceeding, after this, to examine the ovary, which was emptied of its eggs, I discovered, in dissecting the body, three different species of muscles; namely, straight ones, intersected by four lines, and oblique descending and ascending muscles, lying under the former. When I had laid open the abdomen, I observed a very remarkable singularity in the ovary. In the first place, I could discern in it eggs of four different sizes and colours. Some of these were very small and white, Tab. XLVIII. Fig. 111. *aa*; others a little bigger, and yellow, *b*; a third kind was a good deal bigger still, *c*, and of a dusky colour. There were likewise in this part a great many black little spots, *d*, which, at first sight, I took for so many eggs; but the microscope proved they were irregular particles, or eggs beginning to decay.

\* It had been supposed that this method of impregnation was peculiar to Fishes; but this is one instance of the contrary. Something nearly analogous is the case with the Water-Newt, and probably future experiments will shew it in other water animals.

On opening afterwards some of the lobes, all the foregoing particulars appeared still more distinctly; the cause of the blood-vessels amongst the eggs being very discernible, *e*, as likewise the manner in which the eggs were placed upon the smaller ramifications of these vessels. When I had attentively surveyed and considered all these things, I judged them to be the rudiments of the eggs, that were to be shed the ensuing season; tho' afterwards the irregularity of their figure, and their difference in size, made me alter my opinion.

Finally, I found at the bottom of the membranes, which constituted the globules, and amongst the eggs I have just now mentioned, some empty and very delicate membranes, Fig. IV. *aaa*, which had served to invest the eggs that had been already discharged from the ovary; in the same manner as it appears in the cluster of eggs in Hens, which still retain, after the yolks have left them, the little membranes and cells which surrounded those yolks; though, in course of time, these traces contract themselves by degrees, and entirely disappear.

*Of the manner in which the young Frogs or Tadpoles grow in their parent's eggs, and are in due time hatched or delivered from them.*

THE very next day after the eggs had been discharged, being the 18th of April, they were of the bigness represented at (1); and the albumen, or white, which surrounded them, was very inconsiderable: but I could see they grew from one minute to another, so that the day next following they were of the size at figure (2). The white, in proportion as the water gradually penetrated it, grew on every side more and more clear and transparent; but the inside, which immediately contained the embryo Frog, rather looked like an agate. As to the fœtus itself, I could discern no alteration in it. But not content with external appearances, I resolved to examine thoroughly these eggs; but the surprising toughness of the white threw such obstacles in my way, that all my endeavours ended in nothing: and though I, at last, stripped the embryo of the coats and other substances in which it was wrapped up, it was so crushed, and otherwise disturbed by my handling it in the operation, that I could not by any means satisfy my curiosity.

This disappointment obliged me to take another method. I put a large number of these eggs into different liquors, in hopes some of these fluids might prove a sufficient menstruum to dissolve the white. At the same time I boiled, with the same view, some of these eggs in water; by which means I indeed succeeded, but not as perfectly as I desired. However, I could see that the skin of the enclosed Frog was regularly wrinkled, as in boiling it had lost by evaporation some of its humours.

These particles were most beautifully interwoven with blood-vessels, to which they were fixed as to so many stalks, *bb*; as I have endeavoured to shew both one and the other, and at the same time one of the largest blood-vessels, *cc*; but all of them considerably magnified.

This observation gave me reason to think, that the eggs I have been last speaking of, might be, as it were, like fruits, which had not as yet attained their due point of perfection, and might wither and drop off, before they did so; and I found this to be the case, even with perfect eggs, that had remained in the ovary and abdomen, as I have in part represented under the letter *f*, of the third figure. These little membranes, which I have been describing, were torn, as it were, and so collapsed as to form a smooth plain surface; for which reason I exhibit only a few of them. But it is time to see now what becomes of the eggs, when they are discharged by the creatures now under consideration.

On surveying the next day the eggs I had put into the other liquors, I found that the whites had been coagulated by the liquor, whose effects I first attended to, so as to appear of a beautiful roundness, like bunches of grapes. In colour they in a manner resembled an agate, or the boiled egg of a Lapwing. The little enclosed animal was also coagulated, so as not to fall asunder on dissection, though I could then more easily divest it of the yolk.

In another liquor the eggs had acquired a purple colour; but very little of the white was dissolved. I therefore passed to a third liquor, in which I found the white of the eggs was become more milky, and was a little dissolved; and it had besides lost a great deal of its clamminess and tenacity. The little Frog itself was increased to twice its size, and all its contents had in some measure contracted a colour: both which circumstances afforded me a very convenient opportunity of examining thoroughly, and with great care, the first rudiments of this little animal.

The whites of the eggs in the fourth liquor had assumed a greenish hue, and wanted little of being entirely dissolved; so that here also I could very conveniently survey every part of the young Frog, especially as this was also entirely coagulated in the same manner with the yolk of a boiled egg. These were the different effects, on various parts, performed by one and the same liquor. On examining, therefore, with a microscope; the enclosed young creature, I found it to consist entirely of minute grains, which were in a manner uniformly divided, and were yellow and transparent,  
without

without any other contents or viscera, that I could discover. The little animal was also divided throughout, as it were, into two parts, by a very considerable furrow or fold, Tab. XLVIII. Fig. v. *aa*. In the upper part there still remained some traces of a little yellow spot, that appeared there by some little openings, cracks, or crevices, *b*. But on opening afterwards the egg, according to the course of the furrow just now mentioned, I could discern that, on one side of the fœtus, this furrow reached almost to the middle of its body, where this body was also somewhat convex, Fig. vi. *a*, in one part; and in the other part, to which that furrow equally penetrated, it was hollowed into a cavity, *b*, which received the convexity of the first. On the opposite side of the fœtus the furrow was not, by a great deal, so deep, *cc*, so that it just looked like a superficial cut on the skin. The broken substance of the young Frog's body, composed of grains, *dd*, shewed itself in the place where these furrows terminated within.

I afterwards discovered in a perfect Frog also this parting or division, which I at first observed by mere chance in the embryos of this animal; and this new discovery procured me great facility in accounting for that sudden expansion and elongation of the young Frog's body, on the fourth day, when it explicates or unfolds itself. Hence I believe, that one part of the unfolded embryo forms the head and thorax of the future perfect animal, and the other part the abdomen and tail, which grows larger and larger by degrees.

In the fifth liquor, where I had put some of the eggs, their whites were grown a little redish, and were almost dissolved; but the enclosed embryos had shrunk up a little: by which means I obtained a sight of a very limpid humour, that surrounded the young Frogs, and was itself enclosed in a delicate distinct coat or membrane. On examining these appearances with a great deal of attention, I discovered, that, on one side, this membrane looked like the allantoies, Fig. vii. *a*; and I could even discern, in the cavity of it, a little white coagulated particle, floating in the enclosed liquor. The furrow, already mentioned, was likewise visible in the midst of this egg, *b*; and, on the other side, the little yellow spot, discernible in the fœtus, shewed itself through the transparent membrane which invested it, *c*. This yellow spot differs in nothing from the other parts of the embryo Frog, except that the folds of the body are here larger than elsewhere; and for the same reason, in proportion as the Frog grows, this yellowness gradually wears away, and changes to black.

This second discovery gave me room to suspect, that the Frog's egg might likewise leave its amnion and its chorion; and I had afterwards the pleasure of discovering these membranes, though I cannot take upon me to say, that they can be distinguished one from another. But I know for certain, that the Frog is wrapped up in a coat or membrane,

which is very distinctly conspicuous; and that it floats, moves, and turns itself in a most limpid fluid contained in this coat, just in the same manner as the Chicken does in its colliquamentum, or white.

This singular observation made me excessively eager to search, to the bottom, these wonderful and surprising mysteries of Nature. I therefore examined this egg again, touching it a little more roughly. By this means the allantoies dilated itself by degrees, Fig. viii. *a*, as I thus forced into that membrane all the liquid contained in the amnion; from which however, on removing the little instrument with which I had pressed it, it returned to its proper situation.

At length, by treating this egg still more roughly, I succeeded so far as to make the allantoies fall off from the Frog; and as, in so doing, I wounded the creature, I could discern its black fluid particles flowing into the allantois, and at the same time disturbing the liquor of the amnion, which it distended, thereby giving it the shape of a Pear, Fig. ix. *a*; I therefore continued this operation, till every part of the allantoies was thoroughly expanded by the fluid particles of the wounded fœtus; as may be seen in the tenth figure, done after nature, but enlarged. With all this harsh usage, I had not as yet broken any of the membranes.

I next took a survey of the Frog's inside; but I discovered nothing distinct enough to deserve mention. I could only discern the little grains I have already described, and from which, as from a congeries of coagulated and united globules, this little animal seems to derive its origin. The menstruums had produced in this granulated substance a beautiful variety of colours, as yellow, white, purple, and many others.

The observations already mentioned, had thrown so much light upon the subject of my present inquiries, that the third day after the eggs had been discharged, Tab. XLVIII. (3), I could pretty clearly discern the young Frog floating in the liquor of the amnion, and see that it was now gradually expanding itself. The whole egg also was grown much larger, by the water and food it had imbibed. The albumen that lay next the Frog was somewhat whiter than before; and I even thought that I could perceive in this substance some white vessels, which, as I suspected, might serve to encrease the white of the egg, and convey it to the embryo. We may therefore reasonably conclude this has its umbilical vessels, though too small to be discerned. I unhappily neglected this day to put any eggs into the menstruums I had prepared to coagulate them, and thereby to obtain an opportunity of looking for these umbilical vessels.

On the fourth day 4444, all these particulars were so visible, even without the assistance of a microscope, as not to leave the least room to doubt of their existence; especially as the colliquamentum, or white, and the coats

investing the embryo, were likewise greatly increased in size, and the Frog had unfolded and displayed itself under a variety of forms; as may be seen in the figures I have given, to represent them of their natural dimensions.

The same was to be seen on the fifth day, and formed a most surprising and beautiful appearance. I could now also discover by what means the chorion and amnion dilate themselves gradually, in the middle of the white. The ring also, formed by the white vessels of the chorion growing round its circumference, was now extending itself; but with all this, no umbilical vessels yet appeared in the colligamentum of the amnion, though this liquor was as transparent as chrystal. I could now also most distinctly discern the division of the young Frog into head, thorax, belly, and tail, as well as the manner in which it was beautifully adorned about its thorax, and near its head, with some black spines, disposed like a border, and highly worth our notice, as I shall hereafter explain. All these things may be seen in the figure, number 5, Tab. XLVIII.

I must here observe, that I could not now any longer discover the allantoies; but whether the sight of it was intercepted by the dilatation of the chorion or amnion, or whether it had only consisted originally of the folds of these membranes, or in what other manner this difficulty may be explained, I cannot take upon me yet to determine. It was matter of great entertainment to me, this day, to see the embryo Frogs rolling and tumbling about, almost perpetually, in the surrounding amnion.

On the middle of the sixth day I could perceive, that some of the young Frogs had disengaged themselves from the chorion and amnion, and deserted the albumen, or white of the eggs; whilst others were only preparing to break loose, and others again had not even attained so much strength and perfection as these. I observed also, that some of the eggs had increased in size, without unfolding themselves; and these, I believe, were such as had not been impregnated by the male's sperm. I afterwards met with two albumina, or whites, which did not now contain, and never had contained, any Frogs, though I could discern in them a white spot; so that perhaps these were imperfect eggs, which had dropt from the ovary with the rest, and had received equally with them their proportion of albumen, in passing through the tubes. Thus did I, in this subject, discover a great many of Nature's miraculous operations.

The tenth day (10) I had the pleasure of seeing the young Frogs, which had deserted their albumina, in an almost perpetual motion, swimming alternately to this their primitive habitation, and then from it again, for the sake of rest and food. These Frogs were of the form represented by the figure, number 10, and they were grown very little larger; but I thought it very remarkable, that the little black appendages, like borders, before mentioned, were greatly increased in bulk. These spines,

it is probable, were intended by Nature to assist the little animal in swimming, as well as in remaining quiet and reposing itself in the white. They greatly added to the beauty and singularity of its appearance, according to the judgment I had at first sight formed of them.

On the 15th I diligently surveyed, through the microscope, the external parts of the young Frog, as I have represented in two separate figures, of its natural size, in Fig. XI. and in Fig. XII, *a*, of the size given by the microscope, when laid upon its back. I could now most plainly discern its division into head, thorax, belly, and tail. The eyes lay on each side of the head, Fig. XII. *aa*, and were beginning to project a little, though they still appeared as if they were shut. On the fore part, between the eyes, appeared the animal's wide mouth, *b*. A little lower than the head, there were fixed to the thorax several particles in two arrangements, twelve on a side, very much resembling, in form, the little fimbriated appendages already mentioned; which I here represent as rising from the sides of the body, *cc*. I observed, that the little Frog could expand these particles at pleasure, and draw them up towards the abdomen, and afterwards reduce them to their former situation. The division of the thorax and abdomen was pretty distinct. In the belly lay an intestine, which swelled beyond the external surface; and, tho' not completely coiled, formed a great variety of windings in its way to the root of the tail, where it at last seemed to terminate, *d*. The *ee* tail on each side was somewhat transparent, but more opaque in the middle, owing to its being thicker thereabouts, and to its having also there a great many cartilaginous parts, each furnished with its peculiar muscles for moving the tail. I could therefore plainly discern, that this cartilaginous and muscular portion of the tail, extended to its very extremity, *f*, in the midway between the two membranaceous lateral one. The skin of this young Frog, viewed with the microscope, looked exactly as if it was thick set with black spots, upon a lighter ground, which appeared in their interstices.

On my dissecting this animal, and opening its abdomen for the first time, the intestine appeared very conspicuous; but so delicate, that, with the slightest handling, it dissolved into a great many globular particles; as did likewise the appendages, which were disposed with great art, like beautiful round spots, on each side of the thorax. Even the skin itself, when handled, fell into particles of the same form. I could not discover the stomach, on account of this wonderful tenderness of the animal's internal parts. I thought, indeed, I saw the heart; but I could not perceive either blood or vessels. The contents of the thorax fell also into little globules, in the same manner with the other parts already taken notice of. The eyes exhibited themselves much more distinctly within the head, than in its outside. The cartilaginous rudiments of the tail were grown to  
such

such a degree of firmness, that I could but just separate them from the adjacent parts. Tho' the tail moved about pretty violently, I could not clearly notwithstanding discover its muscles, as well because they were extremely minute, as because the same wonderful fluidity and spherical configuration shewed itself in the parts of these organs of motion. However, I could plainly perceive them growing in another little Frog, near the root of the tail. The colour of the animal's internal parts was a dark gray. This proved another obstacle to my anatomical inquiries, by causing, in all their appearances, an immediate confusion. I could discover nothing more than I have already mentioned in some of these Vermicles of Frogs, which I had set apart as larger, and consequently fitter for dissection than others. I could only observe, that those round particles or grains, of which I said, at my setting out, that the eggs consisted, went likewise to compose the skin and internal parts of the Frog. A circumstance that could not fail of surprising me greatly, and the more so, as they were considerable and distinct enough to be seen with a common microscope.

At this time, namely, on the 2d of May, I caught a Frog, which had not as yet discharged her eggs; for which reason I opened her, and fed with them my young Frogs. This animal's missing the usual season for this operation, might be owing to her wanting a male, or to her being in a sickly condition. Be that as it will, her eggs did not unfold themselves on being thrown into the water, like the others.

On the twentieth day of these experiments, which was the 7th of May, the fimbriated appendices, Tab. XLVIII. Fig. XII. *cc*, had begun to disappear; and were no more to be seen on one side of a Frog, somewhat bigger than the rest. This made me eager to investigate the cause of such a change, especially as the appendages of the left side, which had not as yet totally vanished, still continued in motion. In the course then of my inquiries for this purpose, I observed, that the skin of the body, which lay between these particles, had grown over so as to cover entirely that of the right side; and had already begun to take in, after the same manner, the particle on the left. I afterwards discovered, that the two particles I have exhibited as lying on the animal's thorax, under its head, with a direction downward, had each of them a passage to that part under the skin, which appeared to extend towards the fimbriated appendages; but I could not be sure of this circumstance, on account of the extreme tenderness of all these parts in the young Frog. However, I hence, with great reason, suspected that these particles might afterwards possibly grow into the young Frog's branchiæ; for I also observed, that the particle, which the skin had already

over-run on every side, had likewise lost somewhat of its original appearance and form.

The protuberant intestines might now be more easily discerned; and their termination, at the place already mentioned, Tab. XLVIII. Fig. XII. *d*, was become much more conspicuous. The pulsations of the heart, at this period very strong, were likewise very visible through the transparent skin\*. In the tail the cartilaginous vertebræ, and the muscles fixed to them on each side, shewed themselves very distinctly, and, in a beautiful manner, resembled a goose-quill branching on both sides into smaller feathers; for thus, nearly, those muscles hung to the cartilages which they were to move.

In dissecting the little animal, I found its intestines were increasing every way by degrees, but in length especially; to favour the increase this way, they were rolled up into coils, on account of the shortness of the body in which they lay. But they were, however, as yet tender, and their external coats still consisted of little globules. I could now just discern the stomach, as likewise the liver and gall-bladder of an aqueous or watry colour, and composed likewise of spherical particles. The entire liver consisted also of grains of the same form, and the very heart itself, which I took panting out of the body, and at every systole used to fill with those grains, the little tide of whitish blood it drove into the arteries.

Upon the whole, it was manifest, that the heart was formed in the little Frog, in much the same manner with that of Chickens, according to the account given us of them, by that illustrious anatomist, Marcellus Malpighi. The blood-vessels also, now shewed themselves. The eyes, and all their humours still consisted of little globules; as did even the black part of the uvea. The mouth, contracted like the mouths of Fishes, was grown a great deal more wide and spacious, tho' not so large in proportion, by many degrees, as that of a Frog, arrived at its full growth; or even of a young Frog that has just thrown off its tadpole skin; as shall be illustrated with a figure in its proper place. As to the particles which formerly lay on the outside of the thorax below the mouth. I could no longer see any thing of them; nor have I made any other observations concerning these appendages, beside those already mentioned.

May the twenty-third, which was the twenty-sixth day after the young Frogs had left their white substance, I received a supply of little Frogs from the country, in a flat-bottomed earthen pot.

Having before dissected all those that I had hatched and and raised myself, lest the little animals should be killed in the passage by the continual tossing of the water; and in order to afford them resting places, I ordered, by way of preservation, that the pot should be nearly

\* No creature affords more entertainment or instruction, by the microscope, than the Frog. The animalcules in the semen of the male we have already mentioned. The circulation of the blood is seen in the mesentery, by the help of the solar microscope, more beautifully than in any other creature.

filled with duckweed : and have with this soft matter, only a little water. This contrivance answered so well, that I received all the Frogs in good condition. The smallest species of them was of the size exhibited in the thirteenth figure, Tab. XLVIII. Fig. XIII. and these were the Frogs I now took under my consideration, as I had set out by considering those of the smallest kind. This pot contained a good many Frogs of twice the size of the former, but they were the offspring of a larger species ; so that I only made use of them to obtain better notions concerning such parts of the animal, as I had before discovered them in the smaller species. It is now time to describe the many curious things that occurred in the course of my superficial survey and anatomical inquiry.

The first thing that appeared worth notice, without dissection, was the wonderful contrivance and construction of the mouth, Fig. XIII. *a*. But as these parts of the young Frog are too small to be properly represented in figures of their natural size, I shall rather exhibit them as they appear thro' the microscope, on laying the creature upon its back, with its viscera separated one from another. The external opening of young Frogs mouths, is by no means placed in the anterior extremity of the head, as it is in most Fishes, and even in grown up Frogs, but opens in the thorax a little deeper under the head, as in the Shark, so that the young animal is obliged to turn itself on its back, in order to seize any thing that floats upon the surface of the water ; and I have often seen it throw itself into this posture, either when it happened to be very hungry, or intended to discharge the air from its lungs : upon these occasions, it turned so nimbly, that my eye could scarce follow it.

The aperture of its mouth consists of an under jaw *aa*, Tab. XLIX. Fig. 1. and an upper one *b*, both moveable, of an extreme blackness, and armed with very small teeth like a saw, with which, considering its strength and size, the little animal is able to bite exceeding hard. These parts seem to be made of a slender, horny, and pretty flexible bone. There are, moreover, both above and below the opening, a great many little horny bones of the same kind, furnished with a multitude of little black teeth. All these little bones are placed upon some muscular and very white plaits, which serve the animal like so many lips, and shut its mouth, or keep it shut ; they first seize the prey it aims at, and then help it to draw gradually into its mouth the food it has taken hold of : for this reason the young Frog can move open and close all these muscular parts in a great variety of ways. The skin lying on each side beneath the mouth, consists of a great number of white papillæ *cc* ; so that it affords in the Frog itself a very beautiful appearance. A little lower down are the protuberant eyes *dd*. The skin that covers these and every other part of the body are most neatly coloured like variegated marble with gold stars

and spots as it were upon a black ground. This animal, when turned so as to lie on its back, shews on the forepart above the eyes, its nostrils, thro' which it breathes, lifting the head for that purpose, a little above the surface of the water ; and on this occasion it moves those parts, which it alternately expands and contracts, in a very elegant manner.

On opening at this time the little animal's thorax, there appear very distinctly in this part, and a little below the place where the bone of the breast grows, the branchiæ, or gills, divided on each side into four primary orders, or rather ranges *ee*. We may even see how each of these orders is again, as it were, subdivided into a great many globular prominent parts, along which the blood-vessels run in vast numbers, and in an uncommon and very beautiful manner. At the same time the lungs are also seen lower down in the abdomen *ff*, and they are almost always found swelled with air, in the manner I have represented the right portion of them ; where I have likewise taken occasion to exhibit the blood-vessels disposed over this organ. The left portion is represented as it appears when collapsed ; for then there remains in it but a very inconsiderable portion of air, which, on account of the extreme delicacy and transparency of the membranes constituting the pulmonary lobes, appears no otherwise than as a naked bubble of air, lying externally on the part whose continuation really encloses it.

This is a most curious observation, as it informs us there is an animal, which, at one and the same time, has both gills and lungs, both serving to circulate, cool, alter, and purify the blood. It is probable the air, in this creature, mixes with the blood in its passage through the lungs ; and that afterwards, in company with this fluid, it visits every part of the body ; whilst the water, by passing thro' the mouth at the gills, has at the same time the very same effect.

These gills are no other than the little fibrated appendages, which I represented bigger than the life, in Tab. XLVIII. Fig. XII. as hanging on the outside of the body ; and which, on being taken in by the creature in its growth, are now advanced to the important office of gills. It is in this manner exactly, that the vitellus of the Chicken, which at first lies without the abdomen, comes afterwards by degrees to be shut up in the belly, as Dr. Steno first described this natural process, which he likewise illustrates with an accurate figure ; and immediately after him, that curious Englishman, Walter Needham : for these two gentlemen, who were quite unacquainted with each other, made this discovery at the same time, in different countries. These borders or edgings are very discernible on the little Frog's first appearance from within its albumen, and while they continue on the outside of the body. The learned Oligerus Jacobæus was acquainted with these particles, as appears by his being the first who gave a figure of them, with a short

short explanation, in which he just takes notice of their disappearing in time; but this circumstance might be easily known, and without the help of dissection, and I took notice of it myself more than twelve years ago. The gills heretofore described, may be likewise seen within in the Frog's mouth, through which the water flows upon them, and is then discharged, after altering the blood that passes through these organs.

Nor could I ever yet discover, that these branchiæ or gills, have any openings on the sides of the body, as is usually the case in fishes.

Here it may be probably asked, whether the blood circulates in the young Frog, both through the gills and lungs? This I cannot absolutely determine; for whilst I was engaged in these observations, I was disturbed with the cases of many who were dangerously sick, which prevented my having time and leisure for examining this matter in the largest young Frogs, one of which I have represented, Tab. XLVI. under No. V. otherwise I had resolved to render these observations on the generation and change of young Frogs as complete as possible. I must therefore desire the reader to accept what I now exhibit on this subject, as the prelude only of a more perfect work, to be hereafter published. Though I have already observed many things concerning this matter, I have not such confidence in my memory, as to presume to publish, before I re-examine them.

In order to make some answer from my former observations to the question I have just now proposed, I am thoroughly persuaded, that the greatest part of the blood circulates in the young Frog through the gills; and that only a small part of it is conveyed through the lungs; and this designed probably only to nourish them, and to supply the remaining mass of blood with air. The reason why I propose this opinion is, that only a very small portion of the blood circulates thus in full grown Frogs, in which the gills, being probably thrown off with the last skin which the Tadpole casts, wholly disappear; and, on the other hand, the greatest part is after this distributed into the whole body, out of the heart through the arteries, without touching the lungs. This is made evident in a letter, which I formerly wrote to the celebrated Oldenburg, secretary to the royal society of London, and which is to be found in the philosophical transactions of that society. I hope also, that by this observation, I have at length proved it, against the opinion of the famous Malpighius and Needham, who think the blood is perfected in the lungs; that sanguification, or the making of blood, must be wholly attributed to the liver. I am persuaded, that I can demonstrate it very easily: though some, stimulated with envy and vain glory, bark against it, like dogs against the glittering brightness of the moon. My experiments concerning this matter, indeed, penetrate further than any person hath ever probably thought. But I return to the Tadpole or young Frog.

The heart, Tab. XLIX. Fig. 1. *g*, is placed between the gills in the Tadpole; and out of it, one may very distinctly see produced the great

artery: this is divided into two branches; and these are further divided into very conspicuous sprigs or shoots, which have all gills annexed to them: but whether some of those branches are likewise transmitted to the lungs, as is the case in full grown Frogs, I could not at this time, for the reasons beforementioned, examine: I am still doubtful also, whether all these shoots are distributed to the gills alone.

Near the heart is placed the auricula *b*, which has not yet such a situation or figure, as it has in full grown Frogs. But in the examination of the auricula, and its vessels, I have not yet arrived so far as to satisfy myself: therefore, I cannot exactly declare, whether those two veins, which I delineate under the Auricula, reach to the gills, and carry back the blood from them to the heart, or whether they communicate with the vessels of the lungs. All these matters still remain to be inquired into. But for this reason, I do not scruple to delineate those parts, as they appeared to me, without examining them more exactly.

Below those two veins is situated the vena cava and liver, *i*; this I observed to be divided, as it were, into four lobes: it is at this period whitish, and somewhat redish. It is plainly discovered, that the liver is composed of very regular glandulous granules, which one may take for very small glands. Near the liver in the Tadpole is placed the gullet, *k*, which descends from the mouth to the stomach, and is delineated here in that form. But, in order to avoid confusion, I delineate the gall-bladder, *l*, near the other side of the gullet. That little bag of gall was at this time of a white, diaphanous hue: nay, the bile itself was limpid and perspicuous, and without any bitterness; though in the full grown Frogs, it is sometimes so green and fluid, that it may be used to draw lines. The fluidity of the gall seems to me to depend on its piercing bitterness, which is manifest some months afterwards, if paper, rubed over with such gall, be put into the mouth. The spleen in the Tadpole is very small, triangular, but somewhat irregular, and much more red than the liver: this is likewise the case in full grown Frogs.

There was nothing more beautiful to observe in this dissection, than the course of the gullet, stomach and intestines; for these parts were observed to be very admirably convoluted in the body of the Tadpole. The first sinus, into which the gullet was twisted, was about the liver, Tab. XLIX. Fig. 1. *m*, under which I have delineated, *n*, a certain portion of the mesentery, together with its blood vessels. The stomach was in the beginning, and in its state of accretion, like a piece of red flesh, which being partly situated over the gullet and small guts, began to swell and grow thick. But there was likewise observed a great number of blood vessels, which distributing themselves through the stomach, formed as it were a beautiful net.

I here discovered most clearly, that the stomach in the beginning of the young Frog's accretion, did not yet perform its office, which was in the mean time performed by its gullet and

intestines, which were for that reason made proportionably larger and longer in the young Frog, than even in the full grown one. On measuring the length of the intestines in this little creature, I observed it to be five inches. When I thoroughly viewed the contents of the gullet, stomach and small guts, I observed they were all of the same nature, and contained some parts, of aquatic plants, little grains of sand, clay or mud. Therefore, when I fed these young Frogs with Duckweed for some time in my chamber, in stone basons, I observed that they eat all the roots of it so clean, that none remained; but not the round little part or leaf, which is full of air, and swims on the surface of the water. But afterwards, when they had nothing to eat under the water, I observed them continually rolling about on their back for hunger, and constantly catching the residue of the Duckweed in their mouth, though it was too big for them to swallow.

At the same time, I observed also, that the orbicular leaf of the Duckweed is not only full of air-bubbles, and for that reason necessarily floats on the surface of the water; but that even its very root of the plant, contains air, tho' not in a proportional quantity: this is probably the reason why the root subsides. I further observed, that the extremity of the peduncle, or root of the Duckweed, is thicker in proportion, and more porous than the stalk itself: and consequently the nourishment seemed to me to penetrate through that extremity to the leaves. I likewise observed, that when I nursed up one plant of Duckweed in a bason of water, and exposed it to the rays of the sun, it insensibly put forth many roots; nay, that the very leaf of these little plants multiplied and increased into two, three, or four other leaves; the least of which, afterwards separating from the parent, formed several other small ones; so that this little plant seemed to multiply itself without seed, in a very short time. I had indeed resolved, yet more accurately, to investigate and delineate these things: but the reasons before mentioned, have likewise diverted me from this resolution.

Some years ago, examining the tubercles, which are found on the back of Fern-leaves, I observed that they consisted of some thin plates, or laminæ, in which the pods, containing the real seeds of the plant, were enclosed: though many authors deny that this, and such like species of plants have any seed\*. Since the art and structure observable in these pods is admirable, I shall

give a brief description of them, until I have time to delineate them magnified; as I have formerly done to oblige Dr. Arnold Syen, professor of botany, to whom I freely communicated this uncommon observation, since it regarded his profession: of which, however, no further notice need be taken here.

Those pods are of a round figure, and are composed, as it were, of two hemispheres, placed close to each other; but they may be parted in the middle. About this joint or seam is beautifully twisted a little herbaceous cord, which keeps the two segments of the pod in their situation. One extremity or basis of this little rope grows to the fern-leaf; but the other is affixed to the lower hemisphere of the pod; and at length, after surrounding the whole pod, it terminates in the upper part of it.

In the cavity of this pod the Fern-feed lies, and it is indeed so small, that it is with great difficulty to be discerned by the naked eye; and when blown upon, it vanishes into the air like fine dust.

But this is only a small part of those beauties that are observed about the pod, and its cord. I beg leave to observe from hence, that when the seed grows ripe on the inside, and the pod dries away, then the cord, twisted round the pod like a rope, is so strongly curled, on account of its contorsions, that it makes the pod fly into two parts, and forces a passage for the seed to disperse itself.

This may be seen clearly and distinctly, if the seed be examined in autumn with a microscope: for as the head is, under this inspection, very near this seed, I have often observed, that a great number of these pods, burst asunder by force of the twisted cords, which are contracted by the breath and heat of the body, and the seed, is by this means thrown out. But these things are only said occasionally in this place †.

The pancreas in the Tadpole was observed, Tab. XLIX. Fig. 1. *p*, to be situated near the stomach, and composed of distinctly conspicuous glandules. Below the stomach appeared *q* the small gut, with its blood-vessels and contents, which were of a greenish transparent colour. But the convolutions of the intestines exhibited the most beautiful sight of all; for these were orderly and regularly rolled *rr* into two distinct serpentine forms. One of their extremities was joined to the rectum, *s*, which at length constituted the fundament between

\* Every part of natural history is greatly improved of late time. This author first discovered the seeds of Fern, unknown to former writers; and we have since discovered those of Duckweed, which were unknown to him. This little plant is now known to produce its like in the manner of all others. Small as the whole plant is, it produces flowers of all kinds from the same root. In some of them are the filaments, two in number, and a single style rising from a small oval rudiment of a fruit: in others, there are no filaments, but only the rudiment of a fruit with its style. The cap which contains these, is alike in both kinds; it is rounded, and splits on one side: there are no petals in either flower. The rudiment of a fruit decays, and comes to nothing in those flowers which have the filaments with it; but in the others it becomes a globous seed vessel, terminated by a point, and contains several oblong seeds. This is established on the opinions of Micheli, Dillenius and Buxbaum, and is confirmed by Linnæus, and by experience.

† The world owes great acknowledgments to this author for many discoveries; and he with justice claims that distinction, in regard to the seeds of Fern, of which he treats more largely hereafter. The science of Botany is so far improved since his time, that we have discovered distinctly the seeds, and their peculiar distribution on the leaves, in all the capillary plants. In Osmund they are enclosed in distinct globular capsules, which burst sideways; in the Louchilis they are laid in lines, like crescents, under the hollows of the leaves; in Hartstongue and Trichomanes they are disposed, in straight lines, under the disk of the leaf; in Polypody they are arranged in round dots; in the true Maidenhair in oval assemblages, at the tops of the leaves: the Horsetail has them in oval spikes; and the Adderstongue in cells, placed in two rows along the spike. These plants are now found to belong distinctly to the four kinds; and in the Rutta Muraria they cover the whole under-part of the leaf.



the two hinder legs, *t*. The difference, however, between the small and great guts was not very considerable in the Tadpole; nor is it very remarkable in the human fœtus, in which there is, at first, very little difference between the small gut, colon, and rectum; as I can demonstrate in a human fœtus six months old.

The most remarkable thing in this little animal was, that only the rudiments of *uu* the two hinder feet of the Frog were yet seen; and from them the toes, not yet strengthened inwardly with bones, began to swell, as a branch does out of a tree; though the figure and construction of the feet was, however, pretty perfect and evident. But as to the two fore legs, not even the least vestige of them yet appeared outwardly, because they lay *xx* hidden, covered and enclosed under the skin: nor did they come in view before the skin was cut open in that part, and then they were seen situated above the lungs and below the gills, though they were not so perfect as the hinder feet.

It is evident, from what has been said, that this animal may and ought to be considered, in its original, as a real insect, since it hides its limbs under the skin, and these increase there until the change of the last skin is near at hand; at which time it is observed in insects, that they are, as it were in an instant of time, transformed into other creatures, and exhibit to view such limbs as they did not before appear to have. The same thing likewise holds in young Frogs or Tadpoles: wherefore this animal ought to be placed in the second order or class of our natural changes, unless the just laws of method had commanded me to treat of it at the end of this work, in order to make the likeness between animals which have a red blood, and those which contain white, yellow, or green blood in their heart and vessels, the more evident.

As we see insects lose many parts with their old skin, this is likewise the case in the Frog; which, besides other things, plainly casts off its mouth and tail: so that, however admirable the art, order, construction, and parts of its members may appear to be; yet the nerves, arteries, veins, cartilages, muscles, and many other remarkable parts, which gradually vanish, and are, as it were, become insensible, are destroyed at once, cease their motions, and stop their several functions, on the change. Are not these changes admirable? And do not they lay before our eyes the omnipotent hand of God, conspicuous in his inaccessible radiancy and infinite majesty? He, in this case, forms another out of one and the same animal, which though different in appearance, yet remains one and the same creature. May not the resurrection of the dead be exemplified in this illustri-

ous instance? All this is very elegantly manifested in various insects.

As the want of subjects now prevents my being able to investigate further the most artificial compositions and changes of the limbs in the Tadpole, I shall here describe only the muscles, which are most regularly placed in the middle of the tail, and merit very particular notice. Those muscles are laid somewhat obliquely, and converge, Tab. XLIX. Fig. 1. *yyy*, to each other from the two sides of the tail towards the middle; and each of them is likewise divided into many moving fibres. That this may appear the clearer, I have delineated them as if they lay outwardly on the skin. On each side of the muscles is seen *zz* the membranous skin of the tail, marked with beautiful points: by the help of this part the Tadpole moves its tail, and swims, since it uses it like an oar, to push its body forward, with a serpentine motion.

Before I proceed to other observations, which I have made on the full-grown Frog, I shall give the method whereby the Frog changes its skin. I would have it observed, that I here treat of the largest species of Tadpoles, since the other kinds are much smaller. To which I must add, that I increased it a little above its natural size, in order to explain more intelligibly the metamorphosis of the skin. The time when the young Frogs begin to cast their skin, and to put on the form of a Nymph, is with us about the middle of June, or somewhat later; that is, a little more than two months after they come out of their eggs. When this time approaches, the skin of the young Frog is first usually burst in the back, near the head, and through this chink the young Frog immediately puts forth its head. Then is seen the mouth lying, Fig. II. *a*, in the Tadpole's exuvia; and this is observed to differ much, *b*, from the wide opening of the Frog's mouth. Then the Frog turns out its first pair of legs, which lay till now hidden under the skin, *cc*, and at the same time it presses back the skin towards the hinder parts. Thus the rest of the body, the hinder legs, *dd*, and also the tail, are stript of their skin: after which we see the tail contracted more and more every day, until at last no vestige of it appears. If the Frog thus produced be a male, two pneumatic kidneys *ee* are discovered on each side of the head, behind the eyes; and the great toes of the fore feet appear also thicker and longer *ff* than in the female. But what parts in particular are left in the exuvia, and whether the gills be discovered adhering to them, I have not yet examined. After the same manner Toads and Water-Newts cast their skin.

*Of the circulation of the blood in a full-grown Frog.*

THE manner in which the blood circulates in the full-grown Frog, is not a point of small moment: indeed, it very much recommends comparative anatomy, since, when that is not thoroughly known, it seems that one cannot arrive at the real knowledge of the use of the viscera. The famous Malpighius, Needham, and many others, say that the Frog has visible lungs and respiration. Nay, they also think that the blood circulates through the lungs, is there elaborated, lessened in the globules, and brought to its full perfection: and hence the office of sanguification, which, in former ages, was supposed to be done by the liver, is now transferred from thence to the lungs. Besides, since the same gentleman has observed gills in Fish answering the purpose of lungs, thro' which all the blood circulates; and as they saw the water strike against these in the manner as the air does against and into the lungs, in other animals, they have therefore made the gills perform the office of making blood.

I confess, this opinion is very ingenious; if it be supposed, that the liver does in no wise contribute to make blood. But from whence shall sanguification be derived in this animal, which has lungs; but at the same time they are so circumstanced, that the blood does not pass thro' them, but is immediately distributed all over the whole body, out of the single ventricle which their heart hath, without touching the lungs? This plainly is the case in Frogs. The same thing, probably, holds in Toads, Water-newts, Lizards, Chameleons, Tortoises, Serpents, and other creatures of that kind; all which I have observed to be provided with membranaceous lungs: tho' I have not yet accurately examined their blood-vessels. We shall certainly be obliged to return to the liver, and restore it to its former degree of dignity. Nay, this holds more strongly in the Frog, which is destitute of the lacteal veins: since its chyle must, for that reason, necessarily enter the great numbers of its meseraic veins, and be thus conveyed thro' the vena porta to the liver. In the extremity of this vein, the blood, which is to pass from thence into the cava, is broken and divided; and it seems to me to acquire its last perfection in the cava itself. As, I am confident, I shall, at some time, more fully demonstrate, with respect to those animals, which have lacteal veins. But I cannot now, for want of time, finish the experiments, which I have began, concerning this subject: and which, tho' not many in number, are yet so important, as to promise great discoveries.

Having premised these things, I shall now briefly describe the principal arteries and veins in the Frog, and shall shew the manner in which the blood circulates thro' them. The Frog's heart, Tab. XLIX. Fig. III. *a*, as is the case in most Quadrupedes, is found situated in

the cavity of the breast, which is indeed very small. To the upper part of the heart, the auricle *b* is observed to be joined: but it has, like the hearts of Fish, only one ventricle, out of which likewise there issues only one artery; which is in the beginning considerably muscular, and sufficiently dilated, and immediately afterwards dividing into two trunks; one of which is detached to the right region *c*, the other to the left region of the breast *d*. Each of these arteries, which are like the subclavian veins, is further divided into three principal branches. The first of these, which is the least *ee*, stretches on each side to the lungs, and gives them nourishment: and therefore I call these the pulmonary arteries, and they are of the nature of those called Bronchials in man and brutes. These, in their course to the lungs, are commonly divided into three branches, which I here exhibit as cut off; and after this stretching to the coat that surrounds the lungs, thereon form a very admirable piece of net-work, and communicate with each other by several anastomoses: hence they also pass down by very small shoots, into the inward irregular vesicles of the lungs, among which the pulmonary vein is diffused, and with the latter they form a very conspicuous anastomosis, visible even to the naked eye. This is manifest, if these veins and arteries be filled with quicksilver. I keep some prepared in this manner. Out of the pulmonary arteries likewise proceed two small branches, Tab. XLIX. Fig. III. *ff* on each side, turning upwards, which are distributed thro' the parts of the mouth.

The second pair of the principal branches, arising out of the trunk of the great artery, are observed to be dilated into two remarkable swollen knots; these are of a grayish black colour *gg*, in the living Frog. Both these arteries are after this extenuated, and, together with the little branches issuing from them, seem designed only to serve the muscles of the mouth, and those of respiration. But as each of them ascends higher, it is again dilated into a knotty little bladder. I should think these arteries are duplicates of the nature of those which before served for conveying the blood to the gills. This I cannot affirm for certain; but it may be hereafter examined into by repeated dissections.

The third pair of the primary branches are particularly worthy of consideration; since these properly constitute the trunk of the arteria magna in the region of the loins, and are there for that purpose united by a very conspicuous anastomosis. They rise out of the trunk of the arteria magna, then they bend *bb* circularly under the lungs; and, after sending out some branches, they likewise emit *ii* the axillary arteries from off their sides. We observe, that a little deeper beneath the heart, the carotid arteries arise from them; and that these ascending *kk* from thence towards the head, bury themselves

themselves in the bones of the skull. The arteries of the vertebræ, also arise // from these branches; and at length uniting together by a manifestly conspicuous anastomosis, they constitute the trunk of the loins; out of which rises the cæliac artery, which afterwards sends out from it *m*, the mesenteric artery. Some arteries also, as those of the loins *nn*, and those that are detached to the testicles, ovary *oo* and reins *p*, have their origin from the same trunk; and this same trunk is itself afterwards divided in the last place into the iliac *qq* branches.

The blood being driven out of the heart through all these arteries, to the circumference of the body and viscera, at last returns by a manifest circulation through the veins to the heart, as to its center; whilst in the mean time only a part of it circulates through the lungs, and indeed exactly in the same manner in which it circulates through the muscles and the rest of the viscera. Therefore, the blood in the Frog circulates in a quite different order, than is observed in other animal quadrupedes, or in fishes; in which all the blood passes either thro' the lungs, or thro' the gills: that is, the upper trunks of the vena cava, which are united to the auricle of the heart, and are here delineated under both trunks of the great artery, do not in the Frog deduce their blood from the lungs; but they imbibe it directly from these veins, which run in the upper part of the body, and from some others that are situated next to the skin in the sides lower down, and they likewise get a small portion, that returns from nourishing the lungs. The blood, on its return from the lower parts of the body, does not touch the lungs, but discharges itself thro' the porta and cava, into the auricle of the heart, without coming near the lungs. Therefore, by inflating only one vein of the Frog's body, the arteries may be all inflated also.

The distribution of the Veins differs here considerably from that of the arteries; for the two trunks of the the cava, are conspicuous above at the auricle, Tab. XLIX. Fig. iv. *aa*, where I have opened *b*, the arteries, emit pulmonary veins out of their lower side, (here cut off) *cc*, which are twice as large as the arteries. These veins are properly placed in the cavity of the lungs, and particularly in the extremities of the pulmonary vesicles, and in the loins; and they diffuse their capillary, and almost invisible branches all over the cells; nay, even thro' the coat which invests them. Here, therefore, in the lungs of the Frog, a considerable blood-vessel, namely, the arterial vein, is wanting: the animal has no need of this artificial canal; since Nature did not intend that all the blood should pass thro' the lungs. Besides, the two upper trunks of the cava pass above the arteries in the Frog, and are also divided into various branches. Some little veins are from thence detached *dd*, to the parts about the mouth: others, which bend very beautifully in their passage, go towards the head *ee*, and give a part of themselves *ff*, to the muscles of the first pair of legs. The axillary veins

also, spring *gg*, from the same trunks, and emit two very considerable *bb* branches, which in the ilia beautifully bend themselves back under the skin above the muscles of the belly; and from thence ascending again towards the thorax, and being there considerably dilated, they communicate, by a mutual anastomosis, with the rest of the veins that are situated about these places. The trunk of the cava, which is situated beneath the heart, is simple *i*, and is there divided into three branches, which are dispersed thro' *kk* the liver. A little lower, the mesenteric vein rises *l* out of the liver: under which the trunk of the cava very beautifully diffuses *m* itself, by many branches over the kidneys; and at length, after dividing into two parts, constitutes the iliac *nn* branches, from which the epigastric vein is observed to rise *oo* very beautifully. This vein goes back along the straight muscles into the liver; where I represent it cut off. But if this little vessel, and all the integuments of the belly, be dissected near the liver, and then turned above the hind legs; all the veins of the body may be conveniently inflated through it. By this means veins are discovered in the liver, the kidneys, and all the viscera. And from thence I took an opportunity of making, with very little labour, the following very remarkable experiments. Let what hath been hitherto said, suffice in regard to the circulation of the blood, and the blood-vessels in the Frog.

Having finished the observations now recited, as quick as possible, I afterwards examined some muscles, and also the skin, eyes, and blood of a full-grown Frog. I found it easy to divide the moving fibres of the muscles so small, that they resembled a Spider's web. But when I put them divided in this manner under the microscope, I found they consisted of still smaller fibres, and those of very minute globules. I first discovered the epidermis in the skin; it supported the real skin, the latter being adorned with beautiful colours and black spots, and appearing composed, as it were, of globules. I further separated the skin into a glandular substance, which was composed of very numerous globular glandules. Those glandules secreted that viscous or slimy matter, which is observed to be spread over the surface of the Frog's skin, and rendered the latter very smooth and slippery. This species of mucous matter tastes bitter, and offends the eyes with its acrimony; nay, it causes a sensible pain, if rubbed to our skin when wounded a little; so that we must be cautious in the use of it. I next examined the aqueous humour of the eye in a glass tube; but I perceived nothing more than the clearness of the liquor. And hence, then putting both extremities of that tube to a lamp, I boiled that and the whole Frog's eye in water: but there were no globules conspicuous in it from this process. Both the white part of the crystalline humour, which resembles chalk, and surrounds it, and the other fibrous diaphanous portion, which is divided into several lamellæ or plates, consisted entirely of globules. I saw a serum in the blood, in which were

a vast number of orbicular particles, of a flat oval but regular figure. These particles seemed also to contain another fluid: but when I viewed them sideways, they resembled crystalline clubs, and several other figures; that is, according as

they were turned about in various directions in the serum of the blood. I observed besides, that the colour of objects always appeared the more faint, the more they were magnified with a microscope.

*Experiments on the particular motion of the muscles in the Frog; which may be also, in general, applied to all the motions of the muscles in Men and Brutes.*

**H**OW important and difficult it is to explain the real causes of muscular motion, is sufficiently evident from numerous experiments; which though made by very ingenious men, yet have not hitherto discovered its true nature. The great utility and foundation of further knowledge, which we should acquire from that discovery, lie yet involved in the thickest clouds of obscurity. This is the reason which now induces me to publish the experiments I made concerning the matter; which, as they seem to me to have great weight, and to contain some useful consequences, I would therefore advise my readers to consider seriously, and examine them by the touchstone of truth.

In the construction and motion of the muscles, it merits particular consideration, in what manner the nerve is actually joined to the muscle; how it is constructed in the muscle; what is its course, entrance, middle, distribution, and end; as also how it communicates with the moving fibre, and what effect it produces in it; also what that very subtle matter properly is, which is undoubtedly conveyed to the muscle through the nerve. The knowledge of all these particulars is not sufficient for our purpose: one must likewise know the construction of the membranes, that invest both the surface of the muscle and its inward parts, and the delicate lesser fibres that reach from one moving fibre to the other, and, like a very fine web, diffuse themselves through the interstices of the latter. It would be likewise necessary to know the structure of the vein and artery belonging to the muscles, and their real constitution or disposition in the muscle, and to understand accurately what belongs to the composition of the moving fibres. But all these things are still obscure and unknown, and will not be probably discovered till we employ all our time, and the greatest diligence, in investigating them: but all difficulties are conquered by industry, and an unwearied application. As to myself, I candidly confess, that I have not brought every subject, which I have advanced, to the greatest perfection possible; for, in order to attain this, I should have spent my whole life in discovering one thing, and this course is not agreeable to me: for I am thoroughly persuaded, that, if I came to the utmost extremity, I should at last discover nothing but my own ignorance. For this reason, I thought it better to employ my time rather on various things than on one; lest, whilst I was too intent on a thorough knowledge of one or two particulars, many of God's work should lie hidden from me: for, indeed,

all the knowledge we are capable of, consists only in this, to love God as we ought.

With respect therefore to all the subjects hitherto recited, I still find many indissoluble difficulties. And though the excellent anatomist, Dr. Steno, hath discovered many curious things relative to this matter, yet he stops also in the middle of his course. Besides, how far are we from knowing the motion and effect produced by the subtle spirit, that continually passes through the nerves into the muscles! This matter lies buried in impenetrable darkness. Since I have made many experiments, at different times, on the motion of the muscles, I shall now, however, set forth the chief of them, and submit them to the examination of the learned.

It is a matter eternally certain, and of greatest moment, that whenever the nerves of living bodies are handled, there is immediately observed a considerable motion in the muscles to which they are sent, and this motion does not at all differ from the contraction of those muscles. If we lightly pinch or prick the nerves of the diaphragm in a living dog, opened for the experiment, with the point of a very fine needle; or if we stimulate them by putting them near the fire, or by pouring acrid liquors into them; we immediately see the diaphragm performs its natural function: it contracts itself, from being arched becomes smooth, raises itself from the thorax, pushes out the viscera of the abdomen, and the cavity of the thorax is enlarged in proportion as the diaphragm contracts itself and becomes more smooth, and is more stretched out of the breast.

This experiment is very fine and elegant, since the motion also, which is then observed in that compound muscle, appears admirable; and the same experiment may be often repeated in the same subject, if the nerves of the diaphragm be first irritated, where their beginnings run near the pericardium. In order to irritate them a second, third, and fourth time, we must descend by degrees, and choose a lower part of them, until we come to the very place where they are inserted in the diaphragm.

This experiment on the nerve may also be very easily made, not only in this but all the other muscular parts of the animal's body, with the same success. Hence we often observe, on dissecting living animals, that when the nerves are wounded with a knife, considerable motions arise in the muscles to which they belong. This the celebrated Steno hath likewise observed in his *Myolog. Specim.* p. 78 and 79, after I had shewn him my old and common experiment on Frogs. This is observed to  
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happen not only in quadrupedes, but in birds and fishes, but especially in the Wray-fish; in the muscles of which there are very strong motions, when the nerves are irritated.

On the foundation of these motions, which are produced in the muscles, when their nerves are only disturbed or stimulated, I determined to provoke the nerves of the entrails in the same manner, in which I found very remarkable fleshy fibres. I had a mind to make the same experiments on those nerves which reach to the kidneys, liver, spleen, lungs, and genital organs; for I would scarce presume to affirm, that any remarkable contractions are produced in those parts, especially in the kidneys, by such irritation; and therefore one may penetrate much deeper, by that experiment, into the real uses of these parts. But I have not yet been able to execute my purpose, for want of time. It is therefore sufficient for me here to have hinted at these things in a few words, that others may have an opportunity of labouring further in the disquisition of them; for Nature must be investigated by the joint labours of many. One man can make no great advancement in matters infinite.

I beg leave to observe here, that the motions of the muscles, now mentioned, are not so considerable in animals which have warm blood, or rather they do not last so long, as in those that have the blood cold; as fish, and many other aquatic creatures, which have few or no feet, and in amphibious creatures in general. Hence I chiefly made my experiments on the Frog; for the nerves are very conspicuous in these animals, and may be easily discovered and laid bare. The spinal marrow and the brain have this peculiarity in the Frog, that, like a fluid salt, they lie enclosed in coats, and, being interwoven with blood-vessels, are every where adjacent to them; so that they are to be discovered plainly even in the cavity of the vertebræ, and in the skull. The spinal marrow glitters like pearl, and is disposed, in the form of knots, all down the back, along the vertebræ, where it appears very conspicuous. This native salt, mixed with an acid liquor, ferments very strongly. Its substance answers very nearly to that granulated and gravelly powder found in the head of the Shark, and sold in the shops, and erroneously taken by the ignorant, for the brain of the fish; but this is nothing more than a stony and gravelly substance, which is placed in the head of the Shark, as what is called the Perch-stone is in the head of the Perch. I have likewise found such a powder in the Wray-fish's head, which fermented very strongly with an acid: and, therefore, I think that the alkaline salt, observable in the little stones called Crabs-eyes, is like this. But though that saline substance in Frogs is fluid, like water, it will notwithstanding be dried immediately by the heat of the hand or fingers; but it never hardens to such a degree, but it may be very easily reduced to fine powder with the tips of the fingers. The same thing likewise holds with

respect to that calcareous fluid matter in the Wray-fish. Whether this salt has any medicinal virtue, I cannot yet say; nor can it be known, except from experience. I return to the muscles.

Another very delicate and useful experiment may be made, if one of the largest muscles be separated from the thigh of a Frog, and, together with its adherent nerve, prepared in such a manner as to remain unhurt. For if, after this, you take hold, Tab. XLIX. Fig. v. *aa*, of each tendon with your hand, and then irritate *b* the propending nerve with scissors, or any other instrument, the muscle will recover its former motion, which it had lost. You will see that it is immediately contracted, and draws together, as it were, both the hands, which hold the tendons. This I formerly (in the year 1658) demonstrated to the most illustrious the now reigning Grand Duke of Tuscany, when he graciously vouchsafed to pay me a visit. This experiment may be repeated in the same muscle, as long as any part of the nerve remains unhurt; and we can thus make the muscle contract itself, as often as we please.

If we have a mind to observe, very exactly, in what degree the muscle thickens in its contraction, and how far its tendons approach toward each other, we must put the muscle into a glass tube, Fig. vi. *a*, and run two fine needles *bb* through both its tendons, where they had been before held by the fingers; and then fix the points of those needles, neither too loose nor too firmly, in a piece of cork. If afterwards you irritate, Tab. XLIX. Fig. vi. *c*, the nerves, you will see the muscle drawing *dd* the heads of the needles together out of the places; and that the belly of the muscle itself becomes considerably thicker *e* in the cavity of the glass tube, and stops up the whole tube, after expelling the air. This continues till the contraction ceases, and the needles then move back into their former places; and the belly of the muscle, parting again from the tube, affords a free passage for the air through its cavity. But if the muscle be left to itself, or put into cold water, with all the apparatus just now described, we observe it contracts itself by degrees not long after; and is finally so remarkably bent, as to fill the whole cavity of the middle region of the tube.

Having therefore duly considered those experiments, which I have hitherto set forth, and at the same time attentively weighed the force of contraction or muscular motion, which the muscle resumes every moment, when its nerve is again and again irritated: one may ask, whether any other communication be necessary between the nerve and the muscle, but only that simple irritation on the touch or commotion? But as a similar motion is likewise excited in the muscles of animals which have hot blood, whose nerves are stimulated; the same question indeed may be likewise asked here, that is, whether in this class of animals also, any other communication be necessary between the brain and marrow, the nerves  
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and muscles, except this stimulus? for I have constantly found, by all the experiments that I made, that the muscles are contracted when the beginning of the marrow, or the nerves issuing from thence, are moved.

Hence I propose it, as a matter worth considering, whether we should not reject that opinion, which supposes a spirituous matter to be necessary to excite muscular motion, and that it flows out of the brain; and that this influx happens with such great rapidity and velocity, that these new spirits constantly propel the former, and in an instant of time, at the least intimation of the will, or otherwise spontaneously should, and may, be in the most remote extremes of the body.

I am persuaded, those who derive the contraction of the muscles from inflation, fermentation, or a kind of explosive motion, will differ from me as to this matter: they will object, that the inflation or expansion of the moving fibres, is evident even to the eyes, in the contraction of the muscles; and besides, that all the muscular parts are filled with spirits: and therefore, that only a small quantity of animal spirits is requisite to inflate either these, or those muscles, and to expand them by contraction, as is evident to the sight.

But all these opinions are certainly destroyed, if it be considered, how often the motion of each muscle is restored by only stimulating, provoking, or irritating the nerve in my experiment before mentioned: and this, when the nerve hath been for a long time cut off, and the requisite animal spirits dissipated, or grown weak, after many times discharging their duty; and when there is no further communication between the nerve, brain, and marrow. Therefore, I would have it seriously considered, that it cannot be demonstrated by any experiments, that any matter of sensible or comprehensible bulk flows through the nerves into the muscles. Nor does any thing else pass through the nerves to the muscles: all is a very quick kind of motion, which is indeed so rapid, that it may be properly called instantaneous. Therefore the spirit, as it is called, or that subtile matter, which flies in an instant through the nerves into the muscles, may with the greatest propriety be compared to that most swift motion, which, when one extremity of a long beam or board is struck with the finger, runs with such velocity along the wood, that it is perceived almost at the same instant at the other end; nay, that it is further propagated through the nerves into our muscles; and thus produces various motions in them, as those who attentively consider this singular, though plain experiment, well know.

Add to these another argument of yet greater weight, which is, that the muscles themselves, when contracting, are not in the least inflated or swollen, but rather they lose their thickness; though the moving fibres in the mean time acquire a different situation; or, to express the matter more exactly, they are pressed closer to each other. We observe something like this in a long piece of sponge, made even and smooth,

which becomes thicker and more solid by force of compression; though in reality it possesses a much less space. Therefore, for the many reasons which shall be mentioned hereafter, I think it may be rightly inferred, that the shortening and closer compaction of the moving fibres, by reason whereof they are contracted into a less space, is really the true action or contraction of the muscle; and which is therefore erroneously called inflation, tumefaction, &c.

For what reason can any one imagine it possible for the muscle to be inflated? since it consists of such subtile filaments, as are almost invisible; though even these are finally composed of globules. What matter can effect this inflation? Is it not necessary, that it should pass through those very fine fibrillæ, which constitute the nerves, and when curiously examined, without hurting them, are likewise so small as to be almost invisible? Certainly, if the nerves be considered to have their origin from the marrow, it is very evident, that they are so subtile there, and so closely surrounded by the meninges, that the smallest bristle, or thread of spun glass, can scarce pass through the aperture. How fine therefore must that spirit be, which can penetrate into this very cavity, which is likewise stopt up by the nervous filament that issues out of, and is contained in, it? Yet authors establish such notions; nay, they proceed so far, as to imagine, that the nutritious matter, to which some attribute the thickness of the white of an egg, passes through these very nerves: but this opinion is so idle and absurd, that it does not deserve a serious refutation. In the same light I consider the imaginary fermentation between the spirits and blood, by which the muscle is said to be inflated; though the very method of this inflation is contrary to the known construction of the muscles.

Another thing that plainly contradicts the inflation and influx of the supposed spirit into the muscles, is that we clearly see, tho' the muscle be cut, and its moving fibres separated from each other, all these parts move again, as it were naturally, as soon as the nerve which belongs to them is irritated: and this experiment, as well as others, may be made on the Frog, and several other water-animals, and it succeeds very particularly in the Duck.

From these experiments therefore, it may, I think, be fairly concluded, that a simple and natural motion or irritation of the nerves alone is necessary to produce muscular motion, whether it has its origin in the brain, or in the marrow, or elsewhere.

Therefore, we likewise observe in many animals, that as soon as the beginning of the spinal marrow is moved in the brain, all the subjacent muscles are suddenly contracted. And this happens in the same manner with respect to all those branches of the nerves which arise out of the marrow, at least whilst they are handled; tho' only some of the muscles, or perhaps that only, through which the irritated nerve is distributed, are put in motion. We must also take particular notice, that in this experiment, it is never observed,

served, that the part of the nerve above the irritated region, contract also those higher muscles, that have their nerves from thence. We very clearly find also by experiments, that the motion produced in the muscle by irritating the nerve, is always propagated out of the larger into the smaller branches, and goes afterwards continually descending. The nerves designed for the senses are circumstanced in a quite different manner; for in these, the sensitive motions, doubtless, tend upwards. In order to contract any muscle, it is necessary that its nerve be irritated in the region above the muscle, or at its insertion into it; since that motion never tends upwards, but always downwards.

It may now be probably asked, wherein I think the beginning of that natural irritation, stimulus or provocation of the motion, thus communicated to the muscles through the nerves, consists? Since I deny, that any visible flowing and inflating spirits, are locally moved through the nerves; and, on the contrary, think that a certain instantaneous irritation is much more subtle, and capable of the effort, than the spirits supposed by some necessary to move the muscles: and that, from thence, it follows, that this irritation should not only have its origin elsewhere, but that a force is likewise wanting, by which that motion is transferred through the nerves into the muscles. I confess these things are requisite, since experience demonstrates it even to the eye.

To give a proper answer to this question, I think, the beginning or principle of that motion lies in the spinal marrow, and is also in all the nerves of the body; so that the marrow, and all the nerves, are constantly and perpetually irritated to give motion to every muscle of the whole body. I would have it particularly observed, that I admit no essential difference between the natural and spontaneous contraction of the muscles, and that performed by the will. I consider this difference as merely accidental; but, because we move all these muscles, which we move voluntarily, in a contrary direction; that what is said to be essential in the contraction of all muscles, is a natural contraction. For this reason, voluntary motion ceases, or is changed in us, as well as in all other animals; when either the antagonist muscles are wanting, or when one of a pair is more powerful than the other, as I have formerly demonstrated in my treatise on Respiration. And indeed we cannot move muscles at will, unless we have the power of determining the natural motion of the antagonists to the contrary side. But if all the motions of our muscles are continual and natural, when the antagonists are wanting, as is the case with respect to many muscular parts of our body, which we have not power to move at our pleasure; only so far as those muscles are first dilated by their contents. These perform the office of antagonist muscles, and give us the power of moving them in a contrary direction at the command of our will:—but otherwise, all things acquiesce in the perpetual contraction.

In order further to explain the origin of this natural and perpetual contraction of the muscles;

I think indeed it arises from the continual impulse of the arterial blood upon the marrow and nerves: for, by means of this blood, all those parts seem to be continually moved, excited, and irritated to convey that motion perpetually and uniformly to the muscles, and to prepare the latter for their perpetual contraction. For this reason, all the nerves without exception, have not fewer arteries in proportion, than the brain itself, and the spinal marrow have. I should think indeed, that this matter might be easily ascertained by experiments: for which purpose, I once thought of injecting a peculiar liquid through an artery into the marrow, by a small siphon, and then to observe carefully, whether any motion was thereby excited in the muscles. But I would again advise the reader, to consider well that wonderful motion and power of the muscle, when its nerve is in the least disturbed or stimulated.

It is now time to proceed further; and I shall, by a curious experiment, demonstrate to the eye, that the muscle is not at all swollen in its contraction, or becomes thicker by inflating it, and therefore occupies the larger space; nay, on the contrary, that its swelling decreases: and therefore, in its contraction or action, fills less space than when it rests flaccid. I say rests, because I cannot observe that the muscle in the living animal, ever absolutely ceases from all motion. And therefore it should be rather said, that it is less strongly moved at the time of its relaxation; or then only recollects its elastic strength, that it may be able, the moment after, to make the stronger effort to contract itself. This may be seen very clearly in regard to the motion of the heart and auricle in the Frog; for the blood is there brought back from the circumference of the body, according to the laws of circulation, and being driven in to the auricle, it may be considered as the auricle's antagonist muscle, which dilates it: but the auricle itself is the antagonist of the heart, since by means of the blood, which it protrudes into its cavity, it likewise dilates its substance, so that the wonderful, repeated, and continual pulse of the heart, has its origin from this alone: that pulse is therefore perfectly natural and necessary; for those two muscles, that is, the heart, and its auricle, are unequal in size and strength, and therefore their motion is necessarily varied. If the auricle were as firm and as strong as the heart, the motion of each would absolutely cease; for, wherever the power of the antagonist is equal, there is observed no motion of the muscles, and all things are in both in equilibrio, until there arises another determination, which, causing one muscle, to be contracted somewhat more strongly than another, at length moves our limbs. Such a determination may proceed from various causes.

If, for example, a man's skin be very gently rubbed and irritated with a hair doubled several times; I often observed, that the motion of the antagonist muscles of the arm and hand was immediately determined; so that the person instantaneously, as it were, unknown to him; has put his hand to the place where he felt the titillation,

and then scratched the skin until he made it red, imagining that it was probably occasioned by a Flea, or some other insect. But when I stopt, his hand and arm rested likewise, because the natural contraction was then equal in all the muscles. If the same experiment be made on sleeping dogs or cats, it is likewise observed, that a determinate motion is produced in the muscles which move their skin; and therefore it is pleasant to see them suddenly draw it up, pricking up their hairs, and sometimes shaking them in their sleep. By this familiar instance, it is evident how our muscles are in like manner voluntarily moved without any great attention of the will, by something of this kind, which is proper to determine the natural motion of the antagonist to the contrary side.

Now, in order to make it certain from experiment, that the muscle is not inflated in its contraction, but on the contrary possesses less space, we are to take a very lively and sound Frog, and dissect it, uncover its heart, and carefully take away the pericardium from it. After this, we must choose one or two veins or arteries, which are large enough to be conveniently opened, and to admit a thin glass tube. By this tube, all the veins and arteries of the body, and consequently the heart, may be very easily inflated; since, as I have before hinted, the lungs are in this animal no obstacle.

When the heart is filled with air, it must be dexterously, together with its auricle, tied with a fine thread, and cut away from the body: then let a glass siphon be ready, one end of which must be a narrow and small tube. Let the heart thus inflated, and its auricle, be put into the flat end of this tube, and let all be immediately put into that glass siphon; the long tube of which must, in the mean time, be stopt with a very small drop of pure water, or, that it may be the better distinguished, water coloured with blood.

Having duly observed these directions, it will manifestly appear, that at the time the heart, Tab. XLIX. Fig. VII. *a*, contracts itself within the little siphon, *bb*, the drop of water adhering near the extremity of the tube, *c*, descends in a very remarkable and surprising manner to the other end of the tube, *d*, where it springs from the siphon; and, on the contrary, it will likewise distinctly be seen, that the drop thus fallen down, *d*, will, on the heart's dilating itself again, rise to its former situation, *c*.

This experiment furnishes us with an evident proof, that when the muscle of the heart contracts itself, not only all the fibres which serve to move it, are pressed closer to each other, but that the heart itself also, occupies a smaller space in its systole, than it did before in its diastole.

This also is the reason why the drop of water *c* moves downwards, *d*, as it cannot but follow the heart, when this contracts itself. But if at the very instant of the heart's contraction, any inflation, tumefaction, or dilatation, had been produced by the animal spirits on the inside of this organ, the drops, instead of descending towards the belly of the siphon, *d*, would infal-

libly have risen towards the extremity of the tube, *e*.

As the former never happens; and the latter, the very reverse of it, is constantly the case, I may fairly and plainly conclude, that the muscle of the heart requires less room by a great deal in its contracted, than in its dilated state; and that hence the supposed spirits, by which it has been hitherto believed, that the heart, or its muscle was puffed up at the time of its systole, has not the least share in producing that effect.

Moreover, if we open a living Frog, and carefully attend to the motion of its heart and the auricle, we shall find, that in this experiment, every thing proceeds exactly in the same manner as it did in the former. For, when the auricle contracts itself, it very sensibly grows smaller, and more compact; but when the heart is again contracted, it undergoes the same alteration; and this observation is sufficient to convince us, that there is no manner of difference between the two contractions of the heart, one of which takes place within the siphon, and the other naturally, except that the heart, out of the siphon, is inflated with blood, and with air in the siphon.

As to the other experiment made in the siphon, we must here particularly observe, what happens in the heart during its dilatation, and what change is seen afterwards during its contraction. When the heart dilates itself, we plainly perceive that the auricle begins first to contract, and while it does this, the air is forced from it into the heart; by which means it is considerably expanded, and appears in the siphon as if full of bubbles or bladders of air. It even becomes pale and transparent on this occasion, and appears irregularly affected. This is owing to its moving fibres, and fleshy columns, not being every where of the same thickness, so that some of the parts of the heart lying between these columns, are more distended by the impelled air than others. Thus at length is effected, the ascent of the drop of water adhering to the glass tube.

When the moving fibres of the heart again contract themselves, we observe that the heart draws itself in, and becomes smaller, and immediately after, we see the air forced from it, in its turn into the heart; upon which this last immediately becomes more red and opaque, and shrinks up so as to put on an unequal appearance: but as the heart at this time cannot return to the auricle, all the air it had thence received, its moving fibres approach towards each other with so violent an effort, that they likewise condense the air contained in them: and thus is the drop of water adhering to the tube of the glass siphon pressed downwards, on account of the heart being then reduced to a less size.

This is likewise the case with the heart, which is naturally full of blood; for when this organ in its systole is distended by the blood, it draws away the circumambient air; but when it again contracts itself, and discharges its blood, it grows less, and yields to the air in proportion as it shrinks up, a thing which ought to be well attended



tended to, as it is very conspicuous in a living animal. The blood itself undergoes some condensation, when violently compressed by the contraction of the heart, and forcibly expelled out of it; but is also on the other hand somewhat rarified, when the heart is dilated by a new intromission of blood, so that this natural action of the heart and blood corresponds exactly with that artificial one of the heart and air in the foregoing experiment.

It may be objected, that naturally in the live animal, the air by no means approaches the heart, and therefore cannot be repelled by it. But the contrary is plain in the case of Tadpoles, in which we see the external skin sensibly affected by the pulsations of the heart, and swell out and sink in alternately, as that organ dilates or contracts itself, which is the same as if the air pressed immediately against the heart itself. It cannot be denied, but that the same thing must happen in all animals that have lungs and gills, and a moveable breast; nay, it must, without doubt, take place in some motions of the muscles.

If you cut a Frog's heart out of the body, and place it in the glass siphon, in the manner before described, without first blowing it up; you will plainly see the drop of water move in the same way it did before, though not so much as if the experiment were made with an inflated heart. In the mean time, the water also will sink in like manner, when the heart contracts itself. Experience teaches us, that the descent of the drop of water in this experiment becomes sometimes so inconsiderable, that it cannot be perceived, even by the help of the microscope, which is owing to this, that the heart then continues partly contracted, and is not dilated by the auricle, which is now become insufficient to produce that effect, as it neither propels any blood, or air, with which the heart could be distended. Hence, of course, the contraction of the heart must become proportionally weaker, and the motion of the water in proportion less discernible. But if you blow into the auricles at this time, that this auricle, by contracting itself, may force a quantity of air into the heart; the success of the experiment will immediately become much more conspicuous.

If, instead of the heart, we should chuse to make use of some other muscle, we may proceed in the manner represented in the eighth figure, where the glass siphon, Tab. XLIX. Fig. VIII. *a*, contains within its hollow the muscle, *b*, and the nerve hanging from the muscle is fastened, without being cut or bruised to a slender twisted silver wire, *cc*, that runs at the other end, an eye made in a piece of brass wire, soldered to the embolus or piston of the siphon, *d*. Things being thus made ready, a drop of water, *e*, must be let into the slender tube of the siphon by a very fine funnel. Now, if after this, the silver wire be cautiously drawn with a lieisurely hand *f* through the ring or eye of the brass wire, till the nerve is irritated by the compression, it must by this means undergo, the muscle will contract itself in the same manner with the inflated heart, whose alterations, upon a similar

occasion, I have already described, even the drop of water will in some measure sink, though afterwards it never rises again. But this experiment is very difficultly sensible, and requires so many conditions to be exactly performed, that it must be tedious to make it; for which reason, I have bethought myself of another that may be more easily understood and performed.

You must have ready a little glass siphon, Tab. XLIX. Fig. IX. *a*, cut through with a diamond near the extremity of its slender tube, *b*; then pass through the hole thus made, the nerve of the muscle *c*: but as the air can easily make its way through this hole, while the nerve is irritated, till it contracts itself, so as to keep the water from sinking; it is absolutely necessary to stop that passage on the outside, which may be easily done with a little ising-glass and starch. But I must own, that in this experiment, the sinking of the drop is so inconsiderable, that it can scarce be perceived: for this reason, the heart is fitter for this experiment than any other muscle, as it continues and keeps up for a considerably long time, and with sufficient strength, the motion it has once received.

There are sufficient reasons why this experiment should succeed better when tried upon the heart, than upon the other muscles; the principal seems to be this, that in the other muscles, there is no antagonist to dilate them externally, nor any blood, which introduced into the blood-vessels, can extend them, and disband the muscle itself from within; though all these conditions are absolutely necessary to affect a perfect contraction in any muscle.

The experiments which were some time ago published with a view of proving, that a quantity of blood is requisite to contract the muscles, do in reality no such thing. Their principal weight lies in the constriction of the aorta, effected after D. Steno's method; but this is truly nothing to the purpose, and can only impose, at first sight, even upon those who examine matters of this kind with the least circumspection. For, by only considering with a small degree of attention, that the vertebræ, many nerves, and even the spinal marrow, which are all fastened by the ligament, directed by D. Steno, to be used on this occasion, undergo thereby a violent compression, it must plainly appear, that no conclusions can be fairly drawn from such a trial. Much less can we infer any thing from the other experiment, in which the blood is expelled from the muscles, to make room for water introduced into them by a siphon; since the moving fibres of the muscle are considerably injured by this rough procedure; so that this coarse experiment can only support a weak argument with unthinking people, being calculated merely to confirm the experiment of D. Steno just now described. Stronger proofs may be reasonably insisted upon, to demonstrate a thing of such importance, and the ligatures of the arteries of the thigh, particularly, in Frogs, must be allowed to be a great deal more to the purpose.

We ought, however, greatly to commend D. Steno's circumspection, in not taking upon him-

himself to determine the manner in which the motion of the muscles is performed; neither was he bold enough to pronounce, for certain, that this motion proceeded from the influx or afflux of any new matter. But after I had, some years ago, made him acquainted with the experiments I had made on this occasion, as already related, he made no difficulty of telling me plainly, that he was in no measure afraid of absolutely denying the accession of any new matter in the contraction of the muscles; so that our opinions of this important operation perfectly coincide.

Even I myself, relying on the propriety and certainty of the experiments I have proposed, can now, without any difficulty, maintain, that a muscle, at the time of its contraction, undergoes no inflation or tumefaction, from the afflux or effervescence of the supposed animal spirits; but that, on the contrary, it in this state becomes smaller, or collapses; or, to express my meaning more clearly, it takes up less room than it did before.

Nothing can be more evident than this alteration, when a heart filled with air instead of blood, or one quite emptied, is made use of; in the first of these experiments, there occur many other things worth our notice, which may all have place and force in the contraction of the muscles: first the enclosed air in the heart is condensed, and forced together; secondly, the circumambient air is dilated; thirdly, the fibres of the heart are most violently compressed and strained in this action, and the little cavities within, or between them, are compressed; so that whatever has lain in these cavities must be discharged. And all these things appear chiefly at the time the heart relaxes, as it were for a moment in its contraction: fourthly, the internal air is afterwards again rarified in the heart: fifthly, the external air is on the contrary condensed, and driven from its place: and sixthly, the fibres of the heart are again extended or dilated.

If any one object, that the air in this case is out of the course of Nature in its place, I can readily answer, by assuring him, that I have found air in the hearts of human subjects, opened immediately after their death. But as this is not a common case, I am content, that blood may be substituted to the air which I supposed to be found in the heart: the blood contained in the cavity of the heart, is on that cavity's contracting, shaken, condensed, and expelled; the same thing also happens to the blood which then flows through the coronary veins of the heart, and shaken, or violently driven out of them; upon which account also, the substance of the heart grows considerably paler at this particular time. Now, while the heart is thus contracted in its substance, the circumambient air is likewise rarified; and lastly, the fibres which serve to move the heart violently, become powerfully contracted in the same manner with the inflated heart, as already mentioned. But the last appearances I took

notice of on the same occasion, and which were the reverse of the first, deserve to be here likewise considered, as they act in the ensuing dilatation of the heart, when in its natural situation, and when it is moved in its natural manner.

From all these particulars it evidently appears, that there occur in the contraction of the muscles, a great many more things to exercise our reasoning and industry, than authors have hitherto considered. And above all, we ought most carefully to observe, with what strength the moving fibres of the muscles draw themselves up while the fibres are contracted. This power is so great, that I have seen them in some animals become three times smaller than in their natural state of constant contraction. And on this account, all their contents, being all the blood and juices which had flowed into the blood-vessels running through them, were most violently forced out by this powerful motion. Hence also it happens, that the muscle of an animal, whose blood is red, is much paler in a contracted, than in an expanded state. This D. Steno likewise has observed.

By this observation we are enabled also to account for the considerable heat caused in the body by the determinate and reiterated motion of the muscles. For as the muscles propel the blood from themselves by their violent contractions, it is impossible the motion and circulation of the mass of blood should not be thereby considerably increased; a circumstance which surgeons, who are informed of it merely by experience, have contrived in blood-letting, to take proper advantage of it; for at this time they give the patient a case of instruments, or something of that kind, to employ his hands, that the muscles being thus put in motion, the blood may more freely issue from the veins: the imagination alone is often powerful enough to have the same effect, as our muscles are at that time variously influenced according to the lively or gloomy nature of the thoughts which then possess us, and proportionably contract and shut, or expand our hearts.

I saw myself, in the hospital of Leyden, a boy from whose feet the skin and flesh had lately fallen off in a gangrene, who by the bare motion of his muscles, without retaining his breath, could contrive to discharge at will a considerable quantity of blood from the wounded part. And I have likewise observed the same in the motion of many animals, whose blood, tho' they wanted lungs, flowed much more freely from them in motion, than when at rest.

This case even extends so far, as to account for lassitude or weariness itself, which is occasioned by the muscles being too much distended by blood, and consequently rendered less fit for contraction, as I first observed, in shaping with my breath a piece of glass melted with a lamp heat; for the muscles called Buccenatores in my face, came at last to be so violently distended

tended with blood by this operation, that entirely lost the power of contracting them again, so as to be able to discharge the air at my mouth, in a manner requisite for the business I was about.

It is very wonderful, how insects in winter, when all their blood and humours are congealed, as it were, in their vessels, lose likewise all power over their muscles; so that if their legs and other limbs be extended without doing them violence, they will remain in that posture till the creature recovers the power of moving them, on the return of warm weather, or by being placed near a fire; for a very small degree of warmth communicated to them in the best manner, is sufficient to restore them to life and motion, to enable them to turn about, run, and even fly, till their blood and humours congeal again, which they do in a very short time; and the little animal is thereby reduced to its former state of inaction. I have likewise observed that famous vegetable called the Sensitive plant, is much less sensible in autumn, than in the summer season.

It may be asked how is the effect of the natural determinate irritation of the nerves, or even of that which is produced from without, and by art produced; since it is not possible to prove, or reasonable to suppose, that any sensible matter is at that time conveyed, or locally carried into the muscle; but, on the contrary, it must be allowed, that the muscle discharges the matter it contained, so as to fill a less compass?

I must confess it a very difficult task to answer this question, and perhaps impossible, till the true contraction of the muscles shall be exactly known. For this reason I shall enter upon a method for attaining some certainty in this matter, like that pursued in acquiring just notions concerning the use of the eye; for the manner in which vision is performed, was discovered without any true knowledge of the structure of that curious organ, by which we enjoy that great blessing. Hence, were I permitted to make use of a coarse similitude, I might conceive it effected in the same manner with the alterations visible on handling, or touching ever so gently the parts of the *Herba Impatiens*, called *Touch me not*, or podded *Ars Smart*, or the *Balsamita alteria* of *Fabius Columna*; the parts of which plant being extended according to the course of two or three nervous or herbaceous fibres, in consequence of any momentary irritation, most suddenly contract, and the pods burst.\* And certainly, if these fibres, which cannot so expeditiously contract themselves, before the seed of the plant to which they belong has arrived at its due maturity, did not curl up and fall off, but

instead of thus perishing, could be again dilated like leather, when forcibly bent, and excited by a new irritation to a new contraction, we should have in them a most curious example of the action of the muscles, the principal of which consists in a contraction following a dilatation; so that it is the contraction of the muscles, and not the dilatation of them, that we ought to consider as their principal office, since even when the animal is dead, they will still endeavour to contract themselves. I have even seen a muscle contract itself, when boiled in the same balsam in which I had preserved it for several years.

Let people think what they please of the above-mentioned similitude, or comparison; at least the experiment informing us that the muscle contracts itself as soon as its nerve, is put in motion, rests upon a most solid foundation: but as I demonstrated at the same time, that a muscle takes up less room in its contracted, than in its dilated, state, it most evidently follows, that there does not flow into it at that time, as has been supposed, any expanding or rarefying matter, but that that substance must be inconceivably fine and delicate, which at that moment of time can produce in the muscle so wonderful a motion; though we are not certain that this effect differs in any thing from that which the wind, a finger, a stick, or a bristle, has in contracting the little fibres in the contractile pod of the *Touch me not* plant.

I therefore think, that, as I said before, it may be from hence fairly inferred, that whenever the nerve is immediately irritated, the muscle, to which it belongs, must be in a state of perpetual contraction, or at least in a state of perpetual effort, and endeavour to contraction. This is a circumstance, which I formerly observed in my treatise of *Respiration*, and shall hereafter more clearly explain, as I intend to publish a new method, in which we may in some measure consider the constant motions of the muscles.

But before I undertake this task, and thereby make an end of the present treatise, I must consider in what state or condition the muscles were before they exercised any motion. This may be very easily seen in insects, and even in the rudiments of the muscles belonging to larger animals, whose muscles at that time are generally compact, white, membranaceous, and seem composed at their very first appearance of a kind of glutinous humour. In insects, it is very remarkable, that at the time of their changes, their muscles become in a manner invisible, and afterwards increase in size to a prodigious degree; nay, even their limbs disappear, and grow in the same manner, but more

\* To the plants here mentioned by Swammerdan, may be added several others, in the seed-vessels of which there is this elastic power, which he supposes in some degree analagous to the muscular motion in animals: in the multitude of examples, the truth will be best discovered.

The Wood-forrel, wild Cucumber, and Lady-smock, among the common kinds; and in the *Momerdica*, *Phylanthus*, *Euphorbia*, *Justicia*, *Ruellia*, *Dianthus*, *Ricinus*, *Tragica*, *Jatropha*, *Cretan*, *Clusia*, and *Realypha*, among the more rare; and most of all in the *Hura*, or *Sand Box-tree*, which bursts with the report of a pistol, and scatters its separated parts throughout.

These are the subjects in which the origin and causes of this motion in vegetable parts may be traced, and the subject is worthy a full disquisition.

particularly their legs, and the muscles of those parts, which swell and extend every way in a surprising manner, by means of the blood and humours driven into them, just as if they had been injected with additional liquors; so that in course of time, they are as it were unnaturally stretched, and bent in the manner of a bow. But this alteration obtains chiefly in insects, whose muscles also move much longer than those of any other species of animals; and even retain their motion, in many species, after the head has been separated from the body. We observe also, that as soon as insects break from their old skins, their bodies grow larger every way, almost instantaneously; and the same thing happens, in proportion, to animals whose blood has an extraordinary degree of heat in it. Hence it is, that their muscles endeavour the more violently to contract and draw themselves together. In fine, we likewise very plainly see that the muscles, when first they begin to exert their powers, grow much redder, on account of the blood penetrating at that time into their substance, and in some degree expanding it; and they become likewise much larger, by means of the blood-vessels which run through them, and extend their moving fibres.

From these particulars it evidently follows, that every contraction of a muscle must be preceded by some degree of dilatation; and this dilatation I suppose to be of three kinds. The first is performed in the natural and voluntary contractions of the muscles, by the blood forced into, and thereby partly dilating them. The second, which obtains, in natural contractions, I attribute to the contents, which by extending and dilating the moving fibres, and thereby drawing the blood more copiously to them, occasions a relaxation of their contractile powers. The third kind of dilatation is that which precedes the voluntary contractions, and seems to be produced by the determination of the antagonist muscles; for these act upon the muscles, opposed to them, in the same manner that the contents act upon muscles, whose motions are natural.

Now what does that subtile matter, which constantly flows through the nerves into the muscles, contribute to their contraction? Is it derived to the moving fibres, serving to open some of the blood-vessels that surround the nerves lying within the muscle? Or does it, by mixing with the blood, make it suddenly effervesce and ferment, and so excite that motion, by which the muscles may again shake off such subtile matter, so as to cause an immediate contraction of the moving fibres? I must own myself unable to give a satisfactory answer to any of these questions, and therefore leave them, as a most fruitful matter of contemplation, to the discussion of others.

As to the other things which I have hitherto proposed, I think I may thence most fairly conclude: First, That all the muscles are naturally contracted; that is, they are in a state of contraction before they have performed any mo-

tion. Secondly, That their contraction is, in part, destroyed by the blood, and such other humours as flow into them from their particular vessels; and that this is, as it were, the first cause of the dilatation or expansion of the muscles, though they still persist in a state of contraction in a lesser degree. By this power also, the circumambient air is driven out of its place, and becomes condensed, in the same proportion wherein the muscles are expanded. Thirdly, The contents of the viscera, cavities, and little tubes of the body, about which the moving fibres are disposed, contribute greatly, as a secondary cause, which obtains in natural motions, to the complete distention or dilatation of the muscles; whereas, in voluntary motions, such complete distention and dilatation must be attributed chiefly to the contrary determination of the antagonist muscles: for the moving fibres in these two species of muscles, which are differently situated, are considerably expanded by these two causes, which likewise dispose the blood-vessels, belonging to the muscles, to receive a far greater quantity of blood; so that the dilatation being once arrived at its highest pitch, the returning contraction may be the more powerful. Fourthly, The air, already repelled and condensed, contributes greatly to produce this effect; for, by being immediately urged to dilate itself by the equilibrium of the atmosphere, it, in its turn, acts with the greater violence upon the muscles, to oblige them to return into their late state of contraction; which is besides so natural to them, that they would reassume it of themselves, sooner or later, without any such compulsion. Fifthly, We must add to the causes already assigned, the perpetual and natural irritations which the nerves are constantly exciting in the moving fibres of the muscles themselves, and which are continually engaged in urging them to contraction. I would here be understood to mean those stimuli, which are produced by the blood in its circulation, and in its passage through the arteries to the origin of the spinal marrow, and all the nerves; or else those stimuli which are communicated to the beginning of the spinal marrow, and the nerves, by external objects, which make an impression upon the blood. Hence therefore, in the sixth place, the muscles, as well the natural and moveable ones as those subject to the dictates of the will, are necessarily disposed, and in a manner constrained, to return to their original and natural state of contraction. Hence, seventhly, I may reasonably conclude, that in all the reciprocal contractions of the muscles, their contents are again forcibly discharged, since the moving fibres, which were before extended, at this time come nearer again to each other, and become very compact, so as to recover the situation they were in, previous to their being dilated. For this reason also, they must then take up less room, though we may see some tumours arise at this time on the surface of the muscles; these tumours being produced by the extraordinary compactness of the  
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the fibres, of which the muscles are composed, and consequently by the subsiding of the adjacent parts, rather than by any inflation of those parts of which they themselves consist; as the authors, who have hitherto treated this subject, have falsely imagined. Seventhly, and lastly, therefore, I from hence conclude, that all the actions of the muscles consist in contraction, or in a return to that form and disposition they had before they were dilated; so that the muscles, as often as they are again dilated, or determined a contrary way, by the cause already assigned, or by means of their contents, or by the action of the antagonist muscles, constantly return afterwards to their former state of contraction, whether the motions they are to give be natural or voluntary.

Though this be usually the case, and principally with regard to the natural motions of the muscles, it nevertheless is observed to take place in their voluntary motions also; though, to effect these last, the consent of the will is likewise necessary. For we find, that, in all the voluntary motions of the muscles, there is likewise absolutely required some internal or external cause, by means of which a contraction of the antagonist muscles may be determined another way.

Therefore, since all the muscles are in a perpetual state of contraction, it is easy to conceive, that the least degree of determination, whatever cause may serve to produce it, is sufficient to dispose them to move the body, make it advance, remove it from place to place, and actuate it in a thousand other different ways.

Nor is it in natural motions alone, that things are observed to proceed in this manner, as plainly appears by the contraction of the pupil of the eye, which instantaneously expands and dilates itself, by means of its muscles, as the eye is more or less irritated by the particles of light. The same may be observed of the moving fibres of the intestines, which constantly also contract and expand themselves, in proportion to their contents; so that their motion perfectly resembles that of the sea, whose waves follow and mutually press upon one another.

We often observe, that a natural contraction takes place in those muscles, which are said to move as the will directs; as is manifest in our walking, standing, and making use of our hands: for we certainly move our limbs almost every moment, without reflecting in the least upon what we do. Thus, with regard to external objects, we often salute a person we meet, merely because another in our company takes off his hat, or because we are affected by such external object, though we do not know who the person is we have saluted, nor so much as think of our saluting him. For this reason therefore it is plain, that as our memory is local, and is assisted by the image of one thing in passing to that of another, and so on without end, the contractions of our muscles are in like manner natural; and the muscles themselves are urged by one cause of motion to another,

and from this to a third, and so on without any interruption.

It is for a similar reason, that, when we find ourselves too near the fire, we retire to a greater distance from it, and put our limbs, by means of various motions, into their former posture, without attending in the least to what we do; but merely in consequence of the impression made upon us by the irritating object. From hence it appears, that we can never be truly said to move voluntarily, unless when the will itself is put in motion by the object, and then by its own motion produces a third; for whenever the light happens to be too strong, we shut our eyes, turn our head aside, and give ourselves many other motions, as we are variously excited to them by the objects that present themselves.

All these facts abundantly prove, that those very muscles, by whose assistance we perform our voluntary motions, are notwithstanding always themselves moved in a natural manner, not only because an internal or external principle, cause, or object is alone requisite to determine them; but likewise because a voluntary motion is never produced, unless such a determining principle, whatever that may be, precedes it, though it should be but a thought merely casual, let alone one previously excited. Cannot a simple dream, or some absolute phantom, presenting itself before us in the night, so affect us? Even in this case, we immediately start, tremble, and perhaps get out of bed, shriek, and call for assistance. And all this we do merely because we then just determine another way our muscles, already prepared for action. We may observe the same things also in our spontaneous or natural motions, though such motions can be but very seldom determined by us, and that also under certain conditions only. For our will, as I took notice in the beginning, has very little power in determining such of the muscles as have no antagonists; and indeed, if nature had not bestowed upon us such antagonist muscles, we should have been little better than vegetables, which cannot stir from the place wherein they have taken root.

It is evident, from the foregoing observations, that a great number of things concur in the contraction of the muscles; and that we should be thoroughly acquainted with that wonderful machine our body, and the elements with which we are surrounded, to describe exactly one single muscle, and explain its action, in a satisfactory manner. On this occasion, it would be necessary for us to consider the atmosphere, the nature of our food, the blood, the brain, marrow, and nerves, that most subtle matter which instantaneously flows to the moving fibres, and many other things, before we could expect to attain a sight of the perfect and certain truth. For my part, I own that I have endeavoured to offer something on this important subject worth the publick's acceptance; but yet I am sensible, that all this time I have been, as it were, representing with a coal the sun's

sun's meridian rays: so that this my little essay can pretend to no merit, on any other account, but that of its conformity to Nature, which I hope I shall, in time, be allowed not to have misrepresented. And that time will be, when happier geniuses shall have made all these things clear and evident; for this may certainly be attained by laying aside all little thoughts of our own glory, in investigating the works of Nature, and thinking of His only, without whose assistance we could not even know any thing of them. At that happy period, the desire of writing for the sake of being talked of, will no longer prevail: we shall not then be anticipating our own praises, since all our intentions being directed to the honour of the Creator, we shall of course resist the corrupt

motions of our hearts, apt to be delighted with flattery, and fond of obtaining the title of learned and ingenious men: all which I only consider as vanity of vanities, since truth is the only thing upon which we ought to depend, as on a firm foundation, and for which we ought to value ourselves. Who is it amongst us, that shall discover the truth, considering our blindness in judging even of the visible objects that surround us? Hence therefore, to conclude this essay, I shall observe, that every true and valuable discovery is the gift of the Divine Grace, which God distributes as he pleases, and makes manifest at his own time. My observations, concerning the nerves, may be found in my history of the Rhinoceros Beetle.

*The End of the Natural History of Frogs.*

*A comparison of the changes in the Clove-Julyflower, with those in insects during their Nymph-state.*

TAB. XLVI.

I Exhibit in the figure of this Table,  
N<sup>o</sup>. I. The garden Caryophyllus, or Clove-Julyflower, under its first coat or tunick, within which it goes by the name of the seed of the plant.

II. The said coat or tunick fallen off from the latent rudiments.

III. The little new germen, or first shoot of the plant.

IV. The said germen opened into a few leaves.

V. The same germen or bud, when its folliculus or flower-cup is called a gemma, or bud; in which condition I consider it as a Nymph.

VI. The Caryophyllus or Clove-Julyflower itself, after it has burst open its gemma or bud, and is become ready to shew its seeds.

Having shewn in general, in the first part of this work, the similitude there is between the changes of vegetables and those of insects, I shall now, to make it the plainer, give a particular instance of it in the Caryophyllus or Clove; adding figures, to make every thing the more intelligible\*.

Tab. XLVI. Fig. 1. First then I give a figure of this plant's seed, as it appears to the naked eye; and then, at the letter A, I represent it as it appears through the microscope. Near the middle of it there appears a white protuberance; by which, while it remains in its cell, it receives life, nourishment, and increase, in the same manner with the eggs of insects in the ovary; so that we may consider

this first principle, which is likewise found in other seeds, as the cicatrix of the navel-string, after it has been cut and tied up. There appear also, on the surface of the seed of the Clove-Julyflower, some very pretty little jagged unevennesses, interspersed with black spots; by means of which it looks not unlike that rugged skin called chagreen, and may indeed be very aptly compared to that kind of skin.

Fig. II. Secondly, I exhibit the coat, skin, shell, peel, rind, or tunick, which the Clove-seed throws off, in order to appear under the shape of a germen, or first shoot, III, just as insects cast their skins at the time of their changes.

After having represented the external appearance of the Clove-Julyflower-seed, N<sup>o</sup>. I. and A, I give the form of the skin it has cast off under N<sup>o</sup>. II. At the letter B, I give the true appearance of the seed contained within that skin or coat, drawn after nature; and at the letter C, as it appeared through the microscope, that my readers may be able to form juster notions of it. There are two things in this seed which deserve particular regard; namely, its prominent apiculus, or point, and that bivalve division or parting which is to be seen in the rest of its body. On the seed's being committed to the earth, we observe that the point or cone bends downwards, and divides into roots at its extremity, N<sup>o</sup>. III. whilst the rest of the body of the seed, opening more and more, at last throws off its external coat, N<sup>o</sup>. II. and constitutes the two first leaves of the future plant.

\* In the course of vegetable nature, if the system of vegetable generation, just published by Dr. Hill, be found to answer equally in all other plants as in the instance there proposed, the origin of this part of Nature's products is very simple. There remains nothing of that incomprehensible doctrine of invigorating atoms, or a seminal air; but the whole operation is a continued growth. The fibres of the root are composed of five substances, laid over one another, and these terminate in the several parts belonging to the flower. The fleshy substance of the stalk terminates in the antheræ, and each termination of it is in a minute plant, which is lodged in a grain of farina, and defended by a watry substance: it is with this carried down the style into the seed-vessels, and lodged in the seeds. These cover it with new membranes; and when put into the ground, it casts off these membranes, and acquires its growth, just as this author observes of the Clove; confirming all his observations.

Fig. III. As represented after nature, under the third number. I here exactly exhibit the two first leaves of this plant, with its root, and the fibres belonging to that part, and all the tender little rudiments of the infant Clove-Julyflower, which at this period exactly resembles an insect; that has just crept out of its first coat or skin.

Fig. IV. Fourthly, I exhibit the germen of the Caryophyllus, or Clove-Julyflower, somewhat more grown, and adorned all round with excrecent leaves, which may very well be compared with the little bundles of hair springing from the skins of Caterpillars.

Fig. V. I shew in what manner the germen, or first shoot, has at last grown to a gemma or bud, calyx or cup, which contains the latent Clove-flower, neatly folded up; in the same manner that the Nymph or Chrysalis contains the future flying insect. But there is this difference, that the parts of the Clove are uniformly surrounded with one continued coat or skin, like the embryo Chicken in the shell of its egg; whereas all the limbs of Nymphs or Chrysalides are wrapped up each in its own peculiar covering, without being ever found under one common coat, unless it be in such insects as never throw off their last skin; as is the case in the fourth order.

Fig. VI. Lastly, I give a drawing of the Clove, at the time when it is in flower: when, after having burst its calyx, gemma, or bud, in the same manner that the new Butterfly breaks from its Nymph or Chrysalis, and acquired its full size, and age proper for shedding its seed; it seems to wait, in its gay attire, for the coming of its mate, just as insects do for an intercourse with theirs. But as the Great Architect has not allowed plants a power of motion, and has ordered that they should propagate the species without copulation, this little flower by degrees breathes forth its life, by a continual evaporation of the most fragrant odours, re-

sembling the breathing forth of so many amorous wishes; and finds only in its death the means of making itself immortal in its offspring.

There are likewise insects, as I have elsewhere observed, which, though distinguished into males and females, propagate their species without any venereal intercourse. Of this kind is the Ephemerus. Even animals that have blood, as fishes, for example, are found also to perpetuate themselves in the same manner.

If, therefore, we attentively consider the order in which the parts of insects, larger animals, and vegetables increase, and alter from one form to another, and the other particulars belonging to such increase and changes, we shall evidently see, that all God's works are really founded upon the same rules, and agree together with an inconceivable regularity. But who is it, that, after seriously reflecting upon such an agreement, dare maintain, that the meanest being under the heavens can owe to mere chance its essence, existence, preservation, and rank in the creation?

As the generation, breeding, increase, and changes observable in the Louë, the Dragon-fly, the Ant, Butterfly, and common Fly, how often soever repeated, are observed to obey constantly the same laws, remain within the same limits, and proceed in one uniform and certain manner; what reason can there be to suppose, that the other parts of the creation should be governed with less wisdom, power, and goodness? What grounds for the least diffidence in the Great Lord and Master of such an universe? What powerful motives rather have we not, to acquiesce humbly in his counsels, adore his omnipotent hand, and praise his works, whose exquisiteness infinitely surpasses the strongest efforts of the most subtle and daring imaginations?

### *The Conclusion.*

**C**ONCLUDING this work, I cannot but observe that the manner in which the insects I have treated of, and all others, escape the injuries of the cold and rainy seasons, is of too much importance, and too surprising in itself, not to deserve some share of our attention. Experience has taught me, that they do this in four different ways.

First, I have observed that the insects themselves, which have acquired their full growth and perfection, outlive the rigours of winter; at which season they so entirely lose all power of motion, that when taken from the little places of retreat they had chosen for themselves, during the autumnal months, as best agreeing with their several natures and dispositions, they cannot by any means reinstate themselves. But if you cherish them gently with a warm hand, or hold them at a proper distance to the fire, they not only soon recover the

power of moving themselves, but likewise the use of their wings, with which they fly about as before, till the coldness of the circumambient air has again numbed them, or they have found other convenient winter-quarters. That all insects do not equally lose this power of moving themselves, is plain, among many others, in the case of Bees; for these not only open and shut the doors of their hives in the winter season, but tenderly and diligently nurse and rear their young offspring in the very depth of it. Hence it is, that not only young Bees may be found in the hives at the first dawn of spring; but that even it is a common saying amongst those that delight in this useful insect, that young Bees and Swallows make their appearance at the same time.

Swallows feed upon Bees and other insects, which they seize in their most rapid flights. For this reason, in rainy weather, when no in-

fects are to be found in the air, these birds, in order to take them, fly near the ground ; a circumstance which has given a handle for that very absurd notion of some people, that Swallows can foresee an impending storm ; whereas, as I have been just saying, they skim the earth in heavy, cloudy, rainy, or stormy weather, merely to come at the insects, upon which they prey, and which, at these times, always betake themselves to rest. For the same reason I believe Swallows constantly follow the course of the Sun ; and when winter comes upon us, retire to the other climates which enjoy at that time a pleasant spring, a fruitful summer, or a temperate autumn, and are therefore qualified to supply them with a sufficiency of food.

I have observed, that some insects can only endure the winter in the worm-state. These are found not only above and under ground, in the hollows of trees, between the leaves of plants, in the hearts of fruits, and in vegetable excrescences, but even in the water, and are often enclosed in ice. But then it is observable of these insects, that most of them are much stronger at this period, than ever they are afterwards, when they have gone through their changes, and are become capable of propagating of their species. Thus we find that the Water-worm, which changes to an Ephemerus, is so tenacious of life, that it can live many days after being run through with a pin ; whereas in the Fly-state it lives even without receiving the least injury, but four hours at longest. However, we likewise know by experience, that these creatures, tho' vigorous and robust, perish very suddenly, if they do not happen to find quarters adapted to their nature. Of this the Worms found in Hazel-nuts and filberts, are a striking instance ; for unless you place them in moist sand, where they dig themselves holes to serve them for winter-quarters, not only they die very soon, but even in the space of one single night, will harden, and dry to such a degree, that they will in a manner fall to dust between the fingers. I have observed also, that this is the case with the Worms bred in the tubercles of Mallow-leaves, tho' they never make holes for themselves in the earth, in which they may pass the winter, but defend themselves against its rigours, by spinning a commodious covering for their bodies.

Thirdly, I find that other insects pass the winter in the Nymph-state, in which they may be found as well on the surface of the earth, as buried under ground ; and even in the water, where they will live for some months without any food ; for at this time, they want strength to take any, as well thro' the weakness of their limbs, as on account of the great quantity of superfluous moisture with which their bodies are charged. I have likewise remarked, as I already mentioned, that the greatest part of these insects, which outlive the winter in a perfect state, require no food from one end of that season to the other ; for at that time their

juices move very slowly, and are in a manner condensed by the coldness of the circumambient air ; both which are sufficient to account for so long a fast.

Hence it is also, that these little creatures, when cherished with the least warmth, recover their former senses and motion ; whereas, before, they were so entirely motionless, as even not to void any excrements. And this circumstance affords us another proof of their not taking any food at that time ; for where there is no loss, there can be no necessity for any nourishment to repair the waste.

Fourthly, and lastly, I have found insects to survive the winter in their eggs ; in which, as I have heretofore observed, they often wear the form of Nymphs.

But I shall hereafter explain the advantages that accrue from this condition of Insects in the Nymph, and other states, when I come to describe after what manner they bury their eggs in spring, on the approach of warm weather, in the tender germina or buds of plants, and in the leaves of trees ; a thing which I mightily long for the satisfaction of seeing with my own eyes. Perhaps I may at last find the means of satisfying my curiosity. And, as no descriptions or drawings can impart full and just notions of the form and external appearance of these little creatures, I have formed a resolution of collecting some hundreds of them, in order to preserve them in balsam, after having sufficiently dried them.

I could prove by the testimonies of people of all ranks, that I have in my museum specimens of all the insects I have spoken of in the foregoing treatise, to the number of more than twelve hundred, with their Nymphs, Chrysalides, and Vermiform-nymphs. But here, in order to do myself justice, I appeal to that most curious and learned gentleman the Abbé Boucaud, who, after he had been first to see me, in company with the celebrated Olaus Borrichius, Professor of Physick in the University of Copenhagen, thought it not beneath him to return often to my house to examine the great number of natural curiosities I have there treasured up.

I might likewise appeal to the most noble and accurate Paul Falconier, who some time ago did me the honour of a visit, and was pleased to approve my occupations and studies. But I would not have the readers imagine, that I have minutely examined every single insect of my collection ; I have only reduced a great many of them to my four orders, as may appear to any one, that will be at the pains of considering what I have said of these orders. And this caution I gave in the same place, for fear of deceiving others, and perhaps myself, with expectation of more being done in this branch of natural history than there really is. Though, let us do as much as we can, I believe it so far from possible to know every species of insects, and the changes of each, that I believe the labour of ages would not be sufficient to discover all the kinds of them. In the mean time, I challenge any one to produce a single



single insect, that may not be referred to one of the four orders of mutations which I have proposed; for to me, if I may here trust my reason, the thing appears impossible. I leave it to time to discover the truth of this assertion; and do not desire any credit to be given to my relations, unless the things I speak are found to agree exactly with the originals, as I have described them after nature with all the exactness and perspicuity I was master of.

Having thus produced every thing, which in my opinion could be said in general, or in particular, concerning insects, I had resolved to add another dissertation on their eggs, worms, and Nymphs: but I must defer this to some other opportunity. I had even flattered myself with the hopes of being able to present the public with a separate account of the little insects found in the bodies of others of a larger size; but as yet I want sufficient experiments for that purpose, though I am firmly persuaded that nothing is to be attributed to chance in the generation of them.

I shall now say no more on this subject, as it is most evident that all God's works are governed by the same rules; and as the true and primitive origins of them are infinitely beyond the reach of our comprehension, so that we cannot be said to know more than the bare outlines of that infinite Being's image, to whom they owe their existence; so I may hence, for certain, conclude, that all the knowledge and wisdom of philosophers, consists merely in an accurate perception of these elegant appearances or effects, which are produced by first causes, and are often themselves, in their turn, the causes of other effects. For this reason, we should strenuously endeavour to make ourselves well acquainted with these appearances, and then draw from them firm rules and principles; otherwise, as I have hinted in my preface, we may easily lose our way, and stray into the paths of error, as disputing on nature, which is quite inexhaustible, without sufficient experiments, which, on such an occasion, are as necessary to find us a path, considering with what darkness of ignorance we are surrounded, as a staff is to the blind. It often happens, through our own fault, that those things, of which we might acquire competent notions with very little trouble, become not only dark, but quite incomprehensible to us, so as to encrease our blindness, by the erroneous inferences we draw from them, rather than add to our knowledge. Of this our great weakness, Goedaert alone is a sufficient example; for that author, by falsely imagining to himself, for want of proper experiments, that Caterpillars, degenerated into crippled and imperfect insects, as often as they performed their mutations, without being properly grown and fed for that purpose, not only in consequence of this false position, involved all his other experiments in the most perfect darkness, but contracted himself such a blindness, that he could not perceive one of the most excellent principles of natural history, though it lay directly under his eyes. I omit naming many other naturalists, who, too lazy,

or too proud, to make experiments, and guided only by their weak reason, or weaker imagination, have argued on the mutations of insects, with just as much propriety, as a blind man may be supposed to speak of colours; insomuch that I should be ashamed to put my readers in mind of their empty and childish reasonings. Nor is there the least shadow of excuse, for the unwarrantable boldness of such persons, who were not ashamed to speak without any hesitation or doubt of things, whose causes and principles they were utterly unacquainted with. But, to speak my mind with freedom and candour: if we are to regard as idle and vain, all those reasonings of ours, which cannot be primarily demonstrated by experiments, and do not ultimately terminate in them, no reasonings can be so strong and certain, as those which are drawn from the very observations and experiments, in which they may likewise be found to terminate. All such arguments, therefore, as want this firm and immoveable basis of experiments, are to be greatly suspected of error, whatever syllogisms and enumerations people may think proper to build them upon; and when they do not exactly agree with experiments, they deserve to be rejected. Of this opinion was likewise the illustrious Des Cartes, who, in his essay upon method, has the following words. "For I was always of opinion, " that more truth is to be found in those reason- " ings, which men make use of in the com- " mon affairs of life, whose bad success may " prove a kind of punishment for their reason- " ing ill, than in those which some idle doctor, " cooped up in his study, has invented concern- " ing this *entia rationis*, and such other empty " questions, that conduce nothing to the ease and " happiness of life, and from which he expects " no other advantage, unless that of reaping so " much the greater harvest of empty glory from " his arguments; as they contain less of truth " and common sense, on account of the extra- " ordinary strength of genius, and application " requisite to give an imposing air to such ab- " surdities."

If we duly consider the words of this able philosopher, and the great weight and importance of experiments, I believe we shall find it not unjust to dignify with the name of reason that faculty of our minds, by the assistance of which, we form clear and distinct notions of things, whilst we make proper use of our senses in sufficient experiments, so as to be able afterwards to effect exact copies of the originals we have thus endeavoured to be thoroughly acquainted with. For this reason it is, that our idea of any thing is said to be more or less clear and distinct, according as we can produce another thing more or less like it; and are therefore said to have more or less the power of it. This being granted, it should follow, that we have no clear, distinct, or perfect knowledge of any things, except of such as we can truly and effectually produce, according to the notions we have of them: so that solid and perfect knowledge must be allowed to be a very uncommon thing in man, and to be confined within very narrow bounds. This is an

imperfection we should readily confess, if a principle of vain glory, cherished by that very ignorance, did not prevent us. To give an instance of these things, which are in some sort understood by us, I believe physicians, if they had clear and distinct ideas of the structure of our bodies, and of the motions of the blood, and other juices belonging to them, would be able to mend radically any unnatural disposition in these parts, as they could then prove the validity of such clear and distinct ideas, by reducing them to the test of experiments, which is allowed in every country to deserve credit, more than reason itself. But as hitherto they are very unhappy in their attempts to cure our disorders, and are always perplexed by cross events, from the weakness of their reasonings; we cannot but allow from this, and all, that the great Descartes has bestowed no commendations on experiments which they do not highly deserve.

It is plain, from what has been said, that something may exist in the understanding, which never before had been taken notice of by the senses, tho' we cannot comprehend them clearly and distinctly, unless they terminate in the senses, or at least may effectually terminate in them. Besides, our understanding becomes at length so discerning, as through a frequent and attentive observation of experiments and sensible effects; sometimes we are enabled to judge truly and solidly, without any previous experiment of things, which have never fallen under the cognizance of our senses. To this purpose, is what Aristotle says in the tenth chapter of his third book concerning the generation of insects. " We must trust our reason, if what it demonstrates be found to agree with the informations of our senses."

All things therefore duly considered, it does not seem unreasonable to determine, that if we had clear and distinct ideas of the structure of the human body, the motions of its juices, and every thing else relating to that wonderful fabrick; not only we should be able, by making a proper use of such ideas, to mend it when impaired, but might even so far go beyond the bounds of nature, as to restore its health and vigour, when entirely lost and decayed. For our industry succeeds the better, in producing things the more clearly and distinctly it comprehends them; whilst ignorance, on the other hand, is attended with a proportionable degree of weakness.

But as it is not always in our power to make accurate experiments or observations, so neither are such experiments always sufficient to give us clear and distinct notions of the things themselves. Such, for example, as on account of their extreme minuteness or remoteness, elude the sharpness of our sight. Let therefore no one be childish enough to persuade himself, that we can, by the bare efforts of our reason, ever thoroughly understand the genuine causes of such things; not to say the true effects produced by them.

For the highest degree of wisdom we are capable of attaining, does not consist, as I observed before, in the knowledge of causes, but

only in the clear and distinct comprehension of the true appearances or effects, by which such causes discover themselves to our senses; but we afterwards make use of these effects, as so many steps by which we may climb to the first causes, and by the just notions we thus acquire, we are enabled to produce an infinite number of things requisite to make life easy and happy. Nay, even this knowledge reaches no higher than the perception of these effects, as they are made known to us by a circum-spect use of our senses. And therefore, all our reasonings that are drawn from experiments already made in one case, and then applied to another, in which we have not as yet made any, are to be held as dubious and susceptible till they end in, and are confirmed by immediate experiment.

For this reason I am greatly pleased with the illustrious Harvey, when in the preface to his treatise on the generation of animals, he speaks of the methods of finding truth, in the following words: " The present method therefore, of investigating truth, is altogether erroneous and childish, whilst the generality are taken up in inquiring not what things are; but what others say of them, and then drawing an universal conclusion from singular premises, to which they often afterwards add analogical reasonings, and almost always palm upon us for true, things that are seldom more than at the utmost probable. Hence it is, that many sophists, after ransacking the inventions of others, present them to us as their own, though they have done no more than change the original author's order and words, and made, perhaps, some few inconsiderable additions; by these means they render philosophy, which ought to be certain and perspicuous, dark, intricate, and confused. For those, who whilst they read an author's words, do not abstract the images of things, comprehended in their words from their proper senses, instead of furnishing their minds with true ideas, fill them with false idols and empty fancies, which they work up in their imagination, into shadows and chimeras; so that all their fine theories or contemplations which they dignify with the name of knowledge or science, ought rather to be considered as the dreams of men awake, or the ravings of lunatics." And a little before, he says, " For the images of things that come under the cognizance of our senses, remain when the things themselves have disappeared; and these images constitute memory, which, by taking in a great number of objects, forms in its turn, what we call experience; and from experience we derive universal reason, definitions, and maxims, or common axioms, which are the certain principles of knowledge." He again speaks to the same purpose in his forty-fourth exercitation, and in the following terms. " It is therefore, no such wonder, that so many errors should have descended  
" even

“ even to our times from the remotest anti-  
 “ quity, with the unanimous consent and ap-  
 “ probation of mankind; or that men of great  
 “ abilities in some respects, should have com-  
 “ mitted mistakes, as they thought it sufficient  
 “ to be wise with the wisdom of others, or  
 “ learned with their learning, and to fill their  
 “ memory with the opinions of learned men.  
 “ But those who philosophize in this manner  
 “ by tradition, if I may thus express myself,  
 “ are not a whit wiser than the inanimate  
 “ books through which they come at their  
 “ ill-digested notions.”

Thus also, the great Descartes spent his whole life in endeavouring to make philosophy a practical science, instead of a merely theoretical one, as it had been to his days, that thereby he might make it subservient to the most important purposes of life and health. But as he considered he might not perhaps live long enough, or be able to make enough of experiments to accomplish so noble a design, he warmly exhorts men of superior abilities to such a task, and to lose no opportunity of making experiments, and reducing every thing to that sure and infallible test. To this purpose he speaks as follows, in his essay on method. “ But as I had proposed to spend my  
 “ whole life in the acquisition of so necessary  
 “ a science, and fell upon a method, which I  
 “ thought would ensure me success in the en-  
 “ terprise, unless death, or a want of expe-  
 “ riments should interpose; I judged the best  
 “ thing I could do to remove these obstacles,  
 “ would be to lay before the publick a faith-  
 “ ful account of all the advances I had made,  
 “ however inconsiderable; and at the same  
 “ time endeavour to persuade men of extra-  
 “ ordinary genius to pursue what I had be-  
 “ gun, and make each of them in particular  
 “ as many experiments as he could, and then  
 “ inform the publick of every discovery made  
 “ this way, that by the last beginning where  
 “ their predecessors in this useful undertaking  
 “ had left off, and then joining together the  
 “ lives and labours of a great many, we might  
 “ sooner obtain our purpose, than could be  
 “ done by the unassisted endeavours of single  
 “ persons. I have always found the more any  
 “ person knew, the more he stood in need of  
 “ making further experiments.”

The illustrious Boyle, to whom mankind is so highly obliged for his admirable writings, not only constantly endeavoured, and that with great labour and expence, to add to the number of useful experiments already made, and thence derive certain, and solid conclusions, but likewise strenuously, tho' candidly, endeavoured to prove by the weightiest arguments,

the great usefulness and necessity of experi-  
 mental physiological. These are his words, in his proemial essay to certain physiological essays.

“ If men could be persuaded to mind more  
 “ the advancement of natural philosophy,  
 “ than that of their own reputations; it were  
 “ not, methinks, very uneasy to make them  
 “ sensible, that one of the considerablest ser-  
 “ vices that they could do mankind, were  
 “ to set themselves diligently and industri-  
 “ ously to make experiments, and collect ob-  
 “ servations, without being over-forward to  
 “ establish principles and axioms, believing it  
 “ uneasy to erect such theories as are capable to  
 “ explicate all the phænomena of Nature, be-  
 “ fore they have been able to take notice of  
 “ the tenth part of those phænomena that are  
 “ to be explicated. Not that I at all disallow  
 “ the use of reasoning upon experiments, or  
 “ the endeavouring to discern as early as we  
 “ can, the confederations, and differences, and  
 “ tendencies of things: for such an absolute  
 “ suspension of the exercise of reasoning were  
 “ exceeding troublesome, if not impossible.”

But that I may at length conclude, the success of my labours so apparent in every page of this work, proves abundantly all that I have advanced on this occasion. For when I consider within myself, that by the help of experiments, I have here been able to discover things, which not only men of moderate parts, but even the greatest geniuses, from the age of Aristotle, to the present, during an interval of about two thousand years, have in vain endeavoured to find out, I cannot but look upon this happy result of my labours as the best proof of the superior excellency of experimental philosophy. Nor is there here any occasion for a great parade of words to demonstrate the absolute necessity of diligently examining things in themselves; for if our justest reasonings ought to terminate in experiments, to be built upon experiments, and pursue the course prescribed us by experiments, who is there, that would not, in forming his judgment of things, much rather trust to experience, than to the idle fancies of his imagination; nay, I may ask, who will hereafter dare to affirm, that we may depend upon our reason alone, to come at the knowledge of every kind of truth? whereas it is most certain, that by making a proper use of our senses, we may from the things we see, gather sufficient information concerning those that we cannot: the end of the general and particular treating of insects, all which I have reduced to four orders, and proved to rest upon one single foundation, which is the Nymph.

# MUTATIONS and ACCRETIONS

A General Analogy, or Comparifon of the

As to PARTS and LIMBS,

As well in Eggs, Worms, and Nymphs, as in Infecfs among themfelves :

Alfo in thofe Mutations, and Accretions which we obferve in an Animal of the red-blood Species, and a Vegetable clearly exhibited at one View.

TAB. I. TAB. XII. TAB. XVI. TAB. XXXIII. TAB. XXXVIII. TAB. XLVI. TAB. XLVI.  
 Caryophyllus, or Clove July-flower.

- FIRST ORDER.

I. The Loufe in its firft ſkin, within which it is called a Nit.

II. The faid ſkin, or coat thrown off.

III. The Loufe divested of its faid ſkin.

IV. The Loufe more grown.

V. The Loufe confidered as an Animal-Nymph.

VI. The Loufe full-grown, and in a condition to propagate its ſpecies.

SECOND ORDER.

I. The Worm of the Libella, or Dragon-fly, in its firft ſkin, within which it is called an Egg.

II. The faid ſkin, or coat thrown off.

III. The Worm of the Libella divested of its faid ſkin.

IV. The Worm of the Libella more grown.

V. The Worm of the Libella changed into a Worm-Nymph.

VI. The Libella full-grown, and in a condition to propagate its ſpecies.

TAB. XLVI.

The Frog.

I. The Worm of a Frog in its firft ſkin, within which it is called an Egg.

II. The faid ſkin, or coat thrown off.

III. The Worm of the Frog divested of its faid ſkin.

IV. The Worm of the Frog more grown.

V. The Worm of the Frog changed into a Tadpole.

VI. The Frog full-grown, and in a condition to propagate its ſpecies.
- THIRD ORDER.

I. The Caterpillar of the Phalæna or Moth in its firft ſkin, within which it is called an Egg.

II. The faid ſkin, or coat thrown off.

III. The Caterpillar of the Phalæna divested of its faid ſkin.

IV. The Caterpillar of the Phalæna more grown.

V. The Caterpillar of the Phalæna changed into a Chryfalis.

VI. The Phalæna full-grown, and in a condition to propagate its ſpecies.

THIRD ORDER.

Second Species.

I. The Worm of the Fly in its firft ſkin, within which it is called an Egg.

II. The faid ſkin, or coat thrown off.

III. The Worm of the Fly divested of its faid ſkin.

IV. The Worm of the Fly more grown.

V. The Worm of the Fly changed into a Vermiform-Nymph.

VI. The Fly full-grown, and in a condition to propagate its ſpecies.

TAB. XXXVIII.

FOURTH ORDER.

I. The Worm of the Germ of a the Caryophyllus in its firft coat, within which it is called a feed.

II. The faid coat thrown off.

III. The Germ of the Caryophyllus divested of its faid coat.

IV. The Germ of the Caryophyllus more grown.

V. The Germ of the Caryophyllus changed into a Follicle or Nymph.

VI. The Caryophyllus full-grown, and in a condition to form its ſeed.

## A P P E N D I X.

*The anatomy of the\* Sea-Sepia or Cuttle-Fish. Incribed to the most excellent Francis Redi, physician to the great Duke of Tuscany, a most indefatigable searcher into the miraculous works of Nature.*

## T H E I N T R O D U C T I O N.

**T**HERE is not among the soft fishes, which are said to have no blood, any that claims our attention so much as the Sepia or Cuttle-fish; as well on account of its external figure, which is wonderful beyond all description, as for the structure, order, and disposition of its internal parts, which most evidently shew themselves the work of infinite wisdom. I shall not speak of the common mistakes and errors of the generality of mankind concerning this creature, much less attempt to censure those eminent writers, who before me have treated of this subject; for every one of them wrote of natural history according to his own genius and fancy. I choose rather to exhibit in a few words the external and internal parts of this extremely singular animal. And whilst I do this, I appeal for the truth of my relation to the reader's own eyes, by desiring him to inspect the creature itself. Certainly, those who would avoid being imposed upon, should study nature in herself; for so many fallacies and errors have crept into the writings of preceding ages, that people cannot but be led astray by them, as often taking things upon trust, they neglect to see for themselves. This will evidently appear by the following history, which, tho' a new relation, does no more than exhibit in a new dress the truth itself, than which nothing can be more ancient.

The Sepia or Cuttle, is a creature that has eight legs, two long arms or claws, a short head, very large eyes, and the beak of a Parrot. The body is somewhat oblong, considerably broad and thick; and the back is prettily marked with several whitish furrows, and elegantly dotted. The Sepia or Cuttle is frequently found dead on the Dutch coasts in the summer months; it was there I first met with some of them, and made drawings of their viscera. But the history I am now about to give, is no more than a bare narration of what I observed in two of them, which were brought me from the sea about the middle of May, and of which I took short notes and drawings, in great haste, during four days that I spent in this inquiry.

The most considerable parts of the Sepia,

which first offer themselves to our view, are its legs and arms or claws. The legs to the number of eight, are seated round its mouth. The two forefeet, Tab. L. Fig. 1. *aa*, are very thick, and appear broad, when the fish lies flat upon its belly. The other six are very like one another in size and form. One side of all these feet is covered with a common skin, which is pretty strong, and of a purple colour interspersed with many black spots; besides which, the two larger legs are marbled as it were with some white furrows *b*.

But the most remarkable thing in these legs, is their being all thick set with a prodigious number of particles like flattish but hollow globules, and each fixed to a kind of stalk *ccc*; Yet the extremities of the arms or claws, to which authors have given the name of Promuscides, are still more largely furnished with these kind of tubercles. These brachia or arms are very long, if compared with the legs, and they are placed near the bill or beak, in the midway between the broadest pair of legs, and the pair next to it *dd*. They are of a cylindrical figure, and of a white colour intermixed with black and purple spots. The substance of them, as well as that of the *xx* legs, is soft; and they have the same kind of skin, but it covers them all over, which is more than it does in the legs. The extremities of the legs and arms are pretty much of the same form, only that the tubercles of the arms are larger, and the stalks upon which these tubercles grow much longer and stronger than those of the legs *e*. The extremity of one of the arms is always larger than that of the other.

As these globules are hollow, authors have thought proper to call them Acetabula or sawcers. Rondoletius tells us, that this strange fish can fasten itself by its arms to any body it meets with, in the same manner as cupping-glasses stick to the skin by a kind of suction. And certainly this is a very just comparison, as appears from the most wonderful contrivance of these parts, which I shall presently describe.

It is to be remarked, that the same kind of skin which covers the under surface of this animal's eight feet, does not extend to the upper; it

\* The Sepia or Cuttle-fish is one of the animals of the sixth class in the Linnæan system, which he entitles Vermes: it comes under the second order, to which he has given the name Zoophyta, and is arranged with the Star-fish and Polype. The characters of the genus are these; the body is oblong and depressed, the feelers or tentacula are ten, and two of these are much longer than the others, and have a kind of foot-stalks. Beside the Cuttle-fish, this genus comprehends the Loligo, which the French call the Calamarié, and the Octopedi described in the Upsal-transactions. Of the Calamary we shall have occasion to speak largely hereafter.

goes no further than the globules *fff*, and there it forms a loose border to the feet, which when the creature swims, floats in the water. For this reason, that loose skin can cover all the surface of the feet, and their acetabula at the creature's pleasure, as the edges and corners of a cloth, may fold over any thing that is laid upon it. Nor is it to the middle and basis of the legs only that it performs this office, but even to their sharp ends, where the acetabula *gg* are smaller than in any other part. But these borders are more conspicuous about the extremities of the arms than elsewhere; for which reason I have represented those belonging to one of the arms *bb*, as they appear when they cover the globules, except its being a little turned back.

The skin which spreads itself over the intervals of the globules, and covers the inside of their stalks, and even the external skin's borders which I just now mentioned, is in some measure as it were muscular, and is of a much more delicate texture than the other skin. It must likewise be observed that the parts supporting the acetabula tho' called stalks, are not really such, but pretty conspicuous muscles administering to the acetabula.

I have observed also, that these little muscles are here and there distributed over the inside of the borders of the external, so as to be able to move those parts as well as the acetabula. For this reason I consider what is called the skin in these places as a muscular substance.

I have represented some of the muscles belonging to the acetabula of their natural size, in order to give the reader a more just idea of them. Tab. L. Fig. 11. N<sup>o</sup>. 1. shews, how the muscle is inserted underneath into the base of the globule, where it is somewhat hollow; and how by expanding itself, and then contracting again a little, and afterwards expanding itself again, it in a manner entirely forms the globule. For as far as I could inform myself by dissection, the acetabula are altogether muscular, and the tendons of those muscles are inserted into a ring of a substance between horn and bone, which lies between the moving fibres of every acetabulum.

It appears, on examining the upper side of the acetabulum, and the structure of its hollow, N<sup>o</sup>. 2. that it is likewise muscular in these places; the little ring now mentioned shews itself very plainly on this occasion. The upper edge of this ring is generally black, but this blackness is only superficial, being no more than a portion of the external coat of the globule, and therefore it may be easily removed.

By taking out this ring, and placing it on its side, N<sup>o</sup>. 3. we obtain a good view of its construction, and the blackness of its upper edge; we even discover by placing it in this situation, in what manner it is perforated in the middle, and its upper and lower edges waved in a serpentine manner. This construction, so well contrived for receiving and holding the muscular fibres, wonderfully contributes to keep the ring firm in its situation.

The better to shew the black edge of this ring, and the manner in which it is turned, I have represented it, N<sup>o</sup>. 4. in a convenient situation

to shew all its upper circumferences: and have added a small segment of it, N<sup>o</sup>. 5. to make the construction of this part as intelligible as I possibly could; for it would be extremely difficult to understand the use of this ring, without knowing exactly in what manner it is formed.

The advantage of this singular construction consists in this, that the muscular fibres of the acetabulum can by contracting themselves raise the stalk or muscle of the globule very high within the cavity of the ring, and thereby of course streighten the cavity of the acetabulum, whilst on the other hand the muscle of the stalk, by exerting itself at the same time, again raises itself and its fibrous parts out of the globule, so as to make its cavity much wider and more spacious than it was before.

Nor do I in the least doubt, but all the Cuttlefish's power of fastening itself to bodies, or taking hold of, and conveying any thing to its mouth, depends entirely on the singular construction, and exertion of the part just now described. Whenever this strange animal applies to any body that prodigious number of globules, with which its arms and legs are furnished, and then immediately withdraws the muscular stalks of these globules, from within the hollows of the acetabula, taking care at the same time, not to let any water into these cavities, the water repelled in this manner must press such parts against the body, against which they lie, with an extraordinary force: And this end is the more certainly obtained, as the borders of the skin which covers the arms and legs are likewise muscular; and by containing and enclosing the globules at the time of their action, contribute greatly to hinder any water from insinuating itself within the cavities of the acetabula.

We must therefore be more than blind, not to discover by this single instance, how wonderful God is in his works, seeing he has here effected, by means of repelled water, such a suction (to make use of a common expression) as he has produced by means of repelled air in the vital element we breathe. Hence also we may easily understand, what Rondoletius says of the brachia or arms of this animal; and of the manner wherein it remains in the most stormy weather immovably fixed, and as it were at anchor at the bottom of the sea; for at such times no doubt it dilates its acetabulum to the utmost breadth, and fastens itself in its post, by their means with an extraordinary degree of power.

The beak, Tab. L. Fig. 12, which lies in the center of the legs, is like that of a Parrot, and consists as it were of two maxillæ or jaws, both moveable. These maxillæ join each other in the same manner with the body and the lid of a box, when the former slides up within the latter. The flesh which surrounds this beak, instead of lips *k*, is regularly orbiculated and sometimes appears plaited or folded back in wrinkles, like a purse that has a border to it.

Under the beak and legs appears the head, in which the eyes *ll* are very conspicuous. The most remarkable part of these is the cornea, which lies  
upon

upon them so loosely, that it may in a manner be moved backwards and forwards like the membrana nictitans or winking membrane in birds. The operculum *mm* of the pupil, makes its appearance very elegantly thro' the cornea, which is transparent: but this operculum does not appear any where to so much advantage as in the Ray-fish, as Stentor has most exactly described it. I have likewise discovered this operculum of a black colour in the eyes of horses; at one side of the eye, the pupil projects a little, nor is it exactly round in this place. On drawing this operculum over the pupil, the eye loses its sight. Some time ago, I observed that the crocodile has a cat's eye, having an aperture to its pupil, which in the day-time resembles a long slit.

The Cuttle-fish's neck is very short, and like the head is elegantly covered with black spots upon a purple ground. The upper extremity of the back *n* rises by a remarkable process over the neck; so that the creature can hide its head under it, in the same manner that the naked Snail hides its head under its verge or border.

All the parts of the Cuttle-fish, yet mentioned, are soft, except the beak, and the cartilaginous rings of the acetabula. But the back is hard, firm, and incapable of motion, as the bone of the creature lies here, running quite thro' the back to the tail, without any vertebræ or like divisions. The muscles of the creature are inserted into this bone. That part of the body which lies at the two sides of the bone, is soft and muscular *ooo*, which makes it probable, that this extremity, which terminates the back and belly of the Cuttle-fish, may be of great use to it in swimming. The back-bone also is well contrived to answer the same purpose, for it floats on the surface of water, even when it is just taken out of the sea, and before it has had time to lose by drying any of those pieces, which may be supposed to make a considerable part of its weight.

The colouring of the back afforded a very entertaining sight, for its surface was raised with a great many white streaks and furrows like so many veins interspersed with very small black spots; but between these streaks the skin was of a deeper colour, and marked with larger black spots. Where the streaks ended, there appeared a great number of white spots, which were either round or oval, even the extremities of the streaks were either round, or shaped like a pear. The soft margin of the body was of a somewhat deeper purple, sprinkled with smaller black spots, and some others that were round and white; but it then grew whiter towards its extremity, where it ended in a deep purple edge. On the hinder part, where in other animals are seated the arms and tail, the margin was somewhat divided or dented in, *p*; so that from this nick, the body of the Cuttle-fish appeared naturally divided into a right and left side.

On handling the beak a little, it fell from the head, which gave me a very convenient opportunity of examining its substance, colour, and construction. The substance of this part is be-

tween bone and horn, and thicker and more compact on its upper part, with which the animal bites, but on the lower, to which the muscles of the beak are fixed, more tendinous and membranaceous. In figure it resembles the Hawk's or Parrot's beak, and has many things in common with it. The upper part, which, as I said before, in the thickest, is of a deep brown colour, which grows redder and redder in proportion as the beak grows more and more membranaceous. But as the beak consists of two maxillæ or jaws, an upper and a lower, which meet together, and move one upon and towards the other, so likewise they differ in construction. The lower part spreads as it were into two wings Fig. III. *aa*, between which the upper part sinks, and so meets this lower. The lower maxilla, or jaw, is on its hinder part folded back within itself *bb*, not unlike a paper tube bent back, by which means its sharp extremity becomes twice as thick and strong as it would otherwise be. On the lower part it bends itself back, so as to form a hollow furrow *c*. This beak appears altogether fibrous, and seems to be composed of membranaceous tendons, hardened by degrees into a horny bone. The upper jaw of the beak *d*, is of the same substance with the lower, from which it only differs in its curvature and form; besides, its internal sinus is much more deep and broad *ee*, to afford the tongue, which lies in this sinus, the greater liberty to move itself. The muscles also find better insertions in the hollow sinuses of this horny bone, in whose membranaceous expansions they are fixed.

The tongue, which is thought to be a fungous substance, consists of seven little cartilaginous bones, which lie very close to each other, and are besides united by means of a particular membrane. The upper extremity or point of the tongue is somewhat crooked Fig. IV. *a*, but the lower part is united with some muscular and fungous flesh, in which it lies, as in a hollow tube. This fleshy portion of the tongue is full of wrinkles and elegant folds *b*, which seem to contain a great many small salivary ducts. I have found by dissection that a very considerable salivary duct *c* opens and discharges into this fleshy part.

This salivary duct descends by a long tube, *d*, through the animal's neck into its breast, where it divides into two branches, that terminate in two very considerable glands, *ee*. These glands seem, on nice inspection, to be of the kind called conglobate, or by anatomists, though externally, they appear of the other kind, known by the name of conglomerate. On opening them, I found a kind of hollow in them, made to receive the saliva, secreted by their fungous substance; but I could not discern the ramifications of these two parts, which, no doubt, spread themselves through the parenchyma or fleshy substance of their glandules; but the coloured liquors I injected, shewed no such thing. These glands lie within the breast, on each side of the gullet or throat, in such a manner, that this last channel runs above and between them: this best appears on opening the body of the fish, af-

ter turning it upon his back. The tongue and parts belonging to it, when taken out of the beak, generally bring along with them some of the muscles, two of which, *ff*, I have here given a cut of. But I return to the tongue.

The contraction of the tongue, which, as I have said, consists of seven cartilaginous bones, becomes very visible on parting it from the fungous flesh to which it is fastened, and in which it is wrapped up; but it may be made still more conspicuous, by drawing off the membrane, Fig. v. *a*, with which the inferior part of the tongue is covered, and afterwards separating from each other with a fine knife, at the extremities, the little cartilaginous bones, of which it consists, *b*. After treating the tongue in this manner, we may see by the microscope, that every one of these bones is furnished with above sixty crooked cartilaginous papillæ, Fig. vi. *a*, in form of teeth, and in some measure resembling the papillæ on the tongues of black cattle. By these the Cuttle-Fish, when feeding, is the better enabled to move its food, and dispose it for an easy swallowing. The fore-part of these papillæ, is of a clear and transparent amber colour, but the hinder-part, which constitutes the base, or root of the tongue, is of a transparent white. The best way to examine the tongue, is to invert it, and then survey it with a microscope on the under or lower side, where its base or root lies; for, by this means, we discover, that in structure it exactly resembles the most regular web, Fig. vii. *aa*, from the frame, or combination of the cartilaginous bones already described. The sight of this admirable contrivance, induced me to take out the tongue and dry it; but all its beauties vanished almost entirely in the operation.

The body of the Cuttle-Fish, when laid on its back, appears much whiter, and has by far fewer spots. But the most remarkable thing in this animal, is an opening in this under part of its body, in which an expanded hand may be entirely buried: this is between the body and the muscular partition that covers it on its fore-part.

On opening this lower part of the body, Tab. LI. Fig. 1. *aa*, in a right line through the middle of the belly, *bb*, from the beginning of the breast to the tail, *c*, and this without injuring the contents; there immediately appear several remarkable internal parts, some quite plain and naked, and others appear more faintly, as lying deeper in the breast and belly, and only shewing themselves through some interposing transparent membranes.

The first thing which presents itself here, is a bag or bladder lying in the superior region of the breast, which I call the common excretory bag, or bladder. The colour of this part is white, its substance is muscular, and its shape is like that of an inverted funnel, very spacious and broad at the bottom, *d*, and slender at top, *e*, it joins on each side with two oval cartilaginous, muscular and hollow little bodies, *ff*, which serve to receive these two greater papillæ, or cartilaginous eminencies, *gg*, which I have represented, one on each side of the muscular partition, loosely surrounding the contents of the belly, and

cut away by me upon this occasion. By this junction of the excretory bladder, and these oval bodies, it is provided, that nothing should move soon, or be discharged by the inferior parts of the body, without passing through this excretory bag; and the same wise disposition of these parts, keeps the Fish's eyes from being injured by the excrements, sperm, eggs, and black liquor, which all make their way through this funnel, as they certainly would, if these discharges were to be made between the funnel, and the muscular partition of the body: for this reason also, nature has formed this bag or bladder of a muscular substance, the better to discharge its contents at the creature's pleasure.

As yet, I cannot say for certain, whether or no the papillæ just spoken of, are naturally and constantly united with the oval acetabula, which I have described; for I have sometimes found them independent and disjoined. But as I could never find in these parts, the least mark of any rupture or fraction, the acetabula, on the contrary, always appearing quite smooth, and the papillæ of a bright polish; I think it very probable, that the Cuttle-Fish has a power allowed it by nature of joining and separating these parts, as necessity requires.

The office of thus joining and separating these parts, I am inclined to attribute to a pair of compact, oblong, white muscles, Fig. 1. *bb*, which at their upper extremities unite with the acetabula, and are contained within the lower edge of the excretory bag or bladder. These muscles are among the parts, which appear naked in the breast, without any previous dissection. Nor do I see any use they can be of except that which I have assigned them, of joining and separating the acetabula, and the papillæ, by doing which, the excretory bag or bladder is at the same time dilated, so as to facilitate the discharge of its contents through the funnel already mentioned.

Hence, it is impossible to thrust all the hand in the manner beforementioned, into the Cuttle-Fish's body, without first separating the papillæ from their acetabula.

On opening this excretory part, it appears compact and muscular, and forms within, on its lower part where it joins the breast, a kind of lobe in the shape of a broad tongue.

The other parts that appear in this place, without further dissection, are the gills, *ii*, of a soft spongy substance, placed on the two sides of the body, and forming a very agreeable appearance, on account of the extreme whiteness of a great number of blood-vessels, with which they are provided; and the colour of these vessels is greatly heightened by the greenish hue of the gills through which they run.

Examining one of these gills, I found in only half of it more than forty divisions or ramifications of the greater blood-vessels; that is more than eighty to a side. But if we consider also the prodigious number of these ramifications, which penetrate into the substance of the gills, Fig. 1. *k*, where the muscles administering to these parts likewise run, we shall have reason to think



think the number of these ramifications is almost infinite.

Words cannot do justice to the contrivance, order, invention, and most elegant construction of these parts; so that my figures deserve only to be considered as the faint shadows of their perfection. The gills are membranaceous underneath, near the roots, where they end in a slender stalk, as it were, and are fastened, as appears, by a pretty strong ligament, *ll*, though as yet, I am not sure but this ligament itself, may be composed of blood-vessels, not having had subjects enough to examine these parts so much as they deserved. On opening the divisions of the gills, this ligament makes a pretty appearance; at the same time, that we may discover how these parts grow more and more slender towards their roots, *m*.

Indeed the construction of the gills is more apparent in other kinds of fish, whose blood is red; for in some we meet with cartilages, and in others real bones, over whose surface the blood vessels are distributed. This circumstance I formerly most evidently discovered in the Sturgeon, the Whiting, and other fishes, by injecting their blood vessels according to a method peculiar to myself, and of my own invention. This I could discover, and I saw it with the greatest astonishment, that the contrivance, structure, and order displayed in these parts by the supreme Architect, and discoverable by those who love to contemplate Him in his works, were infinite in perfection and number, as I shall hereafter endeavour to prove by describing and delineating some of them by way of specimen of the rest. In the mean time, I can shew the curious the parts themselves injected by me with wax of several different colours.

In that part of the Cuttle-fish's body, which I consider as the thorax, there is a protuberance, Tab. LI. Fig. I. *n*, by naturalists called mutis. Upon this part there is always found lying an open pipe, quite loose, so as not to be confined to any one place *o*, but floating freely in the body. This pipe is, properly speaking, the animal's rectum, or straight gut. It has also a remarkable aperture at its end, by which the fish discharges its inky liquor from the bag contrived by nature to contain it. This bag lies in the lower region of the belly, where it shews itself thro' the transparent interposing parts *p*. Near the lower part of the straight gut there are two more short, open-mouthed tubular channels *q q*, for the discharge of the seminal matter, the vessels of which lie under these channels, with an extuberant membrane between them *r*. Lower down in the stomach *s*, and under the stomach, a certain little particle or body *t*, belonging to the spermatick vessels, shews itself thro' the transparent parts that lie over it.

In that part of the body where the extremity of the straight gut floats loosely on the right, there is on the left another loosely-floating tubular aperture *u*, thro' which the testicle itself discharges its sperm, which is afterwards to be carried off into the water, thro' the com-

mon excretory duct. This testicle is placed with its vas deferens, on the left side under the gills *x*, and shews itself faintly without dissecting the parts that cover it.

It is now time to give a more complete enumeration of all the parts hitherto mentioned, with a fuller description of them; and the figures will make it still more intelligible: this I shall do, after having first taken some notice of the parts of the Cuttle-fish belonging to its head, which lies upon the back. It is here that we see its beak, and the muscular circumference of its mouth *a*, which I have here represented a little less than nature; but in every thing else perfectly agreeable to the life. But, not to make my drawings too large, I have taken the liberty of curtailing the legs, and the two arms in this figure *ββ*, which I have exhibited in their natural situation and posture. I have likewise taken great care to shew exactly in what order the acetabula are placed on the two fore-legs, when the muscles of these acetabula are contracted; for it is an easy matter to procure a sight of them in this state, even in a dead fish. This is done by cutting some of them off, with part of the leg to which they belong, and then dipping the whole in boiling water; for in less than a minute they become perfectly contracted.

I likewise give a drawing of these muscles with their acetabula, as they appeared at the extremity of one of the arms, which I had stripped of its internal skin; so that their insertion and construction, Tab. LI. Fig. II. *a*, may, by this means be very distinctly seen, as likewise the order in which the acetabula themselves are united with their muscles *b*. It likewise appears by this figure, that both the acetabula and their muscles, are much larger about the middle of the arms than at either of their extremities *c c*.

I have thought proper to represent in a segment of one of the larger legs, that lie over the head, Fig. I. *γγ*, the internal structure of the legs themselves. Their texture on the outside is fibrous and muscular; but within-side it is a little more fungous. In the middle of them there appeared something that I took for a blood-vessel, and I have here represented by a black dot *δ*.

To take a survey of the Cuttle-fish's inside, it is necessary to cut away the common excretory duct, and the muscles which move its two acetabula, and then very cautiously to open that part which I call the thorax, and raise from it its membranaceous covering. This done, there appears the loose fungous body, called mutis by naturalists, and thought by them to have a great resemblance to the liver. I have always found this mutis regularly divided into very distinct parts. The upper part is very thick, and with gentle treatment it may on each side be easily parted into two lobes, Fig. III. *a*. Otherwise, on wounding the coat that invests it, its substance readily flows off, being exceeding soft, and like a liver bruised by an anatomist, in order to extract its parenchyma,

parenchyma, or pulpy substance. In the middle this mutis is very thick and spongy, and at its lower extremity constantly ends on each side in an obtuse appendage *bb*, which extends to the belly. The upper end of this organ lies in part on the throat, which lies itself also on the salival glands, Fig. V. *b'b*, and thus runs under the mutis to the stomach. Under the throat appears the great artery, which rising upwards from the abdomen (where this animal's heart lies) sends to the mutis two considerable branches, Fig. III. *cc*, that issue from thence, as if they descended from the thorax. The greatest part of this body lies upon the bone of the fish, on each side of the bone, and of the great artery, and it is only divided from the bone by a kind of fibrous membrane.

After this, the course of the blood-vessels running thro' the mutis, is discovered by opening and turning over, Fig. III. *d*, the membrane that encloses it. But the substance of this part is so very soft, that by expanding itself like a liquid, it intirely hinders the view. This makes it necessary to separate with a spatula this pulp from the vessels that go thro' it, and afterwards thoroughly wash the vessels themselves with water. Thus, at length, a satisfactory sight may be obtained of the distribution of the blood-vessels, Fig. IV. *e*. By this process we likewise discover that the substance of this part is in a manner entirely composed of an infinite number of little grains, being loosely connected with the blood-vessels *f*; but then a good microscope is requisite to distinguish these small corpuscles. The colour of the mutis is between red and yellow, somewhat inclining to a brown. I cannot determine what the use of it may be; it lies entirely by itself, within a peculiar membrane, and consists of two distinct bodies, without having the least resemblance to the liver, as heretofore idly pretended. Nevertheless, I cannot take upon me to deny its performing the same office with the liver, as the wonders of nature are inexhaustible, and God the master of nature has, in different animals, formed in a various manner organs subservient to the same purposes; this will evidently appear by the surprising structure of the genital parts of this animal, which are contrived with an art and elegance that surpasses all description.

The throat, as I said before, runs under the mutis, and has its origin in the same place nearly where the fauces terminate. By the fauces, I mean that wrinkled and muscular part of the skin, which reaches from the beak and mouth, Fig. V. *a*, to the beginning of the gullet, or that tube which runs from the mouth to the stomach. This gullet passes under the brain, and then descending into that part of the body, which I call the thorax, it there lies softly upon the salival glands *bb*, and is connected with the two already taken notice of; from whence it runs in a straight line to the abdomen, where it opens into the stomach *c*. The stomach resembles in a manner a spherical bag; but it is some-

what indented in the middle. There run thro' it a great many blood-vessels *d*, which are seen the better by injecting the arteries with some coloured liquid. This organ consists of three coats; the external coat is membranaceous; the middle coat muscular; and, as to the internal coat, it readily separates from the middle coat with the food it immediately encloses, and so may be easily taken out of the stomach with all its contents.

The Cuttle-fish, I could observe, feeds upon Shrimps; for there remained in its stomach the eyes, legs, and tails of Shrimps, with some of the rings of their bodies. I could discern among these, remains of the back-bones and ribs of some very small fishes.

The straight gut, Fig. V. *e*, issues immediately from the stomach, and is the only intestine I could discover in this animal; so that the veins must take the aliment immediately from the stomach, and then convey it to the heart, whose business it is to distribute it over the whole body.

Under the straight gut lies an appendage of the stomach, into which it opens by a particular orifice, after twisting like a snail in a very remarkable manner *f*. I cannot say for certain what this part may be; tho' to judge anatomically of it, I should take it for the pancreas, which, except its not being twisted, appears of the same construction in a great variety of fishes, as may be seen in a treatise of mine on that part of the creation, adorned with figures, printed by Commelyn of Amsterdam, and dedicated to the College of Physicians of that city. This organ is very smooth and slippery on its inside, and contains a matter like the pancreatick juice of other fishes.

The white bag which contains the Cuttle-fish's ink *g*, lies principally in the left side of the body, and communicates by a slender channel with the upper extremity of the straight gut *b*; so that both the faeces and the ink are discharged thro' the straight gut by one and the same orifice. This bag is in part membranaceous, and in part muscular; and is furnished with blood-vessels, which run over its surface *i*. Within I discovered a little glandulous body, or mass, which perhaps serves to generate or prepare the ink; for I had not opportunity to examine it thoroughly, on account of the ink's flowing so conspicuously, that it was impossible to wash it off fast enough to obtain a satisfactory view of this organ.

It is therefore necessary not to wound this part on dissecting the Cuttle-fish, as by pouring out its contents it would infallibly render all the other parts invisible. The ink contained in one bag is sufficient to communicate a blackness to several pails of water, so intense is its colour. I shall not pretend to say absolutely what the use of this ink may be; or whether or no it may serve to obscure the surrounding waters, and thereby secure this animal from other fishes which would devour it; for, as yet, I have had no experience in this matter. But it is certain that the Cuttle-fishes I found  
dead

dead on the sea-shore contained a greater quantity of this ink than those which were brought to me alive. The liquid is insipid to the taste, without the least sowerness or bitterness; so that I cannot see how this insipid substance, by being boiled with the Cuttle-fish, can in the least contribute to give it an extraordinary relish, as those pretend who feed upon it; tho' the most general manner of using this fish; is barely to give it a drying in the open air.

The ink taken out of its bag, and poured into a glass coagulates and grows hard in a few days, when it separates into a great many little pieces, which, ground upon a stone, afford the most elegant black paint. This convinces me that the Indians prepare their ink with nothing but this juice. I have even observed that this substance, while in a liquid form, struck so strong a black, that no washing could get it out; as particularly appeared in a black coat made of a slight dutch cloth, which had some yellow stains from aqua fortis: near the stomach, and between the folds of the pancreas, there lies a glandulous body, which runs to the throat, Tab. LI. Fig. V. *kkk*; but I am as much in the dark, as to its use as to that of the ink-bag; tho' I think it belongs to the organs of generation, which I shall hereafter take notice of, having first described the heart, brain, and nerves; and likewise said something of this creature in particular.

The heart of the Cuttle-fish, contrary to what we observe in most other animals, lies in the abdomen, Tab. LII. Fig. 1. *a*. It is of an oblong triangular form, and in colour very like a muscle that has nearly lost all its blood. Its external surface is tolerably smooth and even, and its internal one fibrous, and divided into little hollows, and prominent columns. I could discover but one ventricle in this organ.

The Cuttle-fish's heart has two auricles; for as the gills in this animal are placed on each side of the body, and at a great distance asunder, nature it seems, has thought proper that, instead of one, this fish should have two auricles *bb*, which I have here represented, as they appeared on separating them from the blood-vessels of the gills *cc*. They are of a membranaceous texture, and, when blown up, are of the same figure exactly with the design I give of them. I have no more at present to say of these parts; for they had almost escaped my notice when I happened to discover them; so that to acquire a thorough knowledge of them, I should have had more subjects; which are not to be obtained without great trouble and expence, on account of the brutality and avarice of the fishermen, who sell the produce of their hardest labours for nothing in a manner, whilst they fix an extravagant price on such things as come in their way without their being at the pains to look for them. In the mean time I must observe, that this fish's heart having but one ventricle, at the same time that it has two auricles in common with other animals, is altogether singular, and may well deserve to be considered as a paradox. The blood

of the Cuttle-fish is white, which is all I can say of it, as I never examined it; tho' I had resolved to save some of it in a glass tube for microscopical inspection, and in order to find out its analogy to the red blood of other animals.

The great artery, which first rises from the heart *d*, is of the same construction with that of fish; but it grows somewhat smaller in its course, and sends forth two pretty considerable branches, which immediately dispatch less ones *ee* to the mutis, whilst the others run to the muscular parts of the rest of the body; so that some of these ramifications are seen plainly thro' the transparent skin under the two muscles, which move the acetabula of the common excretory duct, Tab. LI. Fig. 1. *y*; from whence they extend to the gills and several other parts. After this the artery formed into one trunk, stretches to the base of the brain, Tab. LII. Fig. 1. *f*, where it divides into various branches, some of which run thro' the cartilages, that enclose the brains in place of a skull, whilst the rest distribute themselves to the legs and other parts of the body. But it is yet unknown what is the course of the veins in this creature, and whether it has like fishes a first and second artery, these are things I have not yet been able to discover; neither can I tell for certain, whether or not the two vessels springing from the lower region of the heart itself *gg*, and here most exactly represented by me after life, are really veins, as I think they are. But all these doubts may be cleared up by repeated dissections.

The brain of the Cuttle-fish is very small, and is plainly divided into a right and left portion, Fig. II. *a* To see this conveniently, it is proper to turn the animal on it's belly, then open its head, and cut away with a very sharp knife the cartilages that contain the brain, using great caution for fear of injuring the nerves which issue from it. The brain lies on the back part of the head, in a manner entirely buried in fat, which I have here for distinction sake represented by dots *b*. It is no easy matter to separate this fat on every side without hurting the brain on account of it's exceeding soft and delicate texture. The optick nerves *cc* are likewise at their origin surrounded with fat; but in their progress, after running thro' the cartilages of the brain, they dilate into a considerable knot *dd*, which separating into two tubercles, as it were, sends thence towards the eyes a great number of nerves *eeee*, as I have endeavoured to represent them one side. This numerous body of nerves is intersected by a conspicuous blood-vessel *f*, before they can reach the choroide tunic, or coat of the eye; which is remarkable for its great variety of beautiful colours; and is so invested with these little fibres, which embrace and surround the eye on every side *g*, and have a great share in composing it, that this useful organ must receive great strength from such an accession. About the upper region of the eye, where the iris shews itself in other animals, this coat forms in this

a globular prominence *b*, from which a crystalline lens partly projects *i*.

I have thought proper to give a separate drawing of the pupil's covering or lid, continued to the extremity of the choroide tunic; I first represent it on that side where it was cut from the eye Fig. III. *k*, and looks of a deep green colour, which by degrees grows paler, and is interwoven with delicate vessels. I then exhibit its other side, by which it may be said to float freely in the aqueous humour, and rest against the crystalline lens. In this part it is of a silvery whiteness, and interspersed with very delicate streaks or fibres. These fibres look as if they were continued not only to the filaments of the iris, but likewise to those of the choroide tunic, which I have already represented. This covering or lid of the pupil is of an extreme blackness in that part of it, which lies over the superior region of the crystalline lens.

I could find but very little of the aqueous humour on the inside of the eye, whereas that constituting the crystalline lens was in considerable quantity, and was tolerably compact. But there was something singular in this last part, namely, its coat's being of an extraordinary thickness, and likewise its ciliary ligaments penetrating so deep into the crystalline lens, that it in some measure as it were divided this part of Tab. LII. Fig. IV. *m*, the eye; this may be best seen on the fore part. On boiling this eye, and then peeling off the ciliary ligament, along with the coat of the crystalline lens; and likewise the fore segment of this lens from its back segment, the lens itself appears exactly like a globe contained in a semi-globe, or like a sphere in a hemisphere.

The vitreous or glassy humour was in a manner so perfectly fluid, as rather to deserve the name of an aqueous than vitreous humour. I could not discern exactly the retina, as the black juice of the aveæ happened to get out of its membrane, and thereby spread an impenetrable obscurity all over the adjacent parts. This accident for want of subjects, obliged me, to put an end to my anatomical survey of the eye; and therefore I shall return to the brain, and the nerves that issue from it.

From the fore region of the brain, there arise three considerable pairs of nerves, which, after making their way thro' the cartilages of the brain, run in a most beautiful manner to the muscles of the head, beak, legs, and adjacent parts. But the construction of the middle pair is more admirable than that of the lateral ones, as it swells into a node or globule Fig. II. *n*, from which the nervous branches issue in a most elegant manner, like rays of light of the sun's body.

The better to shew the situation of all these parts, I have given a particular engraving of the cartilages which surround the brain *o o*, as well as those serving for a foundation or prop to the eight legs, *p p*, in the center of which lie the mouth and the beak. From the back part of the brain issue two very large nerves, *q q*, which form each of them a remarkable knot, *r r*, after having passed through the thorax, and under the muscles that serve to move the acetabula

of the common excretory duct. I could count more than twenty little nerves, which sprung from each ganglion, and were distributed to the region of the gills; after running on each side of the acetabula, of the common excretory duct, where they in part shewed themselves through the transparent skin, Tab. LI. Fig. I. *z*.

The genitals of the male Cuttle-Fish may be divided into three parts, one testicle, and two glandulous parts, between which there lies another glandulous body, divided into a great many lobules; and lastly, a peculiar glandulous and spongy body, in shape like a heart, seated under the animal's ink bag.

That part, which I call the testicle, on account of its external appearance, is so admirably contrived, that it greatly surpasses all the wonders I have hitherto related of the Cuttle-Fish. It ends in a particular open-mouthed tube, which floats loose in the body, like the end of the straight gut, *u*. It is through this tube the testicle discharges its sperm, so that it may very properly be called the vas deferens of this organ. I could sometimes observe some very tender and delicate white fibres hanging from this part, Tab. LII. Fig. v. *a*; but I cannot say whether they were natural, or were occasioned by some disorder in the animal, as I never examined them in a live one. This single testicle is oval, but it ends at the bottom in a kind of a point, *b*. In the centre of it there is a little body, which very nearly answers the parastatæ, or corpora variaformia of quadrupedes, and even of man, *c*; but I have not yet been able to discover where this vessel begins or ends. The nearer this little body, just taken notice of, approaches the testicle, the broader it grows: this circumstance may be best seen, by turning the testicle upside down, and then divesting it of the great number of membranes which cover it, *e*. I have some reason to think, that the whole testicle may be unfolded, and wound into one long vessel, somewhat slenderer at its beginning and at its end, than in the middle, and terminating in a curious curled little tube, *d*. The texture of the genital parts already mentioned, is glandulous. In the narrow parts of the channel just now spoke of, there is found a white spermatick matter, which, on wounding this part, issues forth in form of coagulated milk; but the substance contained in the somewhat wider parts, is transparent: the widest parts of all are full of an infinite number of little delicate white parts, somewhat crooked, which are altogether free and loose at their hinder ends, Tab. LII. Fig. VI. *f*; but at their fore ends, they terminate each in a very delicate filament, *g*, by which they are in a manner linked to each other. These delicate fine threads may be unwound, to double the length of the other parts to which they adhere; and on taking both the threads and these parts into the open air, the former immediately harden like the threads drawn from silk Worms, and shine and glitter like a looking glass.

The most surprising circumstance in this part is, that on throwing some of these into water, they, after a little time, begin to move, and then opening

ing at their hinder, and sometimes at their fore, extremity, they suddenly discharge a little white body, which, on its escape, rolls and curls itself up in a serpentine manner, *b*, the larger part, all the while continuing in its former state, without the sides of it falling together. This surprising little body, when viewed with the microscope, looks like a very white Earth-worm, divided into a great many exceeding small rings; and if left in the water for some time, it expands and grows bigger by degrees, by the water it imbibes, which makes me imagine, that the water may possibly be the cause of that wonderful motion observable in these parts, on their being put into it.

These particles, when thrown into spirit of wine, remain perfectly quiet, without any opening.

These parts may be very distinctly seen thro' the transparent coats of the testicle; and they appear divided into a great many rows. Sometimes even they may be observed to have rolled themselves into serpentine coils, and discharged their white particles, before the testicle has been opened, Fig. v. *ii*.

On examining with the microscope one of these minute parts, we may plainly perceive its construction, and can see a transparent space, like an air bubble, at its hinder end, Fig. VII. *a*. A little higher up is the region, within which lies the little surprising moving white particle, just now spoke of, *b*. But I have here represented it much shorter than it appears through the microscope, for fear of enlarging the drawing to too great a size. This little part grows transparent again near its fore end, Fig. VII. *c*. But the fore end itself is very neatly curled, *d*, and it is from this extremity that the filament issues, which hardens in the air, like the Silkworm's thread, *ee*.

Whether these filaments be hollow, and whether the sperm be generated in the cases which contain them, as in so many kind of feminal tubes, or whether all the cases themselves, with their contents, be discharged by the animal at the time appointed by nature, for its shedding its sperm, are very obscure questions, which as yet I am not able to answer\*. Let it therefore suffice, that I have just exhibited, to the glory of the Great Architect, the admirable beauty and  
con-

\* The public received some few years since, an account of these vessels in a species of Cuttle-Fish, from the ingenious Mr. Turberville Needham: but we see the first account of them is owing to this author; and much is yet to be expected in the perfecting their history, from some future philosopher accustomed to these inquiries, who shall have opportunities of obtaining the animal alive. The species mentioned by Mr. Needham is, as we have before observed, the *Loligo* of authors; and his observations on the construction and action of these particular parts, is this—

The outward transparent case is cartilaginous and elastick: its upper extremity is gathered into a round head, which is in reality nothing more than the top of the case involuted into itself, and by that means closing the orifice, through which the interior apparatus springs in the time of action.

Within this is contained a transparent tube, elastick, as it appears from the phenomena, in all directions, and forcing its way wherever it finds a passage, which tho' the continuation of it is not equally sensible in all parts, may be easily discovered in a course of experiments to invest the screw, sucker, barrel, and that spongy substance, which imbibes the semen. The screw is inserted in the upper part of it, and throws out of the head of it two slender ligaments, which fasten it with the whole annexed apparatus to the top of the outward case; the sucker, and barrel or cup, are lodged in the middle of the tube, and the spongy substance containing the semen distends the lower part.

I shall now proceed to the several phenomena's that appeared in the action of this minute machine, which to me at least seemed so surprising and inexplicable, that I think myself obliged to premise, that I am in no wise answerable for any seeming contradictory consequences, which may possibly be drawn from matters of fact I dont pretend to account for: all I can assure the public of, is, that they are literally true, just as they are related, and were seen by several persons, as well as myself. The objects I have now by me preserved in spirit of wine, which, though they retained their activity for more than twenty days after they were taken out of the body of the fish, and immersed in spirits, without any sensible diminution, yet now have in a manner totally lost it, though they remain to all appearance in the microscope perfectly the same. If therefore any of my readers desire to verify the facts I have mentioned, they must apply in the season for fresh objects, and do their utmost to procure the milt-vessels when perfectly ripe for action; for these only will answer to all the phenomena I have taken notice of, though the less mature will suffice for most of them.

Tho' many of the milt-vessels, when they are ripe for action, and disengaged from that glutinous matter which surrounds them while they are in the milt-bag, will act immediately in the open air, for which perhaps the slightest pressure during extraction may be sufficient, yet the generality of them will not only bear a translation to the object-plate, and lie quiet for observation, but also require a drop of water to moisten the upper extremity of the enclosing case, before they begin to operate.

Upon application of this, the extremity begins to evolute and unfold itself, and the two slender ligaments, which emerge out of the case, turn and twist themselves in various directions: at the same time the screw moves upwards with a slow motion, the spires at the top gathering close together, and acting against the head of the case, while those at the bottom advance proportionably, and seem to be continually succeeded by others out of the head of the piston; which succession I believe to be apparent only, and not real, the appearance being owing to the nature of the motion in the screw: in the interim, the sucker and cup, or barrel, move gently on in the same direction; and the inferior part of the apparatus, which contains the semen, extends itself in length proportionably, with a motion at the same time upwards, which may be perceived by an increase of the vacuity at the bottom of the case. Soon after this, the top of the screw, with its enclosing tube, appears out of the head of the case, and as it is there fastened by its ligaments begins to bend: the motion of the whole continues thus slow and gradual, till the screw, sucker, and cup have forced their way, and emerged totally, when at that instant the remainder of the apparatus springs out at once, the sucker separates from the cup, the seeming ligament below the cup swells out to the diameter of the inferior part; the inferior part, though distended considerably in breadth, more than it had been in the case, extends itself to five times its original length; two knots, between which the tube contracts itself in diameter, form themselves, each at about the distance of one third of the whole from both extremities, and the semen flows out of the cup, consisting of small opaque globules swimming in a sort of serous matter, just in the same form, and without any appearance of life, as I had seen it before, when diffused at large in the milt-bag. After the operation, it is to be observed, that the fringed edges between the two knots appear upon examination to be nothing more than the interior spongy substance broke and disjointed at almost equal distances, as will be clear from the subsequent phenomena.

Sometimes the screw, together with the tube, breaks just above the sucker, and the sucker remains in the cup, of which I have also given a drawing: in that case the investing tube closes instantly at the extremity of the screw, as far as it will permit, and contracts itself nearly in a cone, which plainly indicates its great elasticity in this, as its conformation to the shape of the enclosed substance upon the least change does in every other part.

At first view, an observer would be inclined to think, that the action of the whole machine is to be derived from the spring of the spiral screw; but the following experiments, which I tried with a view of satisfying myself in that particular; not only evince the falsehood of that supposition, by demonstrating that the screw can at most act but as a counter to a force entirely latent, but afford a train of phenomena so surprising, that they totally silenced all the hypotheses I was capable of forming. The experiments were tried upon milt-vessels, which though not sufficiently mature for the ejection of the sucker, dilatation of the seeming ligament below the cup, and the expression of the semen, had already attained the full force requisite for the exertion of the interior apparatus out of the enclosing case; thus they completely answered my present purpose, as well as the most mature could, and remedied the misfortune I had of losing the only parcel of mature milt-vessels I have found in the course of my inquiry, which I had laid by for further observation.

contrivance of these parts; contented as I am in being thought ignorant of every thing else belonging to them.

As to the other parts, composing in my opinion, the organs of generation, the construction of them is very remarkable; for they seem as it were to consist of two distinct glands, placed at the sides of the abdomen, and there connected with the gills, Fig. VIII. *aa*, from which I separated them. These glands are white, and there adheres to each of them another glandulous body, by means of a glandular tube, in form of a stalk *bb*. These corpuscles are of a somewhat grayer colour than the rest, and have each of them a considerable slit, with a great many little openings at the bottom, through which issues the seminal matter formed in these and the inferior particles.

This seminal matter, after flowing from its glands, is conveyed to a bag that lies at one side, and is represented under the letter *r* of Figure 1. Tab. LI. from whence it is discharged out of the body by two distinct tubes. The mouths of these tubes appear very plain at the sides of the straight gut; and the matter they contain, may even be squeezed out of them. These tubes are exhibited in the figure and table last mentioned, under the letters *qq*. But I cannot as yet take upon me to say whether or no they ought to be called the prostaæ, or what other organs they may properly be.

Among the parts I am describing, there lies a glandulous body divided into lobes Tab. LII. Fig. *cc*, VIII. and connected by means of some delicate membranes *dd*. These lobes are again most beautifully divided, as it were, into a great many branches, covered with tender, and in some sort membranaceous, glands, which in the animal itself forms a most entertaining spectacle. From this body there arises, on pressing, another kind of spermatic matter. The lobes last mentioned, and their glands, are of different colours, partly white, and partly inclining to gray; the glandulous body itself also, which I heretofore represented as adhering to the stomach, seems to have a communication with these glands; for as

yet I cannot take upon me to affirm positively, that it has any. I must have more subjects to examine, before I can determine any thing in regard to this and several other particulars relating to this Cuttle-fish. The best time to take a thorough survey of the creature, would be when the sperm is not as yet arrived at its full maturity. But such a survey would require a great deal of attention and leisure.

The third part belonging to the spermatic vessels has been already exhibited, as it appears through the transparent skin under the letter *t*, in the first figure of Tab. LI. Fig. 1. It lies in the lower region of the abdomen, under the ink bladder. It is of a glandulous spongy substance, and contains a seminal matter, which may be easily pressed out of it. Its superior region is somewhat broad, flattish, and depressed, Tab. LII. Fig. ix. *a*; the inferior terminates in a manner in a double or forked point *b*, so as in some degree to resemble the shape of a heart. I cannot shew the channel by which this part discharges its spermatic matter, as I tore and broke it, on striving to take it out of the creature's body.

I could not at this time narrowly inspect the genital organs of the female Cuttle-fish, because I wanted a sufficient number of subjects; and those, in which I observed all the particulars hitherto related, were both males. For this reason I cannot now take upon me to give a satisfactory account of the parts visible in the female, or to say whether or no it has any genital organs answering to those, I have already described and delineated, as belonging to the other sex. I shall therefore attempt no more at present, than just to give a drawing of the genitals of a female Cuttle-fish, which I some years ago took care to prepare and preserve, referring to some other time, when I shall have inclination and leisure to perform such a task, a thorough survey of these parts.

The first thing I here represent, is the straight gut *a*, Tab. LII. Fig. x. to the side of which adheres the channel by which the ink is discharged *b*. The ink bag itself *c*, lies upon the ovary *dd*. At the other side of the straight gut

If the milt-vessel be divided just below the cup, that part which contains the semen extends itself instantly; and though a part only, and not the whole of it springs out at the opening, as it does not when severed from the rest of the apparatus, yet upon application of water, it works itself out by degrees with a slow motion, and emerges almost entirely out of its case.

If the lower extremity of the outward case be cut off, it distends the seeming ligament below the cup to an inconceivable tenuity, breaks it without deranging the screw, or causing any alteration in the superior part of the apparatus, and goes out at the opening.

In one of these experiments, the seeming ligament breaking after distention, struck with such smartness the side of the enclosing case, that, though cartilaginous, its extremity forced its way through by its elasticity, and retired twisting itself again into the case; which can be accounted for no other way, than by supposing it extremely elastic, and its force upon this occasion something analogous to that of a silken thread, which, if suddenly emitted after distention, with a certain direction that it receives from a peculiar flight of hand, will open itself a passage through a sheet of strong paper.

If the milt-vessel be divided both above and below the semen, it emerges at the two extremities, by extending itself in both directions, which being contrary to each other, detain it in the case with this additional effect, that it renders the enclosing tube conspicuous, by severing asunder at some of its divisions the spongy substance which contains the semen. I mean by divisions the rings throughout its whole length, resembling those of a Worm, though not so regular, as they appear through the greatest magnifier of the common double reflecting microscopes; yet, with the third magnifier, from which these drawings were taken, they are seen as exhibited in the figures, like a fringe investing the edges. I have sometimes upon this occasion counted no less than nine separations, though no more than four appear in the drawing; for in this particular, there is no determinate regularity.

If the least orifice be opened with a lancet in the side of the outward case, it instantly conforms itself to it, and comes out double.

'Tis observable also, that the screw, upon separation, ceases in every respect to operate, and loses irrecoverably its activity, which is an evident proof, that the whole force of the milt-vessel is to be derived from the action of the inferior part.

The application of water is for the most part necessary, and yet the milt-vessels will often act without it: spirit of wine will also suffice, though the effect is considerably slower, and the spring, with which the inferior part at the close of the operation, when regular, suddenly starts out, is totally impeded; but this was understood of a single milt-vessel placed upon the object-plate; for when the whole bag is immersed in spirits, even so that the liquid has free access to the whole collection, it causes no other alteration, than that the inferior part is somewhat extended in length, and recedes some little from the bottom of the outward case. Oil has no manner of effect in any respect whatsoever, though more lubricating than any other liquid.

is an open-mouthed tube or duct *e*, by which the eggs are voided. I here exhibit three of these eggs *f*, one half less than the natural size. Upon the ovary and ink bladder are placed two very beautiful glandulous bodies, represented at *gg*; but I cannot now say any thing certain concerning them, as most of my former observations are only recorded by drawings, with a bare explanation. Above these two bodies, or rather in the midway between their appendages, appears a remarkable little bladder or bag, which contained a red juice *h*. Lastly, I exhibit at one side all the parts already mentioned, and the gills *ii*, together with their vessels and divisions, in their natural situation.

I should here finish this essay, if for order sake I did not think it proper to add something concerning the Cuttle-fish's bone, being the only one to be found in the body of this wonderful animal. The flesh closely surrounds this part on every side, in the manner observable in man and other animals. To obtain a satisfactory sight of it, no more is requisite than to make an incision in the fish's back, and separate the bone itself from its membranes, and other integuments; all which may be very easily performed.

This bone, when newly cut out of the animal, is of a middle nature between a dry and a moist substance; it floats upon the water, if immediately thrown into it. And this, no doubt, is the reason of its having been called *spuma maris*, or sea-froth. Hence also it happens, that so many of these bones are seen during the summer months floating near our coasts, upon which they are at last thrown, in proportion to the number of Cuttle-fishes that have died since the preceding season. The fishermen gather these remains, and sell them to the different tradesmen, who have occasion for them. It would take me up a large volume to describe all the wonders observable in this bone, in regard to its figure, colour, texture, and other qualities; I shall, therefore, only just account in a few words for its floating on the surface of the water.

This bone which lies in the animal's back, on breaking it, after having first cut with a file thro' the hard crust that covers it, some inches from its fore end, appears to consist of several testaceous plates *a*, Tab. LI. Fig. vi. Of these the upper ones are the longest, and most crooked; and they lie closer to each other than the lower ones, which being applied to the hard crust of the bone that had been filed off, yield somewhat in length to the former. The reason why the lower plates should lie looser, or at a greater distance asunder, than the upper ones, seems to be this; that the former have received more nourishment during the fish's time of growth, than the latter, and therefore increased in bulk a great deal faster. Besides, the hard crust of the bone, by lying nearer the upper plates than the lower ones, is sufficient to make the former full amends for such a deficiency.

Between these plates there are a great many filaments reaching from one plate to the other, like so many props or columns, so as to hinder the plates from closing together. And the great lightness of the Cuttle-fish's bone, in consequence of which it cannot but float like a froth upon the water, depends entirely upon this construction.

To make this very conspicuous, nothing more is necessary, than to separate two of these plates which lie at the greatest distance asunder, from the adjacent ones; and this may be very easily effected, by breaking with the point of a small pin, the filaments which unite these plates together, at the same time that they keep them at a proper distance asunder; for their filaments are so fine and delicate, that they yield to the least impression.

On viewing with a microscope the plates prepared in the foregoing manner, the disposition of the columns or props *c*, between the upper and lower plates *de* immediately appears, as likewise their figure, and how they consist of a great many very small fibres which are composed, as it were of minute globules. We may even observe some transverse fibres, stretching from one column to another, and so strengthening them, and connecting them together. Besides, many of these props have a deeper foundation than the rest; and there is likewise a great variety in their figures.

To comprehend thoroughly the construction of these parts, and their admirable contrivance, it is proper to take a piece of the bone prepared in the manner just now explained, and having fastened it in a safe place, with a little starch paste, leave it there till it dries. After this, care must be taken to separate the upper plate from the props supporting it, without doing them any injury, which however difficult, I have often accomplished with perfect success. By this means it will at length appear, that these columns are so many hollow slender tubes, Tab. LI. Fig. viii. *g*, naturally full of air, which is a sufficient reason, why the Cuttle-fish's bone, when thrown into the water, should always swim on its surface.

In this state, some of the columns appear like perfect tubes, others of a less regular form, and many are beautifully bent, like paper folded in a variety of forms. This inflexion is very like that which we observe within the nostrils of hunting hounds, in the bone upon which the scent acts; as also, in horses. This construction of the props cannot be perceived with the microscope, till one of the adjacent plates is removed, otherwise they all appear cylindrical, because they are transparent. For it is the property of that kind of glasses to give almost all hollow transparent bodies a round appearance.

The substance forming the crust of these plates and their props, is in a manner of the nature of an alkaline salt; it ferments violently with acids. But on separating from it the membrane, that covers the back part, it appears entirely composed of the same matter with the plates themselves, and the interjacent columns, which makes

it not improbable, that this stony and saline bone, found in the back of the Cuttle-fish, is originally composed of hardened membranes, and this conjecture is confirmed by considering attentively that part of the Cuttle-fish's bone, which lies within its tail, and the membranes investing it; for these last when examined with the microscope appear of the same construction with the plates and columns themselves, But it is no easy matter to separate these membranes; they are so firmly connected in that part with the hard crust covering the bone. When cautiously picked off, they leave a view of the manner in which this animal's bone grows at this place into a sharp tale Tab. LI. Fig. XI. *b*, which in full grown Cuttle-fishes is much longer and more pointed, than in young ones, as in these last the membranes are not yet hardened. It may therefore be fairly concluded

from all the foregoing particulars, considered together, that this stony bone of the Cuttle-fish, is formed in the same manner with the bones of men and quadrupedes. Nay, we can very plainly see that the blood vessels not only run over the surface of this bone, but penetrate into its substance.

To close this treatise, I must offer my most humble praises to the great Creator, for having made known to us so many specimens of His inexhaustible wisdom, power, and goodness, all the glory of which we ought to give to his Divine Majesty, praying Him at the same time to make us truly obedient to his will: so that we may henceforward do nothing but what is agreeable to Him, for in this exact conformity to His pleasure our present and future happiness entirely consists.

## T H E E N D

### *A treatise on the Physalus\*.*

**T**HIS creature, which Rondolet describes from his own observations, and from Ælian, is found in the German sea, and sometimes is thrown ashore on its coasts in the summer months. I can produce one of them, which stuffed with tow, by a hole made in its back, and afterwards sowed up, has its skin changed to a kind of real leather. I many times this summer spoke to the fishermen to get me one of these animals fresh, as they gave me to understand they often caught them alive in their nets, but as yet I have not had the good fortune to obtain any of them; I can therefore do no more at present than describe it, and illustrate my description with figures from some slight notes and drawings I formerly took of this creature; these observations, however, may throw great light upon what Rondolet has wrote concerning it, especially what he has affirmed after Ælian of its surprising inflection. The Physalus when turned on its back, Tab. X. Fig. VIII. appears somewhat broad in the middle, on the forepart toward the head it is a little narrower, and at the tail it ends in a point. The abdomen is full of wrinkles, and is covered with a very delicate kind of biffus or cottony matter. This creature has on each side of its body twenty eight protuberances, called by Rondolet dorsal warts, from which there spring very stiff bristles *aaa*. The learned Oligerus Jacobeus, when here in Holland, made me a present of a creature of this kind, and called these bristles its legs; but I cannot see any reason he could have for giving them that name, as the creature cannot use them as such, tho' perhaps it may employ them as oars in swimming†. The Physalus has other protuberances besides those

already mentioned; and except their being smaller and sharper they are of the same construction.

In some of these warts, which I cut from the creatures sides, Fig. IX. *b*, I could count sixteen bristles disposed inwardly into three rows, and united together in each row, by a particular ligament Fig. X. *c*, and all the sixteen by another common one. The first row consisted only of two moderately stiff but very large bristles *d*. The second consisted of six *e*, and the third of eight *f*, differing in length, structure, and firmness; all these bristles were of a shining black, but there are other species of this creature, whose bristles are of a bright gold colour. Such are these mentioned by Jacobeus in the *Acta Danica Medica*; and I have myself seen some of this kind. There are also Physali with green bristles, if we may believe Rondolet, who calls these bristles green hairs. Some of these bristles, which give the creature a resemblance to the Porcupine or Hedge-hog, appear thro' the microscope flattish and sharp Fig. XI. *g*, whilst others appear cylindrick, and somewhat thicker about their fore parts, Fig. XII. *b*, where they at last terminate in a blunt point.

Under the parts last mentioned, there grows on each side of the body a prodigious number of delicate gold coloured downy hairs. I have only represented those on one side Tab. X. Fig. VIII. *iii*, where the bristles are omitted, to afford a better view of them; these delicate hairs spring likewise from the centers of certain warts, over whose surface they afterwards spread themselves, Fig. XIII. *k*. The last warts lie close under the others supporting the bristles, with which the hairy down growing in the form of flocks of wool is naturally intermixed, especially on the

\* This singular creature which former naturalists have universally called Physalus, and have been perplexed in what class to arrange it, Linnæus refers to his class of Worms, Vermes, he arranges it under the second order; the creatures of which he entitles Zoophyta, and to this genus he gives the name of Salacia; by this denomination the creature is known at present among naturalists, and there is no other known species of the same genus.

† These are not legs, nor intended for its office: they approach more to the nature of arms with hands or fingers; and are properly Tentacula of the creature: their use is in finding and securing the creatures prey.



upper part of the body, and on the sides. The opening of the mouth lies forward near the head Fig. VIII. *l*, and over it is a little body resembling in figure and construction one of the beards that are to be seen in some fishes.

What has been said, is sufficient to give the reader some notion of this insects construction on its upper part or back, Fig. XIV. where it appears as if entirely composed of an assemblage of downy hairs and bristles, the surface of this part also is rounder, and more convex, and the warts growing on it are shorter and slenderer than those already spoken of, as lying upon the parts, to which the name of feet has been given.

On opening the back of this creature, I found the skin in that part lay quite free and loose over the adjacent flesh. I likewise discovered in this place on each side of the body, a prodigious number of holes Fig. xv. *aaaaaa*, which by running a probe into them, I found to extend under and between the bristly tubercles, surrounding each side of the body, with openings on the outside, thro' which the creature by an alternate dilatation and contraction of its upper skin, takes in the water requisite to moisten its gills *bbbb*, which are all the other parts to be seen within this hollow of the skin, and are constructed like the scales on the lower part of the bellies of Serpents. As to their texture it is membranaceous, with a smooth surface; and they are disposed in the most beautiful order, for the upper ones, tho' moving freely over the lower, always cover some part of them.

If we duly consider this construction of the body, we cannot be at a loss to account for the manner in which the Physalus, is able to swell and bloat itself up with air, and afterwards burst, or as I think I may more properly express myself, collapse into its former size and figure; to do all this, it need only first dilate the upper portion of its skin, that, on its floating to the surface, as it must necessarily do when its bulk is thus increased, the air may get into the cavity so formed, and then contract the same part, so as to make it ex-

pell the air contained therein; it then falls flat against the lower part so suddenly, as to imitate the noise as well as appearance of a real bursting. Hence we may also see why the Physalus, during this last operation should appear quite transparent, as the subtle air impelled at this time under the skin, cannot but open an easy passage thro' it, for the rays of light.

As to the viscera of this creature, there are many and remarkable singularities in them; but as I have yet bestowed little notice and few designs on them, I cannot say much of them at present. I only remember to have observed that the parts about the mouth of the Physalus are moveable in the manner of those of the Snails, and are of a pyramidical form, and of a very wonderful contrivance; its heart also, and blood-vessels shew themselves in a very beautiful manner. In the middle of the body I found a part which seemed in its upper portion to answer the purpose of a stomach, and towards the tail that of intestines. This vessel was divided into a great many ramifications, which were united, as it were, by mutual anastomosis or inosculation, Tab. X. Fig. XVI. *c*, and were full of, and turgid with, excrements of a kind of earthy clayey colour, divided into little lumps.

As I never saw this creature alive, and even dead, only after it had been tossed about by the waves from one part of the shore to another, I can propose but few things of it as certain. I don't know whether it is to be accounted venomous, as Rondolet seems to entertain that opinion; neither can I take upon me to determine among what species of animals it is to be classed, tho' it seems to deserve a place amongst Echini, or Sea-Urchins. Rondolet reckons it among his Sea-Caterpillars; but I cannot discover in it the least resemblance to these creatures. I shall therefore, for the present, conclude this history; but shall endeavour to complete it, if an opportunity offers, at some other time, when I may have leisure sufficient to bestow on so interesting a subject.

*The end of the History of the Physalus.*

*An epistolary dissertation on the Felix Mas, or Male Fern of Dodoneus.*

SIR,  
YOU do me no more than justice in attributing to me the first discovery of Fern; for which reason I shall now lay before you a very curious observation on this subject, with drawings to illustrate it. Were this a proper season to obtain one of these vegetables fresh and in good order, I should endeavour to send you more particulars worthy of your attention; what I now offer being only the result of a survey taken of it in a dead and dry condition: I may say, however, that it is now several years since, on examining by chance the tubercles growing on the under-surface of the Fern-leaves, I discovered in them certain little capsules,

containing the true seed of this plant; tho' many celebrated writers had denied that it had any, whilst others, who believed the contrary, knew not how to convince the former of their mistake.

The Male Fern of Dodoneus is a plant too common and well known to require a description; so that I shall only give a drawing of it, Tab. LIII. Fig. 1. *aa*, and the tubercles *bb*, which grow upon its leaves. These tubercles, which the ignorance and negligence of writers had considered as little collections of fine dust and dirt, when carefully viewed, exhibit the most wonderful construction that the mind of man can imagine, and so eminently display the contrivance,  
order,

order, providence, and wisdom of the Great Author of all things, that perhaps a more striking specimen of these His adorable perfections is not to be found in any other part of the visible creation.

Every tubercle consists of certain small leaves, which contain the pods, or true capsules of the seeds. At present I cannot tell the number of these little leaves, as I have none but dry plants by me, in which these appear in a disorderly manner, and curled up like the Fungus we call Jews Ears.

The pods just spoken of lie within these little leaves in the same manner as the flowers of the Moly are disposed within the globule scabbard, or cup which surrounds them, before it bursts and expands itself into leaves: at this period, these flowers resemble so many round balls placed upon stalks; and the same construction obtains in the pods of the Fern-seeds, which stand within the leaves surrounding them, each upon its own stalk or pedicle, and look in a manner like so many slender stems with large heads.

To give you, Sir, a still better idea of this subject, I lay before you a drawing of these pods, with their foot-stalks, and I shall add a description of them. These stalks are sometimes single, Tab. LIII. Fig. II. *ccc*, and sometimes double, dividing at a little distance from their roots *d*; in this case each branch carries its own separate pod.

That end of the stalk next the pod, is of the most singular construction that can well be imagined; it there resembles in that part a furrowed or fluted cord *eee*, which beautifully encompasses the pod in form of a crown, and surrounds it like an herbaceous zone; so that the two hemispheres of the pod swell beyond it on each side *ff*. The colour of this little cord, when the seed is ripe, is of a very pale brown, within the flutings; but the oblong intermediate protuberances are of a somewhat deeper brown. There are twelve of these protuberances, besides some certain ones, which sometimes spread over the surface of the pod itself.

The pod is membranaceous, and very delicate *g*; and it is constantly of the same colour with the seed it encloses. Near the middle of it there is a kind of furrow or slit, which divides it into two portions. When the seed is full ripe, the pod which till then, was of a transparent whiteness, turns to a blackish brown.

As soon therefore as the seeds have acquired their perfect degree of maturity, and the little cord is contracted, by drying into the form of an extended line, by a kind of elastic power, it endeavours to form a straight line, Tab. LIII. Fig. II. *bb*, and by that means, on a sudden, very exactly divides the pod into its original, two hemispheres *iiii*, so as to scatter with some violence the enclosed seeds into the air. And when this has just happened, we may see the cavity of the pod divided by little partitions into a number of cells where all the seeds have been separately formed.

All these particulars, Sir, may be very clearly and distinctly seen, by examining the seeds with a microscope towards the end of summer. In doing this myself, I found it necessary to bring my head very near them, and I very often had the pleasure of seeing a great number of the pods burst, and scatter their seed by the force of the surrounding cord, at that time endeavouring to extend itself, in consequence of the contraction or crisping caused in it by the breath from my mouth, and the heat of my body.

As to the size of these pods, it is a hard matter to give a drawing of them after nature, on account of their extreme minuteness, which renders them almost imperceptible to the naked eye. Nay, a dot of so small extent can scarce be made on paper with the finest pencil: but the seeds themselves are of so amazing a minuteness, especially when dry, that the sharpest eyes cannot, unassisted, discern them at all. I reckoned above forty-one of these seeds in one pod, though it had before shed a great number.

Who then, Sir, can pretend to shew in this seed, as may be done in some others, the germen or bud, the rind or bark, and leaves of the future plant? No one certainly; here therefore, the Great Creator gives us a complete specimen of His excellent work; to exhibit which properly, is far beyond the reach of the greatest genius for description and drawing; and it is scarce a wonder, that the greatest naturalists were so far mistaken, as to affirm, this plant was quite destitute of seeds.

I cannot at this time give you a drawing to represent the true figure of this seed, as what I have by me are dried up, and some of them appear larger than others; however, I cannot help letting you have one made as well as I could, from such a dried seed in this cloudy winter season. Its surface is somewhat irregular and angular, with certain tubercles on the upper part; which, under the microscope, appear of a net work form, Tab. LIII. Fig. III. *k*; but it is very difficult to examine these seeds when exposed to the air, or turned to the light, because they are of a deep brown colour, as I discovered, by endeavouring to view them in the open air, fixed to a hair of my head, which, in comparison with these seeds, appeared like the mast of a first rate ship.

Neither can I at present determine what the number of the pods may be, though I believe every tubercle contains more than sixty, from whence it would follow, that every tubercle contained at least 2460 seeds. The pods, when opened in the middle, plainly shew the little seeds distinctly stowed up in them, Fig. II. *l*; and as these grains have then acquired the utmost degree of maturity, and consequently lie loose, they may be easily shook out of their cells: but this is a sight we must expect to obtain rather by chance, than certainly procure by dissection; it so seldom happens, that any attempt to open a pod regularly is attended with success. I can at all times shew the seeds and cords, and every thing besides, which I have here described, as I did some time ago to Mynheer Arnold Syen,  
pro-

professor of botany, and Doctor Justus Schrader of Amsterdam, who both took great pleasure in contemplating these wonders of God in the vegetable kingdom. It is my real opinion, that the Fungi or Mushrooms, Corals, and other natural productions of that kind, have also their seed like the Fern, as I some time ago endeavoured to demonstrate in the Coral in particular, in two letters wrote to Monsieur Boccone upon that subject.

I cannot, Sir, find words to inform you with what wonderful order, and in how regular a manner, these pods burst under the microscope; with what force they then scatter their seeds; or with what a surprising motion the cords extend themselves; and with what incomprehensible wisdom and contrivance, the supreme Architect has so disposed every thing, that each part or portion of the bursted pod, should remain fixed to its cord at a particular place. But I hope the drawings I send, may be found sufficient to give you some notion of all these things.

I have found the same construction to obtain in the pods, seeds, and cords, of several different species of Ferns: and I make no doubt, but it may be found in the Spleenwort, Hartstongue, Hermonites, and other plants of that kind.

Hence you may conceive, with what rapidity these seeds may be waisted about by the wind, so as to account for these plants being found on the tops of the highest trees, and on walls, wherever they can find mould enough to take root in.

The great obscurity of the human understanding, is clearly proved by this observation; for was it not very dark indeed, how could it, during so many ages, deny that this plant had either seed or flowers? infomuch that it was one of the first errors taught young people in books, as well as heard in conversation. We ought therefore to thank the sun of divine grace, and true fountain of all useful knowledge, that we are at last so happy as to attain more just notions of this matter. Should not this mistake teach us modesty in our opinions and our judgment upon many other occasions, seeing, upon this, the most penetrating geniuses have all gone astray? If we are so liable to mistakes in regard to things that lie open to our inspection, what are we to say of our opinions of things which are invisible? How many idle notions are formed on such subjects? how many senseless conceits, with which, however, we sometimes so far suffer ourselves to be deluded, that we make nothing of injuring both in character, and person those who happen to be of a contrary opinion? It is therefore absolutely necessary we should always distrust ourselves, and act with the greatest circumspection. In our present wretched condition, we are surrounded with ignorance on every side, and have no other true knowledge than that of our own weakness and imperfections. Of ourselves we can do nothing; all we have, we receive from the gracious hands of the Supreme Being, the munificent rewarder of good actions, of whose divine favour, I wish you an uninterrupted enjoyment.

A S H O R T

Faint, illegible text, possibly bleed-through from the reverse side of the page. The text is arranged in two columns and is too light to transcribe accurately.

1888

## Short EXPLANATION of the TABLES,

Which are more fully illustrated in the

## B O O K of N A T U R E,

O R,

## HISTORY of I N S E C T S.

By J. SWAMMERDAM, M. D.

## T A B. I.

*Explains the changes of the first order or class, which are represented to the eye, by the assistance of figures; for which purpose the Louse is exhibited as an example.*

*N. B.* The numeral letters distinctly shew, after what manner the several changes succeed each other; some of the figures are represented as they are magnified by the microscope; the reader must observe in general, that the same method is also observed in the examples which belong to the second, third, and fourth orders or classes of the changes of insects.

No. I. **S**HEWS the nit or small egg of a Louse, delineated in its natural bigness, in which the Louse is contained; being yet clothed in its first skin or coat. The same may be seen *fig. 1.* as it is magnified by the microscope.

No. II. Is the empty shell of the egg, or the coat or skin of the nit, cast off by the Louse; after it has crept out of it.

No. III. Shews the Louse just excluded from its egg, where it plainly appears, how the creature has crept out of the membrane wherewith it was surrounded, in a perfect state; and is not obliged to undergo any further change, tho' afterwards it increases in bigness, and often changes its skin. Therefore we have named the Louse in this state, an oviform-nymph-animal: because it issues from its coat or skin, perfect in all its limbs.

No. IV. Is represented the same Louse somewhat bigger, and invested as it were in its third or fourth skin; which also soon after is to be cast off.

No. V. The Louse, having now attained to the full period of its increase, in which state we called it a nymph-animal; from its being then in its last skin that it sheds, and indeed we meet with some insects in the first class, which are also somewhat changed about the time that they cast their last skin, which plainly appears,

among other instances, in the Longipede, or long-legged Spider, the legs of which increase in length when it is casting its last skin. After that is cast, the insects which belong to this first order grow no more, neither are they changed in any respect; as may be more plainly understood from the figures of the following examples of the four orders, under number V. and VI.

No. VI. The Louse, having attained its perfect state, and being fully grown, so that it is now capable of generation; is represented *fig. III.* as magnified by the Microscope.

## F I G. I.

*The egg, or nit of the Louse, as magnified by the Microscope.*

*a* The oviform border or margin, with which the head of the nit is surrounded, within which are visible certain little cups or uvulæ, of no regular or determinate figure. These cups appear a little bent, and then again swell out in the middle, as it were into a whitish top. It is observable that these cups do not wholly fill the internal parts of the border or margin with which the head is surrounded.

*b b* Are two tender swellings or extuberances, wherein are placed the eyes of the Louse; whilst its limbs yet remain moist and soft.

A

These

These eyes, by imperceptible degrees, grow browner, and appear through the skin, and at last become entirely black.

- c* Is a certain white transparent part, in the middle of the nit, which we have often seen beating regularly in the same manner as the heart. This little part is represented in *fig. VI.* by letter *b*, and called by us the pancreas, because it moves up and down with the stomach.

## F I G. II.

*The shell of the egg, or the empty nit, and the first skin which the Louse casts.*

- a* The border or margin of the head burst open, with its little cups or uvulæ, and turned back by the Louse's creeping out at the upper extremity.

- b* The other part of the empty and cast skin of the nit, from which the border of the head is separated, by which means it has the appearance of a tankard without its cover.

## F I G. III.

*Shews the Louse placed on its belly, and magnified by the microscope.*

There appears a shining skin on its head, with some little holes and divisions. Upon its breast or back there is an elegant delineation of a shield, which is as it were painted in the middle; and this shining skin is ornamented with little holes. To the breast are fixed the legs, which are full of little swellings or extuberances, like those on the shagreen skin; but they become by degrees imperceptible at the extremity of the legs. By the assistance of the microscope it has been discovered, that at the margin of the abdomen, the skin there appears also painted and rough, with little grains like shagreen as before described; but by the help of the best microscope, I have at last found that the skin is really formed of irregular chequered work, globules, and such like appearances.

*N. B.* In *fig. IV.* next to be explained, will be pointed out by letters all the remaining parts of the Louse, one after another.

## F I G. IV.

*The external and internal transparent parts and limbs which are seen in the Louse, as lying on its belly.*

- a* The Aculeus or sucker.  
*bb* The antennæ or little horns. *cc* The eyes.  
*dd* The six legs. *eeee* The claws.  
*f* The cloven tail, in which the anus is seen.  
*gg* The white transparent vessels in the belly and breast, which are properly the ramifications of the trachea.  
*1 2 3 4 &c.* The seven orifices of the pulmonary pipes, on one side of the body, which with

seven others on the opposite side make together XIV.

- bbb* The large branches of the aspera arteria, in their first beginning where they open by spreading branches into the extremities of the belly, and afterwards communicate together by an anastomosis, or inosculation.

## F I G. V.

*The Louse, lying on its back, delineated according to its natural size.*

## F I G. VI.

*The Louse delineated with the assistance of the microscope, in which those parts which could not be shewn in *fig. IV.* are here represented.*

- a* A brown transparent part of the abdomen, which is observed to be in continual motion, with its double transparent appendages, which are stretched far into the breast. This brown part with its appendages, is properly the stomach; in the middle of them is placed the spinal marrow.

- b* A white spot in the middle of the belly, transparent, which I imagine to be the pancreas. In a live Louse it appears to be united with the stomach, and, together with it, is moved up and down.

Further, in this Louse, the articulations of the legs with the breast may be plainly seen, also the bright transparent pulmonary pipes, together with the black coloured contents of the stomach. At the extremity of the abdomen appear the double claws, like crescents, which cover the vulva.

## F I G. VII.

*The branch of the aspera arteria of the Louse, considerably magnified, yet represented in its natural form.*

- a* The rings of the trachea, by which it is always kept open.  
*b* The serpentwindings of those rings.  
*c* The part where those windings appear to be interrupted.  
*d* The part where the rings are largest.  
*e* The part where the rings become small again, when the aspera arteria shoots out into another branch.  
*f* A small membrane in the middle of the rings, which properly contains the air.

## F I G. VIII.

*The seven orifices or respiratory points of one side, separately delineated.*

- 1 2 3 4 5 6 7* These figures shew the natural situation of the respiratory points or orifices of

of the aspera arteria, in one side of the human louse.

- a a* The respiratory points in the belly, which appear with little protuberances like small nipples; beyond the margin of the belly.
- b* The respiratory point in the breast.

T A B. II.

F I G. I.

*The blood of the Louse.*

- a a* A small glass tube, in which the blood of the louse ascends.
- b* The globules of the blood as they appear through the microscope.

F I G. II.

*The muscles of the Louse.*

- a* A broad muscle. *b* Another narrower.
- c* A double-bodied muscle.

F I G. III. IV. and V.

*The sheath or case of the aculeus, or sucker, the aculeus, the throat, the stomach, the pancreas, and intestines.*

- a* The case of the aculeus swelled out.
- b* The aculeus or sucker.
- c* The case of the aculeus delineated a little larger, and the whole of it represented.
- d* Certain claws which are placed at the end of the case of the Aculeus.
- e* The Aculeus a little bent.
- f* The gullet beyond the jaws.
- g* The same a little dilated.
- h* The same part where it becomes narrower again, and is joined to the stomach.
- i i i* The stomach, which appears to be composed of certain globules.
- k k* The two hidden appendages of the stomach.
- l l l l* The pulmonary pipes of the stomach.
- m* The situation of the pancreas.
- 1 2 3 4 5* Five different delineations of the pancreas.
- n* The Pylorus. *o o* The small gut.
- p p p p* The four small guts.
- q* The intestine colon.
- r r* The dilatation or extension of the intestines, or Cloaca; where the excrements acquire their figure.
- s* The straight gut. *t* The anus.
- v* The part where the blood first passes through the aculeus into the mouth.
- x* A remarkable extension, occasioned by the blood's extending the jaws; there it becomes visible, beyond which the gullet is afterwards seen, which conveys the blood into the stomach; as has been already shewn at letter *f*.

F I G. VI.

*The various motions which the stomach makes.*

- 1* The stomach dilated.
- 2* The manner in which the stomach contracts itself.
- 3* The same contractions changed.

F I G. VII.

*The spinal marrow.*

- a a a* Three knotty dilatations, or swellings of the spinal marrow.
- b b b* Six nerves which arise from the marrow, and extend to the muscles of the legs.
- c c* The nerves which spring from the hinder part of the marrow, and are distributed through the rest of the viscera.
- d d* The pulmonary pipes in the membrane of the marrow.
- e* The beginning of the marrow issuing from the brain. *f f* The brain.
- g g* The Dura Mater, with its pulmonary pipes. *h h* The optic nerves. *i i* The eyes.

F I G. VIII.

*The ovary of the human Louse.*

- a a* The vulva, or outward aperture of the ovary, opening into the lower part of the abdomen, closed with double plain claws; under which are some hairs.
- b b b b* The five double extremities of the pipes which form the oviduct of the ovary, explained in the figure of one side, and are also shewn in the figure on the other side; as they are naturally joined together in one point in the body.
- c* One of the ten oviducts of the ovary.
- d* A perfect egg placed in it.
- e* The rudiments of four eggs.
- f f* The division of the ovary into common double pipes.
- g g* The five oviducts of one side, nearly represented in their natural situation.
- h* The uterus.
- i* The egg or nit almost at its perfection, remaining in the uterus.
- k k* The sacculus, or bag which contains a glutinous matter.
- l* The neck of the uterus.
- m* The manner by which the eggs are closely embraced in the oviduct.
- n* Certain pulmonary pipes which are seen in the oviduct.

F I G. IX. and X.

*The structure of the external skin, with its various appearances under the microscope.*

- a* Globular particles visible in the skin.
- b b* Long channels or pipes.
- c* Another

- c* Another kind of globular particles is seen among the channels or pipes where the skin is membranaceous.  
*d* Irregular squares in the margin of the skin.  
*e* Circular grooves. *f* Globules.  
*g* Globules and grooves.  
*h h* The skin marked with points or dots.

*The end of the explanation of the figures of the Louse.*

Observations on Scorpions, represented in Figures.

T A B. III.

F I G. I.

*The common Scorpion, and the particular parts of it.*

- a* The head jointed to the breast like as in a lobster, is conspicuous in the fore-part, in which are two small forceps or pincers, and above are seen four eyes; in the middle of the breast there are also two eyes, there being six in all: which may be plainly known to be the number of the eyes.  
*b b* Its eight hairy legs, each divided into six joints.  
*c c* Two crooked arms with pincers, each composed but of four joints, if you except that by which each arm is joined to the breast. These forceps or pincers are sometimes found broken.  
*d* The seven divisions or rings of the belly.  
*e* The bristly part, composed of six joints.  
*f* The aculeus or sting.

F I G. II.

*Another kind of Scorpion.*

- a a* The crooked arms with their forceps, which differ very much from those represented at letters *c c*. There are in this Scorpion eight distinct eyes, in other respects it agrees with the former.

F I G. III.

*A large kind of Scorpion brought from the East-Indies, in which the parts that were described in the two former are more clearly seen, particularly the following.*

- a* The two forceps or pincers placed foremost under the head and breast.  
*b* Above which there are, on each side, six eyes, some much larger than others: besides these there are, in the middle, as it were above the breast, another pair of eyes. There is also a remarkable difference in the tail; but I am doubtful whether it was so naturally.

F I G. IV.

A smaller kind of water Scorpion, which belongs to the second class or order of changes, represented in its natural size.

- a* The crooked proboscis.  
*b b* The upper pair of wings.  
*c c* The lower pair of wings.  
*d d d d* The four legs, with two claws at the end of each of them.  
*e e* The arms. *f* The double tail.  
*g* One of its nits or eggs represented in its natural size.

F I G. V.

*The water animalcule in its egg, delineated as it appeared under the microscope, which in Fig. IV. letter g, was represented in its nit of its natural size.*

- a* The head. *b* The eyes. *c c* The legs.  
*d d* The animalcule, with its legs, laid on its back.

F I G. VI.

*The parts of generation of the male water scorpion.*

- a* The nervous body of the penis cut off.  
*b* The vas differens, as it is elegantly formed by nature.  
*c* Another vas deferens, unfolded.  
*d* The true vasa deferentia.  
*e e* The testicles, consisting each of five small glands.  
*f f* The vessels of the testicles united with the small glands of the testicles.  
*g* One of these vessels, unfolded.  
*b b* The small seminal vessels.

F I G. VII.

*A particular part of one of the oviducts, with its eggs, cut out of the ovary of a female water Scorpion, represented as magnified.*

- a a* A particular part of one of the oviducts.  
*b* The bristly appendages of the first and lowest egg.  
*c* The same shewn in the second egg.  
*d* The like appearance about the third egg.

F I G. VIII.

*The egg separately represented, more considerably magnified.*

- a* The lower smooth and round part of the egg.  
*b* The part where the seven bristly appendages of the egg begin to grow of a red colour.  
*c* Where they change to a white colour.

F I G. IX.

*The largest kind of water Scorpion.*

- a* Its long and slender body. *b b* The



# A Short Explanation of the TABLES,

v

- b b* The two sharp small points to which the two crooked claws of the arms are united.
- c c* The slender legs fet with rough small hairs.
- d* The membranous ornaments of the upper wings.

## T A B. IV.

*This table exhibits the covered or common Snail.*

### F I G. I.

*The Snail with all its parts entire, without its shell.*

- a a* The two upper antennæ or horns, with a certain black spot; which is the eye.
- b b* The two lower horns; without eyes.
- c* The outermost lips and the mouth.
- d* The aperture, through which the parts of generation issue; which is very wonderful.
- e* The border or lip of the snail.
- f* The opening through which the excrements are excluded.
- g* The aperture through which the Snail breathes.
- h h h* The extreme fringes of the Snail, which serve it instead of a foot.
- k* The soft part of the body of the Snail, on which appear the same windings as in the shell, in which the liver is placed in the largest part.
- l* The transparent heart; surrounded with dots.
- n* The Sacculus or alkaline bag swelling under the skin.
- t* Transparent particles formed like a chain.

### F I G. II.

*The hard skin or shell of the Snail.*

- i* The shell or habitation of the Snail in which it hides itself.
- s* The incisions or divisions on the surface of the shell.

### F I G. III.

*The Operculum or Cover.*

- m* The operculum of the shell of the snail, which shuts up the shell in the winter, but is again opened in the summer.

### F I G. IV.

*A boiled Snail represented of a less size.*

- o* The alkaline bag swelled quite out.
- p* The extreme convolutions or windings of the liver.
- q* The border of the Snail contracted.
- r* The teeth as they appear under the skin which is drawn back, and the internal lips.

### F I G. V.

*A part of the first pair of horns, represented as magnified.*

- a* The eye in the middle of the extreme point of the horn, placed a little on one side.

- b* The optic nerve.
- c* The extreme point of the muscle of the eye.
- d* An intersection of the eye in the middle, between the muscle and the nerve; where the eye is first drawn in.
- e e e* Small glandulous grains in the outermost skin of the horn.
- f* The inner cavity of the horn, which is said to be possessed of a muscle and nerve.

### F I G. VI.

*The brain, nerves, and muscles.*

- 1 2 3 4* The four horns inverted.
- a a* The muscles of the larger horns.
- b b* The two small muscles of the lesser horns.
- c c* The four horns of the lips, from which the two little ones spring.
- d* The brain.
- e* The skin drawn off the head, by which the hinder brain is moved when the Snail rolls the skin out again.
- f* The part in which the teeth are fixed, described by dots, which are of a substance between horn and bone, and formed like a pear.
- g* The parts of the jaws, mouth, palate and tongue, which are all moveable, and drawn within the body.
- h* A particular part of the stomach and gullet.
- i i* The salival vessels.
- k k* The optic nerves of the upper horns.
- l l* The membranes which extend, and are fixed to the optic nerves.
- m* The part of the muscle in which the optic nerve is inserted.
- n* The spiral windings of the optic nerve.
- o* The muscle, which involves those nerves, open.
- p* The extreme swelling of the optic nerve.
- q* The eye placed in the extremity of the optic nerve.
- r* The nerve of the lower horn of one side.
- s* The origin of the nerves of the lower horns.
- t* Two nerves which are dispatched to the larger horns.
- v* The two nerves of the mouth, jaws, and palate.
- x* Part of a muscle which draws the nerves of the mouth together with the jaws, tongue, palate, and brain, inward, at once; in a very wonderful manner.

### F I G. VII.

*The eye, with its particular parts, represented as magnified.*

- a* The external figure of the eye.
- b b b* A muscle which embraces the optic nerve; unfolded, like a gray-coloured membrane.
- c* The nerve itself, in which the eye is fixed.
- d* A part of the inverted horn.
- e* The inverted cavity of the horn.
- f* The part where the muscle is fastened in the nerve.

B

F I G.

## FIG. VIII.

*The three humours of the eye.*

- a* Two needles with which the tunica uvea, lying under the microscope, is pricked.
- b* The aqueous humour issuing from the wounded eye.
- c* The vitreous humour flowing out in the same manner.
- d* The crystalline humour issuing like the others.

## TAB. V.

## FIG. I.

*The open parts of the mouth and jaws.*

- a* The external skin in the form of teeth.
- b* The tooth, placed high in the mouth, cut, with the skin, from one side, exposed to view.
- c* The tooth spread out into horny bony points, like needles.
- d* The salival vessels, with their openings.
- e* The inner lips, behind which the mouth is folded together.
- f* A cartilage which covers the tongue, when the Snail swallows its food, under which the tongue may be sheltered in the cavity. All these parts are shewn, unseparated, Fig. IV. Letter *r*.

## FIG. II.

*The Tooth.*

- a* The whole horny bony coalition of the teeth.
- b* The eight prominent teeth of it.
- c* The crooked crescent form of the teeth.

## FIG. III.

*The tongue, and certain muscles.*

- a* The tongue, taken out of the mouth.
- b* The root of the tongue, with its situation; the tongue itself, as it appears, where all the parts of the jaws and mouth are reclined to the other side.
- c* The two horny bony teeth in the acute extremity of the tongue.
- d* The three muscles, which move the parts of the gullet and mouth forward.

## FIG. IV.

*The heart, its auricle, and the blood and salival vessels.*

- a* The reins, which are visible in the internal membrane of the border of the Snail, as they are derived from the trunk of the vena cava.
- b* The aperture of the border.
- c* The heart with its two valves, and fibrous columns.

- d* The auricle of the heart.
- e* The alkaline bag, in its proper place, near the heart.
- f* The straight gut, near which runs the pipe of the alkaline bag.
- g* The spreading branch of the great artery.
- b* Certain large branches and sprigs of the great artery.
- i i i i* The circumvolution and shape of the body represented by dots; that the situation of these parts may be the more exactly demonstrated. Here may be further observed:
- n* The oblong grooves or channels of the stomach.
- o o* The salival vessels.
- p p* The trunk from which the salival vessels spring.
- q* A small vessel which runs over that trunk.
- r* All the parts of the mouth.

## FIG. V.

*The alkaline bag.*

- k* That part of the alkaline bag which is connected with the Pericardium.
- l* The angle where the alkaline bag is connected with the intestine and liver.
- m* Another part of the alkaline bag adjacent to its own pipe, and of a waterish colour.
- N. B.* We have joined in one Table the Fig. IV. and V. the explanations of which are here separated, because though we found, in the author's manuscript, the explanation of Fig. V. by itself, yet we could not meet with the figure itself apart in the Table; but that does not signify, as it may be understood by the fourth figure.

## FIG. VI.

*The stomach, intestines, and liver.*

- a* The extreme winding of the liver.
- b b b* The lobes of the liver, where it appears at once, after what manner the intestines are wound about; a certain part of it, with the stomach, is represented out of its place.
- c* The stomach.      *d* The Pylorus.
- e* The straight gut.
- f* The passage of the intestine into the border.
- g* The part where the biliary ducts empty themselves into the intestine.

## FIG. VII.

*The same parts represented, as reviewed from the other side.*

- a* The liver.      *b* The intestines.
- c* The straight gut.      *d* The stomach

## FIG. VIII.

*The biliary ducts.*

- a* The naked biliary ducts, with a small part of the liver.
- b* The

- b* The stomach.    *c* The small guts.  
*d* The straight gut.

## F I G. IX.

*The vessels of the liver.*

- a* Several vessels of the liver separately represented.

## F I G. X.

*The genital parts of the male and female,*

- a* The penis.  
*b b* The length of the penis, and the extreme point of it.  
*c c c* The uterus.    *d d* The ovary.  
*e* The testicles, which are small filaments that spring from two trunks.  
*f* The hidden appendage of the uterus.  
*g* The common duct between the penis and uterus.  
*h h* The oblong vas deferentia.  
*i* Its small tube, which opens itself into the uterus.  
*k* The pear-shaped little ball, in which the purple Snail keeps its purple liquid.  
*l* A little part twisted like a chain.  
*m* Its duct, or little pipe.  
*n n n* The ligament of the uterus.  
*o* The muscle which leads the penis outward.  
*p* The muscle which draws the penis inward.  
*q* The nerve of the penis,  
*r* The mouth of the vulva.  
*s* The broad muscle of the uterus.  
*t* The slender muscle of the uterus.  
*v* The nerve of the uterus.  
*z* The extremity of the chain-like little part.

## F I G. XI.

*The testicles.*

- x* The little tubes of the testicles, consisting of filaments, of which sixty-six are reckoned.

## F I G. XII and XIII

*The blind appendage of the uterus opened, with the saline bony contents.*

- y* The blind appendage of the uterus divided in the middle, between which the saline bony part, which readily ferments in aqua fortis, is seen.  
*a* The root of the saline bony part, by which it is joined to the muscular and nervous pear-shaped globule.  
*b* The fine smooth part of it, which is all hollow; and by degrees becomes more slender and acute.  
*c* The pear-shaped globule, to which the saline bony part is fixed.  
*N. B.* Here again we have marked a single figure with a double number, because we could only find, in the Tables, the XIIth

figure, although in the body of the work, and in the short explanations of the tables, we find the XIIIth quoted: but this is of small importance, as the figure which we have given contains all the particulars that we want.

## F I G. XIV.

*A particular small stony, or saline bony part, as seen by the microscope.*

- d d d d* The four margins, or furrounding backs.  
*e* The cavity stretched out in the middle of the boney part.

## F I G. XV.

*The chain-like part.*

- a* The extremity of the chain-like part unfolded, in order to shew its construction.

## F I G. XVI.

*The uterus.*

- r* Exhibits the cavities of the uterus blown up, in order to shew how the divisions of it are formed.

## F I G. XVII.

- a* Here are seen in the neck of the amorous Snail, the external opening of the vulva, or genital parts, which with the part under the penis, and the appendage of the uterus, together with all the spermatic vessels have been already represented in *fig. X. let. r.*

## F I G. XVIII.

*The penis and uterus themselves turned out and erected.*

- b* The penis and uterus turned out and erected, and stretched out beyond the neck.  
*i i* The two upper horns.  
*k* One of the lower horns, which is then a little removed from its place.

## F I G. XIX.

*The penis, and internal orifice of the womb.*

- c* The penis only, not wholly, turned out of its cavity, and erected.  
*d* The internal orifice of the womb also a little turned out, and extended out of the neck.  
*l* The lower horn removed from its place, toward the horn of the other side.

## F I G. XX.

*Of their copulation.*

- e* The penis of one of the Snails rolled out.  
*f* The apperture of the uterus of the other Snail, admitting the penis of the former.  
*g b* The

*g* The aperture of the uterus of the first Snail, which in like manner admits the penis of the other Snail *b*.

## T A B. VI.

*The brain and nerves.*

- a* All the parts of mouth, jaws and palate.  
*b* The gullet cut off.      *c* The brain.  
*dd* The beginning of the spinal marrow, divided into two strong nerves.  
*e* The knot or swelling formed by the nerves.  
*f* The muscle by which the knot, or swelling of the spinal marrow is inwardly moved.  
*g* The two parts of the muscles, which belong to the inward lips of the mouth, which are inserted by some tendons in the knot or swelling of the spinal marrow, and which, together with the nerves, the muscles draw within the body.  
*bb* A pair of nerves which are seen in the mouth, jaws and palate.  
*ii* A pair of optic nerves.  
*kk* A pair of nerves which reach to the roots of the horns and to the skin.  
*ll* The nerves of the lower horns which arise from the former pair.  
*mm* Two tender nerves, which reach to the muscles of the skin and head, cut off.  
*nn* A pair of nerves situated under the parts of the mouth.  
*oo* Other pairs of nerves which are dispatched to the muscles of the neck.  
*p* A nerve which reaches to the spermatic vessels, to which also a small part of the penis adheres.  
*q* The nerves which are distributed thro' the membranes of the neck.  
*rr* The nerves which are dispatched to the muscles at the sides of the body.  
*s* A nerve and muscle which reach to the uterus.  
*t* A nerve of the verge stretched inward to the right side.  
*v* A like nerve on the left side.  
*x* The nerves fixed in the tendons of the two strong muscles, which move the middle of the body. See *fig.* II. *nn* of this Table.  
*yyy* The nerves which reach to the verge of the foot of the body.  
*z* Some of these nerves cut off from the right side are omitted, to avoid confusion.

## F I G. II.

*The muscles of the Snail.*

- a* The part of the stony bone or shell of the Snail, where the muscles are inserted.  
*bb* The insertion of the two strongest muscles of the Snail, by the assistance of which it creeps and moves.  
*c* The part where these muscles stretch the tail itself backward or inward, and which pass under the pillar of the shell.

- d* The part where the muscles of the verge are inserted.  
*e* The muscles which draw in all the parts of the mouth, jaws and palate.  
*f* The acute extremity of the tongue.  
*g* The basis or root of the tongue.  
*bb* The muscles of the eyes.  
*ii* The curled foldings of the nerves among those muscles.  
*kk* A part left of the first pair of horns, still adhering to the muscles.  
*ll* A pair of muscles which draw the lips and the knot or swelling of the spinal marrow inward.  
*mm* The muscles of the lower horns, which arise from the former pair.  
*nn* Two strong muscles which draw the middle of the body into the shell.  
*o* The part where they are inserted.  
*pp* The internal surface of the shell, in which its spiral windings, cells, and circumvolutions are seen.  
*qqqqq* The fringe or border, or foot of the Snail.  
*r* The cavity of the pillar.

## F I G. III.

*The convolutions, or windings of the shell.*

- a* The outward opening of the shell at which the Snail creeps out, and the winding which forms the first cell or inward division.  
*b* The second division.      *c* The third.  
*d* The fourth.      *e* The fifth and last.

## F I G. IV.

*The internal part of the shell broke open.*

- 1 2 3 4 5* Are seen the inward windings of the shell, when all the partitions are broke open.

## F I G. V.

*The Pillar.*

- a* The upper aperture and windings of the pillar.  
*b* The lower aperture of the pillar, which may be seen more plainly in *fig.* II. *r*.

## F I G. VI.

*The Pillar.*

- c* The aperture, the spiral windings, and the construction of the pillar distinctly represented.

## F I G. VII.

*Shews in what manner the greater or less divisions of the shell may be formed, as it is broken off from the pillar and its partitions.*

- d* A part of the shell broken off, almost to the end of its spiral winding.  
*e. f* Two others, less broken.

## T A B. VII.

T A B. VII.

F I G. I.

*The Turbo or Verticillum.*

- a* The beginning of the windings of the Turbo.
- b* The end of those windings.

F I G. III.

*The voluta, or the cylinder or pyramidal Snail,*

- a* The opening or entrance of it.
- b* Where it becomes narrower.
- c* Another convolution or winding.
- d* The pillar and the other internal spiral windings of it.

F I G. III.

*The Concha Veneris.*

- a* The entrance divided into little teeth.
- b* The windings round the pillar.

F I G. IV.

*The pencil Snail.*

- a* The outward entrance of it.
- b* Another of its winding divisions.
- c* The third. *d* The fourth. *e* The fifth.
- f* The sixth. *g* The seventh.

F I G. V.

*The tubular Snail.*

- a* The beginning like a plain tube or intestine.
- b* Its spiral windings and convolutions.

F I G. VI.

*The tubular Snail.*

- c c* The cavities which the tubular Snail forms, when the partitions of it are gradually convolved together, and applied one to another. But if their cavities are joined to others, the cavity of the pillar is thereby formed. See Tab. VI. Fig. II. r.

F I G. VII.

*A Snail like the Cornu Ammonis.*

- a* The hollow perforated partition in the beginning of the Snail,
- 1 2 3 4 5 &c.* The divisions of the Snail, which are formed by the various number of the partitions.

F I G. VIII.

*The partitions, with the naked surrounding shell,*

- b b* Six partitions, from which the outward shell is removed.
- c* The part where the little tubes of the partitions are mutually received.

F I G. IX.

*A partition, with its little tube represented of a large size.*

- d d d* The extreme compass of the partition.
- e* The aperture of the partition which leads to the little tube.
- f* The perforated handle, or little tube of the partition.

F I G. X.

*Three partitions of different sizes, which mutually receive each other.*

- g* The little tube of the first partition, fixed into the little tube of the second partition.
- b* The little tube of the second partition, fixed in the tube of the third partition.
- i i i i* The partitions, with their little tubes gradually decreasing in size.

F I G. XI.

*The oval Turbo, with its windings turned contrary to those in other Snails.*

- a* The entrance opening into the opposite side, and obliquely winding ascends towards the left.

T A B. VIII.

F I G. I.

*The little Turbo.*

- a* The shell of this Snail, with its windings turned the contrary way.
- b* Part of the body of the Snail creeping out of the shell.
- c c* Its two larger horns, in which the eyes are placed.

F I G. II.

*The shell of the Snail represented, and of an enlarged size.*

- a* The entrance extended to the opposite side.
- b* The aperture of the pillar.
- c c c* The ridges, or ribs of the surface.

F I G. III.

*The shell of the small Snail, found under the barks of the Willow.*

- a* The shell of the small Snail; a little flattened.

F I G. IV.

*The small water oval Snail.*

- a* The oval channelled shell of the Snail.
- b* The hinder part of the shell convolved into a double spiral winding.
- c* The

- c* The body of the Snail which creeps out from thence, marked with black points or spots.  
*d* The two obtuse horns, in which the eyes are placed, also the upper, lower, and smaller horns.

F I G. V.

*The garden Snail.*

- a* The aperture of the genital parts, placed a little lower in the neck than in the common Snail.  
*b b* The uterus.  
*c c* The ligament of the uterus.  
*d* The bag which holds the glutinous moisture.  
*e* The chain-like little part.  
*f* The little legs in the ovary.  
*g* The extreme spiral part of the liver.  
*h* The purple little knot.  
*i* The other small tube of the purple little part.  
*k* The connexion of the purple little knot with the uterus.  
*l* The blind appendage of the uterus.  
*m* The testicles  
*n* The alkaline little bone. *o o* The penis.  
*p* The muscle which draws the penis.  
*q* The common duct between the penis and uterus.  
*r* The acute end of the penis, curled into various windings.

F I G. VI.

*Two garden Snails, in the act of coition.*

- a* The penis of each wonderfully twisted together.  
*b* The penis of one of the Snails insinuating itself into the  
*c* Uterus of the other.  
*d* The penis of the other Snail, in like manner, insinuating itself into the  
*e* Uterus of the former Snail.  
*f* The aperture and divisions of the verge, as seen in this Snail, at this time.  
*g* At the same time nothing is seen of the verge in the other Snail.

F I G. VII.

*The naked house Snail.*

- a* The upper horns, which have eyes.  
*b b* The lower horns, which are much smaller.  
*c c* The velabrum, or eminence which is fixed to the body.  
*d* The aperture in the neck, through which the genitals are extended.  
*e* The aperture of the velabrum, by which the Snail breathes.  
*f* The prominent part of the tail, like a cock's comb.

F I G. VIII.

*The Snail Stone.*

- a* The hollow like Snail stone.

- b* The surface of it, interwoven as it were with vessels.

F I G. IX.

*The genital parts of the house Snail.*

- a* The three apertures of the genitals, in the neck, which unite in one passage on the outside.  
*b b* The penis. *c c c c* The uterus.  
*d* The purple bag  
*e* A small filament, which reaches from the penis to the ligament of the uterus.  
*f f f* The ligament of the uterus.  
*g g* The small eggs sticking in the womb.  
*h h* A bag, containing a glutinous matter.  
*i i* A chain-like little part.  
*k* The ovary.

T A B. IX.

F I G. I.

*The field or path-way Snail.*

- a* Its larger horns.  
*b* The aperture of the velabrum, or the eminence, by which it breathes, and discharges its excrements.  
*c c* Glandulous triangular protuberances, which rise obliquely from the body.  
*d d* The glossy red verge which surrounds the body.

F I G. II.

*The internal parts of the field or path-way Snail.*

- a* The mouth and palate.  
*b b* The larger horns drawn in.  
*c* The skin of the head divided.  
*d* The gullet. *e* The brain.  
*f* The beginning of the stomach.  
*g g* The salival vessels.  
*h h* The glandular corpuscles, from which the salival vessels arise.  
*i* The stomach covered with vessels.  
*k k* The intestines. *l l l* The liver.  
*m* The large gall-bag, which discharges itself into the intestines.  
*n* The aperture of the genitals in the neck.  
*o* The penis.  
*p* The little tube which opens from the penis, into the uterus.  
*q* The purple bag.  
*r* The little tube of the purple bag, which is inserted in the penis.  
*s* The strong and thick origin of the uterus.  
*t* The slenderer part of the origin of the uterus.  
*u u u u* The uterus itself.  
*x x x* Whitish vessels, which connect the uterus and its ligaments.  
*y y* The glutinous bag.  
*z* The chain-like little tube.  
*a* The small gut. *β* The ovary.  
*γ* The heart in its place. *δ δ* The alkaline bag.

# A Short Explanation of the TABLES. xi

## F I G. III.

*The ovary of the field or path-way Snail.*

- a* The ovary large and expanded, as it appeared some months after coition.
- b b* The little eggs, visible in the ovary.
- c* The chain-like little part.

## F I G. IV.

*The common water Snail.*

- a* Its turbinated shell.
- b b* The eyes placed at the bottom or root of the horns.
- c c* The horns, which terminate in sharp points.
- d* The aperture of the verge.
- e* The aperture through which the penis comes out.
- f* The opening of the uterus.
- g g* The verge fitted to the internal surface round the shell.
- h* The tooth.
- i i* The body, by which the Snail creeps and swims.

## F I G. V.

*The internal parts of the wonderful viviparous Snail.*

- a* The Snail taken out of the shell.
- b* The head. *c c* The horns.
- d d* The eyes. *e* The vulva. *f* The gills.
- g* The verge.
- h* The windings of the body.
- i i i* The part which serves as a foot.
- k* The cover of the shell, which is placed on the foot.

## F I G. VI.

*The internal parts.*

- a a* The cover of the Snail pressed close against the fore parts of the body.
- b* The horns and mouth contracted.
- c* The Vulva.
- d* The fringe or margin, beautifully folded.
- e* The end of the straight gut.
- f* The gills.
- g* The uterus, open; containing the living fetus.

## F I G. VII.

*The little Worm found alive in the wonderful viviparous Snail.*

- a* The oblong figure of the Worm.
- b* The oblong transparent furrows or ridges which appear in the body of the Worm.

## F I G. VIII.

*Two smaller Worms, which issued out of one of the Worms in dissecting.*

- a* Its thick head. *b* The slender tail.

## F I G. IX.

*A small live Snail, found in the uterus of the wonderful viviparous Snail.*

- a* The size of that small Snail, equal to that of a common pea.

## F I G. X.

*The shell of that small Snail, as magnified.*

- b* The beautiful construction of the shell.
- c c c c c c c* Seven rows of bristly hairs, with which it is surrounded.

## F I G. XI.

*Perfect eggs found in the uterus of a viviparous Snail.*

- a a a* The little navel-string by which they are fixed to the uterus.
- b b* The double navel-string of one of the eggs.
- c c c* A small Snail, sticking in an egg.
- d d* The same taken out of its egg.
- e* A Snail, sticking in its egg, which fell to the bottom, when the shell was suspended by its string.

## F I G. XII.

*A small Snail taken out of its egg, and magnified by the microscope.*

- a a* Its eyes, black like pitch.
- b* The horns. *c* The mouth.
- d* The rest of the body.
- e* The operculum, or cover annexed to the tail.
- f* The shell of the snail.

## F I G. XIII.

*The shell of the viviparous Snail, represented in its natural size, cleared of its foulness and periostracum; in order to shew, the more distinctly, its form and construction.*

## F I G. XIV.

*The sea Snail, called by the Hollanders Aliekruyk; they are found among muscles.*

- a* The Snail itself, with its little horns, eyes, and foot.
- b* The part where the shell of this Snail is of a globular form.
- c* Prominent hollows or channels on the surface of the shell.
- i 2 3 4 5* The windings of the shell.

## F I G. XV.

*Another species of the Snail, called Aliekruyk, commonly sold in Amsterdam.*

- d* A kind of wreaths, which surround the shell, adorned with a colour like that of musk, in the interstices of which the shell appears green.

*e* Five

*e* Five oblong, crooked, hollow openings; eaten through by worms.

## F I G. XVI.

*One of those worms which eat through the shells of the Snails, represented of its natural size.*

## F I G. XVII.

*The same Worm, represented as magnified.*

*a* The head.      *b* The tail.  
*c c* Many small hairs on each side of the body.

## F I G. XVIII.

*The Snail, called Aliekruyk, represented as magnified.*

*a* The head and mouth.      *b b* The horns.  
*c c* The eyes.      *d d* The foot or verge.  
*e* The cover of the Snail, of which only a small part is seen.  
*f* The shell very large, with its wreaths worn out.

## F I G. XIX.

*The cover of the Snail, represented as magnified.*

*g* The cover, whose convolutions are formed like the windings of the shell.

## F I G. XX.

*The tongue of the Snail, called Aliekruyk, of its natural size.*

*b* The fore part of the tongue, situated in the mouth.  
*i* The part of the tongue placed within the body, beautifully folded in serpentine windings.

## T A B. X.

## F I G. I.

*The small water Turbo.*

*a* The shell of the small water Turbo, which is formed very like the viviparous Snail.

## F I G. II.

*The umbilicated marble water Snail.*

*a* The fore part, formed like an umbilicus, or navel.  
*b* The oval broader part.

## F I G. III.

*The flattened water Snail.*

*a a* The two lips.      *b b* The verge or foot.  
*c c* The black eyes.      *d d* The horns.  
*e* The long slender body.  
*f* The air hole in the verge.  
*g* The aperture of the genitals.  
*b b* The shell of the Snail flat on the left aside.

## F I G. IV.

*The other side of the shell, of the same Snail, represented.*

*a* The right side of the shell, which is concave, and, sinking in the middle, is rolled into itself.

## F I G. V.

*The small flattened Snail.*

*a* A small margin, which surrounds the shell.

## F I G. VI.

*The fresh water Muscle, found in the rivers in Holland.*

*a a* The lips or verge which surround the whole body.  
*b b* The papillæ, or nipples of the muscle.  
*c c c c* The four large gills.  
*d d d d* The four small gills.  
*e* The hard part of the body.  
*f* The soft part of the body.

## F I G. VII.

*The inside of the shell of the Muscle represented.*

*a* The part, in the acute extremity of the shell, where the muscle is fastened.  
*b* The part in the thick or broad extremity of the shell where the muscle is fastened: where are visible four small holes.  
*c c c* The part where the mouth of the muscle is fastened.  
*d* The spiral winding of the shell.  
*e e* The two eminences, by the help of which both valves are strongly joined together, as by ginglymus.

## F I G. VIII.

*The Physalus laid on its back, in order to exhibit the wrinkles on its belly.*

*a a a* Twenty-eight of the greater, and some of the lesser external, parts, extant on each side of the body, and from which there spring black stiff bristles, of which there is but one side to be seen in this place.  
*i i i* Some woolly hairs like down, of a gold colour, and placed under the parts, containing the lateral bristles. But I have here omitted these bristles, in order to render the hair itself more conspicuous.  
*l* The opening of the mouth, above which appears a kind of beard, like that of bearded fishes.

## F I G. IX.

*One of the above eight and twenty greater external parts, separated from the body, and exhibited by itself, with its black bristles.*

*b* An Articulcus, or joint, represented by itself, and shewing in what manner the bristles grow from under it.

## F I G.



FIG. X.

*The said bristles, represented in three orders, as they appear when plucked from the parts producing them.*

- c* The ligament that connects the bristles, and afterwards appears about all the other bristles.
- d* Two of the largest and stiffest bristles with their ligament, which is placed almost in the middle of them.
- e* Six bristles with their ligaments some of which are more fine and delicate than others.
- f* Eight bristles with their ligament, differing in structure, length and stiffness.

FIG. XI.

*One of the said bristles seen through a microscope.*

- g* A flattish bristle ending in a point.

FIG. XII.

*Another bristle viewed likewise through the microscope.*

- b* A long round smooth bristle, somewhat more swollen on the forepart, but afterwards terminating in an obtuse point.

FIG. XIII.

*Some hairs of a golden colour, with their roots.*

- k* Some very fine hairs, like down, springing also from one centre or spot like the bristles.

FIG. XIV.

*The sloping region of the back, covered with bristles and delicate hairs, and moreover of a somewhat convex form.*

FIG. XV.

*The back of the Physalus laid open.*

- a a a a a* The natural openings on each side of the body, thro' which the water flows to and from the gills.
- b b b b* The membranaceous gills which move freely one over another, like the larger scales in fish.

FIG. XVI.

*The intestines of the Physalus rudely delineated.*

- a* The structure of the intestines, which look as if they communicated with one another.

T A B. XI.

FIG. I.

*The Cancellus, with its bony or shelly skin*

- a* The shell, or true skin of the cancellus.
- b* The five spiral windings of the shell.
- c* Two eyes, below which are some bristly articulated hairs.

- d d* Two horns.
- e* The right arm, and its forceps, which is the largest.
- f* The left arm, which is the least.
- g g* The four foremost legs.

FIG. II.

*The Cancellus, out of its skin or shell, lying on its back.*

- a a* The eyes, between which are seen four bristly articulated hairs.
- b b* The horns.
- c* The left and least arm.
- d* The right and largest arm.
- e* The two first pair of legs.
- f f* The third pair of legs, which has small forceps.
- g g* The fourth pair of legs, which are worthy of notice, because perforated by a double little tube of the genitals, to which it yields a passage.
- b b* Three articulated bristly hairs, to which the eggs are strongly fixed.
- i* The tendinous point of the muscles, or the part in which the tendons of the muscles meet, and where the Cancellus is fastened in his shell, that it can never go entirely out of it.
- k* The tail, with its particular part.

FIG. III. IV. and V.

*The tail, the straight and closed guts, and appendages of the Cancellus, represented a little larger than they naturally are.*

- a* The tail, consisting of two testaceous articulations.
- b* The verge of the anus, which being bent inwardly may be hid under the tail.
- c* The straight gut.
- d d* Three little testaceous bones on each side of the tail, which are articulated among themselves and with the bone.
- e* A small part of the intestine.
- f* The blind or closed gut, or what is analogous to it.
- g g* The appendages, which in the living creature are seen beautifully through it.
- b b* The origin of the appendages, which spring from two distinct ducts.
- i i* The appendages, whose situation was shewn at letter *g g*, are seen here separated.

FIG. VI.

*One of the pair of legs separate from the rest, represented magnified, together with the genital vessel, entire, by which that leg is on one side, perforated.*

- 1 2 3 4 5* The five articulations of the fourth pair of legs.
- a a* The winding of the genital vessel.
- b b* Its spiral windings which terminate in one narrow tube.

**D**

**c** The

- c* The extremity of its end.  
*d* The part in which the genital vessel, after a wonderful manner, perforates the fourth pair of legs throughout the fifth articulation.

## FIG. VII. and VIII.

*The heart and one of the gills, represented as magnified.*

- a a* The heart. *b* Four vessels issuing from the upper part of the heart.  
*c* Two other vessels issuing from the lower part of the heart.  
*d* Some blood vessels discharged of their flesh, and rolled out.  
*e* One of the XXII gills.  
*f* The thick and broad part of it  
*g* The acute extremity.  
*h* The division of the gills.

N. B. *Those white hollows or grooves, which run longitudinally through the middle of the gill, shew the cartilages, near which the blood vessels are conveyed; in which part they appear thicker and whiter.*

## FIG. IX. X. and XI.

*The brain, spiral marrow, eyes, cornea, and inverted pyramidal fibres, represented as magnified, beyond their natural size.*

- a a* The brain.  
*b b* The optic nerves, one of which is laid entirely bare.  
*c* The origin of the spiral marrow, which is separated, and affords in the living insect a passage for the gullet to the stomach.  
*d* The first knot or swelling, with the nerves it emits.  
*e e e e e* The remaining five knots of the marrow.  
*f f* Nerves which spring from the marrow.  
*g* These nerves elegantly decussate one over the other, issuing from the right to the left, and from the left to the right side.  
*h* Part of the crust as yet sticking to the eye, near which the naked nerve is visible.  
*i* The cornea tunica, and the manner by which the annular crust like a tooth insinuates itself into it.  
*k* A gelatinous hexagonal matter placed within the eye, above the inverted pyramidal fibres, which appears on removing of the cornea.  
*l* The inverted pyramidal fibres and their situation.  
*m* The black part of those fibres, which spring from the tunica uvea.  
*n* The lower part of the fibres which appears brown.  
*o* The middle part of them which is limped.  
*p p* A certain part of those fibres, enlarged by the microscope, by which it appears, that each of these fibres consists of many other small fibres, all which are again composed of regular globules.

## T A B. XII.

- No. I. The vermicle or worm of the Libella or Dragon-fly, sticking as yet in its first skin, when it is called an egg: represented magnified by the microscope.  
 II. The egg itself, deserted by the worm, represented of its natural size.  
 III. The worm, as come out of the egg, called, by this author, an Oviform Nymph-  
 vermicle.  
 IV. The same worm a little more grown, when the follicles, or membranaceous bags of the four wings are observed to spring.  
 V. The same worm, perfect, with its four follicles or little bags, increased to their due size, called in this state the Nymph-Vermicle.  
 VI. The Libella or Dragon-fly in its perfect state, having attained its full age, and fit for generation.

## FIG. I.

*The egg of the Dragon-fly, as magnified by the microscope.*

## FIG. II.

*The Nymph-Vermicle of the Dragon-fly, casting its skin.*

- a a* The feet fixed with the claws.  
*b* The head and eyes burst forth.  
*c c* The six legs, now cleared from their skins.  
*d d* The wings, as yet folded up.

## FIG. III.

*Of the copulation of the Dragon-flies.*

- a* the tail of the male.  
*b* The female receiving into her neck the tail of the male, and embracing it with her legs.  
*c* The tail of the female turned toward the breast of the male.

## FIG. IV.

*The nymph of the largest Dragon-fly.*

- a a* The eyes. *b b* The horns. *c* The teeth.  
*d d* The legs armed with sharp claws.  
*e e* The little bags, or cases of the wings.  
*f f* The divisions of the abdomen,  
*g* The stings, or prickles of the tail.

## FIG. V.

*The Nymph-Vermicle of the middle sized Dragon-fly.*

- a* The lips and teeth. *b* The hairy legs.  
*c* The little bags, or cases of the wings.  
*d* The stings, or prickles of the tail.

## FIG. VI.

FIG. VI.

The Nymph-Vermicle of a singular kind of a Dragon-fly.

- a The horns.      bb Six long legs.
- c The little bags, or cafes of the wings.
- d The hairy belly.
- e The triangular appendages of the belly.

FIG. VII.

The Nymph-Vermicle of the smallest Dragon-fly, found common in Holland.

T A B. XIII.

FIG. I.

The Worm of the Ephemerus, of the first year's growth, three quarters of a Dutch inch long, in which is not the least appearance of wings; but the five gills are visible on the back, from whence come in sight the ten lower rowing fins.

FIG. II.

The Worm of the Ephemerus of the second year's growth, five thirds of an inch long; the little bags or cafes in which the wings are enclosed.

FIG. III.

The Worm of the Ephemerus of the third year's growth, a female, about two inches and a half long; provided with the little bags or cafes of the wings, which are now visible.

FIG. IV.

The largest Worm of the Ephemerus, in which all the parts elegantly and distinctly appear,

- a The eyes, which are twice as large as those of the female worm.
  - bb The horns, and the distinct articulations of them.
  - c The forceps, mouth, or dentated jaws, by which they dig into the earth.
  - dd The first, second, and third pair of legs, with their articulations or joints.
  - e The little bags or cafes of the wings, which enclose the first pair of wings, like a tender little flower, shut up in its cup.
  - ff The gills, perpetually fluttering, very white and limpid, and covered with innumerable fine hairs.
  - g Three bristly hairy tails, with their appendagee.
- The rowing fins in Fig. I. and III. may also be seen.

FIG. V.

Oblong or hollow tubes, or cells, made in the mud or clay, in which the Worm of the Ephemerus creeps, and is moved and nourished.

- aa The tubes made in the mud by the largest worm.

- bb The tubes that are hollowed out by the smallest worms.

FIG. VI.

The male Ephemerus freed from the first exuvia; or skin, entirely stript of its former likeness of a Worm.

FIG. VII.

The Worm of the female Ephemerus, about to undergo in a little time its change, in which may be seen the wings through their little bags or cafes.

- aa The little sheaths, cafes, or bags of the wings, through whose smooth external little membranes may be seen distinctly, the folded wings lying hid within them.

FIG. VIII.

A female Ephemerus, stript, on the surface of the water, of its skin; and quitting the form of a swimming Worm is changed into a flying insect.

FIG. IX.

The manner how the wings expand themselves. But in the following XIVth Tab. Fig. I. under let.  $\epsilon \epsilon \epsilon$  may be seen the natural foldings of the wings, which here separate by degrees one from another.

FIG. X.

The same wing, first smoothing its serpentine foldings, afterwards its oblong folds.

FIG. XI.

The same wing not entirely expanded.

FIG. XII.

The male Ephemerus, employed in changing its skin, which is very slowly completed on dry land. Here half the body is now stript of its skin. The skin is stript off the head, thorax, and legs, in the same manner as we draw our feet out of our shoes; but as to the wings, the skin is drawn off them in such a manner, that the inside is turned outward.

FIG. XIII.

A male Ephemerus, which has almost gone through the change of its skin, so that its double external wings and tail might be taken only for a slender part as yet to be cast off.

FIG. XIV.

The very slender cast skins of the Ephemerus, which do not retain the form, as here represented, because the parts in which the wings were included, are commonly wrinkled, and by that means change the form.

FIG. XV.

## FIG. XV.

*A male Ephemerus, which has cast both its skins, changed into a flying insect; whose legs, which in the worm-state were short, are now as long again as they were, but the tails which were before twice that length, are now become three times as long.*

## T A B. XIV.

## FIG. I.

*A dissection of the Worm of the Ephemerus.*

- a a* The pulmonary tubes, or two air trunks, running along each side of the body.  
*b b* The tubes reaching to the brain and nerves.  
*d d d d* The pulmonary tubes tending to the muscles of the abdomen, from one side; but from the other side are seen, at the same letters, the naked muscles of the abdomen, with their tubes, also the oblique, ascending and straight muscles, hidden partly under the former.  
*e e e* The air pipes, or tubes, running to the spinal marrow.  
*f f f f f* The air pipes distributed through the small guts, or seminal vessels of the male. One of them represented in its natural situation, and another of them removed out of the body, and represented magnified more than the other.  
*g g g g g* The air pipes distributed to the gills. Only two of the gills are here represented, the other ten being cut off, to give an opportunity of seeing the ten rowing fins underneath them. See let. *r r r r*.  
*b* The air pipes running to the lowest parts of the intestines, and also to the spermatic vessels placed near them. *γ γ*.  
*i i i* The air pipes which supply, refresh, and nourish the fat, membranes, and skin with air.  
*k k* The air pipes.  
*p p p p* Three extraordinary air pipes dispatched beyond the body, towards the gills, cut off.  
*q q* The middle of the three first pipes, being black, but about the middle shining with white, in such a manner, that the black line of the gills appears as if marked with a white point opposite.  
*r r r r* The five rowing fins stretched out from each side of the body, with strong bristly hairs, of an obscure yellow gold colour,  
*s s* A feathery little part situated underneath the first pair of gills.  
*y y y y* The spinal marrow, consisting of eleven knots or swellings, from which spring the nerves that are distributed through the whole body. See *Fig. VI. Tab. XV.*  
*z z* The parts to which the spinal marrow is fastened, by the means of strong ligaments.  
 \* \* The optic nerves, derived from the brain, or origin of the spinal marrow, where it forms the first knot or swelling.

- α α* The muscles of the breast, employed in moving the legs.  
*β β* The muscles of the breast, employed in moving the wings, cut off.  
*γ γ* Two little parts, which I take for the spermatic vessels of the male.  
*δ* The straight gut cut off, in *Tab. XV Fig. V.* that it may be the more perfectly seen.  
*ε ε ε* The extremely artificial folding of the wing, whilst it yet lies in its case or sheath, *k k*. being very easy to be unfolded. See *Fig. IX. X. XI. Tab. XIII.*

## FIG. II.

*All the parts just now represented in their natural size.*

## T A B. XV.

## FIG. I.

- l l* Some branches of the air pipes which run to the ovary of the Ephemerus.  
*m m m m* The same air-pipes running into and over the membrane investing the ovary.  
*c c* The muscles employed in moving the six gills and five rowing fins, placed on each side of the body.  
*f f* The stomach and intestines, which are visible through the membranes of the ovary. See *Fig. V.* of this Table.  
*i i* The muscles of the straight gut employed in voiding the feces.

## FIG. II.

*The little eggs of the Ephemerus, as they appear to the naked eye.*

## FIG. III.

*The double ovary of the Ephemerus, consisting of innumerable little eggs.*

## FIG. IV.

- o o o o* Some air pipes leading to the heart of the Ephemerus, partly cut off.  
*t t* Part of the heart, like an oblong tube, which is somewhat swollen on each side.  
*v v v v* Some air pipes cut off, leading towards the heart, and then to other parts.  
*x x x x* The parts in which the tube of the heart swells up a little.

## FIG. V.

- a* Part of the oesophagus or gullet, cut off near the stomach  
*b* The pylorus of the stomach  
*c* The stomach itself, with certain air pipes, which creep all over it.  
*d d* The small gut continued from the stomach.  
*e* The thick gut or colon, distinguishing itself by some little oblong transparent channels or furrows.

*f* The

- f* The straight gut elegantly folded, or wrinkled.  
*g* Certain femilunar little valves of the small gut.  
 4 5 6 7 8, &c. Eleven annular sections, into which the body is divided.

FIG. VI.

*The brain, spinal marrow, and the nerves, springing from thence, according as they are placed in the living Ephemerus.*

- 1 2 3, &c. The natural situation of the spinal marrow in the body of the Ephemerus. At the same time is shewn how the annular interfections are placed.

FIG. VII.

- n* Air pipes together with a part of the ovary, drawn out of the body, the more conveniently to shew how these pipes stick fast to the eggs.  
*g* The eggs, of a plain round oblong figure.

T A B. XVI.

- No. I The Ant's egg delineated in its natural size, or the Worm of the Ant in its first skin or coat, wherein it is called an egg; which is exhibited in the first figure magnified.  
 II. The beforementioned covering, being quitted by the Worm of the Ant, is rolled up as into an invisible point.  
 III. The Worm of the Ant come forth from the egg, with its parts imperfect; delineated in its natural size and situation. Figure the second represents it magnified by the microscope.  
 IV. The same Worm at the full period of its increase, all the parts of the Ant being contained hidden within it. Figure the third shews it as magnified.  
 V. The same Worm stript of its skin, and now called a Nymph.  
 VI. The same, having quitted the form of a Nymph, changed to a real and perfect Ant.

FIG. I.

*The egg of the Ant magnified.*

FIG. II.

*The Worm of the Ant, as delineated under the microscope, with its head bent towards the breast; called improperly the egg of the Ant.*

FIG. III.

*The former Worm, having arrived at its full bigness, about to quit by and by its skin, in order to be changed into a Nymph. This is also larger than naturally.*

FIG. IV.

*The Nymph of the Ant delineated by the assistance of the microscope, which is represented No. V. in its natural size.*

FIG. V.

*The same Nymph, lying on its back, magnified.*

FIG. VI.

*The same Worm delineated again, as it appears under the microscope; and all its parts distinguished by annexed letters.*

- a a* The two eyes in the head. *b* The teeth.  
*c c* The horns, folded near the legs, upon the breast.  
*d d* The first pair of legs.  
*e e* Another pair of legs, visible under the first.  
*f f* The third pair, laid on the belly.  
*g* The rings of the belly, and margin or border of the belly.

FIG. VII.

*The Ant having completed all its labours, and now attained the full maturity and strength of its age, exhibits the number of its parts and limbs complete.*

- a* The teeth of the Ant, in which it carefully carries its Vermicle, or little Worm.  
*b b* The two very black eyes.  
*c c* The horns, of a light red colour.  
*d* The six sharp pointed prominences, into which the rings of the thorax divide themselves.  
*e* The loins, consisting, as it were, of three knotty joints or vertebræ.  
*f f* Six hairy legs, composed of four joints.  
*g* The shining hairy abdomen.

FIG. VIII.

*The male Ant, in its natural size.*

FIG. IX.

*The male Ant, delineated as magnified, in which all the parts are distinctly represented.*

- a* The teeth, a little less.  
*b* The eyes, on the contrary, larger.  
*c c* The horns.  
*d d* Four wings, peculiar to the male, the first pair of which are much stronger and larger than the hinder ones.  
*e* The loins, and  
*f* The belly are both differently formed than those parts are in the working Ants.

FIG. X.

*The female Ant, in its natural size.*

E

FIG. XI.

## FIG. XI.

*The female Ant, represented magnified; that the external difference between it and the other kind may be made to appear.*

- a a* The teeth.      *b b* The eyes.  
*c c* The horns.      *d d* The thorax.  
*e e* The legs.      *f f* The loins.  
*g* The belly.

## FIG. XII.

*The little bag or case, in which the Worm of the Ant, being shut, is changed into a Nymph; as yet entire, and of its natural size.*

## FIG. XIII.

*The same, opened.*

## FIG. XIV.

*Another kind of Ant, found in Holland.*

## FIG. XV.

*A sixth kind of Ant, found also in Holland.*

## FIG. XVI.

*The largest kind of Ant, found at the Cape of good Hope.*

## TAB. XVII.

Which represents Bees.

## FIG. I.

*The common or labouring Bee, whose external parts, are particularly described in the following figure.*

## FIG. II.

*The same labouring Bee, in which all its external parts are distinctly pointed out by annexed letters.*

- a a* The two oval eyes of this Bee, which are much smaller than those of the male Bee.  
*b* The particular little eyes, placed in the middle between the two former larger ones.  
*c c* The antennæ or horns.  
*d* A kind of horny or bony lip, which is not obvious in the males.  
*e e* Two long teeth, which are shorter in the female, and very small and short in the male Bees.  
*f* The long proboscis or trunk, which is much shorter in the male.  
*g* The thorax is roundish, and in the upper side of the hinder part it is provided with a somewhat prominent margin or border.  
*h h* The two upper wings.

*i i* The two lower wings, which are less than the former.

*k k* The two foremost legs.

*l l* The two middle legs.

*m m* The two hinder legs, larger than the former ones, and that particular part of them which we call the foot.

*n n* The claws of the feet.

*o o* Part of the hinder legs, which is called the shank, the foot of which of one extreme part, is joined to another part called the thigh.

The abdomen. *q* The aculeus or sting.

## FIG. III.

*The female Bee, commonly, but improperly, called the king. By comparing this with the common or working Bee, represented in the last figure, and with that of the male in the following figure, the difference between the three kinds may be observed.*

## FIG. IV.

*The male Bee, which differs from both the female and working Bee.*

## FIG. V.

*The proboscis of the Bee, with its parts as represented by the microscope.*

- a a* The first pair of joints of the proboscis, which are partly of a substance between horn and bone, and partly of a membranaceous substance, and here and there are covered with rough hairs. This cut represents them a little drawn in, and in readiness to move the proboscis backwards, and withal to compress and cover it; and likewise to force the honey through it towards the stomach.  
*b b* The air-tubes, distributed through that part of the proboscis, which is of a substance between horn and bone; and which, by being transparent, affords a view of them.  
*c c* The extremities of the first pair of joints; these extremities are a little crooked.  
*d d* The articulation of these joints with the root of the proboscis.  
*e e* The next pair of joints belonging to the proboscis, constructed much after the same manner with the first. This second pair greatly assist the proboscis in its suction.  
*f f* The lower articulation of these joints, of a pretty considerable length.  
*g g* The two upper articulations of the same joints, which are shorter.  
*h h* The third pair of joints forming the proboscis, which are somewhat of a substance between bone and horn, but for the greatest part membranaceous, and likewise covered with rough hair. These joints also are of service to the proboscis in sucking the honey, which

which they likewise help to forward towards the stomach.

*i* The seventh joint of the proboscis, being a single one; or the proboscis itself, consisting partly of a membranaceous substance, and partly of a substance between bone and horn. It is the underside of it that I have here represented, as it may be supposed to appear, on turning the Bee upon its back.

*k k* Part of the proboscis itself, of a substance between bone and horn, constructed in such a manner, that the Bee can separate it from the main body of the proboscis, and give it a circular form.

*l* The gullet represented cut off.

*m* The membranaceous part of the proboscis itself, which lies beautifully folded up under the other portion of the proboscis just now mentioned, as consisting of a substance between bone and horn.

*n n* The part of the proboscis which consists of a substance between bone and horn, tending inwardly, and forming, as it were, a narrow channel.

*o o* The fore extremity of the proboscis covered with crooked hairs, and furnished with a little head, in which there is a hole that seems to be the cavity of the membranaceous part.

*p* That part of the proboscis, which consists of a substance between bone and horn, divided at its fore extremity into two shanks.

*q q q* Three very black, but shining, joints of the proboscis, of a substance between bone and horn, and forming the lower part of the proboscis. The middle of these joints is the sheath or case of the proboscis, and is furnished with muscles, which belong to the second pair of joints *e e* of this organ. But the two extreme joints of the part now before us, contain muscles that administer to the first pair of joints *a a*.

*r r r r* The articulations by which the three joints *q q q* are united with the parts of the head.

*s s* The strong muscles serving to move inwards the proboscis, its joints and sheath.

*t* A thin transparent membrane, through which the muscles *s s* may be discerned.

FIG. VI.

*More distinctly exhibiting in what manner that part of the proboscis, which consists of a substance between bone and horn, and which is represented under the letters k k Fig. V, can form itself into a circle, and dilate the membranaceous parts of the proboscis at the time of its suction.*

*a a a* That portion of the proboscis, which consists of a substance between bone and horn. This part is much blacker and stronger in the middle of it than elsewhere, as is very discernible.

*b* The circular form or bending which that part acquires at the time of suction.

*c c c c* The expansion, in form of a sail, of the membranaceous part of the proboscis, that lies folded up under the other part that consists of a substance between bone and horn. The former part acquires the said form, when the latter projects itself in that of a circle.

*d* The papillæ, or glandalous protuberances of the membranaceous part of the proboscis. These particles appear most visible when the said part is expanded.

*e* The place where that part of the proboscis, which consists of a substance between bone and horn, tends inwardly, and uniting with the remaining hairy part of the proboscis, forms, as it were, a narrower channel.

*f* The fore extremity of the proboscis, covered, as it were, with crooked hairs, and perforated in the middle.

*g* The hairs of the proboscis, which are not of an equal thickness, but somewhat bigger near the roots.

FIG. VII.

*The proboscis of a Wasp, viewed on its lower side.*

*a* Part of the proboscis of a horny substance, which constitutes the lower part of the insect's head. This part is covered with hair on its sides, and is all of a shining black, except two yellow spots.

*b b c* Three horny particles or joints, which serve in a manner to form the root of the proboscis. The two lateral *b b* contain the muscles, that govern the bristles *d d*; but the middle joint *c* serves, as it were, for a case or sheath to the proboscis.

*d d d d* Four articulated bristles, which assist the proboscis in its suction.

*e e* The place where the teeth are broken off.

*f* The proboscis itself, adorned with four beautiful white particles, or rather protuberances, that terminate in little round knobs.

FIG. VIII.

*The hair of a Bee, as it appears through the microscope, in the form of a feather.*

*a* The stem, as it were, of the feather.

*b b* The smaller lateral branches springing from the stem.

*c* The hairy extremity of the stem.

FIG. IX.

*The lungs of the Bee.*

*a a* The pulmonary vesicles of a white colour.

*b b & c.* The little tubes branching from these vesicles; they consist of spiral rings, which in this place are always open.

*c c & c.* Other vesicular dilatations of the pulmonary

monary tubes, which again degenerate into the tubes *dd* &c.

*ee* &c. Ramifications of the pulmonary tubes distributed through the body.

*ff* Two places, where the greater pulmonary vesicles have a direct communication with each other.

## FIG. X.

*The pulmonary tube, which consists of rings, and is here represented as it appears when drawn out, the better to exhibit the spiral course of these rings.*

## T A B. XVIII.

## FIG. I.

*The internal parts of a Bee.*

*a* The gullet.

*b* The stomach, furnished with fleshy fibres.

*c* The pylorus, consisting of nodules, and full of a substance of a yellowish red colour.

*dd* The small gut, very spacious or wide, full of muscles, and furnished with valves.

*eee* The vasa crocea, or yellow gut-vessels; being an infinite number of little intestines most intricately connected, and most firmly united with the narrowest part of the small gut.

*f* The narrow part of the intestine.

*g* The sudden dilatation of the intestine, that succeeds the constriction of it just now mentioned. In this place the intestine looks like a membrane, and exhibits six protuberant glandulous particles on its inner surface, as best appears by the particular figure placed at one side of that now under our consideration.

*bb* The said six glandulous particles, as they appear more plainly on opening the intestine that contains them.

*i* The place where the intestine, after dilating itself, narrows a second time. I have given a particular figure to illustrate this narrowing.

*k* The place where this intestine appears full of folds, like a ruffled piece of linnen.

*l* The straight gut, over which the sting lies.

*mm* The hinder part of the last abdominal ring, which is covered with hair, and gives a passage to the straight gut.

*nn* Six particles or joints, of a substance between bone and horn, which are articulated with the shanks of the sting.

*oo* Two appendages always found along with the sting, and placed on each side of the sting and the straight gut.

*p* The bag containing the poison, which the Bee injects into the wound made by the sting.

*qq* The blind extremities of the tube that serves to secrete the poison, and afterwards conveys it to the bag that is to contain it.

## FIG. II.

*Representing the sting, and all its parts.*

*a* The sting, composed of a sheath or case, and

two shanks, united to each other, and terminating in a sharp point, so as to look like a single part.

*b* The poisonous bag.

*c* The tube that serves to convey the poison from its bag, to the thickest part of the sting's sheath.

*dd* The two shanks of the sting, mutually conveying to each other.

*ee* The sheath of the sting.

*ff* The thickest end of the sheath, where the tube opens into it, by which it receives the insect's poison.

*g* The extreme point of the sting, formed by the two shanks of that organ, that are in this place closely united.

*bb* The beards with which the shanks of the sting are armed at their extremities.

*e* The tube that serves to secrete the poison, which it discharges into the poison-bag.

*kk* The two blind extremities of said tube.

*llllll* Three pair of cartilages, of different forms, which are for the most part of a deep black, and articulated among themselves, and with the shanks of the sting.

*mm* Two other cartilages less conspicuous than the former, with one pair of which they are articulated. These two cartilages *mm*, are almost entirely of a membranaceous substance.

*nnnnnnnn* Eight places in which the foregoing cartilages are articulated among themselves, and with the shanks of the sting *dd*.

*oooo* Four muscles serving to move the sting different ways, by the assistance of the same cartilages.

*pp* Two muscles which draw the shanks of the sting into its sheath.

*qq* Two appendages of the sting which are moved along with it, and seem to answer no other purpose but that of ornament.

## FIG. III.

*Which again exhibits, but in a more distinct manner, the sting and other parts relating to it.*

*a* The thick or blunt extremity of the sting's sheath, into which the insect sheds its poison.

*b* The sharp extremity of the sting's sheath, to which the poison runs, under the shanks.

*cc* The place where the channel of the sheath grows narrower, the better to retain the shanks that are within it, in their proper situation. This particular may be still better discerned under the letters *dd*.

*dd* The shanks of the sting laid up within the channel of the sheath, and beautifully retained in their proper situation by the two processes of the sheath, already taken notice of under the letters *cc*.

*eee* The borders or edges of the sting's sheath, which are turned in, and received by the channels of the sting's shanks, and not only serve to retain the sting in it's sheath, but likewise allow it leave to move freely.

*f* One



*f* One of the sting's shanks put somewhat more forward within the sheath than the other shank ; but after such a manner, however, that the sting's point still remains entirely within the sheath.

*g* The other shank of the sting, lying higher within the sheath. We may here see by what means the sting, left in the wounds made by it, penetrates deeper and deeper.

*b* The hollow, cavity or channel of the sting's sheath, when widest.

*i* The narrowest part of the said hollow, cavity, or channel.

*k* One of the sting's shanks represented by itself, so as to exhibit

*ll* The cavity or channel within which the edge of the sheath is received, so as to afford the shank a free motion.

*m* A segment of the shank cut off transversely, to give a better view of the shank's cavity or channel.

*n* The same channel or cavity, as it appears in the other branch.

*o* The extremity of the shank's channel or cavity.

*p* Ten crooked heads or beards, with which each shank is generally furnished.

*qqq* Other less considerable hooks or beards.

*rrr* Certain processes of a somewhat cartilaginous substance, and serving, instead of muscles, to move the shanks.

*sss* The smooth unbearded sides of the shanks, by which they join each other.

*ttt* The hinder parts of the shanks, or the ligaments by which they are thrust out.

*vv* Two places in which the sting appears as if there was a joint in it. But this appearance is entirely owing to the air, which makes it appear uneven : the poison sticking to the sheath.

*x* The poison bag.

*y* The tube which conveys the poison of the bag.

*z* The tube by which it discharges its poison.

## F I G. IV.

*The poison bag of the Wasp, and the Hornet, with the other parts belonging to it.*

*a* The poison bag

*b* The tube by which the said bag sheds its poison.

*c c* The two tubes inserted into the hinder part of the poison bag, into which they discharge the poison. In the Bee there is but one tube to answer this purpose.

*d d d* Swellings here and there in the last mentioned tubes.

*e e* The ends of the tubes somewhat thicker than any other part.

## F I G. V.

*Representing the manner, in which the Bee's poison may be extracted or gathered.*

*a* A slender glass tube serving to receive the poison.

*b* The point of the sting placed within the tube, and pouring into it the poison squeezed by the fingers out of the poison-bag.

## T A B. XIX.

## F I G. I.

*The Bee's heart, with the parts belonging to it.*

*a a* Part of the heart seated in the upper region of the abdomen.

*b b b* Pulmonary tubes running towards each side of the heart, in which they at last terminate.

*c c c c c* Certain thin membranes, that serve to keep the fat in its proper place.

*d d* The fat as it appears through the said membranes, which are transparent.

*e e e* The ovary, as it likewise appears through the said membranes.

*f f f f f* The muscular fibres broken off from the abdominal rings, which they serve to govern.

*1 2 3 4 5 6* The six abdominal rings under which the heart is placed, as it were in the insect's back.

## F I G. II.

*The ovary of the Bee, of the size and form it appears to the naked eye.*

## F I G. III.

*The same ovary, represented as it appears through the microscope.*

*N. B.* This double ovary is composed of parts extracted from two different female Bees, viz. The part *a* from a full-grown impregnated Bee ; and the part *c* from another Bee less perfect, and not as yet impregnated. This I did to avoid the necessity of two figures, where I thought one might be made to answer.

*a* Part of an ovary extracted from an impregnated Bee, furnished with an infinite number of ducts, that contain eggs of different sizes.

*b b* The coalition of the oviducts of each side, where they discharge their eggs into a common channel or duct for all the eggs of that side.

*c* Part of an ovary extracted from a female unimpregnated Bee. The eggs of this part differ greatly from those of the other part *a*.

*d* A dilatation of the pulmonary vesicle, which distributes its ramifications, and an infinite number of air-tubes through every part of the ovary, its ducts, and even the eggs themselves.

*e e* The upper parts of the oviducts of an impregnated Bee, where they unite, and the two parts of the ovary bend towards each other.

*f f* The upper parts of the oviducts of an unimpregnated Bee, in which they are hereabouts very slender, contain but very minute eggs, but which bend in the same manner mentioned in the preceding article.

*g g* The eggs of the ovary of an impregnated Bee, which are sensibly bigger and bigger, the nearer they approach the common oviduct of the side, to which they belong.

*h h h* The eggs of an impregnated Bee, which are in every oviduct almost of the same size, at the same distance from the common oviduct.

*i i i* The eggs in the extremities of the oviducts of an unimpregnated Bee's ovary. These eggs are not only very small in themselves, but smaller, paler, shorter, and more delicate than those in the extremities of the impregnated Bee's ovary.

*k k k k k* The eggs in both parts of the ovary, ready to fall into the greater common duct.

*l l l l* The eggs of an unimpregnated Bee, differing in size, but very irregular, some of those furthest from the common duct being bigger than the others that are much nearer, contrary to what appears in the impregnated Bee, as has been already observed under the letters *g g h h*.

*m m* The eggs in the extremity of an impregnated Bee's ovary, which are bigger, and of an oblong, and more regular form.

*n n* Two common ducts, or, as it were, the horns of the uterus, in which all the particular oviducts terminate, and pour their eggs.

*N. B.* Both these ducts are extracted from an impregnated Bee, though one of them supports the ovary of an unimpregnated one.

*o o* The place through which the spinal marrow takes its course.

*p p* Part of the common duct, more spacious than the rest, furnished with muscles, or of a muscular construction, and within which are placed

*q q q q q* A great number of eggs ready to come away; these eggs appear a little through the duct, which is transparent.

*r r r r r* Air-tubes, running through the horns and the common duct of the ovary.

*s* The coalition of the two common ducts or horns into one narrower channel, which is likewise muscular, and the excretory duct of the Bees eggs.

*t* A globular or little round part or organ, containing a glutinous matter, with which the eggs are smeared over before the Bee lays them. The interior coat of this bag is curiously interwoven with an infinite number of air-tubes.

*u u* Two blind vessels, that, after making a

great many turnings, meet, and form a single tube. This tube terminates in the uterus, or excretory duct of the eggs, and serves perhaps to secrete the glutinous matter just now taken notice of, and to convey it to the bag destined to receive it.

*x* The exitus, or end of the uterus, or of the excretory duct of the eggs, as yet not sufficiently examined.

*y y* The external muscular parts of the sting, broken off.

*z* The poison-bag, with

*a* Its single secreting tube, and

*β β* The blind appendages of the said tube.

*γ* The tube by which the poison is discharged.

*δ* The sting of a female bee, naturally crooked.

*ε ε* Two little parts placed by the sides of the sting, and already taken notice of in the anatomy of the working Bee.

*ζ* The straight gut.

## F I G. IV.

*The ovary of a Wasp.*

*a a* The oviducts of this ovary represented by themselves, being seven of a side.

*b b b* The upper part of the ovary, extending to a very great length.

*c* The bag containing a glutinous matter, with its secretory vessels. This bag is shaped like a pear.

*d d* Some minute eggs, of the common oval form.

*e* The meeting of the particular oviducts in one common oviduct.

## F I G. V.

*The egg of a Bee, represented by itself.*

*a* The egg, of its natural size.

*b* The same egg seen with the microscope, which shews an infinite number of air-vessels, distributed all over the egg's surface.

*c c* The oviduct cut off at each end of the egg.

## F I G. VI.

*The poison-bag of the Bee, of its natural size.*

*b* The poison-bag represented under the letter *z* of Fig. III. as it appears through the microscope.

*c c* Two blind appendages which serve to secrete the poison, and afterwards meet so as to form

*e* A single tube, terminating in the body of the bag.

## T A B. XX.

## F I G. I.

*The head of the Male Bee, with the parts belonging to it, especially the eyes, which are here represented much bigger than in nature.*

*a* Three singular, or particular unequal eyes,

eyes, which in the male Bee are placed in the form of a triangle between, but lower than the greater eyes; but in the female and working bees, these unequal eyes appear in the upper part of the head.

- bb* One of the greater eyes, especially the superior external face of it, which is by no means pointed, but of a roundish form.
- c* The internal inferior edge of the greater eye, which is somewhat pointed, so as to leave an intermediate space for the reception of the smaller eyes, and other parts.
- d* Feathered hairs, or hairs in form of feathers, growing in the space between the greater eyes.
- eee* Hairs with which both eyes are well supplied, and which too answer the purpose of eye-brows or eye-lids.
- ff* The Antennæ or little horns.
- gg* Fibres of an inverted pyramidal and hexagonal form; which immediately appear on removing the cornea, and uvea of the eye.
- hh* The upper part of the said pyramidal fibres of a pretty considerable breadth.
- i* The lower part of the said fibres, where they terminate in a point; likewise the internal coat of the eye, upon which these fibres stand.

FIG. II.

*The disposition or situation of the hexagonal divisions of the cornea.*

- kk* A hexagonal division enclosed by six other similar divisions; and this order, or disposition, or arrangement, obtains all over the cornea, and all its divisions.

FIG. III.

*A small portion of the Cornea, along with its hairs, as seen through the microscope.*

- lll* The thickness of the cornea, which is pretty considerable.
- mmm* Hairs like bristles, growing out of the Cornea, which they even perforate with their roots. These hairs project a considerable way beyond the surface of the cornea, and answer the purposes of eye-brows and eye-lids.

FIG. IV.

*The cortical lower fibres of the eye.*

- nnn* The cortical fibres of the eye, which lie like beams or joints on the membranes that support the upper pyramidal fibres.
- o* The manner in which these fibres are placed one over another, like beams intended to form a raft.
- p* The brain, situated under these fibres, and communicating with them.

FIG. V.

*The eyes and brain, as they appear on beginning the dissection of them on the lower side.*

- qq* The cortical fibres of the eye, shewing in what manner they lie transversely or across, under the membranes, that support the pyramidal fibres, and are distributed like the muscular fibres in the papillæ of the kidneys.
- r* The origin of the spinal marrow.
- ss* The cortical substance of the brain divided in the middle, and covering in part the cortical fibres of the eye.
- tt* The manner in which the cortical substance of the brain, communicates at each side with the spinal marrow.
- uu* The thickest part of the cortical fibres, and the place where they have the most apparent colour.
- x* The internal coat of the eye, supporting the inverted pyramidal fibres.
- y* The first nodule or swelling, formed by the spinal marrow, after its leaving the skull.
- zz* The pyramidal fibres of the eye, as they appear on each side, when just divested of the cornea.

FIG. VI.

*The brain more accurately displayed.*

- aa* The cortical substance of the brain, shewing, not only in what manner it communicates with, but likewise springs from the brain.
- b* The second pair of the particles of the brain, from which the cortical substance derives its origin.
- c* The first pair of the brain's particles, from which issue *dd* Bipartite nerves.
- ee* The fourth pair of the brain's particles, shewing likewise in what manner the particles of every pair communicate with each other.

T A B. XXI.

FIG. I.

*The genital parts of the male Bee, as they appear through the microscope,*

- aa* The two testicles.
- bb* The vasa deferentia, twining or curling like the tendrils of a vine.
- cc* The same vessels considerably dilated, so as to appear like a second pair of testicles. These vessels are hollow.
- dd* The feminal or seed bags, into which the vasa deferentia, after growing narrower again, are inserted on each side.
- ee* The nervous root of the penis.

*f* A little part or particle of a substance between bone and horn, of a deep brown, somewhat inclining to red, placed within the oval tube, wart or tubercle of the penis.

*g* The penis, or part like a penis, but without any perforation.

*b* A small part divided into five divisions.

*i* Another particle, seated, as it were, opposite to the former *b* but without any divisions. This particle is shaggy on its inside, rugged, and full of wrinckles.

*k k* Hollow, pointed appendages.

*ll* Ligaments, serving to fasten the genital parts in the abdomen,

*m* A portion of the spinal marrow, from which proceed

*n n* The nerves, that are distributed over the genital parts, and serve to move them, as likewise the purposes of secretion and pleasure.

FIG. II

*o* The genital parts of the male Bee, of their natural size.

FIG. III.

*The genital parts of the male Bee, beginning to unfold themselves.*

*cc* The vasa differentia cut asunder in their thickest part, to shew their thickness and cavity.

*dd* The seminal bags cut asunder for the same purpose.

*ee* The nervous root of the penis.

*ff* A little horny bone, situated in the bulbous portion of the root of the penis.

*b* The five-fold little particle, beginning to unfold itself.

*i* The other particle, without any division, beginning likewise to unfold itself.

*kk* The sharp, hollow appendages coming out of the body

*qq* The horny bone, constituting the extremity of the pudendum,

*ss* Certain particles serving as ornaments to the said bone.

FIG. VI.

*The genital parts of the male Bee, a little more unfolded.*

*e* The nervous root of the penis.

*f* The little horny bone placed within the tubercle of the root, further thrust out.

*b* The quinque fida, or five-fold particle further thrust out.

*i* The other particles without divisions, also more thrust out.

*kk* The sharp, hollow appendages quite unfolded from their roots, but

*ll* Their points still continue out of sight.

*qq* } Denote the same parts, as in the last figure,  
*r* }  
*ss* }

T A B. XXII.

FIG. I.

*The genital parts of the male Bee, still further thrust out.*

*e* The nervous root of the penis.

*f* The little horny bone lying within the tubercle of the root.

*b* The five-fold particle still more unfolded.

*i* The other particle, that has got no divisions, further thrust out.

*kk* The hollow appendages quite inverted, or turned inside out.

*qq* } Denote the same parts, as in the figure of  
*r* } the last plate.  
*ss* }

FIG. II.

*The same parts yet more unfolded.*

*e* The root of the penis beginning to grow straighter.

*bb* The five-fold particle quite unfolded, and exhibiting its five divisions.

*i* The other undivided particle entirely displayed in like manner.

*kk* The appendages perfectly inverted, or turned inside out, and stiffened.

*qq* } Denote the same as before.  
*r* }  
*ss* }

FIG. III.

*The genital parts of the male Bee unfolded to their utmost extent.*

*e* The root of the penis extended, for the most part within the pudendum.

*f* The little horny bone seated in the tubercle of the root, now entirely thrust out of the body, and appearing through the transparent parts which enclose it. The five-fold particle, is now so much dilated, as to be almost out of sight, by lying backwards upon the hairy part of the pudendum.

*g* The penis, or particle resembling one, now perfectly inverted, or turned inside out.

*i* The undivided pyramidal particle in like manner unfolded and displayed.

*kkk* The appendages as before, perfectly unfolded, and turgid withall.

*qq* } The same parts as before.  
*r* }  
*ss* }

*t* The head of the peniform particle beautifully plaited.

*u* A considerable opening, or perforation under the penis, and at the bottom of, and between the divisions of, the little horny bone. already so often taken notice of. The Bee's feed issues copiously at this opening.

FIG. IV.

*x* The head of the peniform particle, which, however, has no opening, and affords no passage to the feed.

FIG. V.

The genital parts of the greater Hydrocantbarus, or Water Beetle.

*a* The penis.

*bb* The horny part of the penis, serving to fasten it on each side.

*cc* The root of the penis,

*d* The other testicle in its natural situation.

*e* The testicle stripped of its air tubes, so as to exhibit its internal structure.

*ff* The vasa differantia.

*gg* The thickest part of the said vessels.

*hhhhhh* Seven blind vessels rooted in the penis, and answering perhaps the purpose of prostates.

*ii* The seed bags neatly curled at their extremities.

FIG. VI.

The spinal marrow of a male Bee, seen through the microscope

*a* The origin of the spinal marrow.

*bb 1 2 3 4 5 6 7* Seven nodules, formed by the said organ in its progress, and the nerves issuing from the said nodules.

*cccc* Some nerves which spring not from the nodules, but from the branches themselves of the spinal marrow.

*ddd, &c.* Clefs, or longitudinal perforations in the spinal marrow.

*e* That part of the spinal marrow, which lies in the head and neck.

*f* That part which lies in the thorax.

*g* That part which lies in the particle joining the thorax and abdomen.

*h* The abdominal part of the marrow.

*ii* Two considerable nerves distributed to the jaw bones, and other parts.

*kk* Two nerves running to the proboscis. These are perhaps the insect's gustatory nerves.

*ll* Two other nerves, administering to the gustatory nerves of the proboscis.

*mm* Two nerves, perhaps the optic ones; but I advance this with diffidence.

*oo* Two strong nerves, distributed to the genital parts.

FIG. VII.

Part of the spinal marrow, as it appears under a greater magnifier.

*pppppp* The branches, or ramifications of the spinal marrow, and the nerves cut away

from about the nodules.

*qqqq* The external substance of the marrow, resembling as it were a cleft or divided nerve.

*r* Another part of the marrow lying between the medullary substance, and forming the nodules.

T A B. XXIII.

FIG. I.

The ichnography of a regular honey-comb of the working Bees, as it appears, when inspected from above, divided into its regular hexagonal sections. This description could not be accurately sketched out, without the assistance of some artificial lines.

*a* A regular hexagonal cell, formed by artificial lines.

*bb* Double transverse lines, serving to determine the angles of the cells.

*cc* Longitudinal lines crossing the former.

*dd* Constitute the sides and diameters of the cells.

FIG. II.

Four cells of the working Bees, separated from the other cells.

*a* Three cells joined side by side to each other, and forming by the union, or meeting of their bases, a cavity exactly fitted to receive.

*b* The bottom of a fourth cell, in case the Bees should build one. Thus it may be seen, in what manner three cells, built one close to another, form by the sides of their bottoms a foundation for supporting the bottom of another cell, to be built a contrary way.

*c* Part of a triangular foundation sloping downwards, and of the cell built upon the said foundation. This is formed by the meeting of the sides of two cells.

*dd* Two pretty long, or longer and unequal angles, or corners, formed by the hexagonal sides of the same cell, and uniting with the former part *c*, so as to form the foundation of another cell.

FIG. III.

A single, regular, hexagonal cell cut lengthwise through its centre.

*a* One entire third of the foundation, that is cut into two by this section.

*bb* The third part of a foundation, which foundation is cut away. One segment of this foundation remains united at one side with the third part last mentioned, and the other segment with the third part mentioned of the divided cell.

G

ε The

*c* The entire remaining third part of the divided foundation, sticking to part of another cell.  
*1 2 3 4 5 6* The six sides and angles or corners of the cell, as they mutually answered one to another.

FIG. IV.

*Fifteen regular hexagonal cells, cut lengthwise on each side.*

*a b* The upper cells.     *c* The lower cells.  
*d* The common foundation of the upper and lower cells, cut off.  
*e e e e* The shorter sides of the cells.  
*f f f f* The longer sides of the cells.  
*g* The third part of a triangular foundation sloping inwards, in its natural situation.

FIG. V.

*A building, consisting of a great many cells for the reception of males and females, in order to shew in what particulars the said cells differ one from another, and from the cells of the working Bees.*

*a* The cell, or little house, of a female Bee, falsely called a king-Bee. This cell resembles a pear, is irregularly built, with hollows here and there on its external surface, and is placed above the other cells.  
*c* Cells of male Bees, one third bigger than those of the working Bees. They are here represented somewhat bigger than nature, the better to shew the difference.  
*d* The triangular foundation of the said cells, which appear the better by removing the cells themselves.  
*e* Triangular cavities, formed each by three similar cells of an opposite side or row, that are built one against another. These cavities receive the bottoms of the cells of the said side or row, in the same manner with the cavities in the constructions of the working Bee, already taken notice of.  
*f* Two cells, whose fore edges are so covered and fastened with wax, that their hexagonal form cannot be seen.  
*g* Four very irregular cells, forming a foundation for the king's cell. These four cells serve, perhaps, no other purpose but that of keeping honey.

FIG. VI.

*Four regular cells of the working Bees, built one close to another, after such a manner, that they all stick to one common or intermediate foundation, at the same time that five of them lie to the right, and the other five to the left.*

*a* Five cells belonging to one side. These cells taken together are an inch long, are joined to each other by their sides; and their bottoms lie contiguous to, and support, the

cells of the opposite side.

*b* Five cells of the opposite side, of the same length with the former, and united to, and supporting them in the same manner.  
*c c* The intermediate foundation, that serves as a common bottom to the cells on each side.

FIG. VII.

*A single, regular, hexagonal cell of a working Bee, divided into three parts; the better to shew in what form they are constructed.*

*a a a* Three longitudinal segments of a cell, each of which contains two sides and one angle.

*1 2 3* The three undivided corners formed by the sides of the cell.

*44, 55, 66* The three divided angles that were formed by the separated sides.

*b* The bottom of the cell, divided in like manner into three parts; these parts united form a hollow triangular sloping foundation. We may here see, how every two sides of a cell form one part of a triangular bottom.

FIG. VIII.

*Nineteen regular hexagonal cells built close to one another, as they appear on their back parts.*

*a b* The manner in which the cells of one side are laid out, so as to form every three of them, by the union of their three bases, *1 2 3*, a hollow, which serves as a foundation for a cell on the opposite side. For this reason, if you run pins through the three parts of *1 2 3* of the bottom of one cell, one pin through each part, every pin will penetrate into a different cell of the opposite side. And on the other hand, on running pins through the bottoms of three contiguous cells of the opposite side, in that part where the said bottoms lie nearest to each other, these pins will all meet in one cell.

FIG. IX. Letter *b*

*The cell of a female Bee represented by itself, to exhibit the more distinctly its pear-shape form, narrow mouth, spacious bottom, its length, and the unevenness of its external surface.*

FIG. X.

*A building, consisting of nineteen cells, eighteen of which contain the rudiments of Bees. Nine of these eighteen cells have got in them eggs, placed on their ends, and four others contain young worms, that have but lately shed their skins; the five remaining cells contain Worms a little bigger, and better grown. Of these last, that marked with letter *a* is the largest,*

FIG.

FIG. XI. Letter a.

Six eggs drawn after nature, and placed on their ends. These eggs are oblong, very slender, but somewhat thicker on their upper parts.

FIG. XII. Letter b.

Another Bee's egg viewed with a microscope. It resembles the skin of a fish, divested of its scales, but still retaining the marks of their insertions.

FIG. XIII.

Worms of Bees of different sizes, drawn after nature.

- a A Worm newly hatched.
- b c d e Four worms that received more nourishment, and are more grown.
- f g Two worms still bigger than the former, having had more time to make use of the nourishment provided for them. They are here represented, as they lie doubled in their cells.
- b A Worm placed on its belly, so as to shew on its back a black line, inclining to a light blue or gray. This line denotes the stomach, which appears in this place through the transparent parts that lie over it.
- i A Worm lying on its back, and beginning to draw in the hinder part of its body, and move its head.

FIG. XIV.

The full grown Worm of the Bee, viewed with the microscope.

- a a a Its fourteen annular incisions or divisions.
- b The head. c c The eyes. d The lip.
- e e Two small parts, which afterwards form the antennæ or horns.
- f f Two other small, and as it were, articulated parts, which form the teeth.
- g The rudiment of the tongue or proboscis.
- b b b Ten breathing holes.
- i The stomach appearing on the back through the parts enclosing it.

FIG. XV. Letter a.

The little house or nest of a Hornet, composed of bits of barks.

FIG. XVI.

A Bees cell full of Bees bread, placed in layers.

- b Little grains, of which the said substance, viewed with the microscope, appears to consist.

T A B. XXIV.

FIG. I. II. and III.

Exhibiting the manner in which the pulmonary tubes, and breathing-holes of a Bee's worm, are constructed.

- a a a 1 2 3 4 5 6 7 8 9 10 Ten pulmonary tubes, open on each side.
- b b Tubes which reach in circumference from one breathing-hole to another, by which means there is a communication between all the holes.
- c c The anastomosis, or inosculation of the pulmonary tubes belonging to the opposite sides of the body.
- d d d The breathing-holes, or orifices of the pulmonary tubes. These holes lie naturally under the skin, though they are here represented, as if they projected beyond it.
- e f Rings composing the pulmonary tubes. Some of these rings e are longer than others f.
- g g The skin cut off.

FIG. IV.

The manner of finding out the blood-vessels of Insects.

- a A glass tube, part of which bellies out in the middle.
- b One of its ends drawn out to a very sharp point.
- c The other end, which is more open and wide than the former. It is at this end that the air is blown in.

FIG. V.

The tubes that prepare both the matter of which the Worm forms its thread, and help it to form them.

- a The tubes themselves in which the said matter is prepared.
- b The place where these tubes meet, and form one trunk.
- c c The divisions of the tubes.
- d d d d The ends of the tubes, broken off.

FIG. VI.

Some of the viscera of the Worm of a Bee.

- a a The stomach.
  - b The oesophagus or gullet.
  - c Glands appearing through the coats of the stomach.
  - d d Pulmonary tubes cut off from each side of the stomach, over which they spread an infinite number of ramifications.
  - e The transparent muscles of the stomach.
  - f The pylorus.
  - g g g g Four blind vessels or guts.
- b b The

- b b* The infertion of these vessels under the pylorus.
- i* The other guts, or intestines, the thick and the straight.
- k* The extremity of the straight gut, with the skin still adhering to it.
- l* The internal coat of the stomach, full of a cogulated matter.

## F I G. VII.

*The web which the Worm of the Bee forms, and in which it afterwards encloses itself.*

- a* The lower part of this web. This part is of a membranaceous substance, pretty thick, and ends in a triangular point.
- b* The enclosed Nymph of the Bee, transparent in the middle.
- c* The upper part of the web. This part is convex, and the threads composing it are very discernible.

## T A B. XXV.

## F I G. I.

*The Worm of the Bee, forming its web.*

- a a* The sides of the cell that contain it.
- b* The bottom of the cell.
- c* The entrance or door of the cell. The Worm is here represented as making its web in the properest manner to shut up this entrance.

## F I G. II.

*The Worm of the Bee taken out of the web, in which it had enclosed itself, and just ready to cast its skin.*

- a* The Worm of the Bee quite destitute of motion, after it has finished its web, with which it is entirely surrounded.
- 1 2 3* The three annular incisions, or divisions next its head; the second and third of which begin to be considerably distended, by the limbs growing under them.

## F I G. III.

*A cell, containing the Worm of the Bee changed into a Nymph, and perfectly lined with the said Worm's web. Likewise the said web entire, with the Nymph contained in it, as they appear on opening the cell.*

- a a* The sides of the cell, lined with the Worm's web.
- b* The mouth of the cell, perfectly closed by the web.
- c* The bottom of the cell.
- d* The web, entire, as it appears on opening the cell, which it greatly resembles in form.
- e* The upper part of the web, of a convex

form. This part shews its filaments pretty distinctly.

- f* The enclosed Nymph appearing through the transparent sides of the web.
- g* The bottom of the web, answering to that of the wax-cell.

## F I G. IV.

*The Worm of the Bee, on the point of changing to a Nymph, and stripped of its skin, the better to shew the infant parts of the future Bee, which are here represented as they appear through the microscope, after extending them a little.*

- a a* The antennæ, or horns.
- b* The proboscis, with its parts.
- c c* The second pair of joints belonging to, or forming, the proboscis.
- d d* The first pair.
- e e* The first pair of legs, lying against the breast.
- f f* The second pair of legs.
- g g* The third pair.
- h h* The greater wings.
- i i* The smaller wings.
- k* The abdominal wings.

## F I G. V. and VI.

*The Worm of the working Bee, changed to a Nymph, of its natural size and form, yet so as to exhibit its limbs, which are folded up in a most wonderful manner.*

- a a* The head.
- b b* The greater eyes, one at each side of the head.
- c c* The antenna, or horns. *d* The proboscis.
- e e* The wings. *f* The three pair of legs.
- g* The abdominal wings.

## F I G. VII.

*The Worm of a Female Bee, changed into a Nymph, shewing its parts disposed in the same manner with the former.*

## F I G. VIII.

*The Worm of a Male Bee, changed into a Nymph, differing externally from the two former Nymphs no other wise than as the Male Bee itself differs from the Female Bee, and the working Bee.*

## F I G. IX.

*The Nymph of the Bee viewed with the microscope, displaying in a distinct manner all the parts of the enclosed insect, and the beautiful manner in which they are laid up.*

- a* The head, bloated with humours.
- b b* The eyes, projecting considerably.
- c c* The horns, or antennæ.
- d* The lip. *e e* The teeth, or jaw-bones.
- f f* The first pair of joints belonging to the proboscis.

*g g* The



- g g* The next pair.      *b* The proboscis itself.
- i i* The first pair of legs.
- k k* Two transparent, stiff little parts, lying against the lowest joints of the first pair of legs. These little parts are not to be found as they remain in the skin it sheds on quitting the Nymph state.
- l l* The second pair of legs.
- m m* The wings.      *n n* The blade bones.
- o o* The last pair of legs.
- p p* The abdominal rings.
- q* The hinder parts of the body. The sting projects a little in this place.
- r* Two little parts accompanying the sting.
- s* The anus.

FIG. X.

*The distribution of the pulmonary tubes through the wings, as they appear through the microscope.*

- a* The origin of the wings, where the pulmonary tubes are biggest.
- b* Ramifications and mutual anastomoses or inosculation of the said tubes through the wing.
- e* The extremities of the said tubes.

T A B. XXVI.

FIG. I.

*The nests or habitation of the Humble Bees.*

- a* One part of the nest, containing eighteen cells. *b* Another part, containing eight cells.
- c* A cell quite empty, and open.
- d* An irregular bit of wax placed against one of the cells, in which I found six eggs.
- e* An irregular bit of wax placed against one of the cells, in which I found twenty-three eggs.
- g* A part of the little cells that contained worms.
- b* A little Worm extracted from its cell, just as it was on the point of becoming a nymph.
- i* A large Worm of that kind, of which I found two in a cell that was shut up.
- k* A larger Worm, found by itself in one of the cells.
- l* A cell divided into two parts, in one of which I found two smaller Worms, and in the other two, a little bigger.
- m* A little worm of that kind, of which I found three in one cell.
- n* A little Worm of that kind, of which I found four in one cell.
- o* The eggs of these insects fastened or glewed by one of their ends, to the surface against which the parent lays them.

FIG. II.

*Exhibiting the Lupus Alvearius, or Beehive Wolf, and the particulars of its history.*

- a* The Vermicle, or Worm called the Beehive Wolf, by those who feed them.

- b* A Butterfly of a pale gray, resembling a moth, from which the Beehive Worm issues; after which it lays amongst the honey-combs.
- c c* A hollow tubulated web, which the Worm Lupus, or Beehive Wolf, forms, and in which it runs about here and there, as in so many burrows.
- d* A smaller Butterfly, producing a smaller kind of Beehive Wolf.
- e* The web, which on the outside appears rough and uneven with the Insect's or Worm's excrements, and contains the Beehive Wolf-Worm, now full grown, and on the point of performing its mutation.
- f* The Chrysalis or Aurelia, into which the Beehive Wolf Worm is changed.

FIG. III.

*The little Worm found in the Nests of Wild Bees, and its mutations.*

- a* The Worm itself. with six feet, and of a reddish colour.
- b* The Nymph, into which the said Worm afterwards changes.
- c* A beautiful Beetle, which, within the space of a year, issues from the said Nymph, so as to make it plainly appear that neither the Nymph nor the Worm belonged to the tribe of Bees.

FIG. IV.

*Another species of Wild Bees, represented a little bigger than nature.*

FIG. V.

*A third species of Wild Bee.*

FIG. VI.

*A fourth species of Wild Bee, having very long and very thick antennæ or horns.*

FIG. VII.

*A fifth species of Wild Bee.*

FIG. VIII.

*A sixth species of Wild Bee.*

FIG. IX.

*A Hornet.*

- a a* The Insect's four wings.
- b b* The two sharp nails with which the extremity of each leg is armed.
- c* The head, with its eyes in the form of a crescent, horns, proboscis, and teeth.
- d* Its formidable sting.

FIG. X.

*A Wasp of a middling size.*

## F I G. XI.

*A Wasp of an unusual form.*

## F I G. XII.

*An Humble Bee of a middle size, having its belly surrounded with hairs of different colours.*

## F I G. XIII.

*A tripilis Musca, or three-haired Fly, being a kind of Pseudophica.*

## F I G. XIV.

*The Nest of the smallest species of Wasps.*

- c c c* Three integuments, or coats of the nest.
- d* The body of the nest, of which a piece is broken off, to shew the
- e* The hexagonal cells in which the eggs are hatched.

## F I G. XV.

*A Wasp's nest, that I found sticking to a nettle, composed of nothing but cells, built close one against another, without any integument, or common covering.*

## T A B. XXVII

Representing the history of the Nasicornis, or horned Beetle

## F I G. I.

*The Male.*

- a* Its horn, which, properly speaking, grows rather from the head than the nose.
- b* Its mouth, seated in the breast, furnished on the upper part with three little teeth, of a substance between bone and horn, and without any periosteum; these creatures differ from men and quadrupedes in this, that their bones do not lie hid within their bodies, but appear naked on the outside of their flesh, to which they serve as a defence and covering.
- c* The shells or sheaths of the wings.
- d* A little triangular, horny bone, placed between the said sheaths, which it serves to keep close to the body, and in the proper situation: this bone lies on the first ring of the abdomen.
- e* The edge or border of the sheath, forming a kind of ornament.
- f* One of this Hornet's eyes.
- g g* Two antennæ or horns: those of the male are bigger than those of the female.
- b* A little horny bone, forming the third joint of one of the Hornet's six legs, which are all of them covered with coarse hairs.
- i* The foot itself, consisting of five joints, the last of which is armed with two crooked nails.

## F I G. II.

*The female, scarce differing from the male in any thing but size, and her not having a horn.*

- a* A small prickle growing on the female's head, to supply as it were the want of a horn.
- b* The wings expanded under the sheaths, and the sheaths themselves a little drawn in, by which means a better view is obtained of the little triangular bone, which serves to retain the sheaths in their proper situation. Between these sheaths there appear on the upper part of the fore or first rings of the abdomen, which in the male can only be seen in the lower part under the sheaths.
- c c* Two joints in the rings themselves, which they serve to fold, so as to make them fit under their sheaths, that they may receive no harm, while the Hornet creeps under ground.

## F I G. III.

*The Eggs.*

- a* Two larger eggs.
- b* Two smaller eggs, but of different sizes.

## F I G. IV.

*The Worm.*

- a* The Worm of the horned Beetle, called Cossus, newly hatched. It here exhibits its very large head, two teeth, and three legs belonging to one side of the body.

## F I G. V.

*The Cossus full grown,*

- a* Beautiful wrinkles and folds, with which the skin is adorned.
- b* Nine reddish spots on one side of the body, having each of them a hole through which the Worm breathes, and supplies with air its pulmonary tubes.
- c* A spot like the former, belonging to the other side of the body, and placed on the first or second ring of it
- d* One of the horns, which consist each of five joints.
- e e* The teeth, or jaw bones.
- f* Two articulated bristles, above which the lip appear seated between the teeth.
- g* Three of the insect's six legs, each of which is composed of five joints, formed of a substance between bone and horn, besides a single nail; and which are moreover covered with hair.
- b* Some pulmonary tubes which appear through the extended out-skin of the thirteenth and fourteenth rings of the insect's body.
- i* The extremity of the straight gut forming the anus.

*k k* Hairs

*kk* Hairs covering the body. I here represent but those that grow on the back and abdomen, to avoid the necessity of making the figure bigger than nature.

F I G. VI.

*The exuviae, or cast skins, and pulmonary tubes cast off by the Cossus.*

*aaa* Nine twisted little threads of the pulmonary tubes, appearing in one side of the cast skin, rolled off from the body through the breathing holes, at the time the Worm undergoes this mutation; accordingly all their extremities lie in a direction towards the fore end of the body, as the skin at this time falls off in a contrary direction from the hinder end.

*bb* Two smaller branches of the pulmonary tubes, one at each side of the body. Tho' these branches do not perforate or pass thro' the skin, nevertheless as they are fastened to it, they come away at the same time. One of these branches is divided into some still smaller ramifications; the other appears exactly in the condition, in which with the other nine it fell naturally from the body.

*ccc* Some branches and smaller ramifications of the nine pulmonary tubes of the other side, a little folded out.

*1 2 3* The skull, which at this time divides into three parts.

*dd* The cast teeth, which are hollow.

*e* The cast lip.

*ff* The horns, which are likewise renewed.

*gg* The two other remaining parts of the parted skull. They are hollow, and of a somewhat spherical form.

*b* Six openings in the skin, that formerly contained the new legs.

*i* The hinder part of the skin folded up.

F I G. VII.

*The fibres serving to move the rings.*

F I G. VIII.

*The heart of the Cossus.*

*a* The heart resembling a membranaceous tube.

*b* The narrowest part of the heart, seated near the head.

*c* Two dilatations of the heart.

*d* That part of the heart, which lies within the last rings of the body, and is very slender.

F I G. IX.

*The fat, composed of globules, like the grains of sand.*

F I G. X.

*The fat examined by the Microscope,*

*aa* The transparent membranaceous foundation of the fat cell.

*bb* Some pulmonary tubes distributed through the fat.

*cc* Globular and oily particles of fat, which float, as it were, in other membranaceous, globular, and irregular particles, so as to make it probable that this fat consists of bladders.

F I G. XI. and XII.

*The stomach, and adjacent parts.*

*aaaa* The dissected skin of the Cossus.

*b* The gullet. *c* The upper part of the stomach.

*dd* Appendages of the stomach, in the shape of teeth, seated about the upper end of the stomach, and divided both above and below, into rows.

*1 2* The two upper rows in their natural situation. *Fig. XII. e.* All the six upper rows of the appendages, as well those belonging to the upper, as those belonging to the lower region are here exhibited, but as they appear when taken out of the body.

*1 2* Two of the rows already exhibited, in an inverted situation, as they naturally lie with their points directed towards the insect's head.

*3 4* Two lower rows in the same direction.

*5 6* The two last rows of the appendages, adhering to the lower region of the stomach, with their points directed backwards.

*f* A future on the lower surface of the stomach, in some measure resembling that of the peritonæum.

*g* Some other appendages of the stomach, lying lower down than those already taken notice of, with their points directed backwards.

*h* The hinder part of the stomach.

*ii* The lowest appendages, which appear as it were in the bottom of the stomach. These appendages are directed towards the head.

*kkkk* The vasa varicosa, or the swollen guts of the stomach, placed on the upper and lower parts of it, and on each side, and forming a most beautiful appearance.

*l* The pylorus with the slender gut, which springs from the stomach. This part the antients call Ecphysis.

*m* The colon.

*nn* Pulmonary tubes running from the last pair of breathing holes towards the stomach, and branching into a great many ramifications, that are distributed over the stomach, the colon, and the straight gut.

*oooo* The other sixteen breathing holes, in their natural situation, as they appear thro' the skin.

*p* The straight gut, displaced.

*q* A rough draught of the parts of the head.

## T A B. XXVIII.

## F I G. I.

*The brain and spinal marrow of the Cossus.*

- a* The brain, with the four nerves that it produces.
- b* Two origins of the spinal marrow at some distance afunder, but meeting lower to form one trunk.
- d d d* Nerves iffuing from the spinal marrow.

## F I G. II.

*A recurrent nerve, as is appears through the microscope.*

- a a* The origins of the recurrent nerves, cut off in that place where they iffue from the brain.
- b b* Recurring nerves, tending upwards; their ascent may be feen on each fide of the infect's gullet.
- c c* Elegant inflections of the recurrent nerves.
- d* The first nodule formed by the recurrent nerves after their union.
- e* A recurrent nerve again changed to a fingle one.
- f* The fecond nodule of a a recurrent nerve.
- g* Small nerves branching from a recurrent nerve.

## F I G. III.

*The spinal marrow of a Silk-Worm when about to enter the Nymph ftate, the better to fhew the difference between its spinal marrow and that of the Cossus. As likewise what little reafon fome people have to confider every dilatation of the marrow as a diftinct brain.*

- a* The brain.
- b b b* 1 2 3, &c. The spinal marrow, confifting of twelve globules or nodules, which are formed as it were by the union of twelve pair of nerves iffuing from the brain.
- c c* A pair of nerves running to the eyes.
- d d* A confiderable part of nerves iffuing from the first nodule of the marrow, and tending towards the mufcles of the head, teeth, and other parts. Every one of thefe nerves form by itfelf a beautiful nodule.
- e e* Two of thefe nodules.
- f* A pair of very fine nerves iffuing from the brain, or origin of the spinal marrow.
- g* The recurrent nerves in their natural ftuation, with the two nodules belonging to them, and the nerves arifing from the faid nodules.
- b* A pair of nerves arifing from the first nodule of the marrow, and running towards the little bags that contain the juice of which the filk is compofed, like a glutinous liquid. This pair of nerves ferves perhaps to animate the moving and extruding fibres of the faid filk bags.

*i i* Two pair of elegant nodules, formed by nerves that proceed from the brain, and first nodule of the fpinal marrow, and are diftributed chiefly towards the mufcle of the head.

*k k k k* Four pair of nerves which iffue from the very origins of the marrow, and by no means from its nodules. In my opinion the origin of all the other nerves is like this, as more particularly appears in the nerves of the Silk-Worm Butterfly, in which the fubftance forming the nodule is of a different nature from that of the fpinal marrow, fo that the whole is enclosed in the latter merely for the fake of procuring it greater firmnefs.

In man, the origin of whose marrow confifts likewise of two parts, the nerves arife in like manner from the nervous part of the marrow, which is full of fibres, and after proceeding a little way beyond the faid nervous part, and growing fomewhat longer, they every one of them unite to form fuch nodules at different diftances from their origin. The fame difpofition is obfervable even in quadrupedes. On placing the warm marrow of thefe infects on cold fpring water, it hardens to a confiderable degree, and very plainly exhibits its fibres, and the heterogeneous matter, of which it is formed. This circumftance I have reprefented by a great many curious drawings, done after nature, in Dr. Slade's houfe, from a fpinal marrow, published by Dr. Blafius with his book of Commelyn. But this laft gentleman added the defcription. My name was not mentioned on this occafion, becaufe fome other Gentlemen, who affifted me in the diffection, not choofing to have their names made publick, I thought it improper that mine fhould.

It is likewise very remarkable, that in men and brutes, the pia mater, enclosing the medullary fubftance that iffues like a fine filament from the marrow, in order to form a nerve, lies fo clofe and firm about the nerves, that it is fcarce, if at all poffible, to penetrate into its ramifications with the fineft threads that glafs can be drawn into. And as this narrownefs is ftill increafed by the medullary fubftance, it is eafy to guefs how fubtile that matter muft be, which flows through thefe and other nerves, and is only reftained by that very fine membrane called the pia mater, I therefore firmly believe, that this matter, called the animal fpirits, is not to be gathered or contained by any veffels, and is, for that reafon, altogether invifible.

But that thefe little nerves fhould be in no danger of entangling one with another, or difplaced, the Author of Nature has contrived that they fhould form various nodules; and that each of them, at its origin, fhould, in men, as well as beafts, be connected by that delicate membrane, which forms the third coat of the brain, and is called, by us, arach-

Arachnorides, on account of its extreme fineness. The cavities of the ventricles of the brain are united together merely by means of the said coat, which likewise serves to keep firm in their proper situation the arteries adhering to the bottom of the brain. As therefore the ventricles of the brain have no other coat to enclose and connect them, but this very delicate one, which gives way to the slightest impressions, we may easily see, that the said ventricles are by no means suited to contain the animal spirits, which no doubt are continually passing and repassing through the whole substance of the brain, marrow, and nerves, in order to contract the muscles. It is therefore the pia mater alone that can be supposed to contain the animal spirits. But I absolutely deny, that, as some people think, these spirits pass in great quantities through the said coat, as there are not to be found in the brain or origin of the marrow any ventricles; or any great quantity of spirits, that we may suppose to be driven backwards and forwards in such a manner. Besides what power should drive them. There are no muscles at hand for that purpose; and as to the opinion of some, who attribute such a motion to the heart, experience sufficiently proves, that the juices secreted from the blood move slower than the blood itself. It would be more agreeable to experience to suppose, that some juices are secreted from the blood into the nerves, in order to move the muscles; nor would a great quantity of such juices be necessary, as appears plainly in the case of the smallest tumours.

In Frogs, the Wray-fish, and other animals, after the nerves have been separated some hours from the spinal marrow, and all motion has ceased in the muscles, I can notwithstanding restore the said motion, by only any how irritating the nerves so cut off. And this makes me believe, that the blood, that continually flows through the arteries into the marrow and nerves, produces in the muscles, by means of the nerves, such a constant irritation, as must keep the muscles in a state of perpetual contraction. To explain the mechanism of this motion; The food we take in, after passing through the heart, increases our blood: the blood drives to the brain, irritates the muscles to contraction, by secreting some few subtile particles, which are moved towards the nerves, and penetrate them. The muscles will, in their turn, put their contents in motion, and thus a perpetual and uninterrupted motion must of course be produced in all the parts of the animal machine. It would certainly be worth while to demonstrate, by a due course of experiments, these operations of the blood, spirits, nerves, and muscles. What I have here said of them is only by way of paren-

thesis, and therefore I think I have said enough.

llll Some very beautiful inosculation of the nerves.

m m m The rest of the nerves issuing from the lower part of the medullary nodules.

n n n &c. Some parts of the spinal marrow, where its divisions are not so conspicuous, as more particularly appears in three places near the breathing-hole, or respiratory points.

i 2 3, &c. Nine breathing-holes, which I here represented, to shew the situation of the spinal marrow, with respect to the annular incisures of the body.

o In this place I have represented the spinal marrow with a greater cleft, than it really has, the better to shew the nerves ll.

*The remaining part of this figure represents the genital parts of the Male Silk-Worm Butterfly.*

p p Two branches of the last and greatest pair of nerves, which branches, proceeding from the lowest part of the marrow, are cleft near their extremities, and form a slit for the passage of the vasa differentia r r.

q q The testicles of the Silk-Worm Butterfly, already discernible in the Silk-Worm itself.

r r The vasa differentia.

s s Places at which the said vessels run in a surprising manner through the nerves of the marrow. I leave others to judge whether or no this disposition contributes to increase the titillation.

t A prostatica, or something analagous to that glandule.

u u The said bags, supplied with their seminal matter from two distinct tubes. These bags are not only separated from the vasa differentia, but have not the least communication with them.

x x The body of the penis, with a perforation from end to end for the passage of the seed.

y y Two nails or hooks growing near that part of the penis, which is of a substance between bone and horn. It is by means of these nails or hooks that the male fixes itself against the vulva of the female, and draws her towards him, the surer to penetrate her with his penis. The same contrivance appears in the horned Beetle, and other insects.

z Part of the penis, consisting of a horny bone. The bone serves as a præputium or sheath, from whose fore end the penis projects.

#### F I G. IV.

*An oval nest, hollowed out under ground by the Cossus, in which it changes to a Nymph.*

a a The earth in which the Cossus had formed its oval nest.

I

b The

- b* The nest itself.  
*c* The Cossus, changed into a Nymph.

## F I G. V.

*The changes visible in the internal parts of the Cossus, a little before its entering the nymph state.*

- a* The gullet as not yet altered, and passing through a cleft in the marrow, while the Cossus continues in the Worm state.  
*b b* The stomach, with its appendages considerably contracted.  
*d d d* The vasa varicosa separated from the upper and lower parts of the stomach, and out of their natural situation.  
*e* The insertion of these vessels; for behind the pylorus they open by four tubes into an ecphyfis.  
*f f* The colon, almost of its former size, owing to the contents of the stomach and small gut being fallen into it.  
*g* Cells of the colon, with its ligament in the middle.  
*h* The straight gut.  
*i i* The vasa varicosa folded and coiled in a most surprising and beautiful manner against each side of the straight gut.  
*k* A rough draft of the Worm's head.

## F I G. VI. VII. and VIII.

*A front view of the Nymph of the Cossus, and all its parts, slightly expressed by the graver, and described by lines only, the better to shew its parts. The eighth figure represents the lower parts of the Cossus's head, that the changes it undergoes may be the better comprehended.*

- a* The horn growing on the nose.  
*b* The root of the said horn; which in the Beetle is covered on its lower part with some stiff red hairs. This part grows in the nose of the Cossus.  
*c c* Two spherical tubercles, being the remains of the Cossus's teeth *d d*. Fig. VIII. And therefore these teeth are four times smaller in the Beetle, than they were in the Cossus.  
*d d* The teeth of the Cossus.  
*e e* Two pair of tubercles like the former, being the remains of the Cossus's horns *f f*. These tubercles are of quite another form in the Beetle.  
*f f* The Cossus's two horns.  
*g g* Two tubercles of a more oval form, grown from the articulated bristles of the Cossus *b b*, and afterwards visible in the Beetle itself.  
*h h* The articulated bristles of the Cossus.  
*i* Three beautiful globules placed in the middle, and growing from the particles of the Cossus marked *k*. These globules are likewise of another figure in the Beetle.  
*k* The four bristles of the Cossus, already taken notice of.

- l* The greatest spherical division of the Nymph, which in the Beetle consists of a horny bone, and is covered with hair on each side.  
*m m* The breast bone.  
*1 1* The first pair of legs.  
*2 2* The second pair.  
*3 3* The third pair, with its joints  
*n n* The sheaths of the wings.  
*o o* A small portion of the wings themselves.  
*p p* The abdominal rings.  
*q* The two shield-like parts of the anus.

## F I G. IX.

*A back view of the Cossus, shewing the fourteen annular incisions of its body, and the transposition of its breathing-holes.*

- 1* The first ring of the body, now armed with a horn on the head.  
*2 1* The second ring, in which the first pair of breathing-holes is seated under the fore legs, one at each side of the thorax.  
*3 4* The third and fourth ring, which form but one ring, and may be said to constitute the hinder part of the thorax.  
*5 2* The fifth ring, in which the second pair of breathing-holes is seated under the wings, one at each side.  
*6 3* The sixth ring, in which the third pair of breathing-holes externally appears, one at a side, on the borders of the belly.  
*7 4* The seventh ring, and fourth breathing-hole.  
*8 5* The eighth ring, and fifth breathing-hole.  
*9 6* } The ninth and tenth ring, and sixth and seventh breathing-holes, all very distinct in the Cossus, but in the Beetle pretty closely united.  
*10 7* }  
*10 8* } The eleventh, twelfth, and thirteenth rings, which now in a manner form but one ring. The eighth pair of breathing-holes, placed on the eleventh ring, is almost closed up in the Nymph. And the ninth pair, which in the Cossus appeared in the twelfth ring, is no longer to be seen in its Nymph.  
*14* The fourteenth ring, visible only in the belly, between the two shield-like parts. I here only mark its situation.

## T A B. XXIX.

## F I G. I.

*The Caterpillar of the swift Butterfly.*

- a* Its head, and some of the hairs growing on its forehead or forepart; likewise its two teeth.  
*b* Its breast. *c* Its belly.  
*d* Its tail, in which are seen its two hinder legs.  
*e* The extremity of the tail, ending in a point. Neither the breathing-holes, the fore, or middle part, are to be seen in this Caterpillar,

pillar, as I have represented it lying on its belly.

FIG. II.

*The Chrysalis or Aurelia of the swift Butterfly, belonging to the second mode of the third order or class.*

- a The eye.
- b The proboscis, beautifully bent back towards the belly.
- c The horns and legs, stretched over the body.
- d The wing belonging to one side.
- e e The rings of the breast, and of the abdomen.

FIG. III.

*The swift Butterfly.*

- a a The eyes.
- b b The antennæ or horns, growing above the eyes.
- c The proboscis, consisting of a double tube, by means of which this insect constantly sips up its food, while flying. It is to be noted that the great length of this curious organ is contrived by Nature, that the insect should take its food without being obliged to fly too near the flowers, which might injure its wings.
- d The extremity of the proboscis, coiled up by means of some minute muscles. Thus the Butterfly can gather up this part into a little compass, and hide it between the forks.
- e A side view of part of the forks. The forks are two particles covered with hairs, formed like a feather.
- f The tail, by means of which the insect, when on the wing, shapes its course; so that its flight is steddier than that of other Butterflies. The rest appears behind the head and breast, and the abdomen, which is beautifully adorned with hairs, made in form of feathers, and of changeable colours.
- g g The upper wings, which are the largest.
- b b The lower wings. All the four wings are curiously ornamented with hairs and scales. And these ornaments, by containing a great deal of air, make the Butterfly lighter than it otherwise would be, and consequently the fitter for flying.

FIG. IV.

*The Sicarius, or Assassin Worm, an aquatic insect.*

- a a Its six hairy feet.
- b. Its hairy tail, furnished, as it were with two oars, by means of which the Worm can float on the surface of the water.
- c c Sharp and crooked teeth with which this insect kills other insects for its food, and sucks up their blood.
- d d Eight of the insects twelve eyes, of which six are at one side of the head, and six at the other.

e e e Four articulated bristles growing under, and between the teeth.

ff Two longer bristles, which may be considered as the insects horns.

g Six breathing holes. This Worm has sixteen.

FIG. V.

*A tooth of the Sicarius, or Assassin Worm, viewed with the microscope.*

- a The point of the tooth, sharp, and crooked.
- b A sharp ridge on the internal surface of the tooth.
- c The convexity of the external surface.
- d An oblong aperture, or slit, through which that insect sucks its food.

FIG. VI.

*The breathing holes of the Beetle, in their natural situation; as likewise the rings of the body, which may be taken from the figure of the Nymph already exhibited.*

- a 1 The first breathing hole placed obliquely backwards in the breast bone, upon the second ring.
- b 2 The second breathing hole, situated higher under the wings in the fifth ring, and in an oblique direction to the first breathing hole.
- c 3 The third hole, situated a little higher up on the edge of the abdomen, and in the sixth ring,
- d 4 The fourth still a little higher up on the seventh ring.
- e 5 The fifth higher up again in the eighth ring.
- f 6 g 7 b 8 The sixth, seventh, and eighth holes, considerably smaller than the preceding ones. They lie on the ninth, tenth, and eleventh rings.
- i 9 The ninth hole, that appeared in the twelfth ring, now quite closed up.

FIG. VII. and VIII.

*The eyes, optic nerves, and brain of the Beetle.*

- a The eye just divested of the cornea, and the uvea, so as to shew its invested pyramidal fibres.
- b A snow white fibrous coat of the eye, in which all the pyramidal fibres terminate.
- c The optic nerve separated from the inside of the said coat's cavity.
- d The dark colour of the said coat. There are in this place a great many ramifications of the pulmonary tubes, of which I have represented three branches.
- e The manner in which the pulmonary tubes run along the inverted pyramidal fibres in a serpentine course towards the cornea, in the eye of a live Beetle. I have represented these pulmonary pistules, somewhat thicker than

than they really are, that they may appear the more distinct.

- ff* Two horny bones growing on the skull, over the eye, which they in a manner divide.  
*g* An expansion of the skull, of a substance between bone and horn, commonly called the nose-horn, with its rugged surface.  
*b* A superficial division of that part of the eye, which lies within the skull; this division is formed by the upper projections of the skull.  
*i* The brain, consisting, as it were, of two united globules.  
*k* Pulmonary tubes of the dura mater, and optic nerves.  
*ll* The finest parts of the optic nerves, just at their issuing from the brain.  
*mm* The same nerves grown bigger.  
*nn* The same grown smaller.  
*oo* The same again increased, on their approaching the eyes.  
*pp* The origin of the spinal marrow, cut off in that part where it forms a slit for the passage of the gullet.

## F I G. IX.

*The Pulmonary tubes, with their vesicles in the horned Beetle.*

- a a* Distended vesicles of the pulmonary tubes, of which I here give an entire branch bigger than nature.  
*b b* Tubes and their literal branches, springing from the upper part of the vesicles.  
*c c* Some tubes issuing from the sides of the said vesicles.

## F I G. X.

*A pulmonary branch and its vesicle, viewed with the microscope.*

- a a* Rings that compose the tube, of a substance between bone and horn.  
*b* The structure of these rings, which is such as to make it probable they are formed by a concretion of spherical particles.  
*c c* Some places, in which the convolutions, composing the rings are terminated, and succeeded by new ones.  
*d d* Membranes binding the rings together; in these membranes there appear spherical particles, of which they are in a manner composed.  
*e e* Some smaller rings at the top and bottom, of the pulmonary vesicle.  
*ff* The structure of the pulmonary vesicle itself. It is of a white membranaceous substance, composed of an infinite number of minute globules, which on account of their convex surfaces give this part, as often as the light shines on it, a white colour, though without any resplendency.

## T A B. XXX.

## F I G. I.

*Visiculæ pneumaticæ, or breathing, or pulmonary vesicles, that appear between the two plates of the sheath covering the wings.*

- a a* The two largest branches of the trachea, which appear through the said plates, on holding them to the light, and examining them with the microscope in that situation.  
*b b b* Pulmonary tubes issuing from the branches *a a*, with their vesicles.  
*c c c* Pulmonary tubes issuing from the said vesicles, and again forming other vesicles and tubes, &c.

## F I G. II.

*The first species of an Exotick, Rhinoceros, or horned Beetle.*

- a* Its eye, from which issue the projecting part of the skull.  
*b* An excrescence of the skull, forming a kind of horn, in the middle of which there appears a tubercle with a sharp point, and a single cleft at its end.  
*c* The breast bone projecting on the fore part in a single tube, which terminates in two teeth.  
*d d* The two lids or covers of the wings, between which there lies on the insect's back about its breast a triangular horny bone. This bone keeps the lids or covers when shut from running one over the other.  
*e* The abdominal rings, in which are the two breathing holes of the Beetle, that are almost closed up; I have left them unshaded, that they may appear the plainer.  
*fff* The three legs belonging to one side, with their joints, nails, and hair. The breast-bone of this insect, and likewise the projecting part of the said bone, and the nose-horn, are all of a deep brown inclining to black; but the sheaths of the wings are somewhat paler, and near to a light red. The legs are black.

## F I G. III.

*A second species of the horned Beetle, which may be very properly called the flying Elephant.*

- a* The eye belonging to one side of its head, in regard to which it plainly appears, that it is covered like that of the Dutch horned Beetle, by a projecting process of the skull, of a substance between bone and horn, and that it is likewise united with the said process.  
*b* Another projection of the breast bone, of the same substance with that of the skull. This projection covers the eye too, but is by no means united with it; for the eye is only hid



hid by the said projection, which serves as an eyelid, and moves backwards and forwards over the eye, as the Beetle moves its head.

- c Some ornaments of the skull.
- d The nose-horn of the skull, resembling the proboscis of an Elephant.
- e A tubercle, in form of a tooth, growing near the end of the nose-horn, which is more-over cleft in the middle; but as this is a side view of the insect, the said cleft cannot be seen.
- f The breast bone.
- g g Two sharp prominent forks, or teeth of the breast-bone, in regard to which I consider this insect as having some resemblance to an Elephant.
- b The lids that cover the wings.
- i The second joint of the legs.
- k The third joint.
- l The fourth joint, or the foot, with its joints, hairs and nails.

As all these parts are composed of a solid horny bone, the muscles are enclosed by them, whereas on the contrary in men and quadrupeds, the bones lie within the flesh. This Beetle is very black, but shining withall, like polished ebony, so as to afford a very pleasing spectacle, especially as its colour has a reddish cast.

FIG. IV.

*A third species of the horned Beetle.*

- a One of its eyes.      b One of its horns.
- c Its nose-horn.
- d d The breast-bone, and its projections.
- e e The sheaths of the wings. All the parts are gray, owing to an infinite number of small hairs, that grow on them, the nose-horn, and projections of the breast-bone excepted: But the ground of the horny bone, on which these hairs grow, is black, as is likewise the horny bone of the foot, whose hairs do not grow so close, as those covering the other parts.

FIG. V.

*The breast-bone of a fourth species of Beetles.*

- a Some ornaments of this part, which is composed of a substance between horn and bone.
- b A thick expansion of the breast-bone.
- c Its two blunt ends.
- d Some hairs growing on the part that unites the head and thorax. These hairs facilitate the motion of the head.
- e Some projections of the skull.
- f The nose-horn, with its teeth.
- g The horn, and one of the eyes.

FIG. VI.

*A fifth species of a horned Beetle.*

- a Its eye.
- b The nose-horn, growing out of the skull, crooked and blunt.
- c The first processus of the breast-bone.
- d The second.
- e The third. All these are only the limbs belonging to one side.
- f A little prominent border, which is turned in, and entirely surrounds the breast-bone; it is found in every species of horned Beetles. Lower down, and more forward than the said border, are to be seen those ornaments of a horny bone, which are covered with loose hairs.
- g g A single joint of the legs; the remaining parts may be conceived from the other figures.

FIG. VII.

*Part of the heart of the Dutch horned Beetle.*

- a a Some broader parts of it.
- b b Some narrower parts.

FIG. VIII. and IX.

*The genital parts of the male horned Beetle.*

- a The part forming, as it were, the sheath or foreskin of the penis; this part is a horny bone.
- b Two horny bones, or nails of the penis, by means of which the male, in copulation, fixes its penis into the vulva of the Female.
- c The thick nervous part of the penis.
- d The body or root of the penis.
- e e The vasa differentia, bigger in the middle than at the extremities.
- f One of the testicles quite unfolded, or laid open, in order to shew thoroughly the testicular vessels.
- g The extremity of the said testicular vessel. This vessel is closed.
- b The other testicle, almost in its natural situation.
- i The blind extremity of the testicular vessel laid bare.
- k k Seminal bags.
- l l Two slender curled tubes, in which the said bags terminate; and which terminate themselves at each side into six other tubes.
- m m Twelve most beautiful glands, six at a side, which are united with the said twelve tubes, and send their seed to the penis by the feminal bags.
- n The upper part of these glands, which is flattish.
- o The lower part, which is globular.
- p The lower side of the said globular part, somewhat magnified, so as to shew in what manner it is united with the tube of

- the seed-bag. This part contains a limpid feminal matter.
- q* A substance surrounding the feminal matter, which resembles the white of an egg.

## F I G. X.

*The ovary of a Female, and its parts.*

- a* The head of the female, separated from the body.
- b* The gullet and stomach.
- c* The intestines.
- d* The exitus, or extremity of the intestines.
- e e* The ovary, consisting of twelve oviducts, six at a side, and still containing eggs of different sizes, or in which there moreover appear eggs of different sizes.
- f* The vulva.
- g* A bag, shaped like a pear, opening into the vagina of the uterus.
- h* A blind vessel, which in the insect appeared like a transparent lymphatic vessel.
- i* Another particle, communicating with that last mentioned, and containing a hard white substance.
- k k k k* Pulmonary tubes, and vesicles, distributed in great numbers amongst the foregoing parts.
- l* A considerable branch of these tubes and vesicles, running at one end of the common ovary duct.
- m* Some other smaller branches belonging to the stomach and intestines.

## T A B. XXXI.

## The History of the Arborecent Flea.

## F I G. I.

*The arborecent Flea.*

- a* The aquatic aborescent Flea, a little bigger than nature.

## F I G. II.

*A side view of the said Insect, taken with a microscope.*

- a* One of the eyes, situated at one side of the snout.
- b b* Its branching arms, issuing from a single trunk. Each of these branches terminates in two branches, which are again divided into joints and lateral hairs.
- c* The insect's sharp snout, with which it sucks its prey.
- d* Its scaly skin, with an opening in it, through which it can thrust out its body and tail.

- e* The tail, or extremity of the body, in which there appears an intestine through the transparent surrounding parts; the feet are to be seen in the same manner on the fore part of the body, near the opening in the skin just now mentioned.
- f* The extreme point of the rhomboidal shell, that covers the body.
- h* Transparent eggs, which lie on the fore part of the insect, upon its pellucid body, with which they move backwards and forwards.

## F I G. III.

*A more front view of the arborecent Flea, with the opening in its skin.*

- a* An eye. *b b* The branching arms.
- c* The snout.
- d* The slit, or opening in the skin, represented in its natural condition, but somewhat on the fore part, in order to exhibit the legs now projecting beyond it.
- e f* The tail, and its hairs, a little more thrust out from under the said opening.
- g* The sharp point, or extremity of the insect's scaly skin.
- h* That part of the body, in which the eggs lie.

## A short History of the Gnat.

## F I G. IV.

*The Worm, which turns to a Gnat, of its natural size, viewed in different situations.*

## F I G. V.

*The same Worm viewed with the microscope, so as as to shew its thorax and belly, and in what manner it can suspend itself on the surface of the water, by means of the appendages of its tail.*

- a a* The eye. *b b* The antennæ, or horns.
- c* The mouth, with its hairy parts, and articulated bristles.
- d d* The thorax, with its hairs and divisions. On dissecting this Worm, feet are found laid up under the said regular divisions.
- e e* Eight divisions of the belly, with its bristly hairs.
- f* The tail.
- g* An appendix to the tail, through which appendix there appear two pulmonary tubes, through which the insect breathes.
- h* Black spots, hairs, and little hollows on the extremity of the said appendage. It is by means of these the Worm suspends itself on the surface of the water.
- i* Bubbles of air, discharged by the Worm from the appendage of its tail.

*k k* The

- kk* The two main trunks of the pulmonary tubes, shewing themselves through the belly. These trunks have their mouths in the appendage of the Worm's tail.  
*l* The anus discharging some excrements.  
*m* Excrements dissolving in the water.  
*n* A little transparent intestine, shewing in what manner the excrements are extruded.

FIG. VI.

*The great Worm changed to a Nymph, of its natural size, in two different situations.*

FIG. VII. and VIII.

*Two representations of the said Nymph somewhat magnified, One of these representations consists of nothing but outlines, the better to exhibit the parts of the insect, which it is intended to represent.*

- a* One of the eyes on the side of the head. The head itself at this time lies higher up.  
*b* One of the two antennæ. divided into black joints.  
*c* A sting, or prickle, with its sharp point lying between the wings.  
*ddd* The legs; the hinder ones coiled up in a very surprising manner, and lying for the most part under the wings, through which however, those belonging to one side shew themselves in this figure.  
*ee* One of the wings.  
*fff* Eight rings of the body.  
*gg* A beautiful edging belonging to the belly.  
*b* The tail, now hanging down, with its rowing fins.  
*ii* The antennæ of the Worm, altered by casting a skin. It is by means of these antennæ, that the Nymph now hangs by its head on the surface of the water, and in this situation breathes, and is enabled to perform its mutation with the greater facility.

T A B. XXXII.

FIG. I.

*The male Gnat, of its natural size.*

FIG. II.

*The male Gnat viewed by the microscope.*

- aa* The eyes, resembling a net.  
*bb* The antennæ, much more beautiful than those of the female.  
*cc* One pair of the antennæ, or articulated bristles. each of which consists of three joints.  
*d* The external sheaths of the sting.  
*e* The sting itself, or one of the five stings projecting beyond the sheath.  
*ffff* The Gnat's six legs, consisting each of seven joints.

- gggg* Sharp, scaly, feathers growing on the two wings.  
*bb* Two little hammers, against which the Gnat strikes its wings, and so makes a buzzing noise  
*ii* The thorax, covered with stiff hairs.  
*kk* The belly, consisting of eight rings, as in the Worm.

FIG. III.

*The stings of the Gnat, and their internal sheath, or horny channel.*

- a* The external sheath of the sting, cut off near the head, and separated from the stings, and their channel.  
*b* The internal tubulated sheath, or channel, containing five stings. The blood flows in this channel along or amongst the stings. There are besides in here two drops of a transparent liquor or humour, which perhaps is the poison saliva that produces the the tumour, in the wounded skin.  
*cc* The very slender stings, extracted from the said channel.  
*ddd* Three thicker stings, pulled likewise out of the said channel.  
*e* The neck of the Gnat separated from its body.  
*f* The head.  
*gg* The eyes of a reticulated form.  
*bb* The horns cut off.  
*ii* A pair of articulated bristles cut off likewise.

FIG. IV.

*The head, and sting of the female Gnat.*

- aa* The antennæ, or horns, which differ considerably from those of the male.  
*bb* The shorter articulated bristles.  
*c* The external sheath of the sting.

FIG. V.

*The female Gnat of its natural size.*

T A B. XXXIII.

*Which exhibits the nocturnal Butterfly or Moth.*

- No. I. The Worm or Caterpillar of the nocturnal Butterfly, sticking in its first coat or skin, and of its natural size.  
 II. The hardened shell of the egg, divided into two parts, as quitted by the Worm.  
 III. The Caterpillar itself, having attained its full size, remarkable on account of its wonderful form.  
*a* Four little bundles of hair, behind the head, like so many cloaths brushes, clipt even at the tops; they are of a white colour, inclining to yellow, and set along the back.  
*bb* Two other bundles of black hairs of unequal lengths, placed about the fore part of the head, and which appear like horns.

*cc* Two

*c c* Two other feathers, like bundles of hairs, placed on each side of the breast like oars.  
*d d* Two more, like the first, but not so beautiful; of a yellowish white.  
*e e* Shorter feathers like hairs, placed all over the skin, and interspersed with other longer ones.

*f* The feather-like ornamented tail.

IV. The same Caterpillar wound up in its web, shortly to undergo its change.

*a a a* The web, in which the Caterpillar has settled itself.

*b* The third and fourth ring swelled by the increase of the limbs within the Butterfly.

V. The same Caterpillar changed into a Chrysalis, or Aurelia, which in a little time is to become a male Butterfly, the limbs of the Butterfly that is by and by to be produced, are now visible, tho' obscurely.

VI. The male Butterfly produced from the former Chrysalis, in which may be seen

*a a* Its elegant horns. *b* Its small body.

*c c* Its large wings, which are wanting in the female.

FIG. I.

*The egg of the nocturnal Butterfly, shewn in No. I. in its natural size, is here represented as magnified.*

FIG. II.

*The egg, broken open by the insect that stuck in it, represented as magnified; which was shewn of its natural size, No. II.*

FIG. III.

*The web quitted by the Caterpillar, with the perforation it makes when about to be changed into a Butterfly; shewing how the eggs are glued in it, which are laid by the female Butterfly, which in like manner are afterwards to produce Caterpillars,*

FIG. IV.

*The Chrysalis of No. V. represented, exhibiting all the external parts of the future male Butterfly: namely,*

*a* The two eyes in the head, under which stretched against the thorax is discerned the proboscis or trunk.

*b* The antennæ, or horns, removed from their natural situation.

*c c* The six legs, also removed out of their proper place, that they may be the more easily viewed.

*d d* Two pair of wings.

*e* The wings of the abdomen.

FIG. V.

*The Chrysalis of the female Butterfly, exhibiting again all its limbs and parts; as constructed in their natural situation.*

FIG. VI.

*The female nocturnal Butterfly, represented No. IV. but far more imperfect in its limbs and parts than the male.*

*a a* Its two less elegant horns.

*b* The thick and distended body.

*c c* The four short wings, or which may be rather called imperfect rudiments of wings.

FIG. VII.

*The female, with her belly distended with eggs.*

*a* The skin upon the back cut open and turned backwards, to shew the great number of eggs with which the belly is filled.

T A B. XXXIV.

The History of Day-Butterflies.

FIG. I.

*The Caterpillar from which the common Dutch day Butterfly is produced.*

*a* Its external form, which is as it were set thick with prickles.

*b* Three of the foremost of its six legs.

*c* Four of the middlemost hinder legs.

*d* The two hinder legs.

FIG. II.

*The Caterpillar magnified, exhibiting its thirteen annular divisions.*

1. The first annular division or ring, constituting the head, in which

*a a* On each side are six eyes.

*b b* The antennæ or horns.

*c c* The teeth, placed under and near the lip.

*d* The little prominent particles, the middlemost of which is formed like a papilla or nipple.

2. Another annular division, with its bristly hairs, which is called the first point of respiration, or breathing hole.

*e* Another of the first pair of legs, with its joints, having a crooked claw at the extremity.

3 4 The third and fourth ring, which have no breathing holes. The third ring, with the two larger ones also is beset with small prickles, of which only those in the fourth are represented.

*f* Another of the second pair of legs joined under the third ring.

*g* Another

- g Another of the third pair of legs, joined under the fourth ring.
5. The fifth ring, on the other side of which there appear three prickly hairs.
- b A prickly hair placed in the middle of the Caterpillar's body, like that which is placed on each of the twelve rings.
- i The first and largest prickly hair, placed on the other side of the body; under and near which is seen a second, and under it another breathing hole.
- k A third prickly hair under the belly.
- 6 The sixth ring, formed like the fifth, containing the third breathing hole.
- 7 8 9 10 These rings are constructed in the same manner with the two former, in which appear the fourth, fifth, sixth, and seventh breathing holes.
- 11 11 11 Four of the middlemost legs, together with their fleshy articulations and crooked claws; joined in the bending part of the body, each with its ring.
- 11 1 The eleventh ring, formed like the former, in which is placed another of the eighth pair of breathing holes.
- 12 The twelfth ring, differing from the rest in the number of its prickly hairs. The rest of the nine breathing holes above it, are seen placed in this side of the body.
- 13 The thirteenth ring, adorned at least with two prickly hairs.
- m m The tail and the last pair of legs, placed in the extremity of it.

FIG. III.

*The kidney-like little parts.*

- a a The divisions which appear on the surface of these kidney-like parts.

FIG. IV.

*The stomach, and its parts.*

- a The gullet, which runs naturally through a slit in the spinal marrow.
- b b b b Some pulmonary tubes dispersed over the stomach.
- c c A tendinous ligament of the stomach.
- d d d Muscular transparent fibres of the stomach.
- e e The vasa varicosa, or swollen vessels, which are the closed intestines, constituting, as it were, twelve little intestines.
- f f The place, in which these intestines, below the pylorus, are produced from the intestine next the stomach.
- g g The manner in which the same is bent into six little tubes, and turned back towards the straight gut, against which they are folded and curled.
- h h Their windings and foldings,

- i One of the thick intestines, in which the excrements receive their form; so that it is not unlike the colon.
- k The straight gut.

FIG. V.

*Two vessels hitherto unknown, which lie in folds near the stomach*

- a a Two tubes, which might very well pass for silk bags.
- b b The origin of these tubes, ascending towards the brain; they are very narrow in this place.
- c Swellings in these tubes.
- d Their sharp extremities, inserted lower down near the blind guts.

FIG. VI.

*The heart.*

- a a The hollow channel of the heart.
- b b b, &c. Muscles situated on each side of the heart, which they serve to dilate.

FIG. VII.

*The brain and spinal marrow.*

- a The brain. b b Origin of the spinal marrow.
- c The first nodule of the spinal marrow.
- d d Two pair of nerves, arising immediately from the spinal marrow, which produces three pair more in the same manner.
- e The second nodule of the spinal marrow.
- f The fourth and greatest cleft or slit of the spinal marrow, below the third nodule.
- g b The fourth and fifth nodules, with the single nerves springing from them.
- i k l m n The sixth, seventh, eighth, ninth, and tenth nodules of the spinal marrow, with the four nerves issuing from each nodule.
- e The eleventh and last nodule of the spinal marrow, with the nerves that it produces,

T A B. XXXV.

FIG. I.

*The web formed by the Caterpillar, when about to enter the Nymph state.*

- a The Caterpillar's web, in which it fixes the nails of its hinder feet, and so remains suspended head downwards.
- b The third and fourth rings of the thorax, considerably distended by the blood and air, that dilate the latent wings and legs.
- c Eight intermediate legs, which lose their skins by degrees, and are at length flipt off towards the tail.
- d The first order of legs, which are likewise about to shed their skins, and roll off one over another.

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FIG. II.

# Ixii A Short Explanation of the TABLES.

## F I G. II.

*The limbs of the future Butterfly, that grew out of sight under the present insect's skin.*

- a a* Its two antennæ or horns.
- b b* The two shanks of the proboscis.
- c c* Parts like forks.
- d d* The eyes.
- e e* The upper and lower pair of wings, between which are to be seen the legs growing from the thorax.
- f f* The rings of the body.      *g* The tail.

## F I G. III.

*The natural disposition of some of the latent limbs represented by the last figure, as appears through the microscope.*

- a a* The place where the horns or antennæ are jointed with the head, and from thence are regularly turned back, and folded in a serpentine manner.
- b b* The two shanks of the proboscis, displaced a little from their natural situation.
- c c* The forky particles in their natural situation.
- d d* The eyes in their natural situation.
- e* A portion of the skin, that lay over the middle of the skull, which is in this place removed.
- f f* The root of the proboscis.
- g* The forks, between which the insect, when become a Butterfly, curls up its proboscis.

## F I G. IV.

*The Caterpillar beginning to shed its skin.*

- a a* The eight intermediate legs rolled off towards the tail, and shedding their skins.
- b* The six fore feet, separating from each other, and slipping forwards.
- c* The skull divided into three parts, the middlemost of which is here represented.
- d* Another portion of the divided skull.
- e* The third portion.
- f f* The forky particles, which are the parts of the future Butterfly, that appear first.

## F I G. V.

*The Caterpillar in greater forwardness towards the Chrysalis state.*

- a a* The eight intermediate legs now driven higher towards the tail.
- b* Four of the fore pair of legs rolled off as far as the middle of the body.
- c d* The forky particles entirely divested of their skin; and the divided skull; and the first pair of the six fore legs rolled off higher upon the body.

## F I G. VI.

*The Caterpillar after it has quite thrown off its skin; so as to acquire the name of Chrysalis.*

- a* The wings, horns, proboscis, and legs, all of them extended, and of another form.
- b* The rings of the abdomen stripped of its skin: These are now more compressed towards each other than heretofore. It here appears in what manner the Chrysalis, by means of the nails in its tail, continues suspended by its web.

## F I G. VII.

*All the parts or limbs just now mentioned, as they appear through the microscope.*

- a a* The forky particles, which are no longer to be seen in the Butterfly. The third figure exhibits them under the letters *c c*, in their natural situation.
- b* The middle portion of the head, which heretofore lay under the skull, and is represented in the last mentioned third figure, under the letter *e*.
- c c* The root of the proboscis represented in the same place under the letters *f f*.
- d d* The proboscis itself denoted by the letters *b b*.
- e* The extremity of the proboscis so much extended, as to reach the rings of the abdomen, and placed between the antennæ.
- f f* The first pair of legs.
- g g* The second pair.
- b b* The antennæ or horns, whose origins or rudiments are exhibited by the third figure under the letters *a a*.
- i i* Their extreme ends, which are very thick.
- k k* The eyes, under which the horns lie bent. These eyes are represented by the letters *d d* of the third figure.
- l l l l* The wings placed in each side of the body.
- m m* The nervous divisions of the wings. These divisions are in reality no more than pulmonary tubes.
- n n* The rings of the abdomen closed and folded one over another.
- o o* Some prickly hairs like papillæ, divested likewise of their skins and seated on the insect's back, from which they project a little. More forwards may likewise be seen four breathing holes.
- p* The tail freed from its skin, as likewise the anus.
- q* The nails of the tail, and the manner in the insect uses them to fasten itself to the web.

## F I G. VIII.

*The Chrysalis lying on its back.*

## F I G. IX.

FIG. IX.

*The colour of the upper and largest pair of the future Butterfly's wings, as they very plainly appear through the transparent skin of the Chrysalis.*

FIG. X.

*The cast skin of the Chrysalis, dividing into four segments.*

- a* The first part of the divided skin. This part contained the Butterfly's two fore-pair of legs, and its proboscis.
- b b* The skin of the back, and abdomen, divided into two parts, that served to enclose the thorax, head, and four wings.
- c* The skin tore off near the origin of the abdomen, whose rings it heretofore contained.
- d* Some of the internal membranaceous cases, or integuments of the horns, legs, and proboscis. These membranes are always broken on the Chrysalis's first appearing in the Butterfly form.
- e e* Some pulmonary tubes, divested of their integuments, and appearing in the skin itself.

FIG. XI.

*The Butterfly, lately stript of its skins.*

- a* Part of the body, which the wings do not as yet cover.
- b b* The small spots and colour of the wings.
- c c c c* Four legs of the insect.
- d d* The antennæ, or horns, growing over the eyes, which are surrounded with hair. Between the horns are two shaggy forks, which hide the proboscis.
- e* The two shanks of the proboscis, hid between the said forks.

FIG. XII.

*A Butterfly, which in little more than a quarter of an hour after its first appearing as such, has acquired its full growth and perfection, so as already to know what it ought to seek after, and what avoid; what may be useful to it, and what prejudicial. In this respect then, the Butterfly infinitely surpasses all other creatures, even man himself; and with a most audible voice, as it were, publishes to all mankind, the praises of their common Creator.*

T A B. XXXVI.

FIG. I.

*The stomach, and contiguous parts, with the vasa incognita, or unknown vessels, heretofore described; all which parts are now altered in a most surprising manner.*

- a a* Folds and turnings of the vasa incognita, exhibited already, Tab. XXXIV. Fig. V.

- b* Their origin, consisting of a slender tube.
- c c* Their divisions and dilatations.
- d* The end of them, near the origin of the stomach.
- e e* The two curled-up or coiled shanks of the proboscis.
- f* The origin of the gullet, near the root of the proboscis.
- g* The channel of the pulmonary vesicle or bladder, arising from the gullet.
- b* The pulmonary bladder, or vesicle itself.
- i i* The stomach, consisting of many beautiful curled prominences.
- k* The hinder part of the stomach, like a wrinkled intestine.
- l l l l l* Six vasa varicosa, or swollen guts, springing by two origins from the little intestine below the pylorus.
- m m* The straight guts, with their twists, and globular contents appearing through them.
- n* The intestine considerably dilated, so as to form the cloaca.
- o* Another dilatation of the intestine.
- p* The straight gut. *q* The anus.
- r r* The two muscles of the anus, furnished each with a tendon of a substance between bone and horn.

FIG. II.

*The genitals of the Male.*

- a* The penis, consisting partly of a horny bone, and partly of a nervous texture.
- b b* Two horny bones, situated one at each side of the penis.
- c* The articulation of these bones, with a border of the same substance, that goes round the penis in the form of a belt.
- d d* Another horny bone, belonging to the penis, divided in the middle.
- e* A back view of the division of the said part.
- f* The nervous root of the penis.
- g g* The body or root of the penis, beautifully curled or coiled.
- b* A granulated matter, like silver sand, that flowed from a puncture made in the penis.
- i* The opening of the root of the penis.
- k* The division of the nervous part of the penis.
- l l l l* Two beautifully curled seminal vessels, issuing from the division of the penis.
- m m* Two other straighter vessels, springing from the same division.
- n* A globular dilatation of the said vessels.

FIG. III.

*The ovary, and its parts.*

- a a a a a* The oviduct, divided at each side into three ducts, which afterwards terminate in very sharp points.
- b b* The common ducts of those already mentioned, ending in a single trunk.
- c c c c c* Five vessels, containing a glutinous substance,

substance, with which the Butterfly fastens its eggs.

- d* The ovary, contracted into a narrower tube.  
*e* An oblong bag, in the same place.  
*f* Part of the said bag, full of a yellowish matter.  
*g* The lower part of it, full of a limpid humour.  
*h* A little transparent part, like a sheath or case, that contained a little horny bone.  
*i* The aperture of the said little horny bone.

## F I G. IV.

*The fat.*

- a a* Some pulmonary fistules, serving to bind up the fat.  
*b b b* The figure of the fat itself, very different from what it had in the Worm.

## T A B. XXXVII.

The Butterfly enclosed in the Caterpillar.

- No. I. The Butterfly, under the Caterpillar form, covered with its first skin, in which it is called an egg, and lies in the same manner that the Butterfly lies within the skin of the Chrysalis.  
 II. The said first skin, or membrane, after it has been cast off.  
 III. The Butterfly-Caterpillar, or the Butterfly in the form of a Caterpillar.  
 IV. The said Caterpillar drawing near its change, and containing, within its skin, the Butterfly, expressed by the I. II. III. and IV. Figures.  
*a* Its protuberant limbs and wings, which are not discernible about the second annular section of the body.  
*b* The same limbs, sprouting out under the third ring.  
*c* The hinder part of the body, growing smaller by degrees.  
*d d* The beam to which this Caterpillar had fastened its flight web.  
*e* That part of the web, in which it had fixed the nails of its hinder feet.  
*f f* A ligament composed of threads, with which the Caterpillar had girt itself about the middle of its body.  
 V. The Butterfly-Caterpillar, after it had shed its skin, in the Chrysalis form. This number shews all the limbs of the Butterfly already exhibited by the fourth, but more obscurely, and disposed in a different manner.  
 VI. The Butterfly itself, or Caterpillar-Butterfly, with its wings extended, and arrived at its full growth.

## F I G. I.

*The egg of a Caterpillar, which is a Butterfly, represented bigger than nature.*

## F I G. II. III. and IV.

*The Butterfly, extracted from under the skin of the Caterpillar, exhibited by No. IV.*

- a a* Its antennæ, or horns. *b* Its proboscis.  
*c c* Its four wings, placed between its six legs.  
*d d* Annular sections of its belly.

## F I G. V.

*All the said parts of the Butterfly, as concealed in the Chrysalis.*

- a a a a* The antennæ. *b* The proboscis.  
*c c* Four legs lying on the upper wings.  
*d d* The upper wings, and part of the lower wings.  
*e* The head and eyes.  
*f* The belly and tail, with their sections.

## F I G. VI.

*The parts, just now exhibited, divested of all their coats, represented more distinctly, and in their natural situation, so as to give an opportunity of even distinguishing the Butterfly's colours.*

## F I G. VII.

*Exhibiting a black spot, appearing through the external skin of the Chrysalis, in one of the Butterfly's transparent wings. It may be certainly known, by the appearance of this spot, whether the Chrysalis is shortly to cast its skin.*

## F I G. VIII.

*The cast skin of the Butterfly-Chrysalis, which almost always divides regularly into four parts.*

## F I G. IX.

*Shewing the manner in which the Butterfly, with its wings as yet very short and little, creeps out of its last skin, under which it was called a Chrysalis,*

## F I G. X.

*The manner in which the wings of the Butterfly, exhibited by the IXth Figure, expand by degrees, and acquire their full growth.*

## F I G. XI.

*All the limbs of this Butterfly, with its wings, in a growing state.*

- a a* The two antennæ, or horns.  
*b* The curled proboscis. *c c* The upper wings.  
*d d* The lower wings. *e e* The six feet.  
*f* The belly, its hairs, rings, and little feathers.

## T A B. XXXVIII.

The mutations of the common Bog-house Fly.

- No. I. The egg of the boghouse Fly, of its natural



tural size. The figure underneath represents it bigger than nature.

II. The double coat or skin of the said egg, left by the Bog-house Worm, which at last changes to the Bog-house Fly.

III. The said Worm newly hatched, a little bigger than nature.

IV. The said Worm full-grown.

V. The said Worm grown immovable, by degrees, under its skin, and changed to what I call a Vermiform-Nymph.

VI. The Bog-house Fly itself, proceeding from the Bog-house Worm, after the latter has changed into a Vermiform-Nymph, and and cast off two skins.

F I G. I.

*The egg of the Bog-house Fly, as it appears through the microscope. It is oblong, full of angles, beautifully coloured, and tessellated like the Dutch cakes, called Woffels.*

F I G. II.

*The double coat of the egg, broken by the Worm it contains. The external coat is of a substance like plaister; the internal coat, which is thinner, resembles a membrane.*

F I G. III.

*The Bog-house Worm, as it appears through the microscope, divided into annular sections, and its body beautifully surrounded, as it were, with little tufts of feathers.*

F I G. IV.

*The same Worm changed into a Nymph, of a size bigger than nature, in order to shew that the little difference, as to external form, between this Nymph and the preceding Worm, (Fig. III.) consists of no more than this, that in the Nymph state the insect's snout is drawn in within the head, and all the annular incisions of the body are become shorter than they were in the Worm state. Add that the insect, in the Nymph state, is destitute of motion, whereas in the Worm state, it was very active and lively.*

F I G. V.

*The true or real Nymph, concealed within the Vermiform-Nymph, (No. V. and Fig. IV.) and thence extracted through incisions made in the skin. This figure is a little bigger than nature.*

F I G. VI. and VII.

*The same Nymph (Fig. V.) viewed with a very great magnifier, the better to distinguish one from another; its limbs, which are chiefly*

*exhibited by the seventh Figure, and denoted by letters, as follows.*

*a a* Are the reticulated eyes, between which, at the same time, may be seen the proboscis, placed towards the thorax.

*b* The two antennæ, or horns.

*c c* The six legs, folded up on each side, against the thorax.

*d d* The folded wings.

*e* The abdominal rings, with the tubercles growing on the edge of the abdomen.

F I G. VIII.

*The Bog-house Fly, (No. VI.) bigger than nature, with its external parts.*

*a a* Two reticulated eyes, of a purplish colour, and parted by two silver belts or borders.

*b* Two antennæ on the forehead.

*c c* A pair of wings of a membranaceous substance.

*d d d d* Six hairy legs, the extremities of every one armed with nails.

*e* The abdomen, its rings, colour, and hairs.

F I G. IX.

*A* Another kind of Bog-house Worm, belonging to the second mode of the third order or class. This worm is very remarkable on account of its legs and horns.

*B* The Vermiform Nymph of the Worm, from which it differs externally more than the Nymph heretofore exhibited, No. V. and Fig. IV.

*C* The Fly produced by the Nymph, elegantly covered, by some preposterously ranked amongst Bees.

F I G. X.

*D* A white Worm, that grew within the Caterpillar of Tab. XXXVII. No. III. and afterwards, when near its time of mutation, opened itself a passage through the Chrysalis of the said Caterpillar, represented by No. V. of the same Table.

*E* The same white Worm changed after its issuing from the said Chrysalis, into a Vermiform-Nymph, that being opened is found to contain a real Nymph.

*F* The Fly at length produced by the said Vermiform Nymph, after it has cast its skins.

T A B. XXXXI.

The History of the Afilus, or Gadfly.

F I G. I.

*The Worm from which the Gadfly issues, hanging over the surface of the water.*

*a* Twelve annular divisions of the Worm, by which

which it is divided, as it were, into head, thorax, and belly.

- b* Hairs growing round the tail, in a circular form, by means of which this part floats on the surface of the water, while the rest of the body remains under water, with its downwards.
- c* The head, whose mouth is divided into three parts. The two lateral parts, which are, properly speaking, the insect's feet, vibrate, while it remains alive, like the tongues of serpents.

## F I G. II.

*Another kind of these Worms, in its descent to the bottom.*

- a* The hairs of the tail, disposed in an oval form, and containing a bubble of air within their cavity.
- b* Two bubbles of air, discharged by the Worm at its breathing-holes, tending to the surface of the water.

## F I G. III.

*A microscopical view of the first Worm.*

- 1 2 3, &c.* Twelve rings, by which it is divided into head, thorax, belly, and tail. This figure likewise shews in what manner the skin is beautifully covered with minute grains and spots. On one side too there appear nine breathing-holes.
- a* The tail, resembling a star, composed of beautiful hairs.
- b b* Delicate hairs, which in this figure appear only about the sides of the body, as I have omitted representing them on its upper part, or on the insect's back.
- c c*. Two larger hairs, growing on each side of the body.
- d* The head. *e e* The eyes.
- f* The crooked snout.
- g g* The legs, situated near the snout.
- b b* Two blackish horny bones, which are, as it were, the thumbs of the feet.
- i i* The horns, or antennæ.

## F I G. IV.

*The grains of the skin, viewed with a great magnifier, so as to shew their construction.*

- a* The skin appearing between the grains.
- b* The prominent part of the said grains, exactly in the middle.
- c* The irregular rings of the said grains.
- d* Sharp prickles growing on the edges of the grains, to whose firmness they contribute.

## F I G. V.

*A leg, magnified.*

- a* Three muscles, furnished with a tendon,

of a substance between bone and horn, and placed on one side of the first joint of the leg.

- b* The said joint, which is black, and likewise of a substance between bone and horn.
- c* Two smaller muscles, with their tendons.
- d* Another joint, of a substance between bone and horn.
- e* The extreme joint of the leg, with its bristly hairs.
- f* The thumb of the foot.

## F I G. VI.

*The snout inverted, and bigger than nature.*

- a* The snout, and all its parts.
- b* The sharp and crooked extremity of the snout.
- c* The internal opening of the mouth, through which the insect's food passes to the gullet.
- dd* The membranaceous divisions of the mouth, by which the palate can be bent, and made to give way.
- e* Part of the mouth, entirely consisting of a black horny bone.

## F I G. VII.

*The salival vessels, or at least two parts analogous to such vessels.*

- a* Two salival vessels curled, and ending in blind extremities.
- b* A single channel, in which they terminate.
- c c* Two particles, as it were, resembling muscles.
- d* The upper part of the mouth, from which the eyes, and two parts of the head, supporting the eyes, have been separated.

## T A B. XL.

## F I G. I.

*The Worms pulmonary tubes.*

- a a* Two very considerable branches of the pulmonary tubes.
- b* Pulmonary tubes in that part where the optic nerves, and the membranes of the growing eyes, are situated.
- c c c* Some pulmonary tubes, which run into each other from each side of the body.
- d d d d d* A mutual communication of the pulmonary tubes, at each side of the body, under the skin.
- e e e e* The circumference of the skin, denoted by dots.
- f* The tail, in which the two main trunks of the pulmonary tubes are opened by two channels.

## F I G. II.

*Curls or folds of the pulmonary tubes.*

- a a* Two portions of the pulmonary tubes drawn asunder.

*b* Their

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*b* Their curly foldings, which represent a silver wire wound up in a spiral form, and then extended.

## F I G. III.

### *The fat.*

- a* Irregular figures of the fat.
- b* Its round particles.      *c* Its oblong particles.
- d* Its broad, jagged, or indented particles.
- e* Its angular particles.
- f* Particles in form of a pear.
- g* Pulmonary tubes distributed through the fat.

## F I G. IV.

### *The heart.*

- a a* The lower part of the heart, in some places a little dilated.
- b b* Part of the heart, represented bigger in the abdomen and thorax.
- c* Part of the heart, seated about the head, and again contracted.

## F I G. V.

### *The brain.*

- a a* The brain.
- b* A cleft or opening in the spinal marrow, to give a passage to the gullet.
- c c* Part of the eyes of a future Nymph, and Fly growing by degrees.
- dd* Eleven prominent nodules of the spinal marrow
- e e* Nerves springing from the origin of the spinal marrow.
- f* Nerves issuing from the origin of the spinal marrow towards the sides of the body.
- g g* Nerves sent from the eleven nodules of the spinal marrow to the viscera, and other parts.

## T A B. XLI.

### F I G. I.

*The Worm changed within its skin into a Nymph.*

- a a a* The external skin hardened, and contracted into three bendings.
- b c d e* The four last rings of the abdomen, which, on account of the contraction of the body, contain nothing but air.
- f* A hollow or empty space in the external skin, between the head of the Worm and the enclosed Nymph. This hollow appears more obscurely than that under the four last rings of the abdomen.
- g* The enclosed Nymph, known by a black spot appearing externally on the skin's surface.

### F I G. II.

*The skin opened, so as to give a sight of the enclosed Nymph.*

- a* The Nymph still wrapped up in its thin and delicate skin.

*b b* Its unfolded pulmonary tubes, of which there are four represented in this figure.

*c* The skull cast off, with the other parts of the horny head, and the snout.

## F I G. III.

*Parts of the future Nymph, discerned in the Worm when stripped of its skin.*

- a a* The antennæ, or horns.
- b* The head and proboscis.
- c c* The first pair of legs.      *d d* A pair of wings.
- e e* Another pair of legs.      *f f* A third pair.
- g* The abdomen, and its rings.      *h* The tail.
- i i* Pulmonary tubes, which have in part shed their coats.
- k* Intestines likewise, which have partly cast their coats.
- l* The anus cut off, but still hanging to the intestines.

## F I G. IV.

*The Nymph, or parts just now taken notice of in the Worm, disposed in a beautiful manner, and much bigger than nature.*

- a a* The antennæ, or horns.
- b b* The eyes, in which the hexagonal divisions do not as yet appear.
- c* The proboscis under the head.
- d d* The first pair of legs.
- e e* The second pair.
- f f* Two wings, elegantly folded.
- g* Annular divisions of the thorax.
- h* The third pair of legs.
- i i* Some black spots on the insect's body,
- k k k k* Four openings of the lungs.

## F I G.

*The fat of the Nymph.*

- a* Changes or alterations in the configurations of its parts.
- b b* Some ramifications of the aspera arteria distributed through the fat.

## F I G. VI.

*The stomach and intestines of the Nymph, to which are added the head and tail of the Worm.*

- a* The origin of the gullet.
- b* The horny bone of the head; the snout, and the legs drawn in towards the body.
- c* The gullet running towards the stomach, through a slit or cleft in the spinal marrow, under the brain. These particulars have been represented in this manner, to make them the more intelligible.
- d* The stomach, with its wrinkled foldings, and pulmonary tubes.
- e* Oblong furrows in the stomach.
- f* An open tube, appearing through the transparent coats of the stomach, within which it is fastened.

*g* The

- g* The small gut, forming six foldings.
- b* A little gut, within the former, where it likewise makes a variety of folds.
- i i* The curled windings of the said little intestine.
- k* The dilatation of the small guts, and places where it produces four blind guts, that spring from a common trunk.
- l* Places where the thick guts unite with the small guts.
- m m* Some globular dilatations in one of the blind guts, and the wonderful divisions of its contents.
- n n* Surprising windings and folds of the blind guts.
- o* The place where two of the upper blind guts unite into one.
- p p* Windings of another, or the other upper blind gut.
- q q* Windings of the third.
- r* The blind extremity of this last.
- s s* Windings of the fourth blind gut.
- t* The blind annular extremity of this last.
- u* Dilatations of the colon, in form of nodules.
- x* The larger dilatation of the colon.
- y* The two smallest dilatations of the colon.
- z* The anus, below the straight gut.

F I G. VII.

*The spinal marrow in the Nymph and Fly.*

- 1 2 3, &c.* Eleven nodules of the spinal marrow, now extended at full length, and drawn out one from another.
- a* The brain; and above it a rough draught of the tunicae corneae of the eyes, and their hexagonal divisions.
- b* The first nodule of the spinal marrow, retaining its primitive situation.
- c* The four following nodules, which now form a considerable knot or swelling, at the same time that the sixth, seventh, and eighth are separated one from another, and the spinal marrow between them is drawn out.
- d* The three last nodules, continuing in their former situation.

T A B. XLII.

F I G. I.

*The external skin shed by the Gadfly, with the manner of its shedding it.*

- 1 2 3, &c.* These numbers, placed in opposite ranks, shew the twelve rings of the Fly, or Worm's skin.
- a* The third and fourth rings: it is in this place that motion is first perceived in the Worm's skin, when the Fly is about to break forth. And for this reason these rings burst open in a longitudinal direction.
- b* The third fore ring, or, counting from the tail, the tenth, which bursts open in a contrary direction into two parts, one of which

- continues fastened to the second, and the other to the fourth ring.
- c* The fourth ring opens almost in the same manner, only that it cleaves more in the middle.

F I G. II.

*A general view of the external limbs and parts of the Gadfly.*

- a* Its two antennæ, or horns.
- b b b b* The six feet, and their joints.
- c c* The wings.      *d* The abdomen.

F I G. III.

*A dissection of the Gadfly. The external skin and internal coat shed by the Gadfly.*

- 1 2 3, &c.* Rings of the external skin.
- a a* Pulmonary tubes, rolled off, in the second, third, and fourth rings.
- b b* The curled extremities of the tubes.
- c* An intestine, shed likewise by this insect, containing some transparent particles like sand, which ferment with acids.
- d* The cast legs, snout, and eyes.
- e* The cast skull.
- f* Coats or skins, shed by the gullet and the stomach.
- g g* The cast internal coat, which immediately enclosed all the limbs of the Nymph.
- b* The place where the coat contained the Fly's tail.
- i i* Pulmonary tubes cast off within the delicate little skin.
- k* The largest of these tubes, with its ramifications.

F I G. IV.

*A rough draft of the manner in which the Intestine sheds its skin.*

- a* The internal coat of the intestine *b*. This intestine comes away full of grains of sand.
- b* The intestine itself, remaining in the body.
- c* The anus, with the internal coat of the intestine *b*, shed by the insect, still fastened to it.

F I G. V.

*The proboscis magnified.*

- a* The two fore parts of the proboscis, of an oval form.
- b* Hairs growing from the skin of the proboscis.
- c c* Two articulated bristles, or appendages of the proboscis, springing from within its root.
- d* A triangular horny bone, surrounding the root of the proboscis.
- e* Another little bone like the last in substance, but of a different form.

F I G.

FIG. VI.

*Some of the pulmonary vesicles.*

- a* Its membranaceous part, which was full of air.
- b* The pulmonary tube, through which the air passes to the vesicle.
- c* Two lateral pulmonary tubes.

FIG. VII.

*The genital parts of the male.*

- a* The penis and its two appendages.
- b b* Two twisted horny bones belonging to the penis; and articulated with the sheath, through which the penis erects itself.
- c* The flexible part of the penis.
- d d* Two little black horny bones, forming a border round the extreme ring of the abdomen; and articulated with the former bones.
- e e* Places where the articulations appear.
- f* The nervous body of the penis.
- g* A dilatation of the root of the penis, with which the vasa deferentia, and feminal vessels empty themselves.
- h h* The testicles. *i i* The feminal vessels.
- k k* Short tubulated feminal vessels, laid bare in one of the testicles.
- l* Vessels for the conveyance of the seed.
- m m* Windings of the feminal vesicles, the extreme ends of which are dilated.

FIG. VIII.

*The ovary of the female.*

- a a* The ovary consisting of two parts.
- b* The last rings of the abdomen.
- c c c* Some protuberances of a substance between bone and horn, appearing like spots on the last abdominal ring.
- d* Hairs growing in the same place.
- e e e* Eggs belonging to one side of the ovary, as yet in their natural situation.
- f* The same eggs a little more magnified, and removed out of their natural situation. The remaining part of this ovary is marked by dots.
- g* Pulmonary tubes interwoven with the ovary.
- h* Some branches of the said tubes dispersed both within and without the coats of the eggs.
- i i* The greatest extreme branches of the said tubes.
- k* Two ducts of the ovary, by which the eggs are let out of the body.
- l* Three beautiful unknown particles, each supported by its stalk,
- m* The point of the inflexion of these tubulated particles.
- n* Their tubes and windings.
- o* That end of the tubes which lies nearest to the duct of the ovary.

T A B. XLIII.

The History of the Acarus, or Mite.

FIG. I.

*The Acarus or Mite, of its natural size.*

FIG. II.

*A microscopical view of the Acarus.*

1 2 3 4 5 6 7 8 9 10 11 12 The twelve rings of the body.

- a* The head, in which are seen two nails belonging to the insect's legs, with which, when about to spring or leap up, it compresses its anus.
- b* The larynges or tops of the aspera arteria, projecting beyond the skin.
- c c* The place where there issue from the main transparent trunks of the aspera arteria, two branches, which unite by a mutual anastomosis, or inosculation with the branches of the fourth ring.
- d d d d d d d* The inosculation of the pulmonary tubes, which appear through the remaining rings of the body.
- e* A particle of the fat appearing through the skin.
- f f* Some blind guts, appearing in the same manner.
- g* A considerable branch of the aspera arteria, which appears through the skin under the tenth ring, between the two principal branches of the trachea.
- h* A beautiful particle of fat, appearing under the eleventh ring, and near which may be discovered the two extremities of the branches of the trachea.

FIG. III.

*The manner in which the Worm bends itself into a circle, in order to prepare for leaping.*

FIG. IV.

*The manner in which the circular form changes to an oblong one; just as the Acarus is about to leap or spring.*

FIG. V.

*The feet, parts of the mouth, stomach, intestines, and some other viscera of the Acarus, as viewed with the microscope.*

- a a* The feet or teeth, and nails.
- b b* Origin of the horny bony parts of the mouth, and palate.
- c c* Four appendages of the said parts.
- d* Horny bones, which serve to keep all the parts in their proper situation.
- e* The dilatation of the gullet, which I call the ingluvies.
- f f* Four blind appendages under the ingluvies.

# I A Short Explanation of the TABLES.

- g g* The stomach, of a considerable length.  
*b b b* Ramifications of the aspera arteria, visible in the stomach.  
*i* Contents of the aspera arteria, appearing through its transparent coats.  
*k k* The origin of the blind guts, of which this insect has four.  
*l l* Two of the said guts, containing a yellowish green substance.  
*m* The two others, whose contents resembled a coagulated substance.  
*n* Pulmonary tubes, belonging to a blind gut, of the same kind.  
*o* The pylorus. *p p* The colon.  
*q* The straight gut. *r* The anus.  
*s s* Two particles of fat, and their divisions, with which one of the blind guts is interwoven.  
*t t* Two glandulous swellings, and channels of the salival duct, which runs along the gullet to the jaws in form of a slender tube.  
*v v* Two other swellings, with their channels and pulmonary tubes.  
*x x* Some particles of fat, and their divisions.  
*y y* Two other particles of the same kind, which shew themselves in the same place like appendages in the form of a chain.

## FIG. VI.

*Divisions of the particles of fat, magnified to a greater degree.*

- a a a* Seven divisions of the particles of fat, in which it is laid up in the form of oily, spherical particles.  
*b* The manner in which the pulmonary fistules pass through the cells that contain the fat.

## FIG. VII.

*The brain, spinal marrow, and nerves, bigger than nature.*

- a a* The right and left lobes of the brain.  
*b b* The nerves, issuing from the upper part of the brain.  
*c* The nodules, formed by the said nerves.  
*d d* Two fine nerves, issuing from the said nodules, and running to the muscles of the head and legs.  
*e e* Two pair of muscles sent by the spinal marrow to the muscles of the thorax.  
*f f* Two strong nerves, with their dilatations, administering to the muscles that serve to move the wings.  
*g g* A great many fine nerves distributed amongst the muscles, and viscera of the abdomen.  
*b b b* Ramifications of the said nerves.

## FIG. VIII.

*A side view of the spinal marrow and brain.*

- a* The brain.  
*b* The sinus of the spinal marrow.

- c* A cleft in the spinal marrow for the passage of the gullet.

## FIG. IX.

*Some of the muscles.*

- a d a* The oblique descending muscles with two bellies, of each of which, one of the tendons is inserted into the muscle itself.  
*b b* The broad transverse muscles.  
*c c* The The oblique ascending muscles.

## FIG. X.

*The Acarus, or Mite, contracted, in which condition I call it a Vermiform-Nymph.*

## FIG. XI.

*The same, bigger than nature.*

- a* The head and mouth.  
*b* The tail and its tubercles.

## FIG. XII.

*The concealed Nymph, extracted from the contracted or shrivelled skin of the Acarus.*

## FIG. XIII.

*The same Nymph, bigger than nature.*

- a* The two horns of the future fly.  
*b b* The eyes. *c* The proboscis.  
*d d* The first pair of legs. *e e* The second,  
*f f* The folded wings.  
*g g* The third pair of wings.  
*h* The rings of the body.

## FIG. XIV.

*Two flies issuing from the Acari, or Mites, of their natural size.*

## FIG. XV.

*A microscopical view of the male fly, produced by the Acarus or Mite.*

- a* The antennæ or horns.  
*b b* The first of legs, their joints, hair, and nails.  
*c c* The second pair. *d d* The third.  
*e e* The wings and little hammers placed under them.  
*f* The rings of the belly.

## FIG. XVI.

*The skins cast by the Acarus, bigger than nature.*

- a* The upper part of the torn skin, where the fly creeps out.  
*b* The lower part.

# A Short Explanation of the TABLES. li

## F I G. XVII.

*The genital parts of the male.*

- a* The horny part of the penis, curled in a surprising manner.
- b* The membranaceous part of the penis.
- c* The fore end of the penis, which is here represented as it receives the vulva of the female, instead of being received by it.
- d* The nervous root of the penis.
- e* The place where the root of the penis is dilated.
- ff* The testicles of a yellowish red.
- g g* The vasa differentia.
- h h* Spherical appendages of the vessels.
- i i* The seed bags.      *k k* The prostata.

## F I G. XVIII.

*The external parts of the uterus and vulva.*

- a a* The two last rings of the body.
- b b* The first joint of the extremity of the uterus, covered with hair, and furnished with two little black horny bones.
- c c* The second joint enclosed in the first. The extremity of this second joint is likewise of a substance between bone and horn.
- d* The third and last joint, formed of the said substance, and covered with hair. This joint is received by the penis.

## F I G. XIX.

*One of the sixty-four oviducts.*

- a* A perfect egg lying in the oviduct, of a white colour.
- b* Three imperfect eggs of a watery colour.

## T A B. XLIV.

Observations on the Vermicles, or little Worms, found in the tubercles of the leaves of Willows.

## F I G. I. II. and III.

*Tubercles of Willow leaves, the eggs, and Worms represented by six several figures.*

## F I G. I.

- a* The external side of the leaf.
- b b* The internal side.
- c c* The warts or tubercles, of an oval round.
- d* Others of an oblong form.
- e* Others full of wrinkles.
- f* Very small warts, which look rotten, as it were.
- g* Warts, or tubercles, growing on the greater or main nerves.
- h* Another on the extremity of the leaf
- i* Another growing on the nerve itself.
- k* Others, which rise on each side to an equal height, above the coats of the leaf.
- l* Some on the stalk of the leaf.

- m* Seven rudiments of tubercles exhibited on each side of the leaf.

## F I G. II.

- n* The egg, that is found in the rudiments of the tubercles.

## F I G. I.

- o* A tubercle with a cleft in it, through which the egg may be seen placed in the middle.

## F I G. II.

- p* An egg magnified, so as to shew the head and two eyes of the enclosed Worm, that appear through its transparent skin.

## F I G. I.

- q* The Bindweed Caterpillar, full grown.
- r* The small hole bored by it through the tubercle or wart.

## F I G. III.

*A microscopical view of the same Caterpillar.*

- s* The eyes.      *t t* The six fore feet.
- u* Six of the twelve middle feet.
- x* The two hinder feet, next the tail.

## F I G. I.

- y* The manner in which the Caterpillar thrusts its anus out of the hole, made by it in the tubercle, and thereby discharges its excrements.
- z z* Two rusty coloured spots of the Willow-leaf; one of them with a hole in it, within which may be seen the nerves of the leaf, and the excrements and head of another Worm, that lives in it. Fig. VIII. exhibits this Worm of natural size.

## F I G. IV. V. and VI.

*The Fly's web, and the Fly itself; likewise those parts of the Fly, with which it bores itself a passage through the tubercle or wart; in five figures.*

## F I G. IV.

- a* The oval web of the Fly.
- b* The Fly itself.

## F I G. V.

*The Fly seen through the microscope.*

- c* The antennæ or horns.
- d d* The black spots on the wings.
- e e* Six legs, their joints and two nails to each leg.

## F I G. VI.

*The parts with which the female bores the leaf.*

- ff* The last rings of the abdomen.
- g* An instrument like a saw.
- h h* Two pointed horny bones.

## F I G.

## F I G. IV.

*i* A little lid or cover, which the Flies at their first appearance thrust out of their web, as out of a little barrel.

## F I G. VII.

*A microscopical view of a very small insect, which rests on the external surface of the Willow tubercles or warts.*

## F I G. VIII.

*The little Worm found between the coats of Willow leaves, of its natural size. See Fig. I. let. z z.*

## F I G. IX.

*A microscopical view of the same Worm.*

- a* The head and two teeth.
- b b* Its broad thorax, and transparent pulmonary fibres.
- c c* The other rings of the body, which is covered with hair, and ends in a pretty sharp point.

## F I G. X.

*The Nymph, in which the Worm is afterward exhibited changed, a little magnified.*

## F I G. XI.

*The same Nymph more magnified.*

- a* Two crooked bristles on the head.
- b b* Its horns and antennæ.
- c c* The second and third pair of legs: The second is armed with two bristles.
- d d* Two sheaths to cover the wings.
- e e* The third pair of legs, and their bristles.
- f* The wings of the body, and the prickles and stings of the tail.

## F I G. XII.

*The Beetle produced by the said Nymph.*

## F I G. XIII.

*The same Beetle magnified.*

- a* Its reticulated eyes.
- b* Its snout or beak, of a substance between bone and horn.
- c c* Its antennæ or horns.
- d d d* Its six Feet, upon the least pair of which this insect makes it springs or leaps.
- e e* The sheaths of the wings.

## F I G. XIV.

*Rudiments of Willow leaves just beginning to shoot or bud.*

- a* Four of these young leaves, with their stalks and rough surfaces.
- b* Red Worms, generally found within the leaves.

## F I G. XV.

*A microscopical view of a Fly produced by one of the Worms.*

## F I G. XVI.

*A tubercle or wart growing in the Willow in form of a rose.*

- a* The tubercle and its stalk.
- b* A pyramidal cluster of leaves, within which the Worm lies.

## F I G. XVII.

*Representing in five figures all the changes of the Worm, and its tubercle.*

- c* The manner in which the leaves of the tubercle may be separated one by one.
- d* Part of the Worm's body, that lies in the middle of the cluster.
- e* A delicate membrane or web, more immediately enclosing the Worm.
- f* The Worm itself. *g* Its Nymph.
- b* The Fly to which the Nymph changes.

## F I G. XVIII.

*An Alder leaf with various Worms between its two coats.*

- a* The coat of an Alder leaf swelled into a tubercle, on account of the Worm that had made its bed under it.
- b b* The upper coat or skin removed, in order to shew on each side, how the other coat is contracted underneath into a small fold.
- c* The web enclosing a Chrysalis, dissected; and near it the excrements of the Worm formerly contained between the two coats of the leaf.
- d* Another Worm with six feet, found likewise between the coats of the Alder.
- e* A third species of Worms found in the same place, with the skin cast by it, and its excrements.
- f* Two oblong webs made in their cells by the said Worms.
- g* Part of the leaf, where the same Worm is found, when as yet very small.
- b* The same part, where the Worm has made itself more room.
- i* Another cell or nest like the former, but a great deal more spacious.

## F I G. XIX.

*A microscopical view of a Chrysalis found in its web within the coats of an Alder leaf.*

- a* The sharp pointed head of this Chrysalis.
- b* The hinder part of its body, formed like a pear.



- c c* Fine hairs growing on its body.
- d d* Its eyes. *e* Its proboscis.
- f f* Its first and second pair of legs.
- g g g g* Its antennæ or horns. *h h* Its wings.
- i* The last pair of legs lying between the antennæ.
- k k* The rings of the body.

FIG. XX.

*The Butterfly produced from the foregoing Chrysalis, drawn after nature.*

FIG. XXI.

*A microscopical View of the same Butterfly.*

- a a* The antennæ. *b* The proboscis.
- c c* The upper pair of wings, beautifully coloured.
- d d* The lower pair of wings, for the most part covered with feathers.
- e e* Three white hairs, like thorns, growing on the hinder legs.

T A B. XLV.

A short explanation of the figures serving to illustrate some of the foregoing histories.

FIG. I.

*The manner in which the Fly lays its eggs, within the leaves of the common Thistle; which eggs afterwards produce Worms.*

FIG. II. III. IV. and V.

*The Tubercles or Warts of the stinging Nettle, with the Worms and Nymphs found in them, and the Flies produced by the said Nymphs, in four Figures.*

FIG. II.

- a* Some excrescencies growing on the stalk.
- b* Some tubercles or warts of the same kind, on the nerve of the leaf, and on the rudiments of the young leaves.
- c* Others growing irregularly on the leaf.

FIG. III.

- d* The Worm found in the tubercles of the Nettle, of its natural Size.
- e* A microscopical View of the same, somewhat broader in the middle.
- f* A fine or slender snout projecting from its extremity.
- g* Fine hairs growing on its body.

FIG. IV.

- b* The Nymph magnified to a greater size, with very large eyes in its head. Here are

likewise to be seen its horns, legs, wings and abdominal rings.

- i* Its little tail bent backwards.

FIG. V.

- k* The Male Fly of its natural size.

FIG. VI. VII. and VIII.

*The downy excrescencies growing upon Oak trees, with little hollow bags or tubes, and the Flies engendered and living in them.*

FIG. VI.

- a a a* The circumference of the downy ball or globe, after its natural condition.
- b* The stalk supporting it.
- c* An Oak leaf growing out of the middle of the ball.

FIG. VII.

- d* Bags or tubes, within which the Worms turn into Flies, and in whose circumference the downy hairs of the ball are principally rooted.

FIG. VI.

- e e* Little holes, which the Flies gnaw in the downy substance in order to escape out of their cells.

FIG. VIII.

- f* The Fly itself of its natural size.

FIG. IX. X. and XI.

*The spongy tubercle of the wild Rose: The same laid open in the middle: Lastly, the Flies bred in it.*

FIG. IX.

- a a* Knobs and inequalities of the tubercles.
- b* The stalk supporting it.

FIG. X.

- c* A section thro' the middle of the said tubercle, shewing the cells in which the Worms grow to be Flies.

FIG. XI.

- d* The first species of Fly that issued from the said tubercles, with a pretty thick body.
- e* The other species of the bifeta, or two haired kind.

FIG. IX.

- f* Round holes knawed by the Flies in the spongy tubercle, in order to get out of their cells.

## FIG. XII. XIII. XIV. XV. and XX.

*The tubercles or warts growing on Oak leaves: One of them opened: The kidneybean-like substance found in them: A tubercle cut off from the leaf: A microscopical view of the bean-like substance: The manner in which the tubercle dries up or withers.*

## FIG. XII.

- a a* Excrescencies found on the fore end of the leaf, and likewise a little higher up, on the leaf's nerve or main rib.
- b* Two tubercles; one of them a double one, growing still a little higher up on the nerve or main rib; the other almost on the edge of the leaf.
- c c* Some tubercles on the extremities of the leaf.

## FIG. XIII.

*Containing five drawings.*

- d* The upper part of one of the tubercles cut off.
- e* Three distinct excrescencies like kidney-beans, found in the hollow of the tubercle.
- f* Three excrescencies like beans, taken out of the hollow cell or cavity.

## FIG. XIV.

*A tubercle or wart of the same kind cut open, and exhibiting two kidney-like beans lying in it, in the same manner that a preserved almond lies within its candied covering, without any intermediate vacancy. This is a microscopical view, shewing the objects a little larger than nature.*

## FIG. XV.

- g* The bean-like substance, with an uneven surface.
- b* That part of the bean, by which it principally adhered to its tubercle, and received its nourishment.

## FIG. XX.

- z z* The manner in which the tubercle begins to lessen, and wither up by degrees, so as to become fit for the impression of the Fly's teeth, and thereby afford it an opportunity of escaping.

## FIG. XII.

- k* A small round hole, gnawed by the Worm in the withered part of the tubercle, and thro' which it issues into the open air.
- ll* Places where the tubercles dry up, and which may be seen without cutting it.
- m* The Worm cut out of its bean-like part, and represented of a size bigger than nature, on an Oak leaf.

## FIG. XVI.

*The same Worm still more magnified, and of the form in which it appears, when about to enter the Nymph state.*

## FIG. XVII.

*The same Worm changed into a Nymph, and viewed with a greater magnifier in order to see its limbs more conveniently.*

- a a* Its eyes, resembling a net.
- b b* The antennæ lying between the legs and the wings.
- c* The abdominal wings.

## FIG. XVIII.

*The same Nymph, changed to a Fly, of its natural size.*

## FIG. XIX.

*The same magnified.*

- a a* The antennæ placed before the eyes.
- b b* The four wings.
- c c* The least pair of its six legs, every one of which is armed with two nails.
- d* The sharp extremity of the abdomen, with which the Fly bores holes in the Oak leaf for the reception of its eggs.

## FIG. XXI.

*Representing, in two drawings, the excrescence growing on the leaves of the black Poplar, with the Worms and their food contained therein.*

- a* A wrinkled excrescence in the external coat of the leaf.
- b* The principal rib of the leaf.
- c* The internal side of the leaf, where the wart or tubercle opens into a slit or opening.
- d d* Windings of the principal nerve or rib, in the external coat of the leaf.

## FIG. XXII.

*A microscopical view of one of these very minute Worms, that is furnished with two horns, two eyes, and six feet; and is moreover divided into head, thorax, and abdomen.*

- e* A woolly or downy substance, which these little insects very beautifully wear on the hinder part of their bodies.

## FIG. XXIII.

- f* The insects glutinous food, contained within the woolly or downy substance, and resembling a vessel with a spout used to feed infants.
- g* The manner in which the downy substance curls up, when its moisture is consumed.

FIG.

FIG. XXIV.

*bb* Two pair of cups or membranaceous buds, in which the wings grow, and are enclosed as it were in little bags.

FIG. XXV.

*A microscopical view of the same Worm changed into a Fly with four wings.*

FIG. XXVI.

*The footless Worm, found on the leaves of the Cabbage, of its natural size.*

FIG. XXVII.

*The same Worm changed into a Nymph, represented lying on its belly, and of its natural size.*

FIG. XXVIII.

*A microscopical view of the same Nymph, and in the same posture, with its limbs as appearing through their transparent integuments.*

- aa* The eyes.
- b* The thorax and some of the hairs growing on it.
- ccc* The abdominal rings.
- d* One of the rings
- e* The curled, or folded, cast off skins, of a pulmonary tube.
- ff* Part of the Cabbage leaf, to which the Nymph glues itself by this membrane.

FIG. XXIX.

*A microscopical view of the same Nymph, divested of its cast skins, and placed on its back.*

- a* An eye, of one side. *b* The two horns.
- c* The proboscis. *dd* The folded wings.
- e* The hinder pair of legs.
- ff* The extremities of the genital, which lie, as it were, out of the abdomen.

FIG. XXX.

*The Fly of the said Nymph, of its natural size.*

FIG. XXXI.

*The cell, or nest of the Moth; the enclosed Worm of the Moth; the same extracted; likewise its Chrysalis and Butterfly; also the manner by which the skin of the Chrysalis remains fastened to the fore end of the cell or nest: Lastly, the very fine threads or filaments, with which the nest or cell is lined.*

- a* The cell, spacious in the middle, but narrower at each end.
- b* The thread formed by the Worm, and by means of which, to avoid falling, it hangs and fastens itself to the beams and walls of buildings.

- c* The manner in which the Worm of the Moth creeps out of its case or cell by the fore feet, and fastens itself with a thread of its own spinning, in some convenient situation.
- d* The Worm itself of its natural size, with sixteen feet.
- e* The same changed into a Chrysalis.
- f* The Chrysalis changed into a winged Butterfly or insect, called a Moth.
- g* The cast skins of the Chrysalis, projecting a little beyond the case.
- h* The internal surface of the case, very even and smooth.

FIG. XXXII.

*A small Worm found in musk-bags, and its changes.*

- a* The Worm. *b* Holes made by it in wood and paper.
- c* Its oval web. *d* Its Nymph.
- e* The Beetle produced by the said Nymph.

FIG. XXXIII.

*A Worm found upon leaves, in very black cases.*

- a* The manner in which the Worm carries its case about with it.
- b* The Fly produced by the said Worm.

FIG. XXXIV.

*Another species of a Worm, that carries its case or cell about with it.*

- c* The cell of a triangular form at its upper end.
- d* A nocturnal Butterfly or Moth, into which the said Worm changes.
- e* A Fly, into which another species of these Worms changes.
- f* A little Fly, into which the third part of the said Worms was changed. I found six or seven of these very minute Worms.

FIG. XXXV.

*A pyramidal cell, formed by a Caterpillar that inhabits it, and moves about with it. This cell or tube is composed of bits of wood, so as to resemble a piece of cheque or mosaic work.*

FIG. XXXVI.

*A tube or cell formed of sand by a Sea-Worm.*

T A B. XLVI.

The slow growths or accretions of the Frog, and Garden Clove-July-Flower, in which they resemble the insects.

*The figures on the left hand side exhibited.*

No. I. The Frog's egg, or the Worm of the Frog, within its first coat, or integument, resembling

- resembling a little globe or sphere, enclosed by another greater globe.
- a* The enclosed globe forming, as it were, the yolk of this egg.
- b b* The enclosing globe, resembling the white of the egg.
- II. The Worm of the Frog divested in a manner, of its first coat.
- c* The coat removed to the hinder part of the Frog's Worm.
- d* The Frog's Worm rolled out from under the said coat.
- e e e* Its food, like the white of an egg surrounding it.
- III. The Tadpole or Worm of the Frog grown bigger, and floating in the middle of its food.
- f f f* The food swimming, or floating in the water, like an expanded cloud.
- g* The head, breast, and abdomen, made up as it were in one globe or sphere.
- b* The tail.
- IV. The same Tadpole more grown, shewing its fore legs, which encrease by degrees as do likewise the hinder legs, but still under the skin.
- i i* The fore legs growing out by degrees.
- V. The Nymph of the Frog, or the Tadpole sufficiently grown, and in a condition to become a Frog, as all the limbs of the Frog have acquired in it their due perfection, so that to appear in the form of a Frog, it need only cast its external skin.
- k k* The fore legs, which by degrees have acquired their perfection under the skin.
- l l* The hinder legs, which are likewise perfect, and project beyond the skin.
- VI. The Frog itself, arrived at length at the state of a perfect animal, after passing through the various forms, of egg, Worm, and Nymph. It is not however, like insects, immediately fit for generation, but must wait some years to attain that degree of perfection.
- m m* Two vesicles growing near the eyes of this Frog, which shew it to be a male one.

*The figures on the right hand represented.*

- No. The garden Clove-July-Flower in its first coat, in which state it is called seed.
- A.* A microscopical view of the seed itself, in which may be seen the cicatrix or scar of the naval string, by which it was fastened to the ovary, and received its nourishment.
- II. The coat cast off by the said seed.
- B.* The seed itself, that lay enclosed within the said coat, of its natural size.
- C.* The same seed stripped of its coat, and magnified, so as to shew its little points and bivalved partition cleft, which divides the rest of the body into two parts,
- III. The younggerme of the Clove-July-Flower.
- IV. The same germe unfolded into leaves.
- V. The case, or as it were the gem or bud of the Clove-July-Flower, which may be considered as the real Nymph of the vegetable.

- VI. The Clove-July-Flower itself broken from its gem or bud, and in a condition to produce seed.

## T A B. XLVII.

## F I G. I.

*The genitals of the male Frog, viewed with the microscope.*

- a a* The testicles. *b b b b* The loins.
- c* Some of the appendages of the testicles, consisting of oily or fatty bags.
- d* A single appendage of the same kind.
- e* Others divided into two branches.
- f* Blood vessels on the surface of the testicle.
- g g* Globular heads or ends of the feminal testicular vessels
- b* Some testicular vessels, consisting of two parts.
- i i* Divided parastatae, or feminal vessels, by means of which the seed is forced from the testicles into the common vasa deferentia.
- k k* The manner in which these vessels run under the membrane that encloses the kidneys, and unite with the vas deferentia.
- l l l l* Vasa deferentia lying round the loins.
- m m* A rough draft of the arteries distributed through the kidneys.
- n n* Two singular and strange bodies seated at the kidneys, under the skin.
- o o* The place where the deferentia form on each side a single trunk.
- p p* Seminal vessels, or seed bags.
- q q* The straight gut, into which the vasa deferentia and feminal vesicles discharge themselves.
- r* The orifice, or end of the said parts.
- s s* The urinary bladder divided into two parts.

## F I G. II.

*All the foregoing parts, of their natural size.*

## F I G. III.

*One of the ovaries, of its natural size.*

- a a* Divisions, or natural ends of the ovary.
- b* A brass tube introduced into one of the little lobules of the ovary, in order to blow it up.
- c c* Eggs appearing through the membranes composing the ovary.
- d* One of the lobules of the ovary laid open, so as to afford a distinct view of the enclosed eggs.

## F I G. IV.

*The heart, liver, lungs, tubes, uterus, &c. in an impregnated female Frog.*

- a* The skin with the sternum and its cartilage drawn back over the head, and fastened with a needle in that situation.
- b* The cavity, or hollow of the membranes, containing the heart, and formed under the breast

breast bone by the concretion of the peritoneum, and the ligament by which the liver is suspended.

- c c* Natural openings of the tubes, growing against the membranes already taken notice of, which extend over the heart, and its pericardium.
- d d* That part of the tube which makes a great many beautiful windings and foldings.
- e* The blood vessels of the tubes.
- f f* The extremities of the tubes, near or about the sides of the uterus.
- g g* The uterus, consisting of two parts.
- b* The straight gut in its natural situation.
- i* The urinary bladder, consisting of two parts, in its natural situation.
- k* The contracted ovary, in which there still remains one perfect egg.
- l* Part of the left kidney, upon which the ovary lies, and at whose side lies the vein of the kidney.  
Appendages of the ovary supplying it with oil.
- n* Two eggs floating freely in the belly, near the tubes
- o* An egg in the tube itself.
- p* The stomach contracted, in its natural situation.
- q* One of the tubes of the liver.
- r* The gall bladder.
- s s* The lungs; the left one contracted.
- t t* The auricle of the heart.
- u u u* Parts of the thorax and abdomen cut off.

F I G. V.

*The manner of finding the eggs dispersed in the Frog's belly, when in their passage through the tube into the uterus.*

- a* Some little eggs in the ovary.
- b b b* Some eggs, scattered up and down the belly.
- c* Six eggs close to the tube's mouth.
- d d d* Eggs in the tubes.
- e* An egg in the tube, near its mouth.
- f f* Some eggs, pressing through the extremities of the tubes, into the uterus.
- g* The manner in which the eggs appear faintly through the uterus.
- b* The manner in which the eggs appear distinctly through the uterus, after it has been for some time exposed to the open air.
- i* The extremity of the double uterus, which opens into the straight gut, about an inch from the place where the tubes empty themselves into the uterus.
- k* The origin or beginning of the great artery, with the auricle and heart.
- l l* Natural openings of the tubes.
- m m* The lungs in their natural situation, in part covering the tubes.

F I G. VI.

*A microscopical view of the fore legs or arms of the male Frog.*

- a* The thick thumb.
- b* Black papillæ, with which it is covered.

T A B. XLVIII.

F I G. I. and II.

*The manner in which the Frogs copulate.*

- a a* The manner in which the male embraces the female, with his arms, and as it were folds his fingers between one another.
- b b* The manner in which the head of the male, lies over the head and between the eyes of the female.
- c c* The drum of the ear, covered only with the external skin.
- d* The manner in which the female ejects her eggs.
- e* The manner in which the male pours out its seed upon them.
- f* The manner in which the eggs flow together in a circular form.

F I G. III.

*A microscopical view of the ovary and its appendages.*

- a a* Some eggs,      *b* Larger eggs.
- c d* Eggs becoming imperceptible by degrees.
- e* Blood vessels interwoven with the eggs
- f* A perfect egg, about to disappear in the same manner

F I G. IV.

*A cluster of eggs magnified.*

- a a a* Hollow membranes, or little membranes full of cavities, in which the eggs lie.
- b b* Blood vessels belonging to the said cluster.
- c c* The main trunk of the blood vessels.

No. 1. to 10.

*The slow increase or growth of the eggs.*

- 1 A Frog's egg newly deposited.
- 2 Another, a day old.
- 3 Another, two days old.
- 4 Another, three days old, as expressed in four different drawings.
- 5 Another four days old.
- 6 The fœtus of the Frog, as it appeared the next day.
- 10 The same viewed on the tenth day from the laying of the egg.

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FIG. V.

*A microscopical view of the fœtus of the Frog in an egg newly deposited, and divested of its white.*

- a a* A furrow in the middle of the Frog's body.
- b b* Remains, or rather rudiment, of a yellow spot, which appears in the skin of these creatures, even before they are hatched.

FIG. VI.

*The same fœtus broken into two parts.*

- a* A protuberance in form of a crescent, visible on the internal surface of one of the sides; in this place the furrow penetrates to a considerable depth.
- b* A little hole or cavity in form of a crescent, serving to receive the foregoing protuberance.
- c c* The place where the furrow is very shallow.
- d d* The surface of the fraction, shewing the Frog's body to consist of globular, or spherical grains or particles.

FIG. VII.

*A microscopical view of the young Frog, within its chorion and amnion.*

- a* A side view of the Allantoies, with the chorion and amnion which entirely enclose the fœtus.
- b* The furrows already taken notice of.
- c* Superficial clefts of the yellow spot, observable in the Frog's egg.

FIG. VIII.

*The same parts, but in another situation.*

- a* The coat, called the allantoies dilated.

FIG. IX.

*Another representation of the same parts.*

- a* The allantoies or coat, stretched out into the shape of a pear.

FIG. X.

*The same parts again, with the foregoing coat extended to its greatest size and bulk.*

FIG. XI.

*The fœtus of the Frog, as it appears fourteen days after the laying of the egg.*

FIG. XII.

*A microscopical view of the same fœtus.*

- a a* The eyes. *b* Its wide mouth.
- c c* Fimbriated appendages, which in process of time are taken in by the body, where they constitute the gills.

*d* The extremity of the extius of the intestine, which forms some windings and protuberances in the belly.

*e e* The tail, of a fleshy substance in the middle, but membranaceous at the edges.

*f* The extremity of the muscular and cartilaginous part of the tail.

FIG. XIII.

*The fœtus of a Frog, thirty-six days after the laying of the egg, exhibiting very distinctly its head, two hinder legs and tail.*

*a* The aperture or opening of the mouth.

*b* The hinder legs and tail.

T A B. XLIX.

FIG. I.

*The fœtus of the Frog represented by Fig. XIII. of the last Table, dissected, and viewed with a microscope.*

*a a* The lower jaw-bone, of a black horny substance, and furnished with teeth.

*b* The upper jaw-bone.

*c c* White papillæ surrounding the mouth.

*d d* A portion of the protuberant eyes.

*e e* Four rows of gills on each side.

*f f* The lungs, one of which is inflated, the other collapsed.

*g* The heart. *b* Its auricle.

*i* The liver and vena cava.

*k* The gullet. *l* The gall bladder.

*m* The winding of the gullet about the liver.

*n* Part of the mesentery, with its blood vessels.

*o* The stomach in the beginning of its growth.

*p* The pancreas in its natural situation.

*q* The small gut.

*r r* Very beautiful double foldings of the intestines.

*s* The straight gut. *t* The podex.

*u u* The two hinder legs, which grow beyond, or on the outside of the body.

*x x* The fore legs, which lay hid under the skin. *y y y* Muscles of the tail.

*z z* The membranaceous skin of the tail.

FIG. II.

*The manner in which the Tadpole casts its skin.*

*a* The small opening of the mouth, in the skin cast by the Tadpole.

*b* The wide mouth of the Frog.

*c c* The two fore legs, which heretofore lay hid in the breast, under the skin, now divested of it. See Tab. XLVI. No. V. letters *k k*.

*d d* The two hinder legs on the point of dropping their skins.

*e e* Pulmonary vesicles, which nature has bestowed on the male only.

*f f* Two

*ff* Two thick thumbs, proper likewise to the male.

FIG. III.

*The Frog's arteries.*

- a* The heart.
- b* The auricle, over which lies the origin of the great artery that issues from the Frog's heart.
- c* One of the two main trunks of the great artery, which is like the subclavian vein, and runs towards the right side of the thorax.
- d* The other main ascending trunk, running to the left side.
- ee* Arteries of the lungs, which they only serve to nourish. I have here exhibited three branches of them, cut off.
- ff* Two minute arteries, issuing from the lungs, and running towards the parts of the mouth.
- gg* Two arteries, each of which swells into two knots.
- bb* Two very considerable branches of the arteries, which arise from the ascending trunks of the great artery, then take a circular turn, and at length unite in the loins.
- ii* The axillary arteries.
- kk* The carotide arteries.
- ll* The arteries of the vertebræ.
- m* That of the mesentery.
- nn* That of the loins.
- oo* Those of the testicles, and ovary.
- p* Those of the kidneys.
- qq* The iliac branches.

FIG. IV.

*Veins of the Frog.*

- aa* The upper trunks of the vena cava.
- b* The place where the arteries are cut away.
- cc* The place where the pulmonary veins are likewise cut away.
- dd* Veins running to the parts of the mouth.
- ee* Others running to the head.
- ff* Two veins, running to the muscles of the fore legs.
- gg* Axillary veins.
- bb* Two considerable branches, which run into the ilia under the skin.
- ii* The trunk of the vena cava, on the back.
- kk* The vena cava in the liver.
- l* The vein of the mesentery.
- m* The emulgent or kidney veins.
- nn* The iliac.
- oo* The epigastric vein, running double at its origin.

FIG. V.

*The motion of the muscles in a Frog.*

- aa* Two tendons of a muscle, held by the fingers.
- b* The dependent nerve of it, irritated; by means of which the muscle contracts itself,

and so draws towards itself, the two hands holding the tendons.

FIG. VI.

*The manner in which the thickness of the muscle increases, during the contraction of the muscle.*

- a* A glass tube, through which the muscle is passed.
- bb* Two pins run through the tendons of the muscles.
- c* The irritated nerve, by which it comes to pass that the pins *bb* are forced from their places towards *dd*, and that
- e* The muscle, in consequence of its contraction, fills the middle of the tube.

FIG. VII.

*The manner in which the heart, during its contractions takes up less room, and lessens in bulk.*

- a* The heart, contracting itself within a syphon or glass tube, upon whose piston it lies.
- bb* A glass tube.
- c* A drop of water, adhering to the inside of the tube, which drop descends while the heart contracts itself.
- d* The part of the tube, shewing how low the drop of water *c* falls at that time.

FIG. VIII.

*The manner in which the muscle, at the time of its contraction, comes to occupy a smaller space.*

- a* The glass tube, or syphon
- b* The muscle.
- c* A silver wire with a ring in it, through which the nerve passes.
- d* A brass wire, with a ring on the upper end of it, through which the silver wire passes.
- e* A drop of water in the glass tube.
- f* The hand that irritates the nerve, in consequence of which irritation the drop on the muscle, contracting itself, descends a little.

FIG. IX.

*The same experiment, shewn after another manner.*

- a* The glass tube.
- b* A little hole bored in the tube.
- c* The nerve stretched through the said hole.

T A B. L.

*The history of the Cuttle-Fish.*

FIG. I.

*The external parts or limbs of the Cuttle-Fish, laid*

# lx A Short Explanation of the TABLES

*laid flat on its belly, somewhat less than nature.*

- a a* The two thickest and broadest of the Cuttle-Fish's eight legs.
- b* White furrows on the purple ground or skin of the legs.
- c c c* The acetabula, or hollows like saucers, with their stalks, pediments or muscles, of which there is a surprising number distributed all over the eight legs.
- d d* Origins of the arms of the creature, in their natural situation.
- f f f* The loose membranaceous and muscular skin of the eight legs, with which skin the acetabula are covered, when the Cuttle-Fish fastens itself to any place.
- g g* Places of the legs where the acetabula are very small, but have notwithstanding the benefit of the skin.
- b b* A more distinct view of the said muscular skin near the extremities of the arms; and likewise of the manner in which it serves to cover the acetabula.
- i* The Fish's snout, or beak, formed like that of a Parrot.
- k* Flesh, which surrounds the snout or beak, like lips or gums.
- l l* The eyes, of an extraordinary size.
- m m* The transparent cover of the eyes, or eye-lids.
- n* The prominent point of the back.
- o o o o* The soft and muscular part of the Cuttle-Fish, on each side of its back.
- p* The place, lower down, where it is divided into a right and left side.

## FIG. II.

*The construction of the acetabula, the muscles and rings of their natural size.*

- 1 A muscle in the centre of the acetabulum, as likewise the manner in which this part is entirely composed of muscular fibres. On the upper part may be seen the black edge of of a horny bone, in form of a ring, of considerable service in the construction of this organ.
- 2 The internal cavity of the acetabulum, its fibrous and muscular structure, as likewise the black edge of the ring, just now mentioned. Lower down is to be seen that part of the muscle, which serves to dilate the acetabulum.
- 3 The ring, already exhibited by its self, placed on its side.
- 4 A front view of the said ring.
- 5 Part of the said ring cut off.

## FIG. III.

*The construction of the snout or beak, of its natural size.*

- a a* The wings of a horny bone, composing the lower part of the beak or snout.

- b b* The place where the beak or snout is bent upon itself, so as to acquire both firmness and thickness.
- c* The place where the said bent back part of the snout or beak turns, and runs forward again, and forms a hollow cavity.
- d* The upper part of the snout or beak, which differs very little from the lower in point of construction or shape.
- e e* Its internal hollow, containing the tongue.

## FIG. IV.

*The tongue, and salival ducts, of their natural size.*

- a* A natural bending, or inflection about the cartilaginous bones of the tongue.
- b* The muscular flesh of the tongue, of a spongy or fungous substance.
- c* The mouth of the salival duct, in the muscular part of the tongue.
- d* The salival duct itself.
- e e* Two glands, from which the salival duct takes its origin.
- f f* Some of the muscles belonging to the tongue.

## FIG. V.

*The tongue by itself, of its natural size.*

- a* The unequal membrane of the tongue.
- b* Seven cartilaginous bones of the tongue, separated from each other at their extremities.

## FIG. VI.

*A microscopical view of part of the cartilaginous bones of the tongue.*

- a* Cartilaginous papillæ, situated on the said bones.

## FIG. VII.

*A microscopical view of the tongue, inverted.*

- a a* Part of the root of the tongue, where its bones appear through the microscope, in form of a regular piece of net-work.

## T A B. LI.

### FIG. I.

*The internal parts of the Cuttle-Fish, that may be seen, without any dissection, by just removing the loose muscular covering of the belly.*

- a a* The muscular covering of the breast and belly, cut off.
- b b* The place on the declivity of the belly, where the said muscular flesh was cut off.
- c* The place near the tail, treated in the same manner.

*d* The



- d* The lower part of the common excretory bag like an inverted funnel.
- e* The upper part of the said bag, narrower.
- f f* Two oval hollow parts, united to the excretory bag.
- g g* Two considerable prominencies or papillæ, adhering to the loose muscular part of the abdomen. These prominences fill up, while the creature lives, the hollow parts just now mentioned.
- h h* Two oblong and straight muscles, which serve to move the acetabula, that are, as it were, supported by them towards the papillæ, and draw them back again.
- i i* The gills, and their blood-vessels, situated at each side of the abdomen, and at a great distance asunder.
- k* Divisions of the blood-vessels in the lamellæ, or plates of the gills, extended on the inside to their roots.
- l l* The place where the lamellæ of the gills terminate in a ligament, which ligament might very easily be taken for a blood-vessel.
- m* The same more distinctly exhibited; as likewise a view of the divisions of the blood-vessels in the lamellæ of the gills.
- n* A transparent part, called *mutis*.
- o* The extremity of the straight gut, which floats in the abdomen, like a hollow tube.
- p* The transparent ink--bag, which likewise discharges itself into the abdomen.
- q q* Two tubular apertures, or openings, beneath the straight gut, and near it, by which the seminal matter is emitted.
- r* The place where there lie deeper, under the other parts, the vessels in which the seminal matter is prepared.
- s* The transparent stomach.
- t* A transparent particle, in form of a heart, belonging to the spermatic parts.
- u* The extremity of the vasa differentia of the testicle, floating likewise freely in the abdomen.
- x* The transparent testicle.
- y* Some arteries, which run to the muscular parts of the skin. Their fellows are to be seen on the other side of the body.
- z* Transparent nerves, which appear in great numbers through the skin, both there, and and at the other side.
- a* The muscular circle of the mouth.
- β β* The arms, cut off.
- γ γ* The order observed by the acetabula during the contraction of the muscles.
- δ δ* The internal construction of the broadest and largest of the eight legs.
- ε ε* The two eyes.

FIG. II.

*A very distinct view of the muscles of the smallest acetabula, in their natural situation and size, as they appear on the extremity of one of the arms, separated from the rest.*

- a* The construction and situation of the muscles of the acetabula.

- b* The manner in which the acetabula are united with their muscles.
- c d* The place where the muscles are shortest and smallest, being where the rows of acetabula begin and terminate.

FIG. III. and IV.

*The body, called mutis, a little less than nature.*

- a a* Its upper part, which is very thick, and may be divided on each side into two lobes.
- b b* Its obtuse appendages, in which the lower part of it terminates.
- c c* Two arteries, issuing from the great artery, and running to or supplying the right and left sides of the mutis.
- d* A membrane separated, and turned back from the mutis, in order to give a view of its internal vessels.
- e* The course of the vessels, exhibited apart.
- f f* A granulated substance, of which the mutis is principally composed.

FIG. V.

*The gullet, stomach, straight gut, pancreas, and excretory duct of the Ink.*

- a* The jaws.
- b b* Salival glands, in their natural situation. The gullet runs lightly over these glands, in its way from the jaws to the stomach.
- c* The stomach.
- d* The blood-vessels of the stomach.
- e* The straight gut.
- f* The pancreas, beautifully wound into a spiral form.
- g* The bladder, serving to force out the ink.
- h* The duct of the ink from the said organ to the extremity of the straight gut.
- i* The blood-vessels of the ink-bladder or bag.
- k k k* A glandulous body, whose use is not yet discovered.

FIG. VI.

*A piece of the Cuttle-Fish's bone.*

- a* A great number of little lamellæ or plates, composing the bone. The uppermost are the largest, and lie closest to each other.
- b* The hard crusty covering of this bone. The lamellæ or plates that are nearest to this crust are the shortest, and likewise at the greatest distance asunder, so as to afford a more satisfactory view of the little columns that support them, one above another.

FIG. VII.

*A microscopical view of two of the lamellæ, or plates, and their interjacent columns.*

- c* The beautiful order in which the columns are

- are placed between the testaceous shelly lamellæ or plates.
- d* The first or upper lamella or plate, in which appear the marks of the columns, broken away from it.
- e* The lower or second plate.
- f* Some transversal fibres of a shelly substance, which bind the columns together, and thereby add considerably to their firmness.

## F I G. VIII.

*Some of the plates, just now exhibited, removed from the columns that supported them.*

- g* Their hollow tubular construction, in consequence of which they must naturally contain a portion of air, and of course the bone can swim on the surface of the water.

## F I G. IX.

*The tail of the Cuttle-Fish's bone, drawn after nature.*

- b* A sharp point, thro' which the Cuttle-Fish's bone grows out.
- i i* The membranaceous parts on each side.
- k* The place where the piece of bone, under our consideration, was broken off from the rest of it, shewing some beautiful globular eminences, which first hardened into a stony bone above the rest of the surface.

## T A B. LII.

## F I G. I.

*The heart and arteries of the Cuttle-Fish, of their natural size.*

- a* The heart.
- b b* The double auricle of the heart.
- c c* Part of the largest blood-vessels belonging to the gills, from which the auricles are separated. *d* The great artery.
- e e* Its two branches, running to the body of the mutis, while others proceed further.
- f* Arteries extended to the base, or root of the brain, where they are afterwards distributed.
- g g* Two blood-vessels, issuing from a lower part of the heart. They are full of veins.

## F I G. II. III. and IV.

*The brain, nerves, and eyes, of their natural size.*

- a* The brain.
- b* Fat lying near the brain, represented by dots.
- c c* The optic nerves, whose origins are likewise invested with fat.
- d d* Knotty dilatations of the optic nerves.
- e e e e* Nerves sent in great numbers from the said nodules or knots to the eyes.

- f* A blood-vessel, that intersects the nerves running to the eyes.
- g* A great many little nervous fibres in the choroides of the eye.
- b* The place where the said coat converges a little more in form of a globe about the crystalline lens, and thereby forms the iris of the eye.
- i* A portion of the crystalline lens, projecting beyond the eye.

## F I G. III.

- k* The cover of the pupil, on that side where I cut it off from the eye.
- l* That side of the said cover, which floats freely in the aqueous humour.

## F I G. IV.

- m* The manner in which the crystalline lens is divided to a great depth by the ciliary ligament.

## F I G. II.

- i i 22 23* Three pair of nerves issuing from the brain, the middlemost of which is beautifully dilated into a nodule.
- n* All these nerves are distributed amongst the fore parts of the head.
- o o* Cartilages enclosing the brain.
- p p* Cartilaginous expansions, in which the muscles of the legs are placed, and in the middle of which the head and snout, or beak of the Cuttle-Fish, is placed.
- q q* Two strong nerves, which issue from the bottom or root of the brain on its hinder part.
- r r* Two nodules, which these nerves form in the breast, and from which great numbers of nerves run to the lower parts of the Cuttle-Fish's body.

## F I G. V. and VI.

*The testicle and its parts, of their natural dimensions, viewed on each side.*

- a* Some little white bodies, which I found hanging in this creature on the outside of the vas differens.
- b* The pointed extremity of the testicle.
- c* The corpus variciforme of the testicle.
- d* Its extremity, as far as I have as yet been able to trace it.
- e* The place where the parastatæ are most ample and spacious, as may be seen in the testicle, turned upon its other side.

## F I G. VI.

- f* Some other minute extracted from the testicles, which was full of them. These parts are all loose in the hinder part, without the least fastening.

*g* Some

- g* Some fine filaments, in which the said minute parts terminate on their fore ends, and by means of which they are there connected together.
- b* The manner in which a white substance, that curls itself in a serpentine form, issues from the said minute parts.

FIG. V.

- ii* The manner in which these white minute parts appear thro' the testicle, and wind themselves in a serpentine manner, while as yet enclosed in it.

FIG. VII.

*A microscopical view of one of these minute parts.*

- a* Its hinder part, loose and transparent.
- b* A white substance enclosed in the said part, and which is forced out of it by the water that penetrates it.
- c* Places where it is transparent at each end.
- d* Beautiful windings of the same on its fore extremity.
- ee* Its fine, delicate, or slender filament, which hardens in the open air like the Silk-Worm's thread.

FIG. VIII.

*Two pair of glandular bodies, belonging to the seminal vessels, of their natural Size.*

- aa* The first pair of these white bodies, cut off from the gills.
- bb* The second pair of glandular bodies of a gray colour, in other respects like the first pair, with which they are connected by means of two glandular tubes.
- cc* A glandular body situated between the two pair just described.
- dd* Some tender membranes, which bind together the said body and its lobules.

FIG. IX.

*A third particle belonging to the seminal vessels, of its natural size.*

- a* Its figure on the upper part, where it is pretty flat.
- b* Its figure on the lower part, where it is somewhat sharp, with a division in the middle, that gives it in some measure the resemblance of a heart.

FIG. X.

*The genitals of the female of their natural size:*

- a* The straight gut.
- b* The duct of the organ serving to press out the ink.
- c* The ink-bag itself.
- dd* The ovary.
- e* The duct by which the eggs are discharged.
- f* Three eggs. *gg* Two glandular bodies.
- b* A peculiar part containing a reddish humour.
- ii* The gills in their natural situation.

T A B. LIII.

The seeds of the Fern.

FIG. I.

*Part of a Fern leaf, with its tubercles.*

- aa* An indented or jagged leaf of the Male Fern of Dodoneus, resembling the feather of a bird.
- bb* Tubercles of a Fern leaf composed of some leaves, and a great many little pods which contain the real seed of the plant.

FIG. II.

*Five of the same kind of pods of their natural size, and viewed different ways.*

- ccc* Three pods with single stalks.
- d* One with a double Stalk.
- eee* The place where the stalk surrounds or girds the pod, as it were like a twisted cord in form of a crown.
- ff* The manner in which the pod swells beyond the said twisted cord on each side of it.
- g* A pod placed in the center of the surrounding cord; as likewise the place where the pod first begins to open.
- bb* The cord reduced to a straight line by some elastic power.
- iiii* The pod burst in two, so that the parts now considered in themselves form as it were four hollow cups.
- l* The membrane of the pod broke open, and turned back upon the coronal cord of the stalk that surrounded the pod, so as to afford a view of the enclosed seeds in their natural situation. But it is by great chance that a pod opened in this regular manner can be met with.

FIG. III.

*The seed.*

- k* Five out of forty-one seeds, that I found in one pod, magnified to a very great degree.

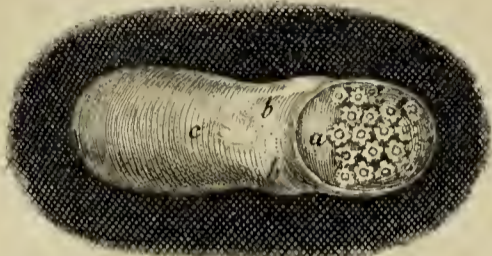
*The END of the Explanation of the TABLES.*



Order the First  
Nymph = Animal.

TAB. I.

Fig. I.



I

Fig. VII.

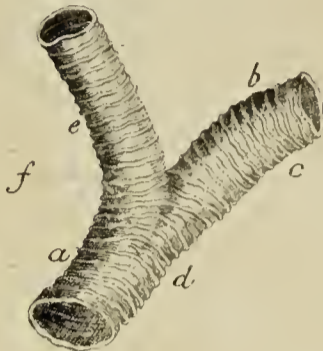


Fig. II.



II

Fig. VIII.

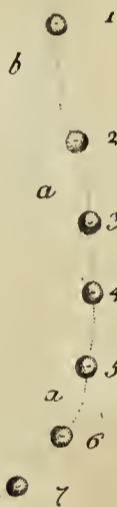
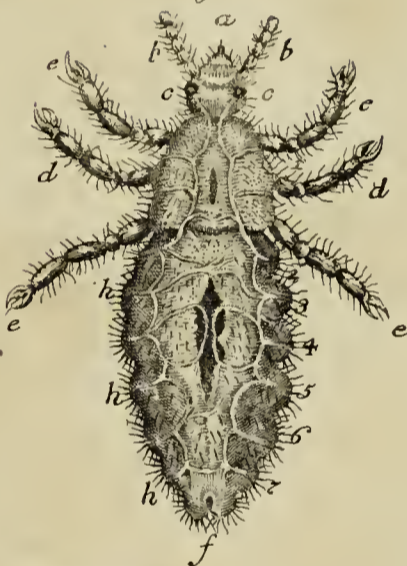


Fig. IV.



III

IV

Fig. III.

Fig. VI.

V

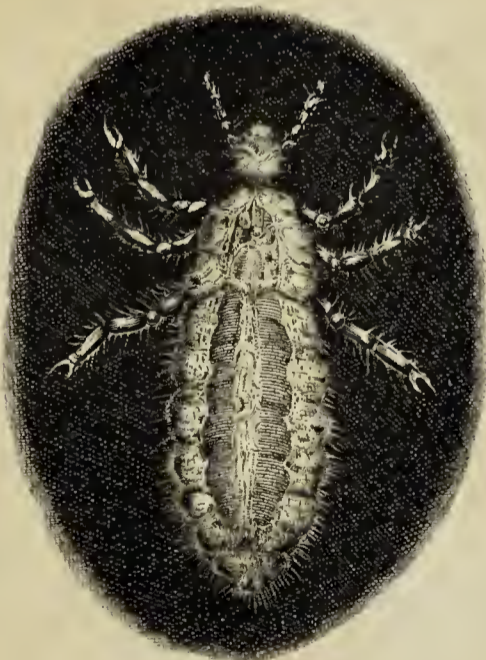
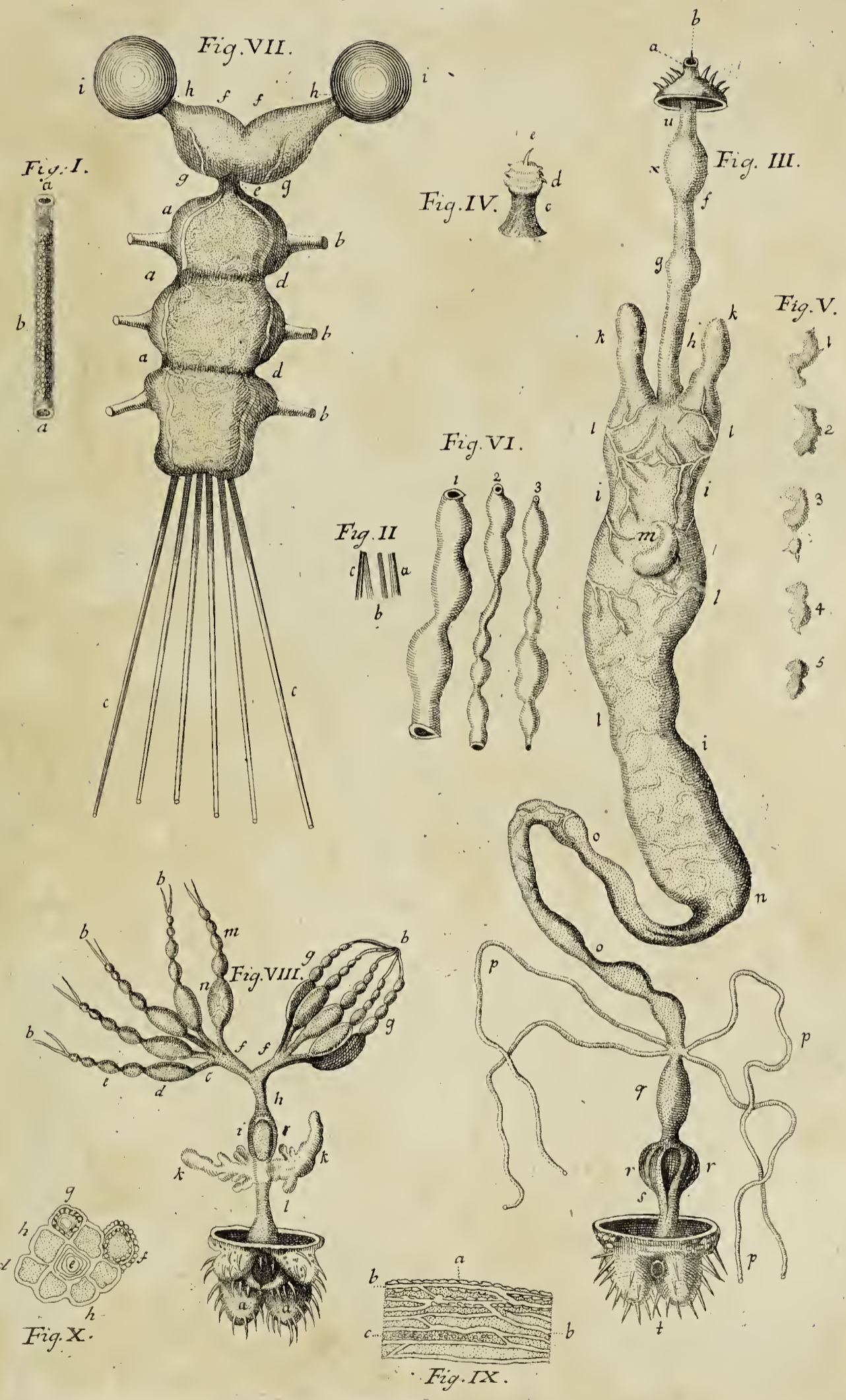


Fig. V.



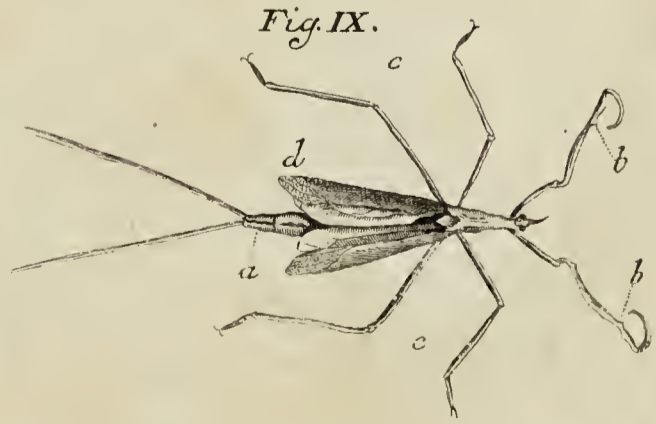
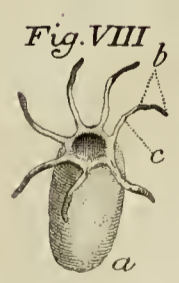
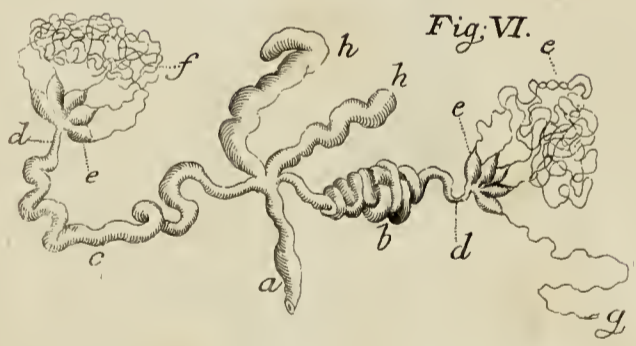
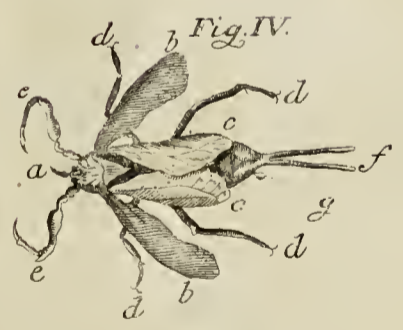
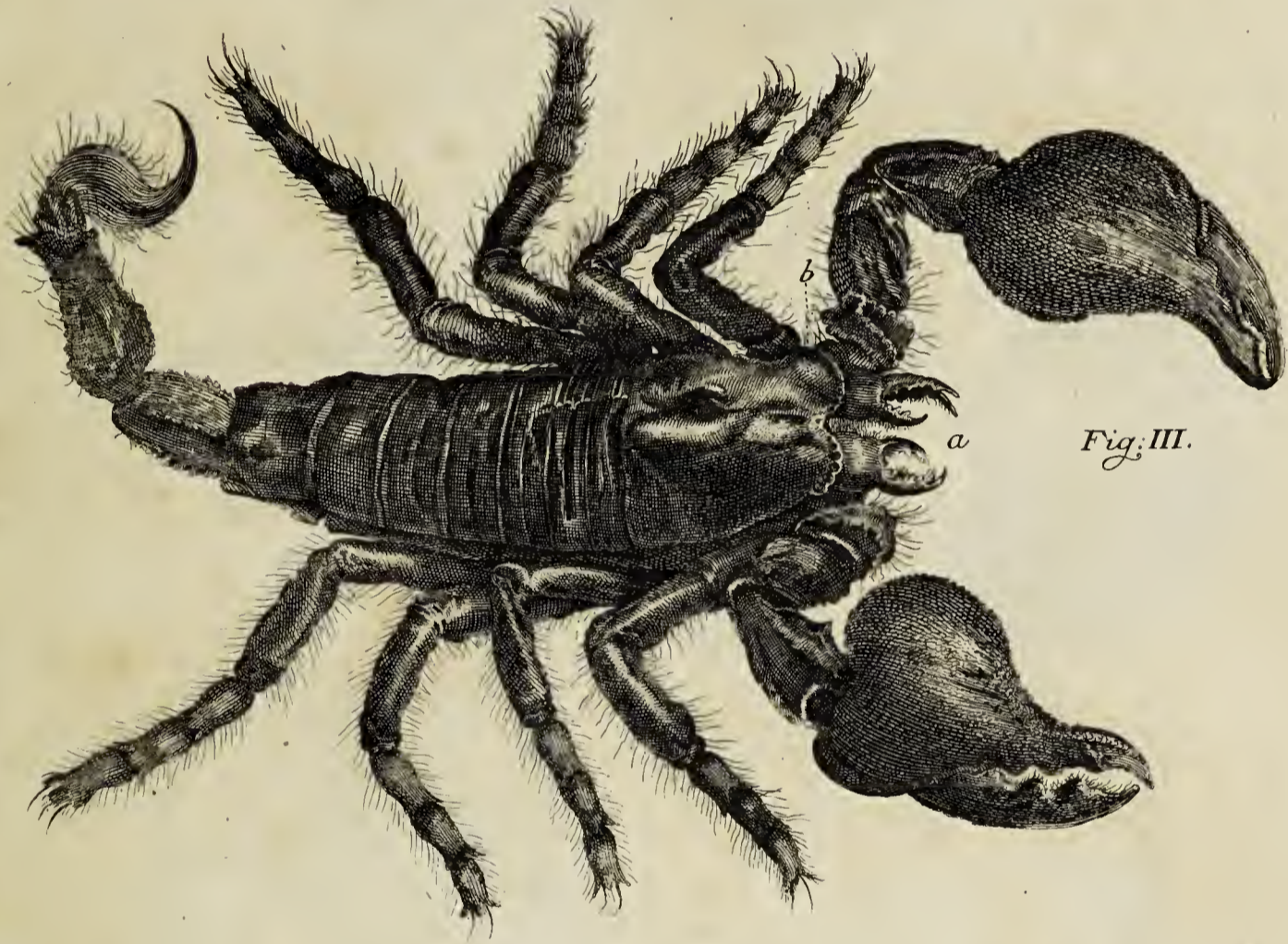
VI













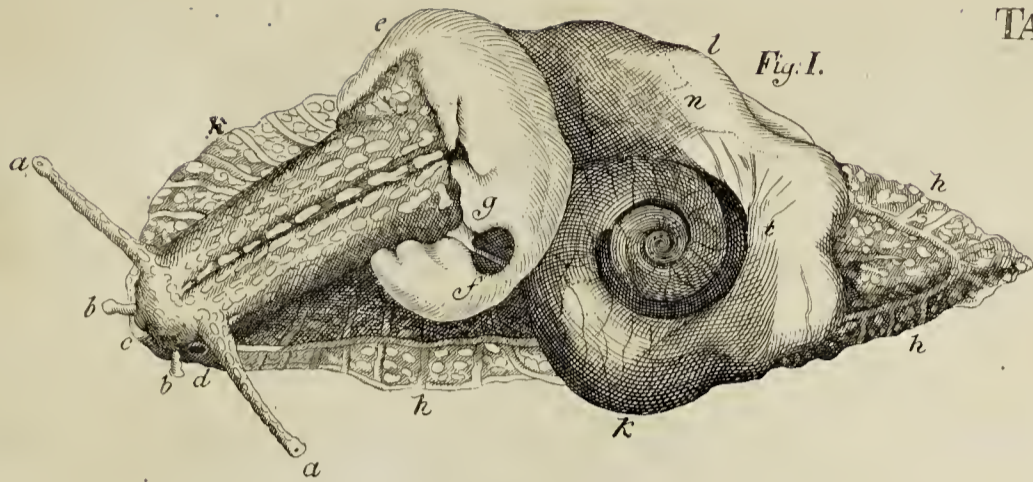


Fig. IV.

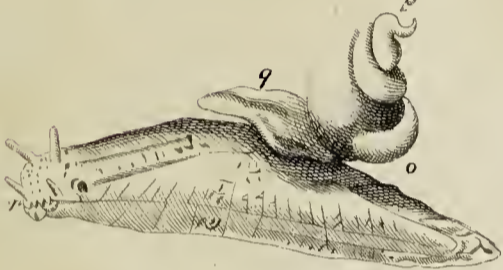


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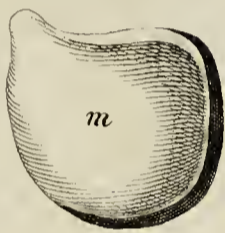


Fig. II.

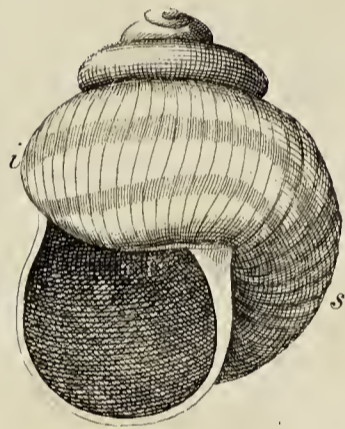


Fig. IV.

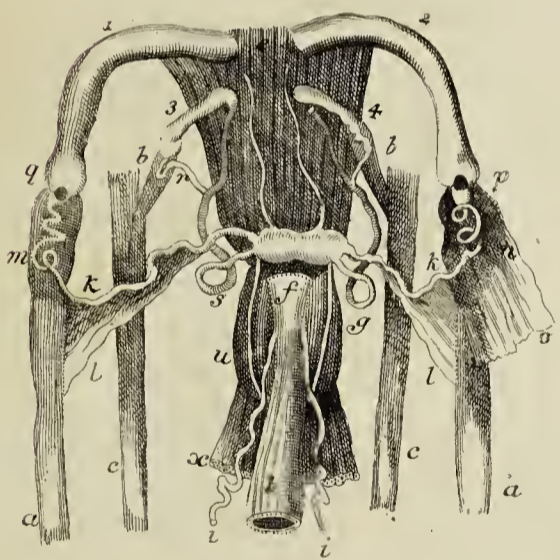


Fig. V.



Fig. VIII.

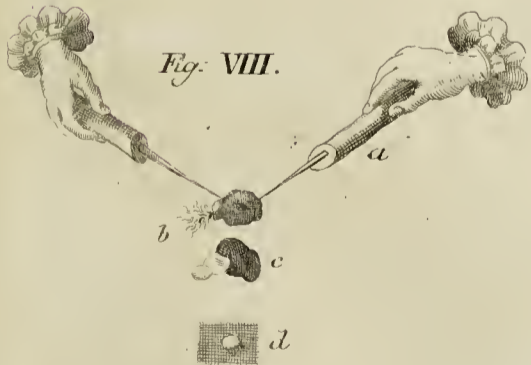
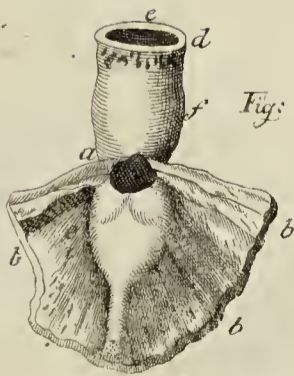
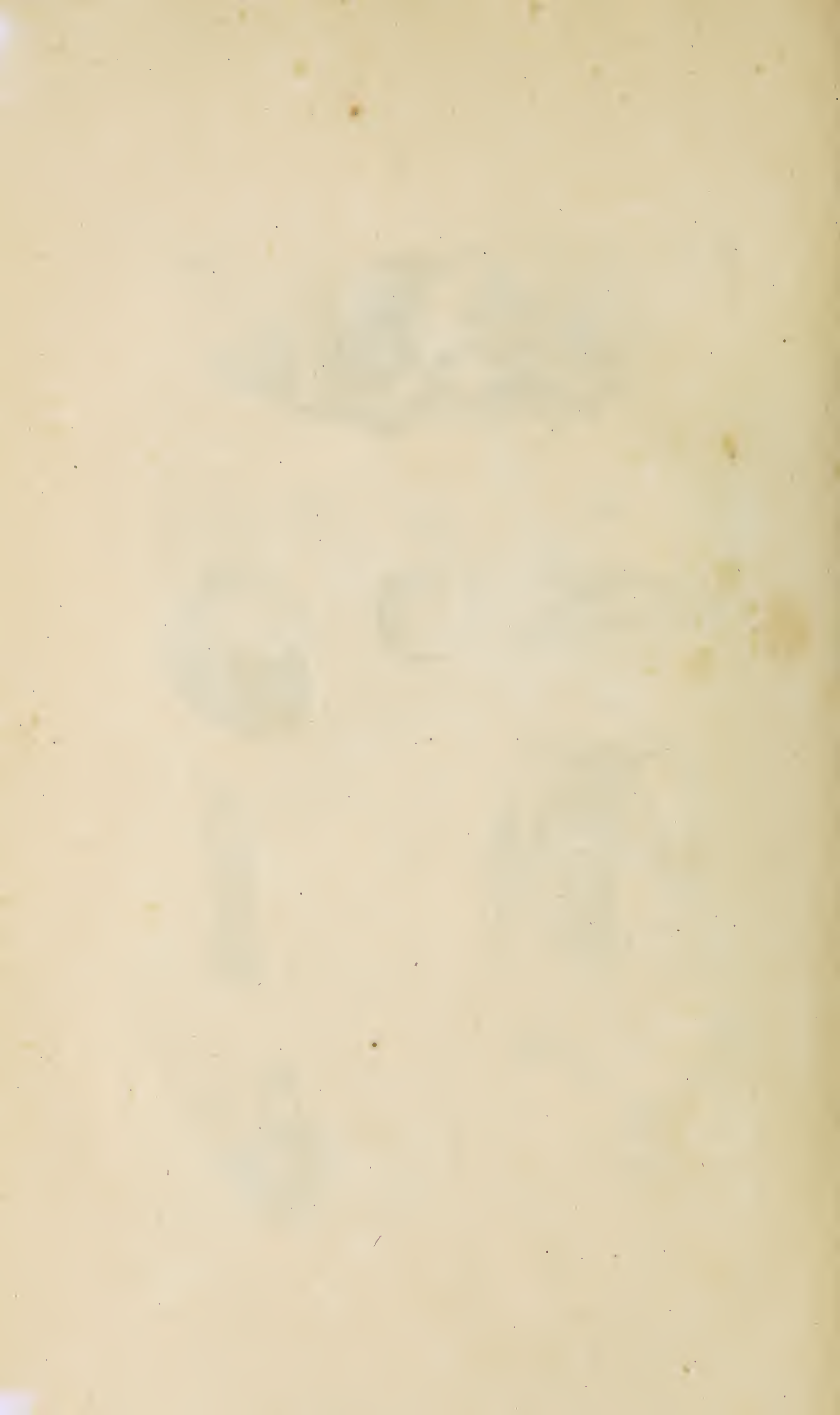


Fig. VII.





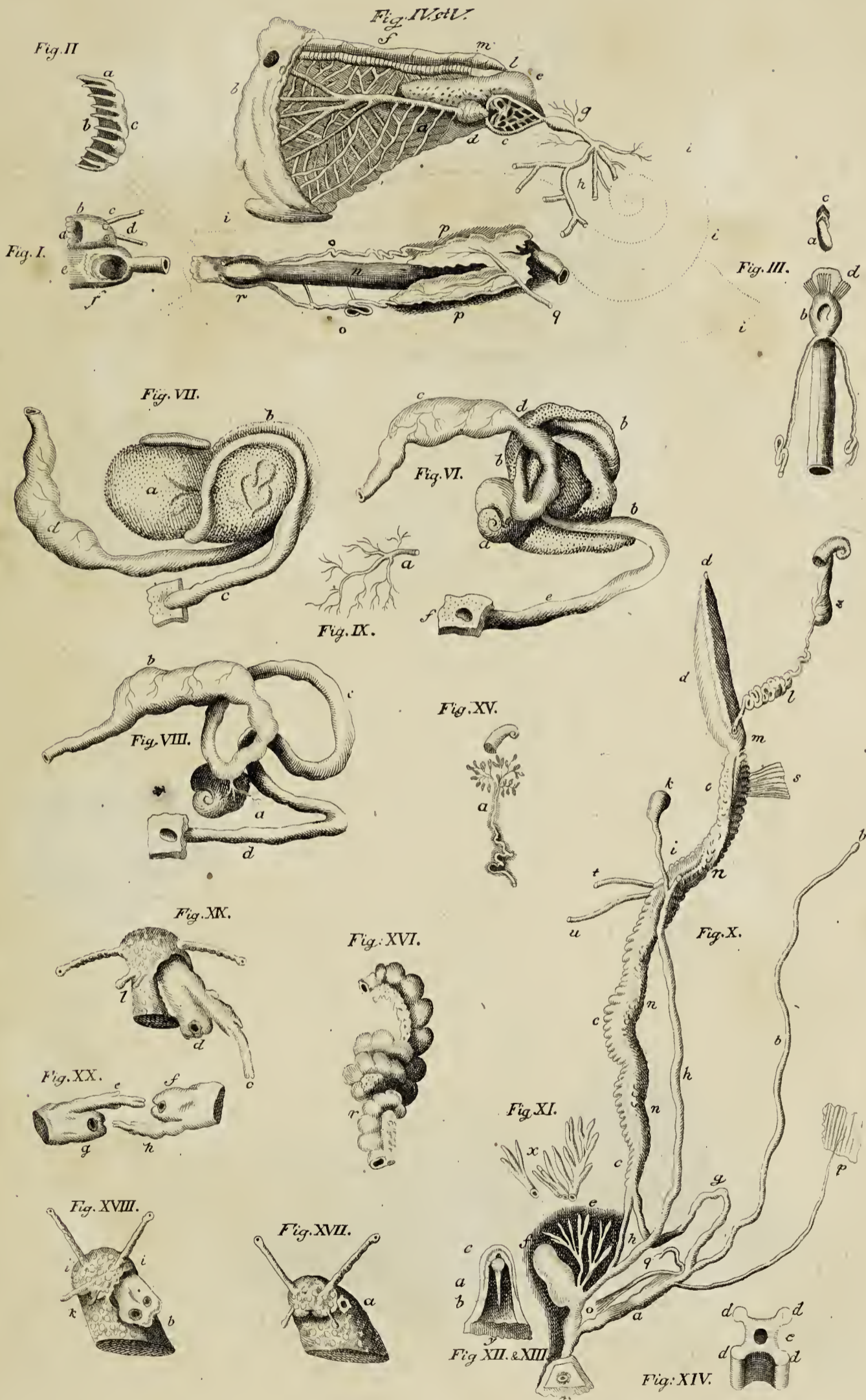




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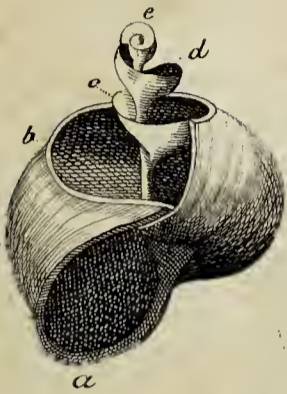


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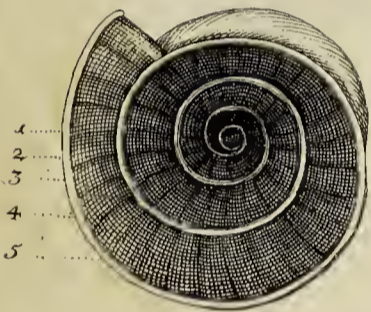


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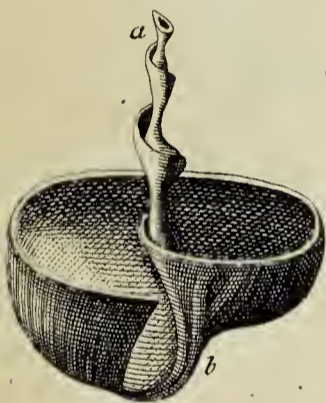


Fig. VI.



Fig. I.

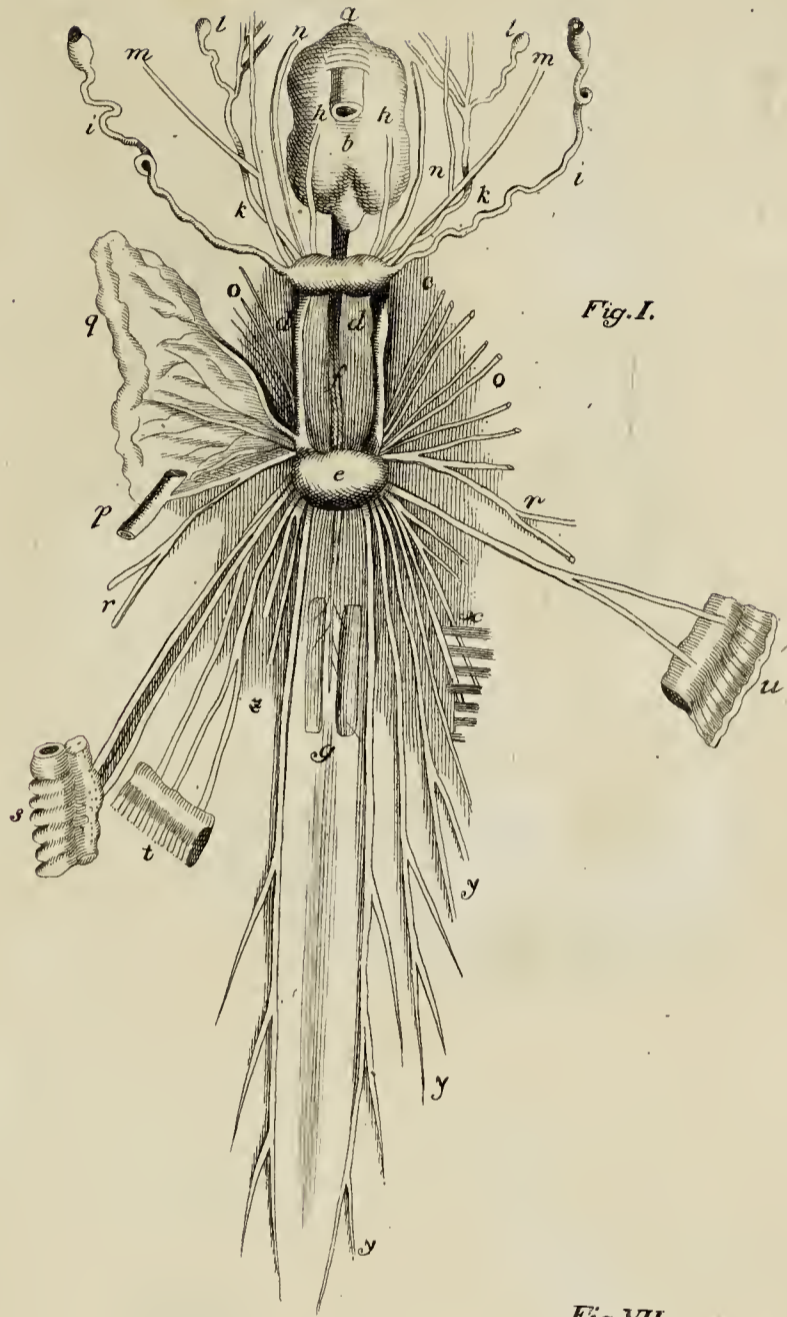
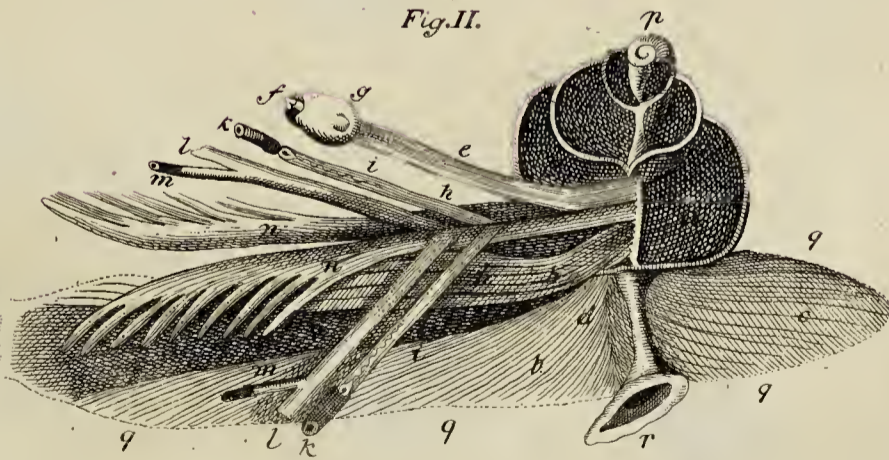


Fig. VII.



Fig. II.







TAB. VII.

Fig. III.

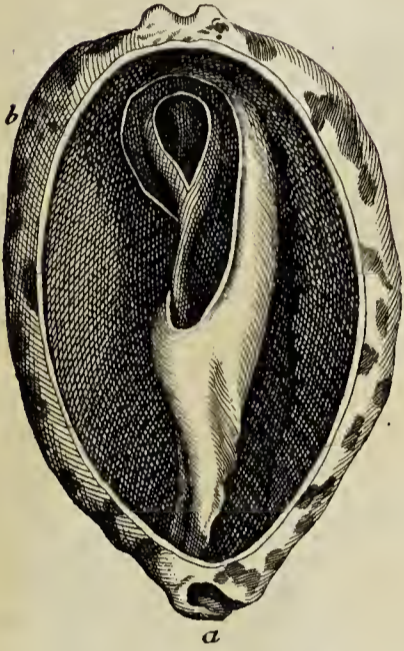


Fig. II.



Fig. I.



Fig. IV.

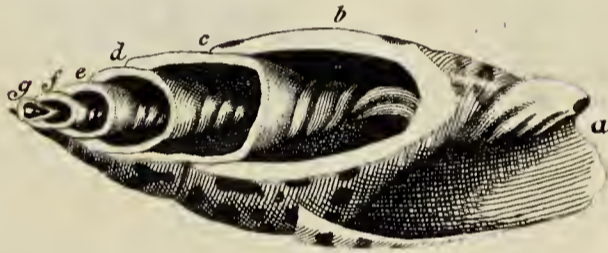


Fig. V.



Fig. XI.



Fig. VI.



Fig. VII.



Fig. VIII.



Fig. X.

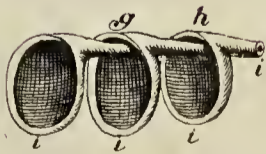


Fig. IX.





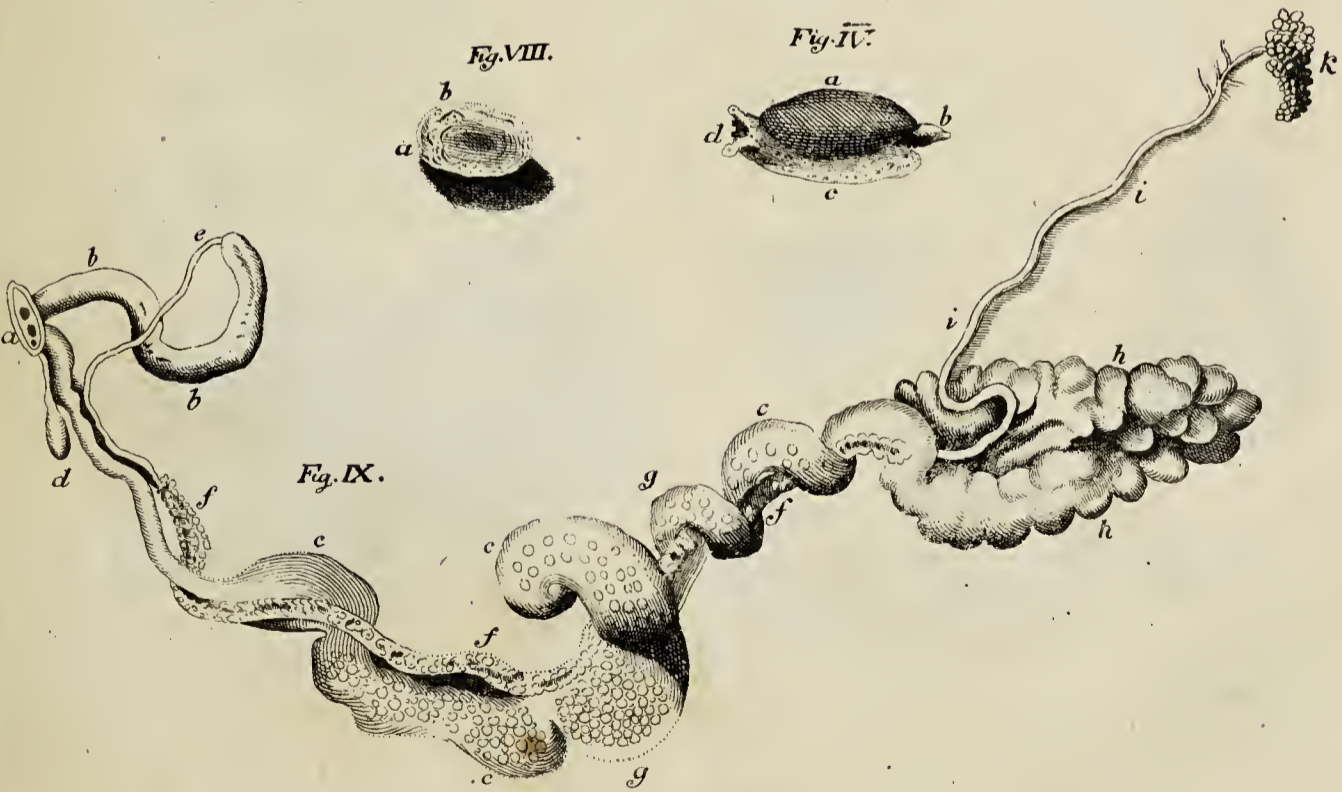
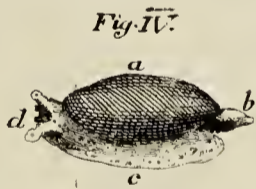
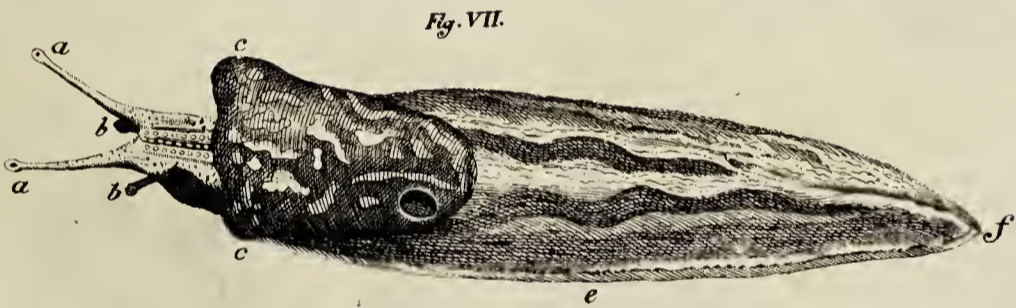
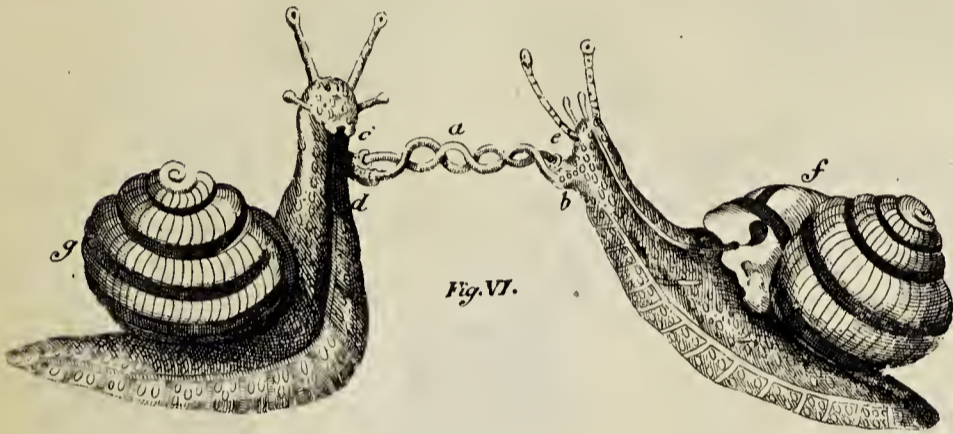
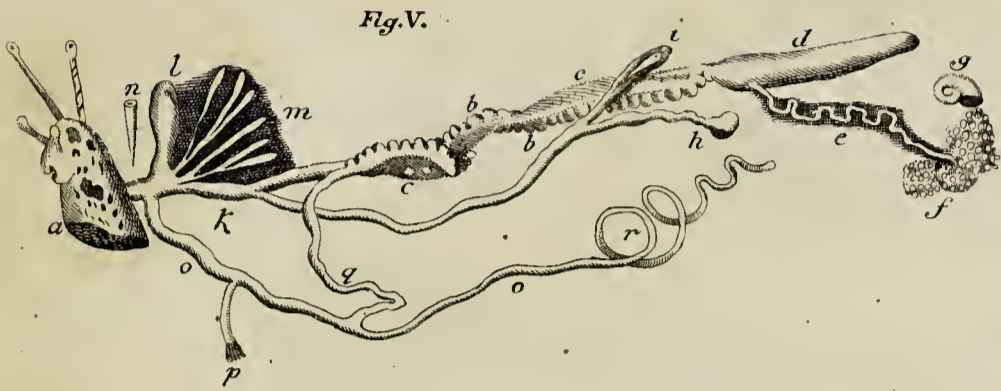








Fig. I.



Fig. IV.

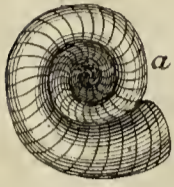


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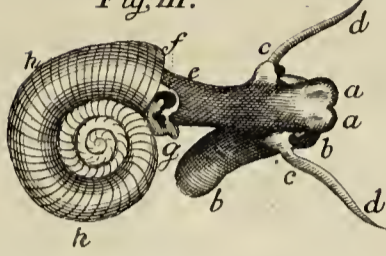


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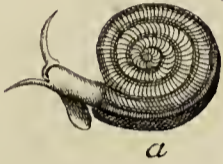


Fig. II.



Fig. VII.

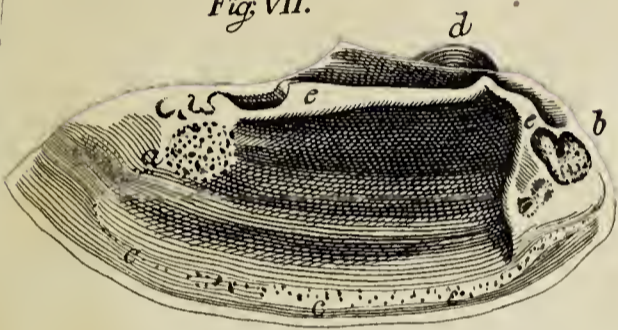


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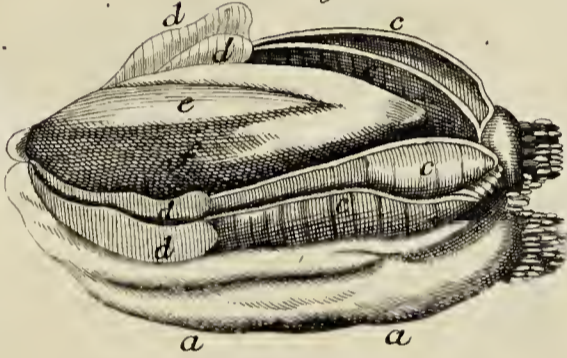


Fig. XI.



Fig. VIII.

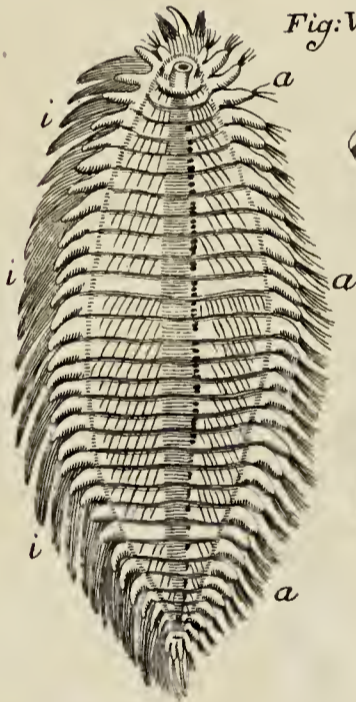


Fig. XIII.



Fig. XIV.

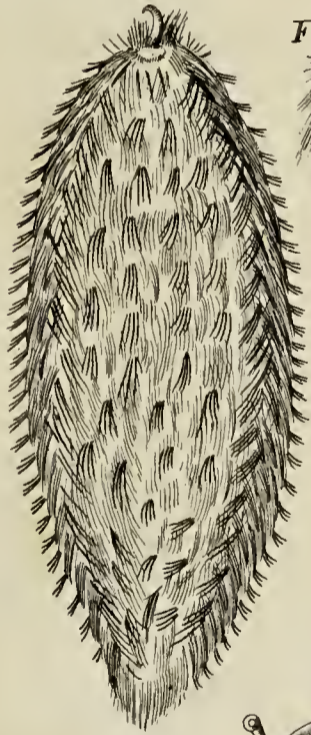


Fig. XII.



Fig. X.



Fig. XVI.

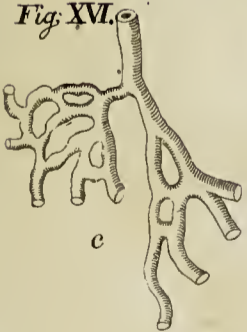
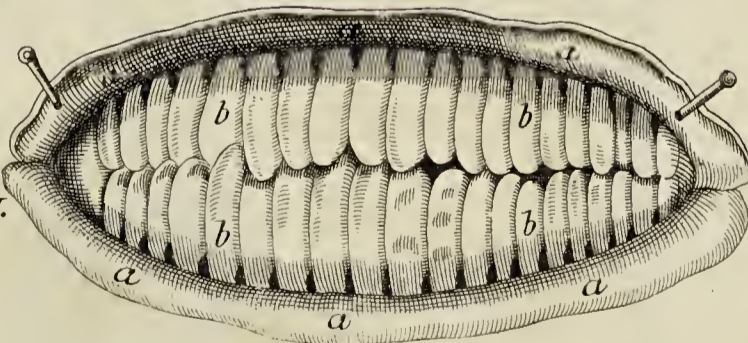
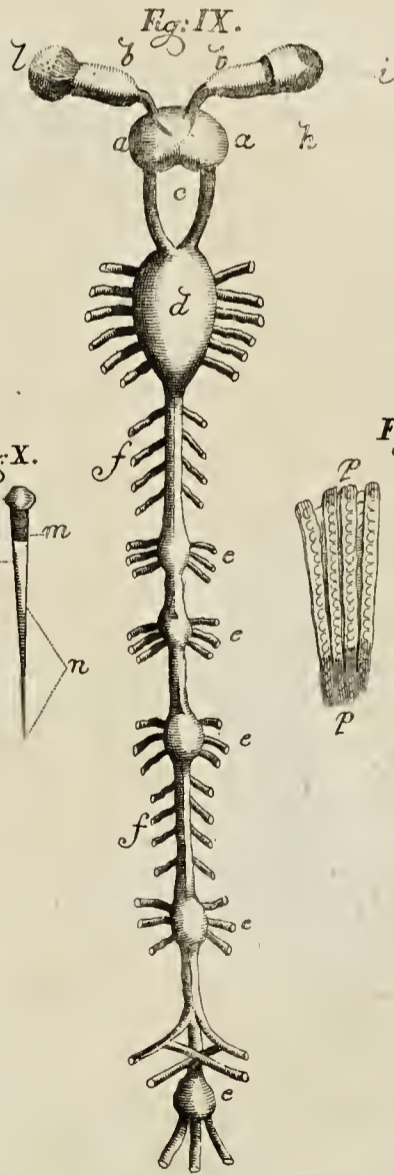
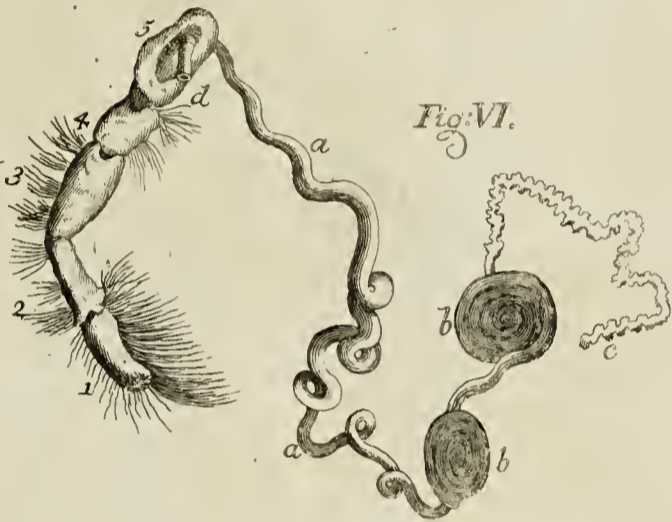
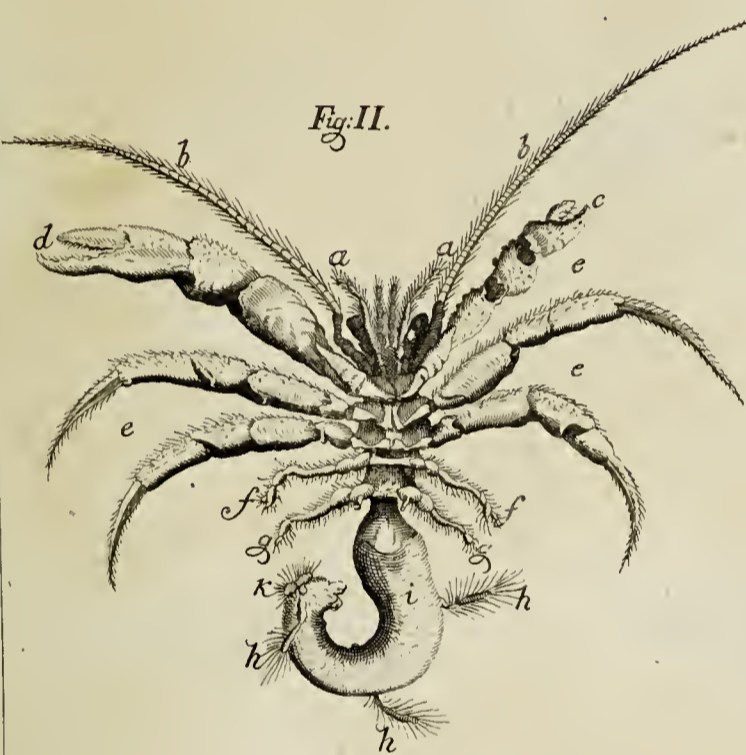
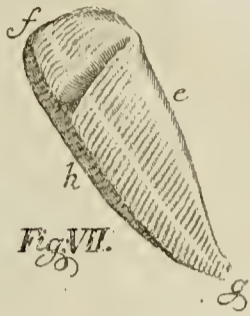
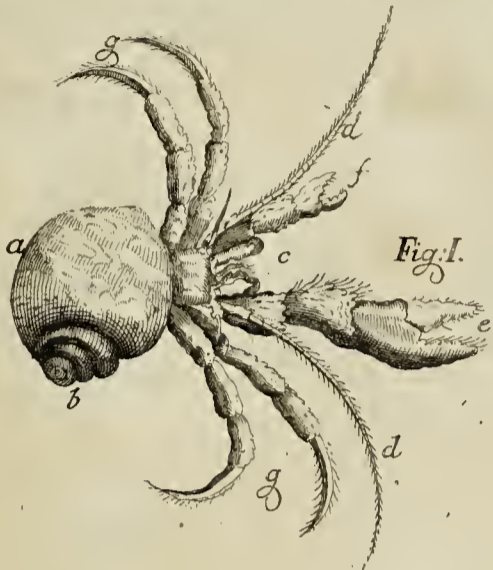


Fig. XV.











Order the Second  
Nymph = Vermicle



Fig. I.



Fig. V.

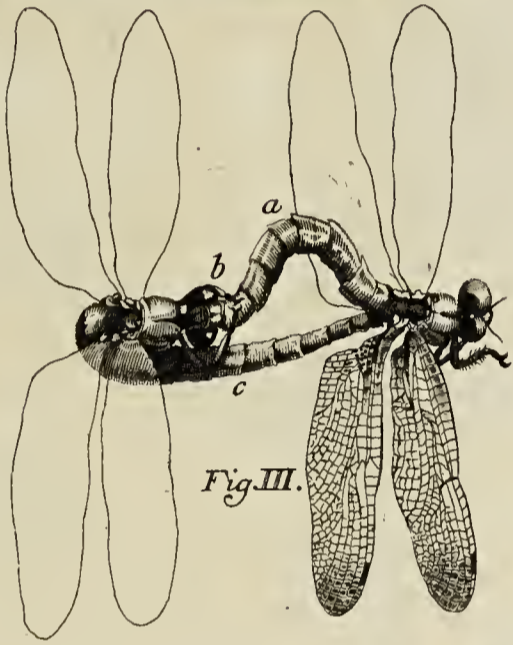


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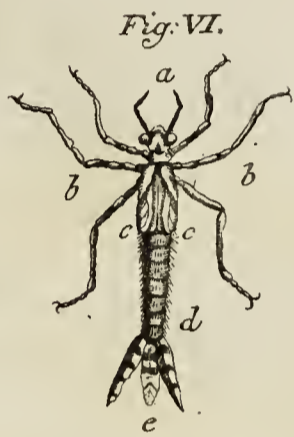


Fig. VI.



Fig. II.



VI

Fig. VII.



Fig. IV.





Fig. I.



Fig. II.



Fig. III.

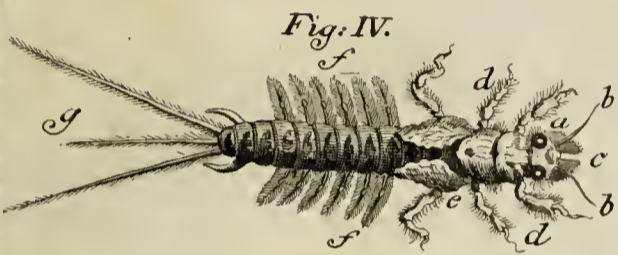


Fig. IV.

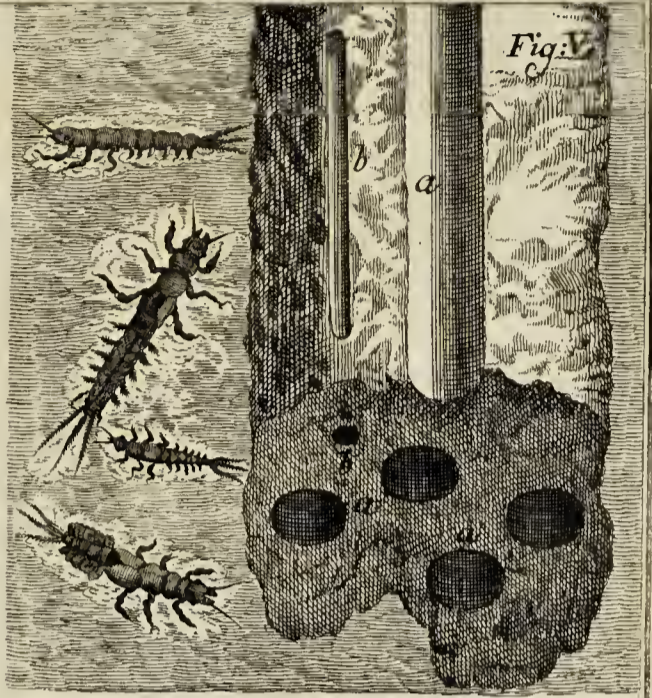


Fig. V.



Fig. VIII.

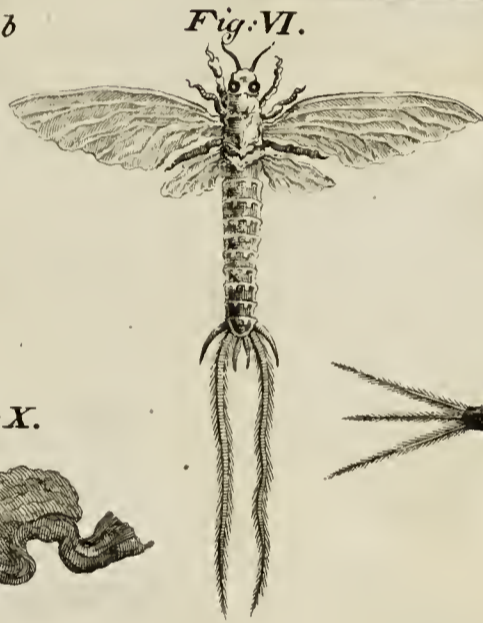


Fig. VI.



Fig. IX.



Fig. X.



Fig. VII.



Fig. XI.



Fig. XIV.



Fig. XII.



Fig. XIII.



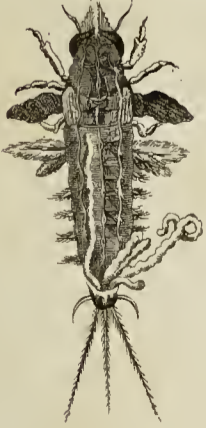
Fig. XV.



Fig. I.



Fig II.







Figl.

Fig. III.



Fig. II.

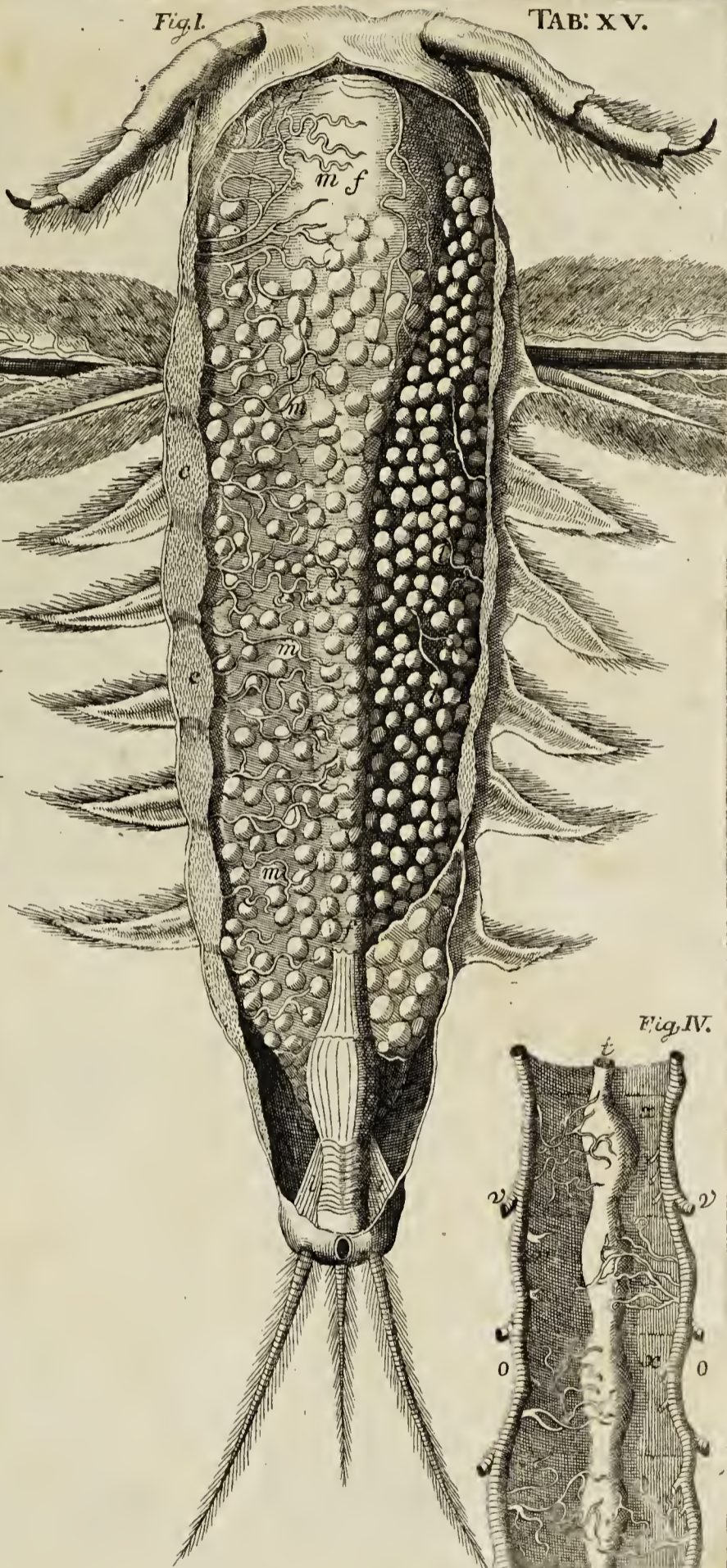


Fig. VI.

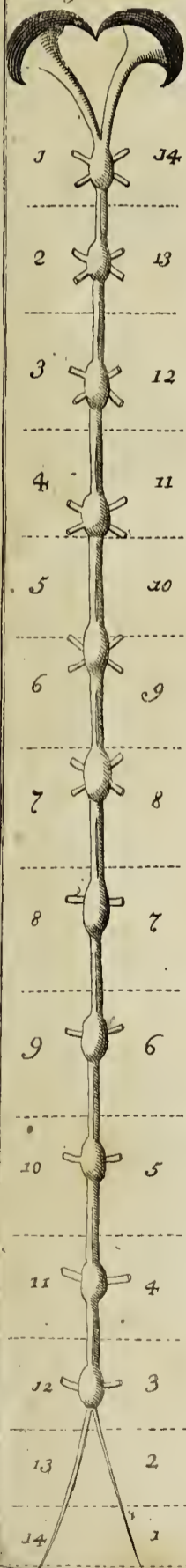


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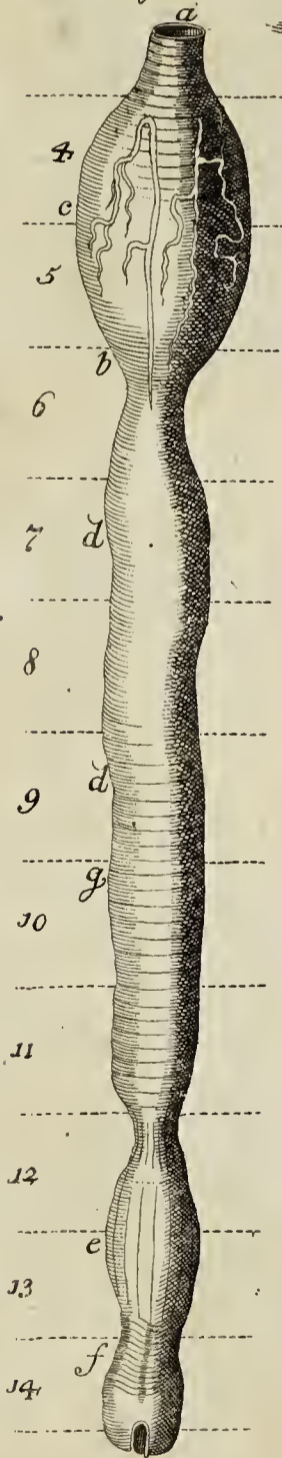


Fig. IV.

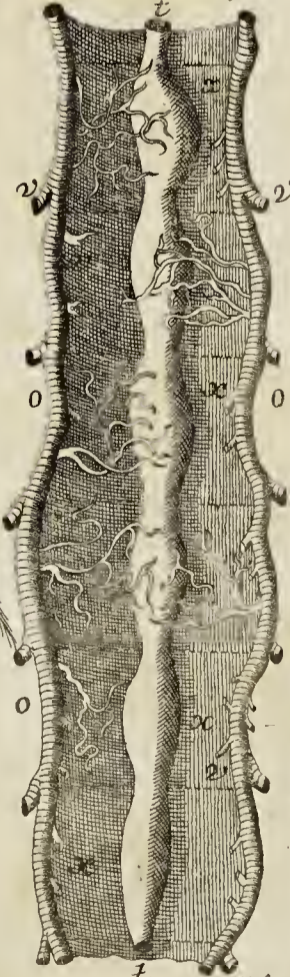
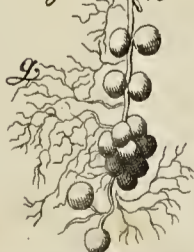


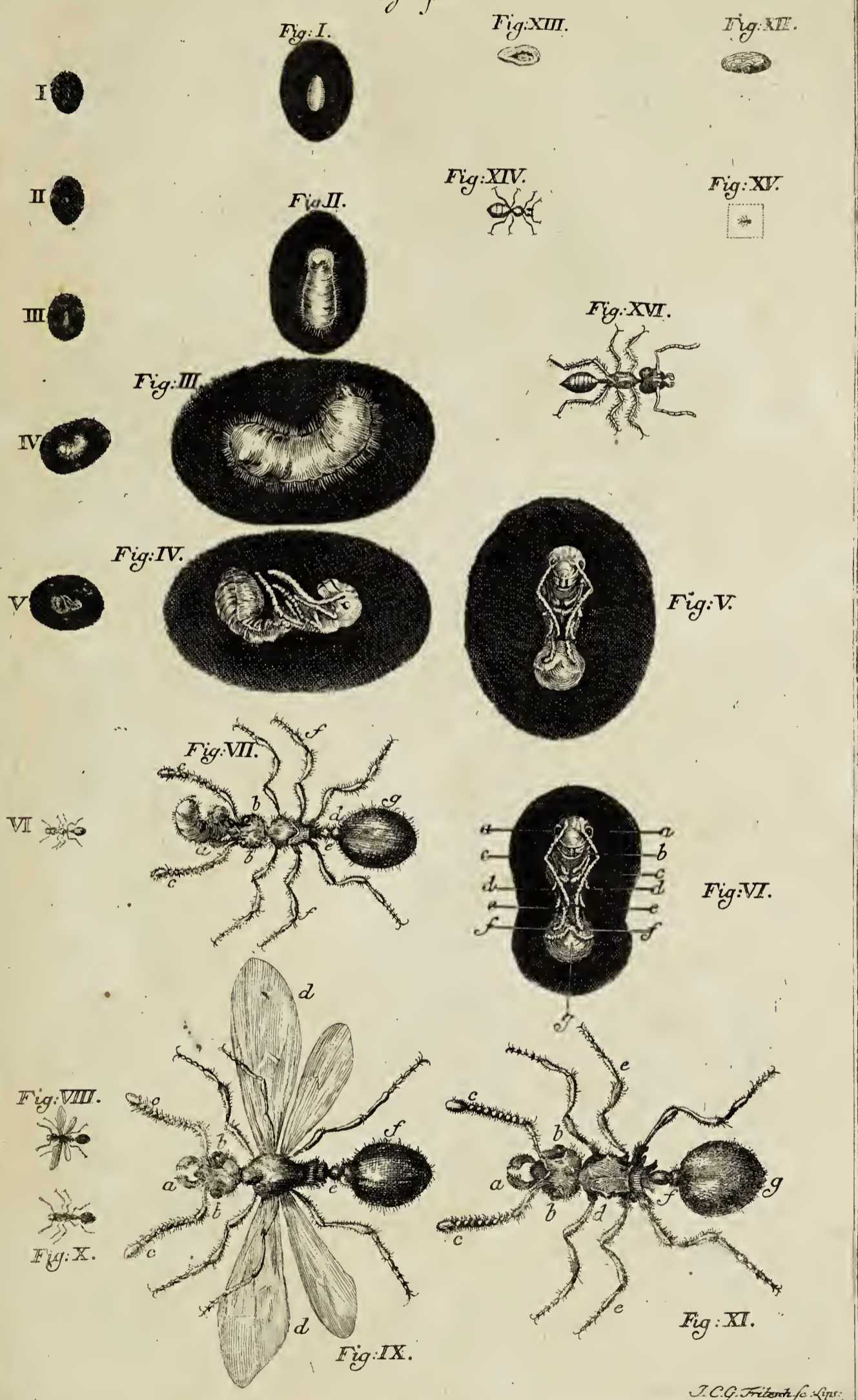
Fig. VII.



J. C. G. F. del. sc.



Order the Third Nymph



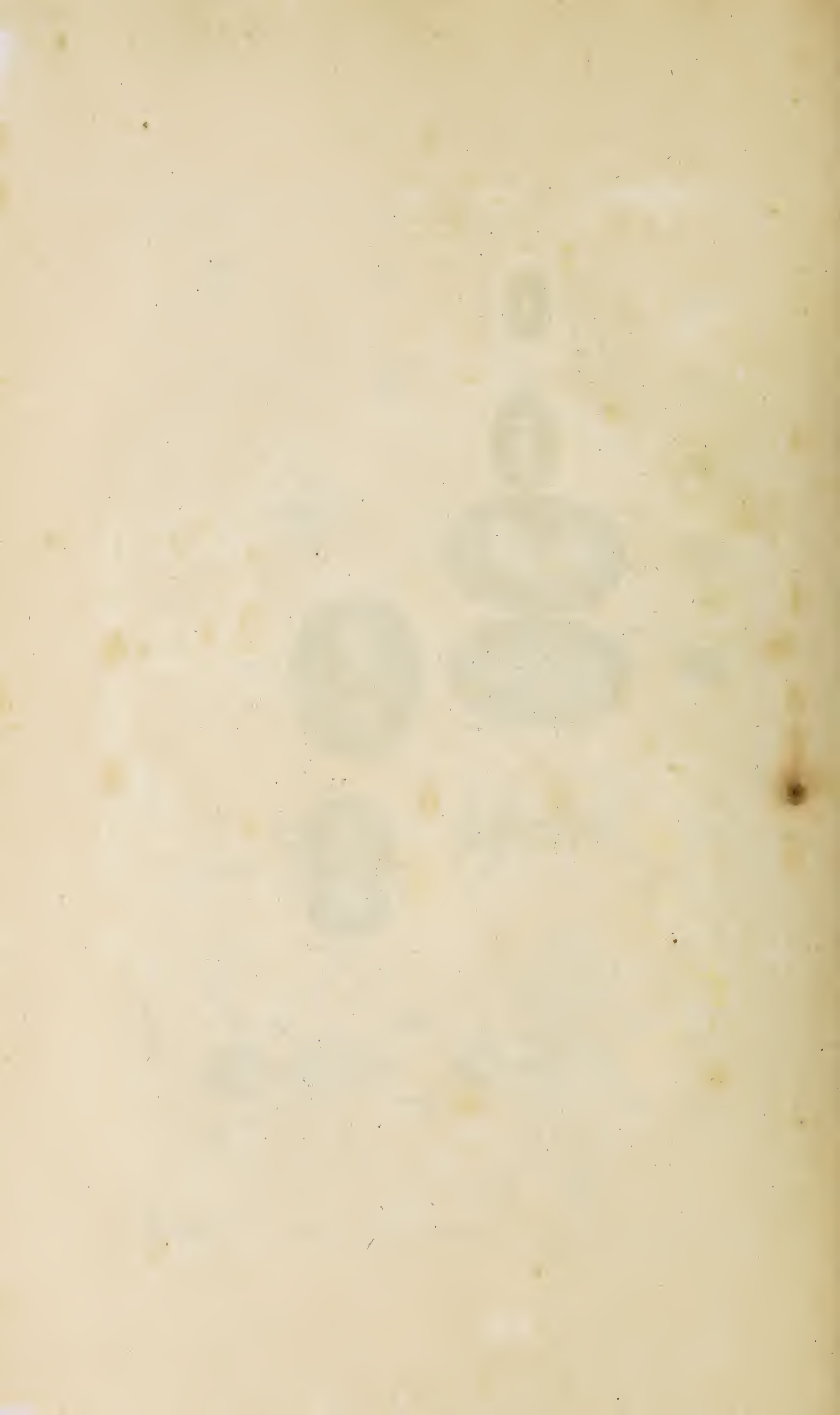


Fig. IV.



Fig. III.



Fig. II.

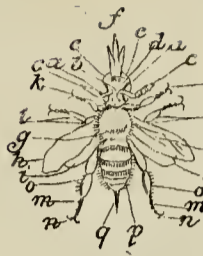


Fig. I.



Fig. VII.

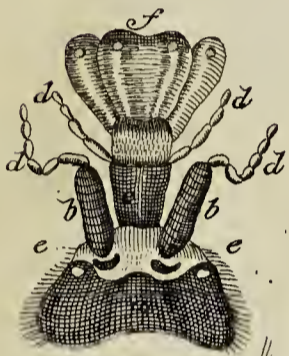


Fig. V.

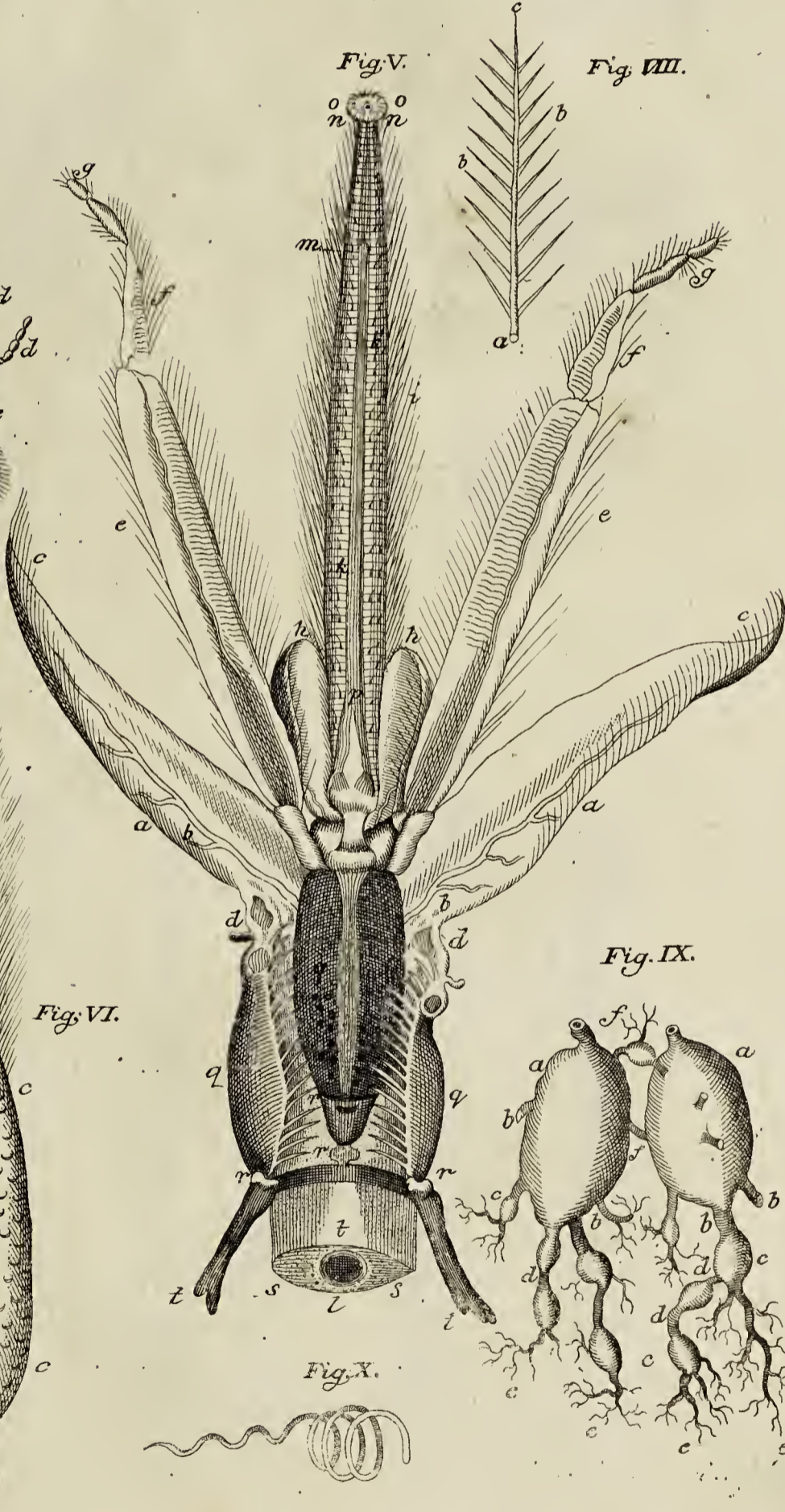


Fig. VIII.



Fig. VI.

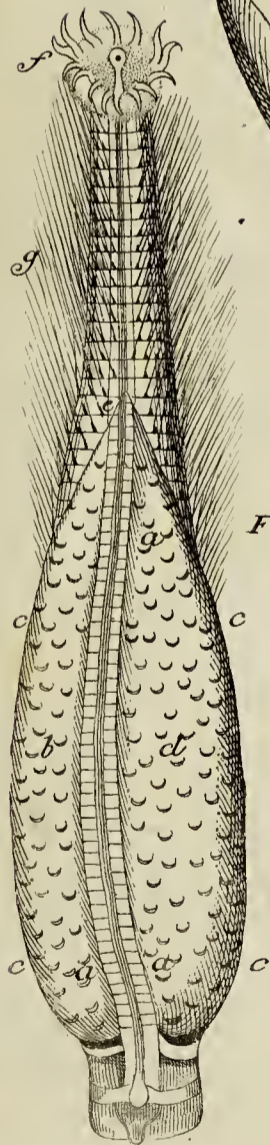


Fig. IX.

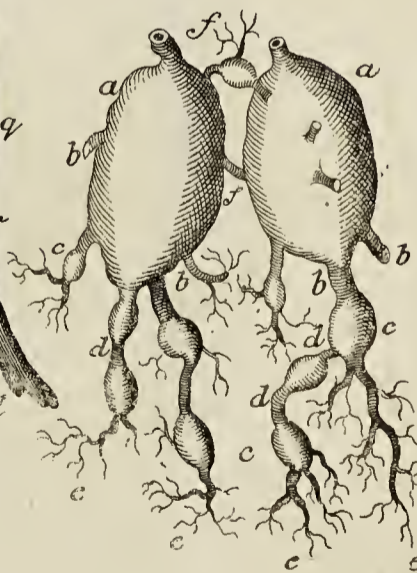
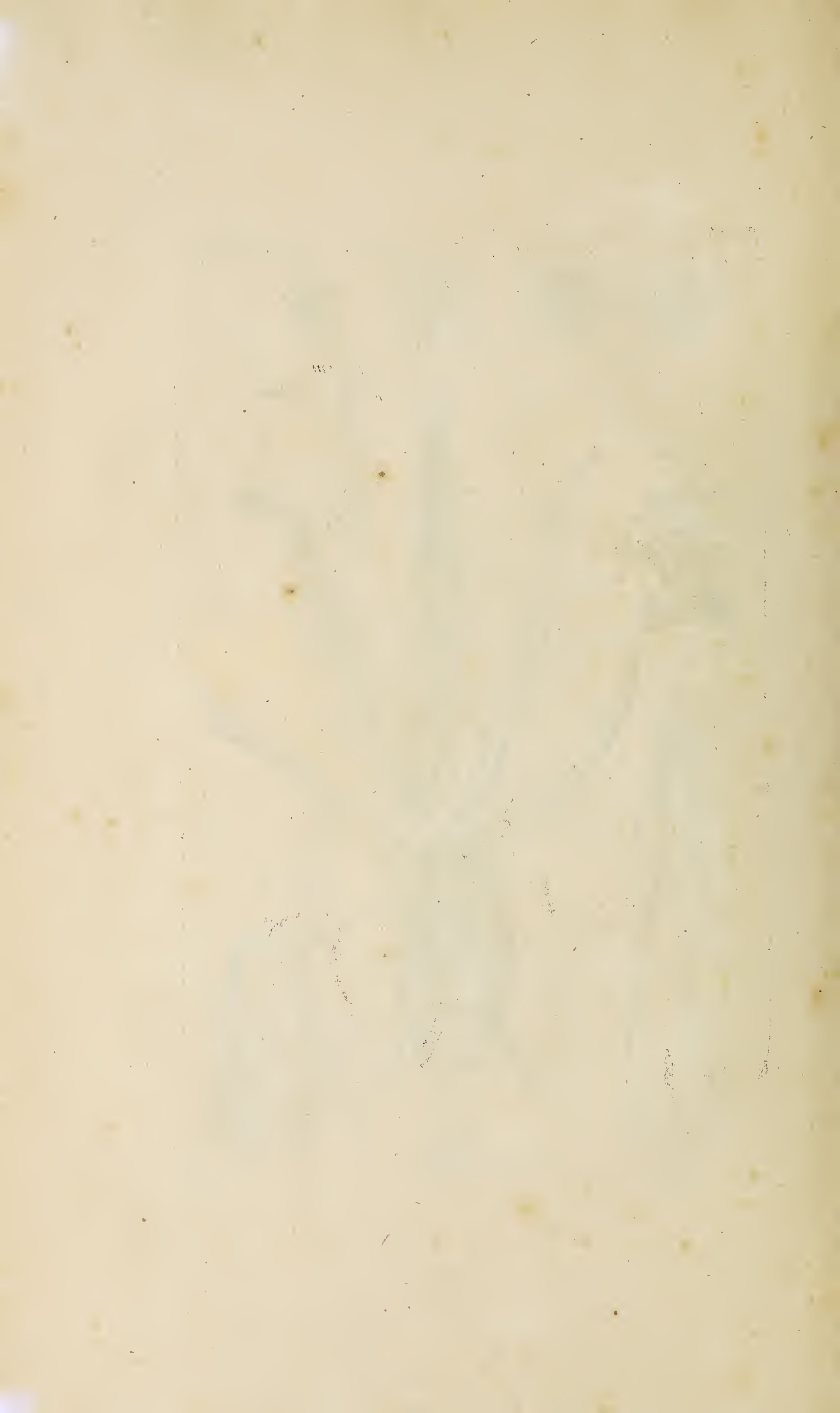
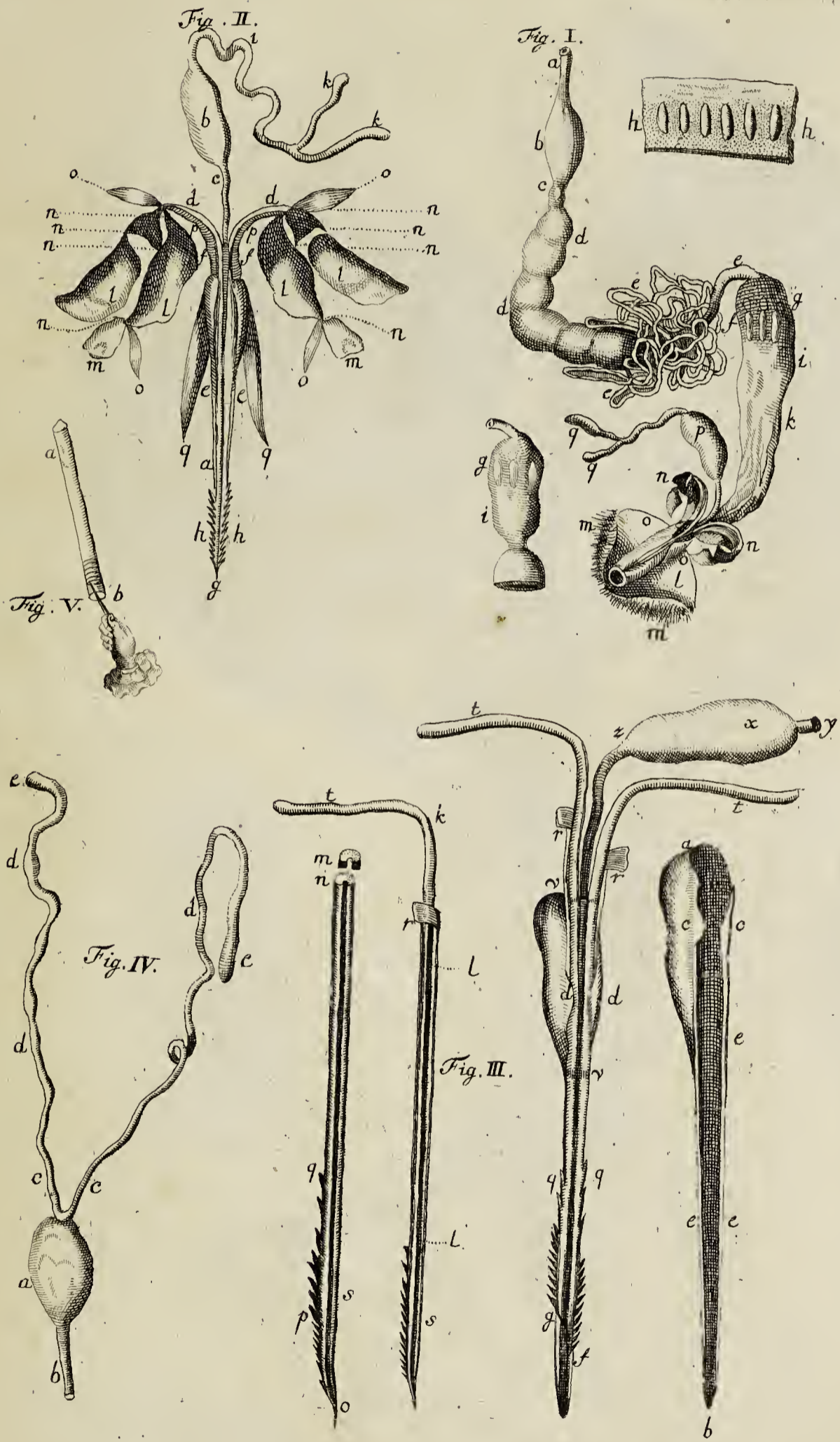


Fig. X.











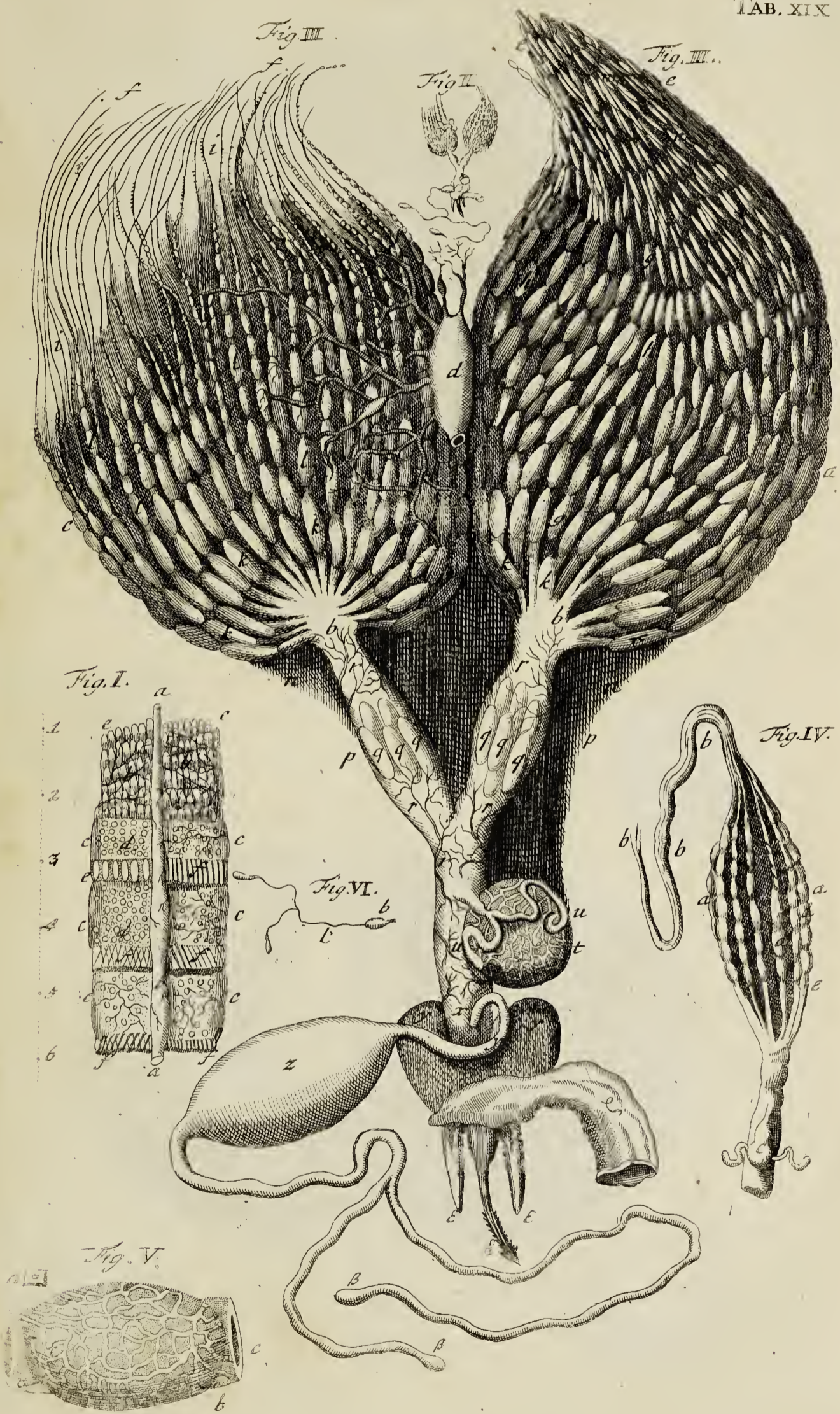




Fig. I.

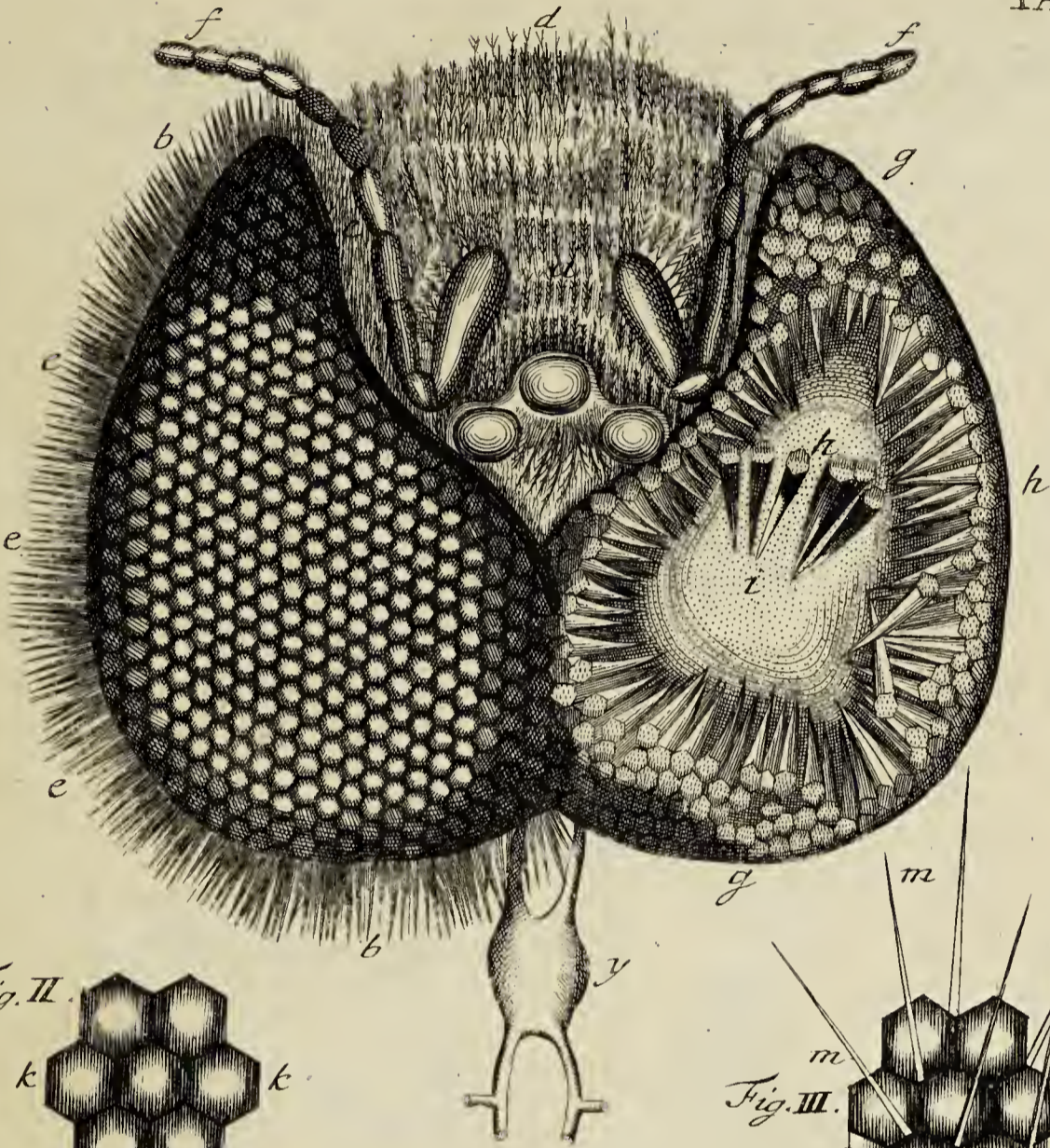


Fig. II.

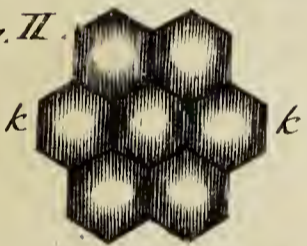


Fig. III.

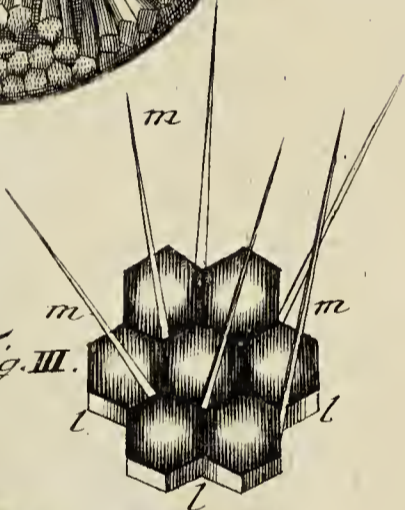


Fig. V.

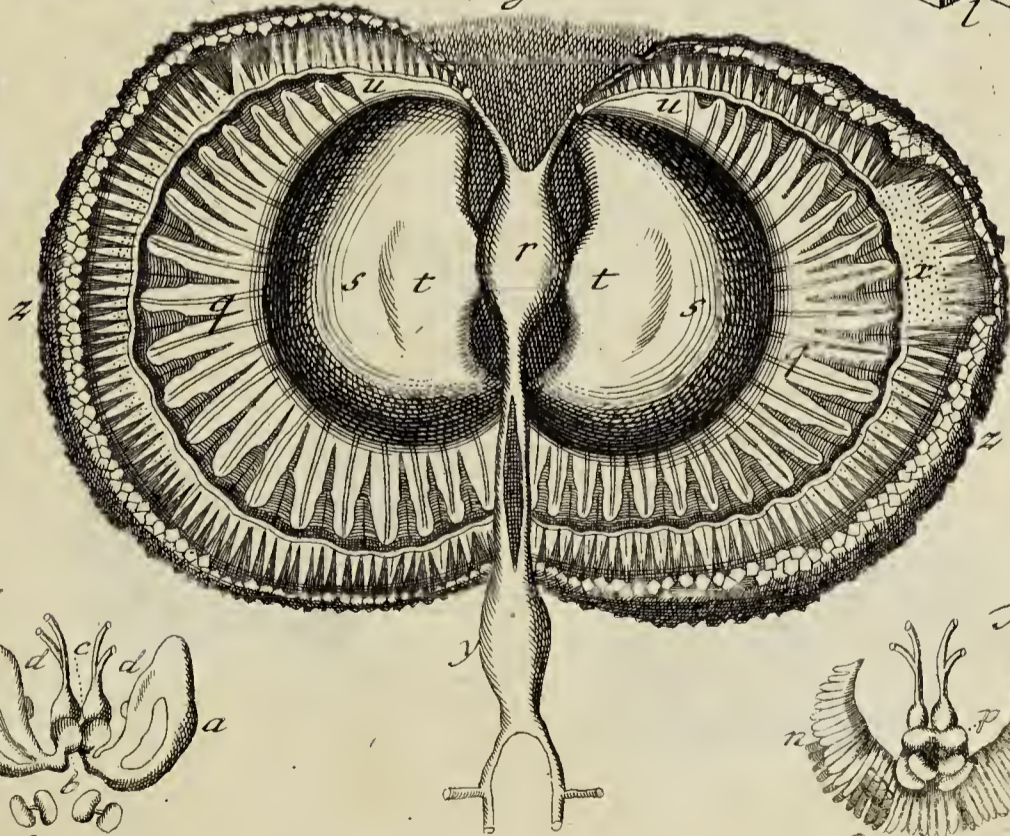


Fig. VI.

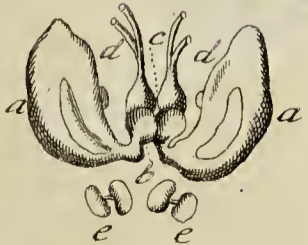


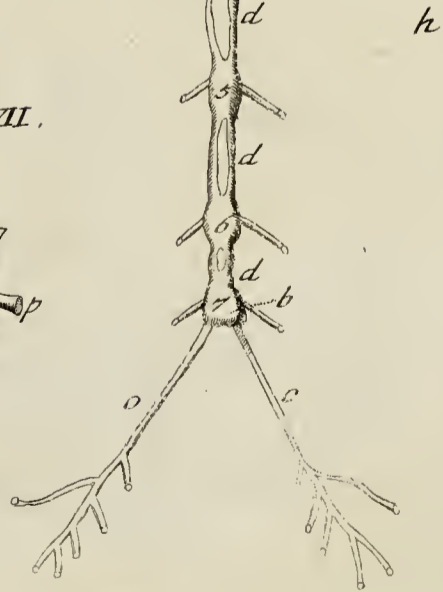
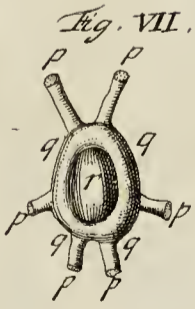
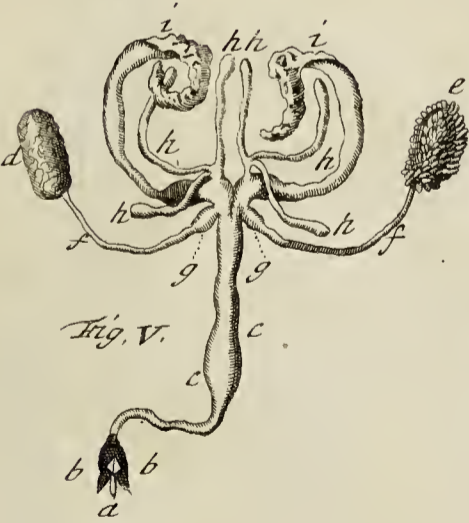
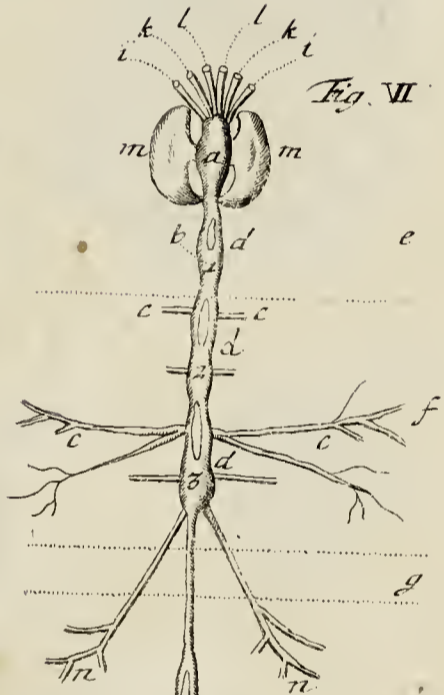
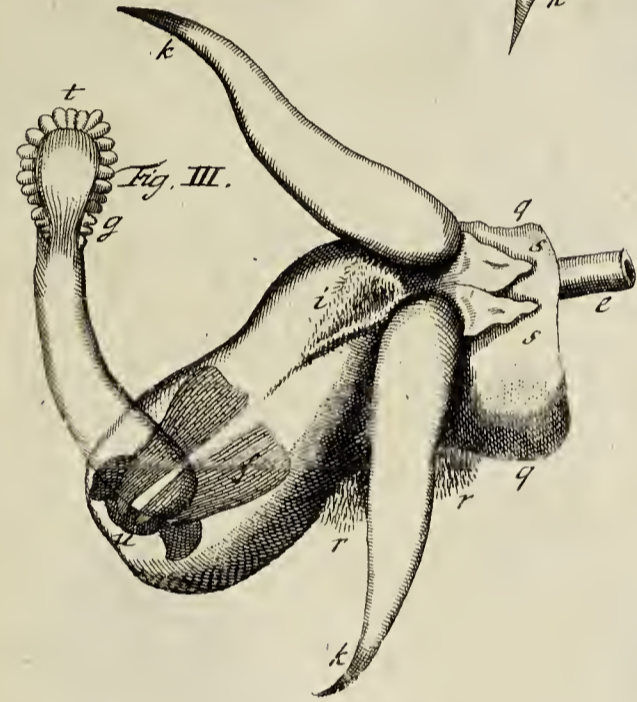
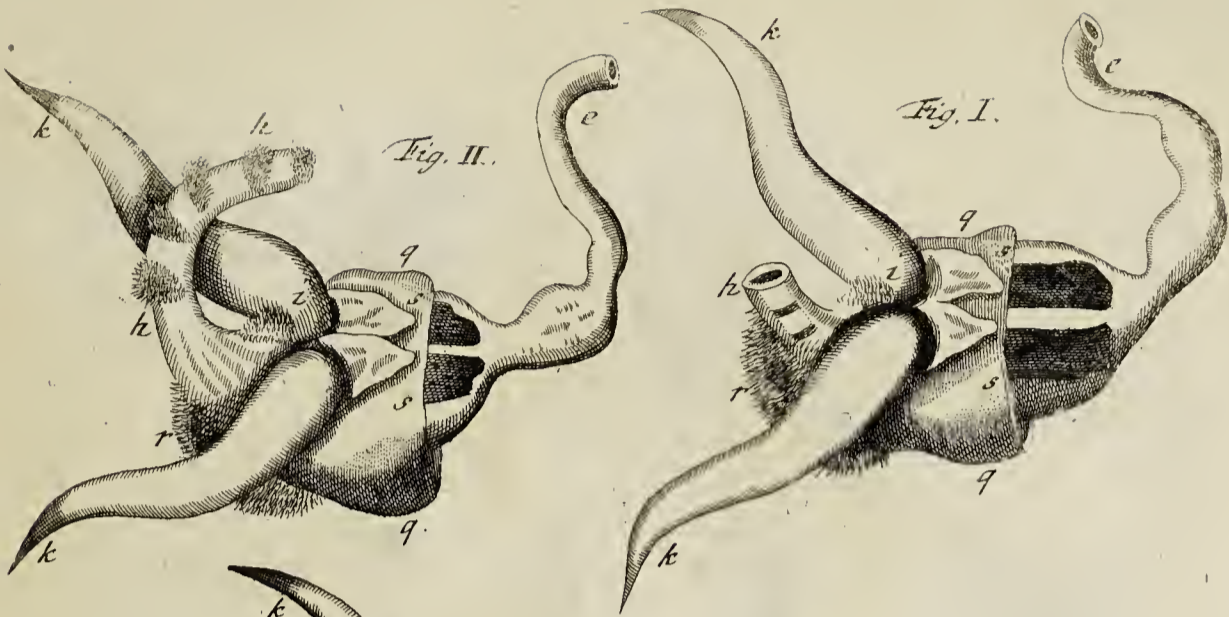
Fig. IV.





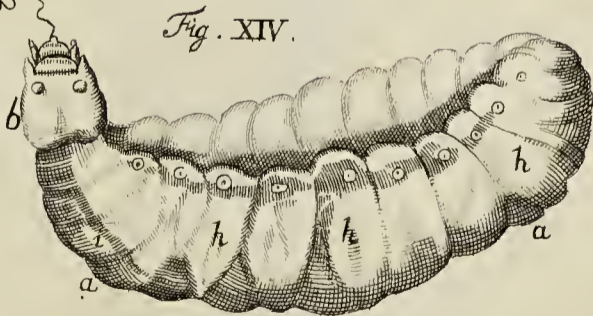
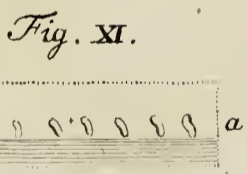
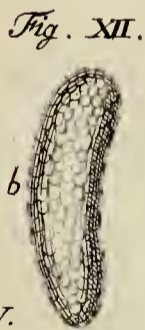
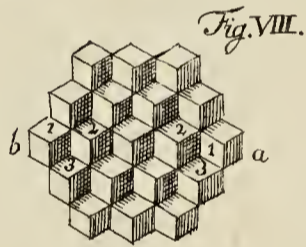
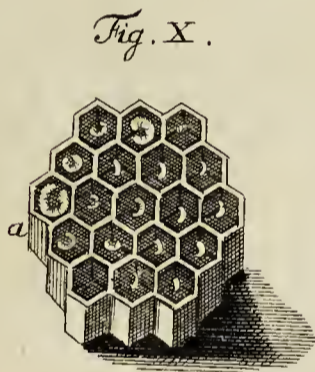
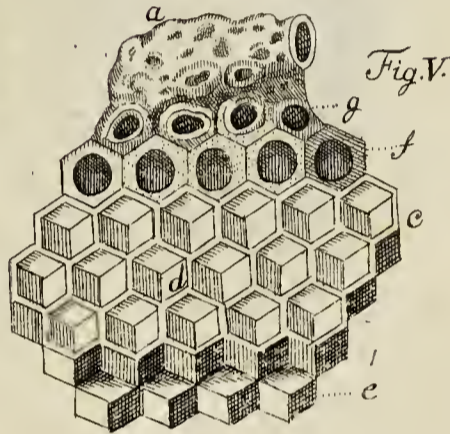
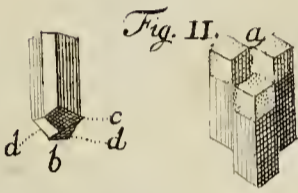
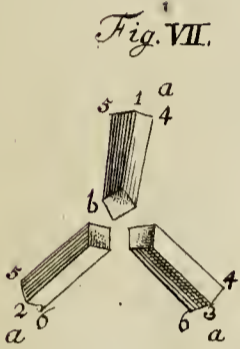
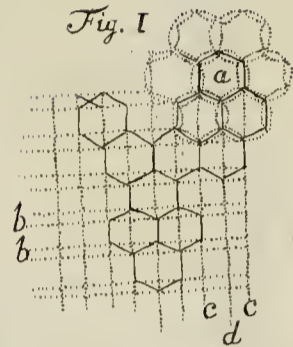
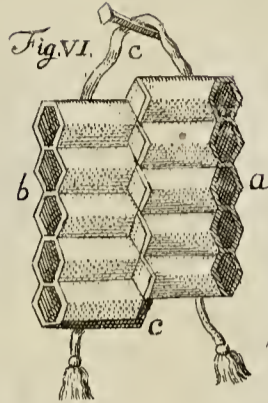
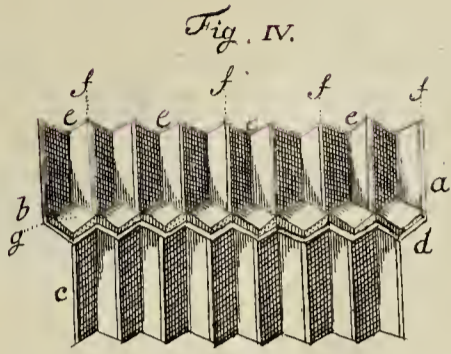














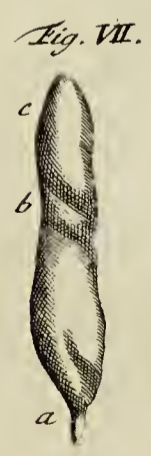
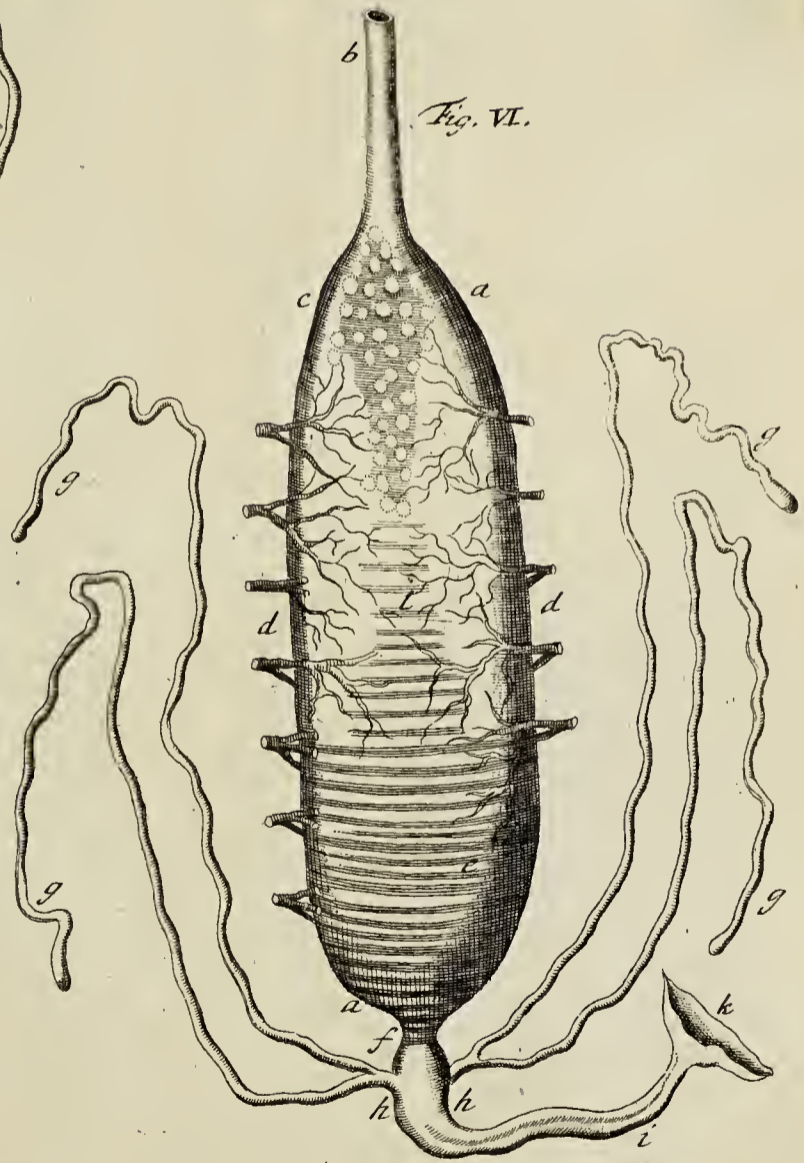
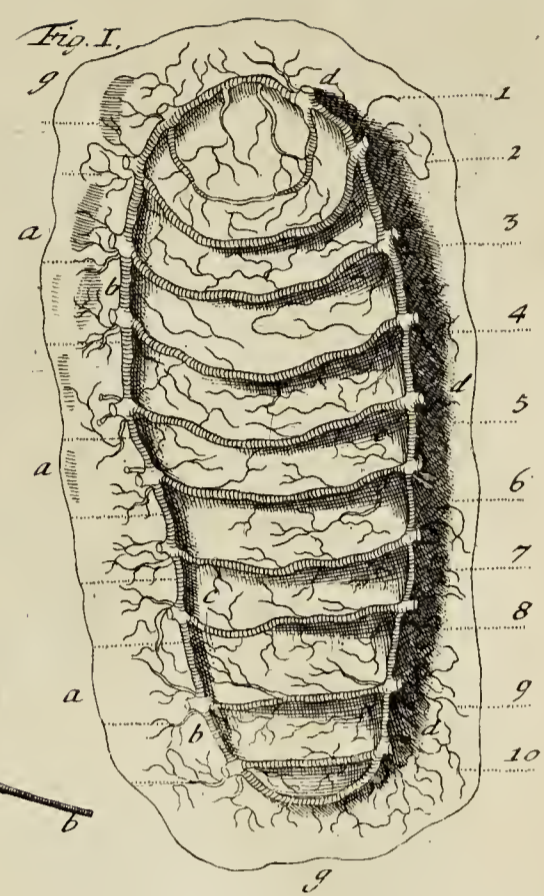




Fig. II.



Fig. I.



Fig. III.

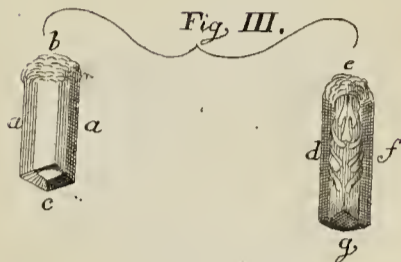


Fig. IV.

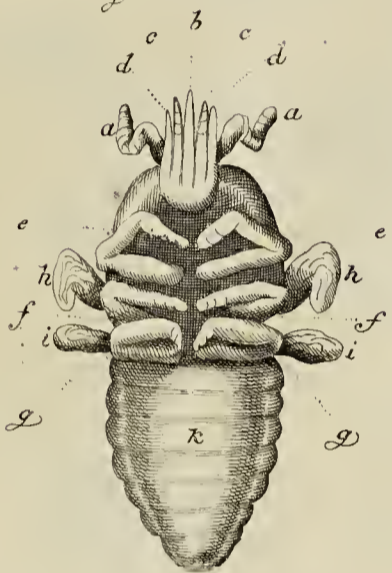


Fig. VI.



Fig. V.



Fig. VIII.



Fig. VII.



Fig. X.

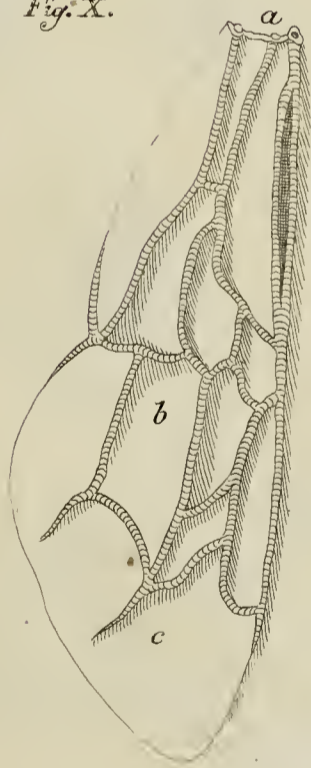
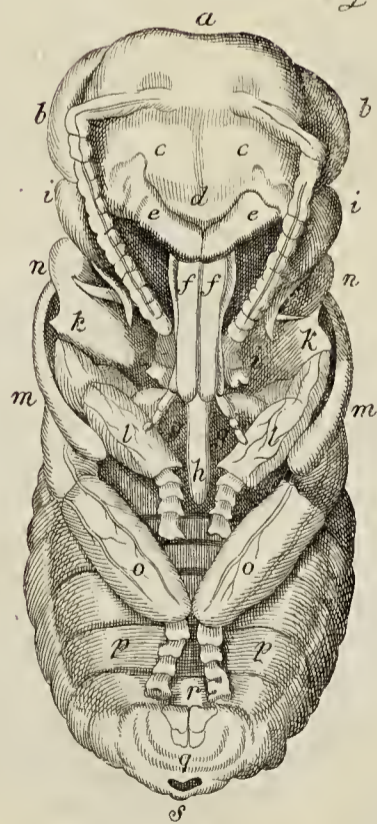


Fig. IX.





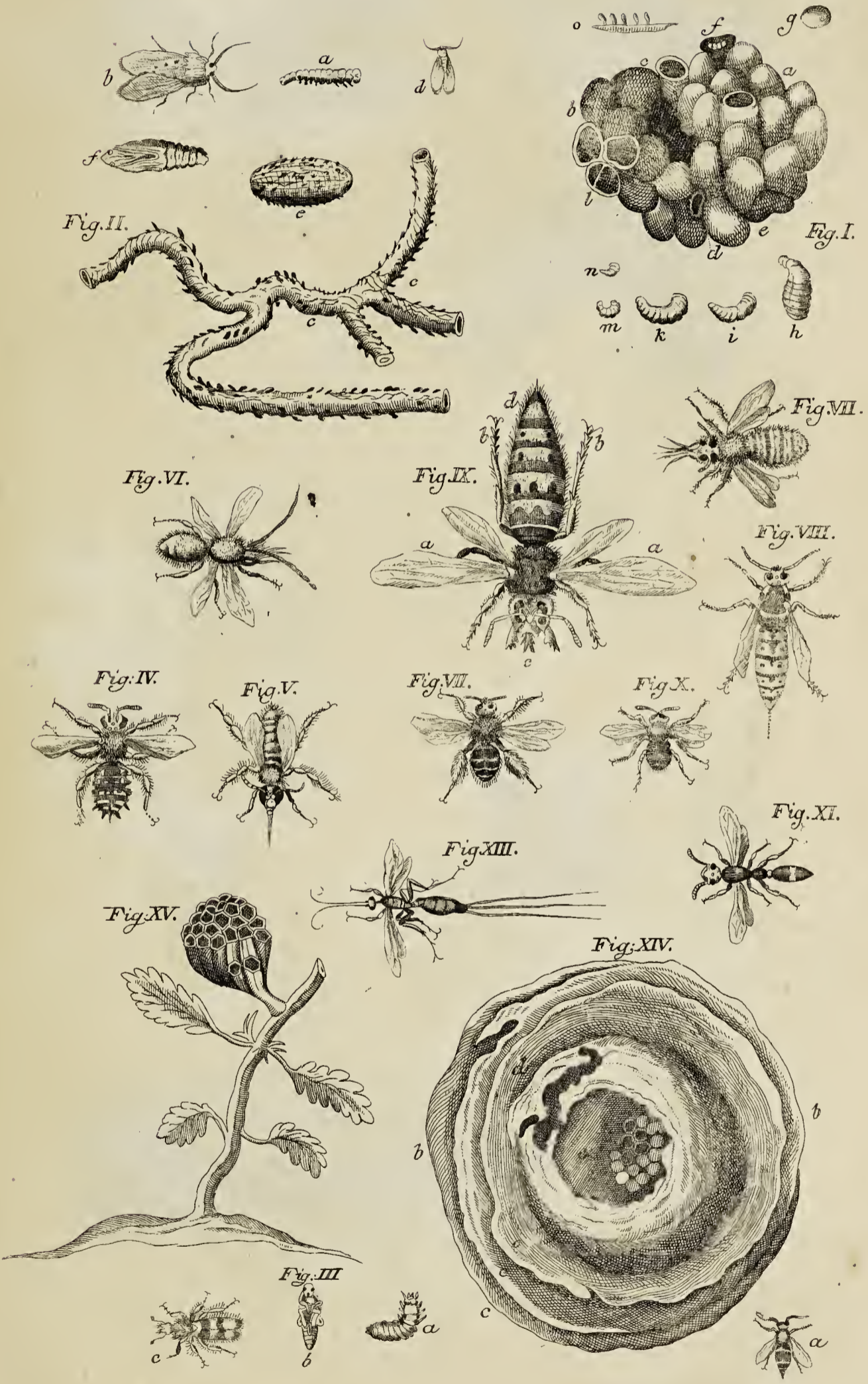






Fig. II.



Fig. I.

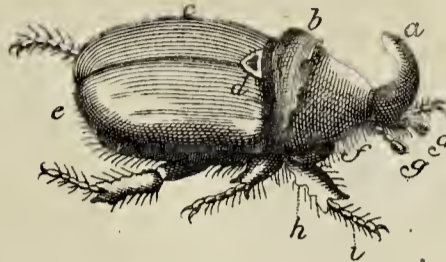


Fig. III.



Fig. IV.



Fig. V.

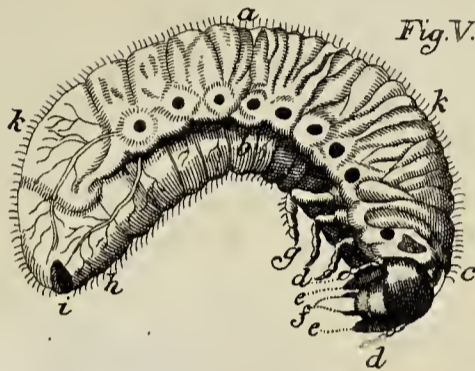


Fig. VI.

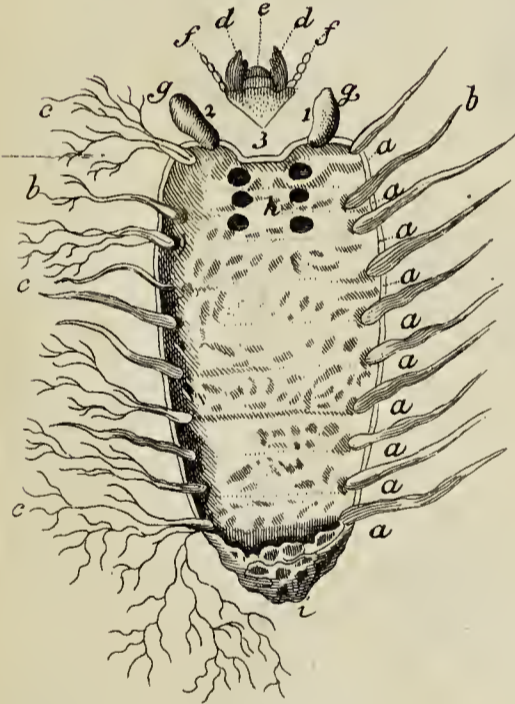


Fig. VII.



Fig. VIII.

Fig. IX.

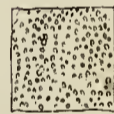
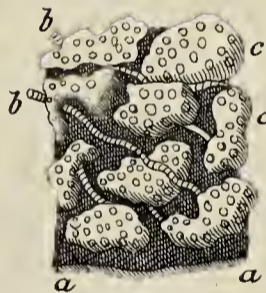


Fig. X.

Fig. XI.

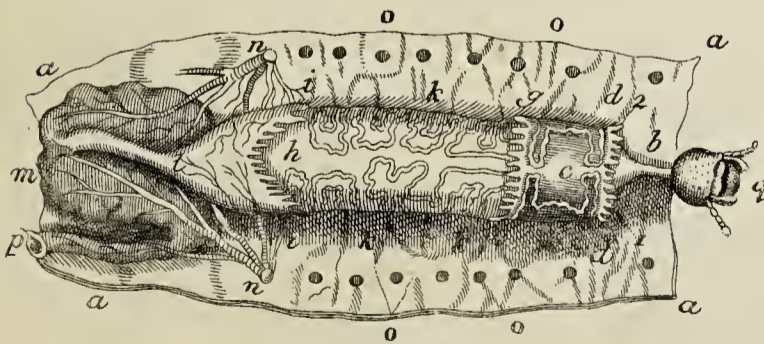


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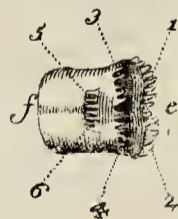




Fig. III.

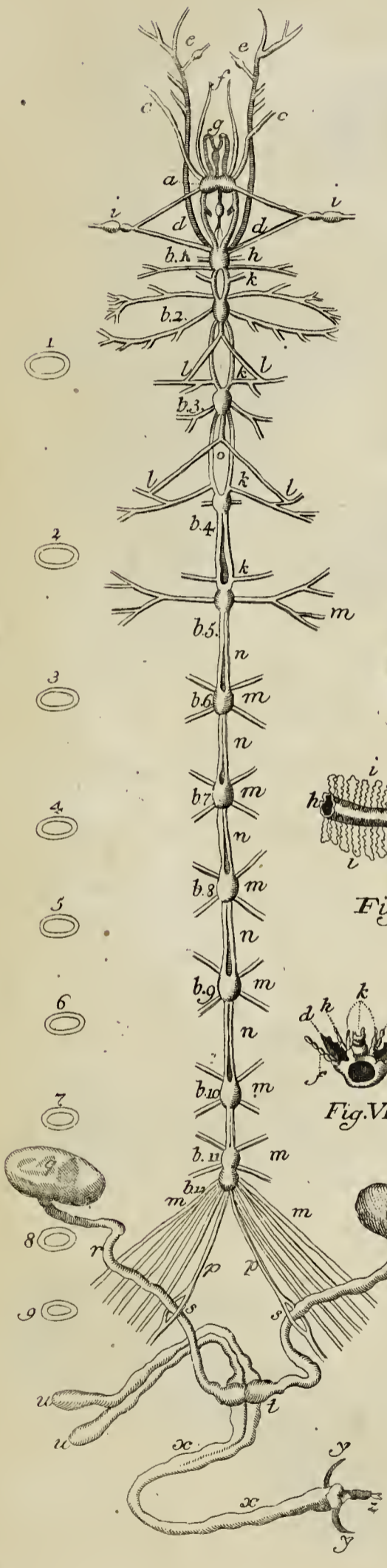


Fig. II.

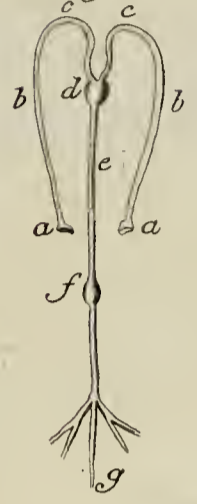


Fig. I.

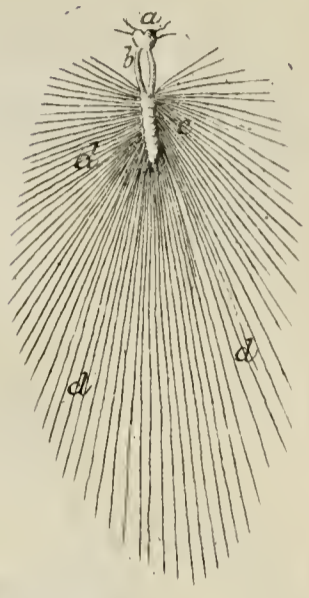


Fig. IV.

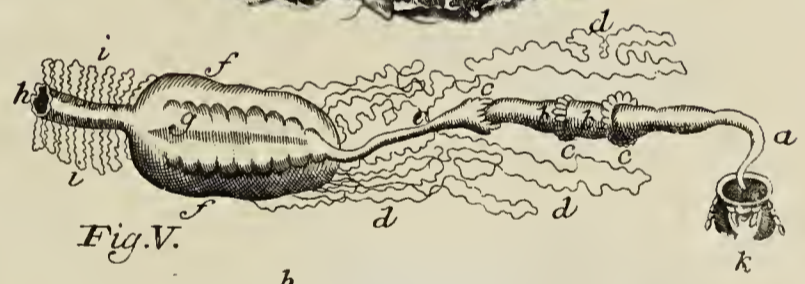


Fig. V.

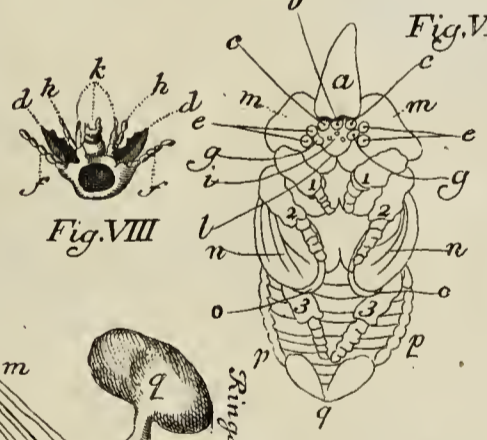


Fig. VII.

Fig. VIII.

Fig. VI.

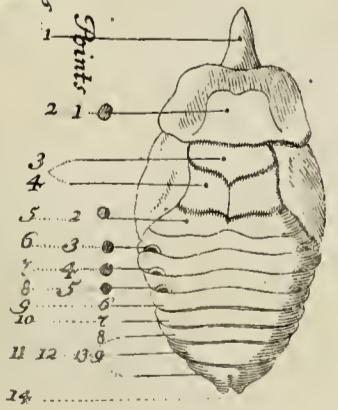


Fig. IX.



Fig: I.

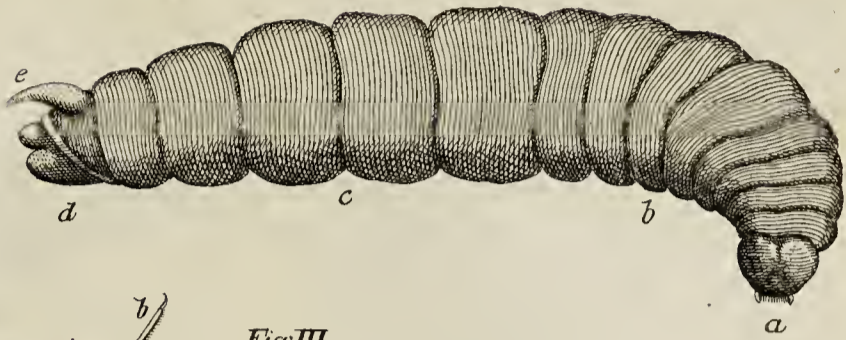


Fig: III.

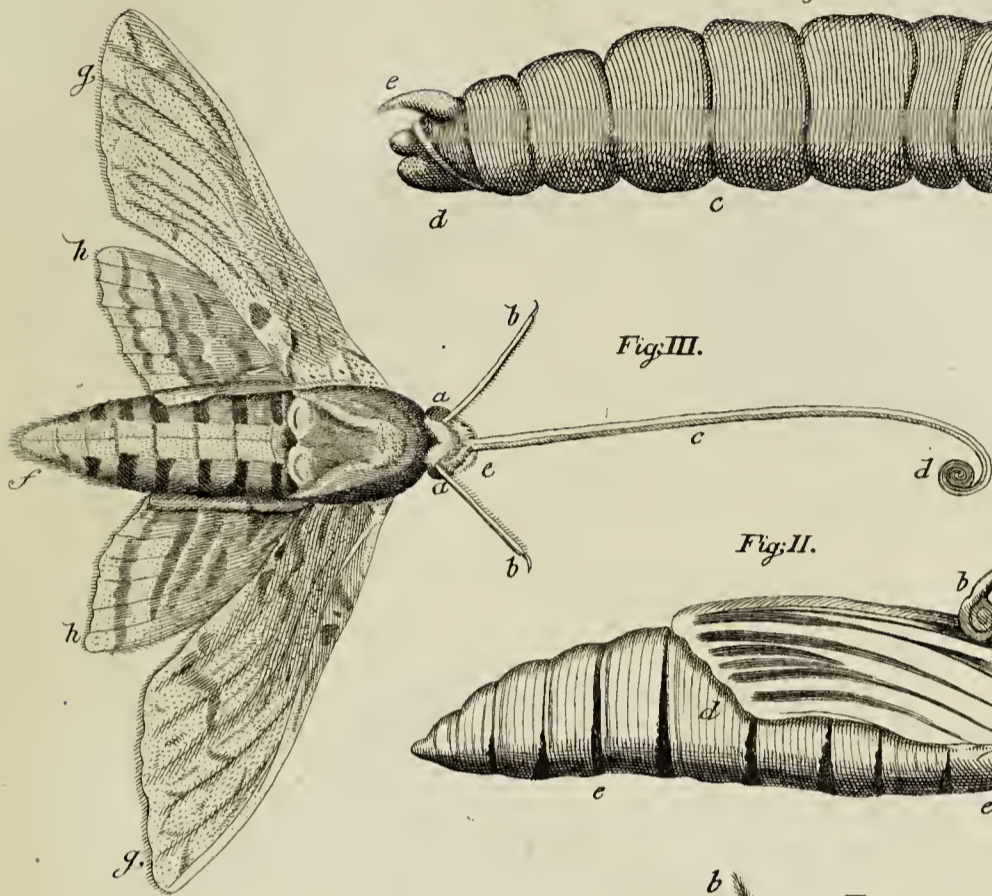


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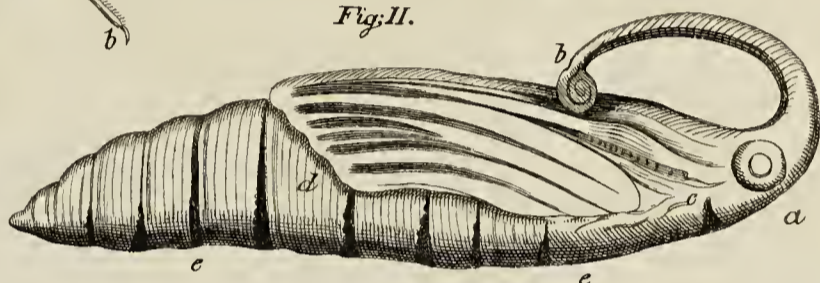


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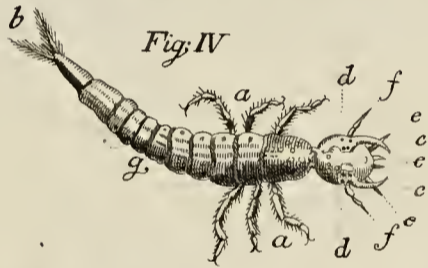


Fig: VI.

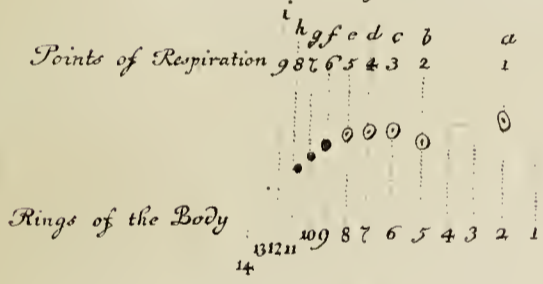


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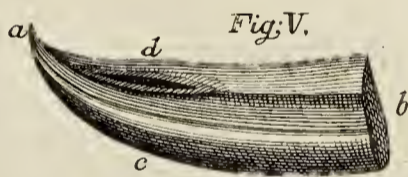


Fig: VII.

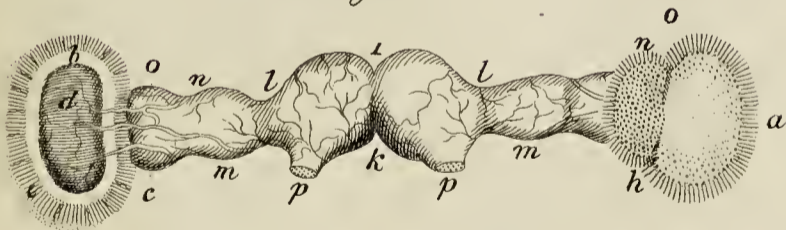


Fig: VIII.

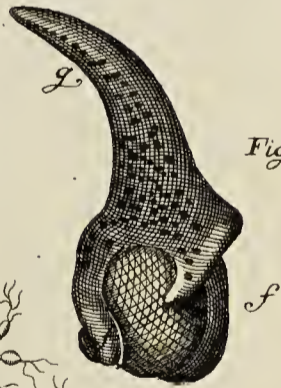


Fig: X.

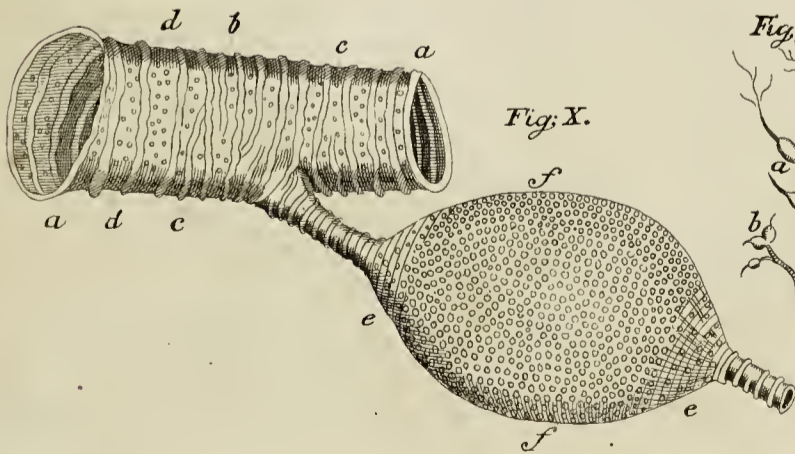


Fig: IX.

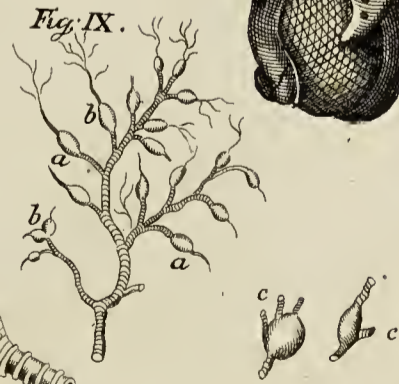




Fig. I.



Fig. II.



Fig. VII.

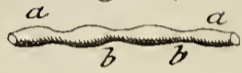


Fig. III.

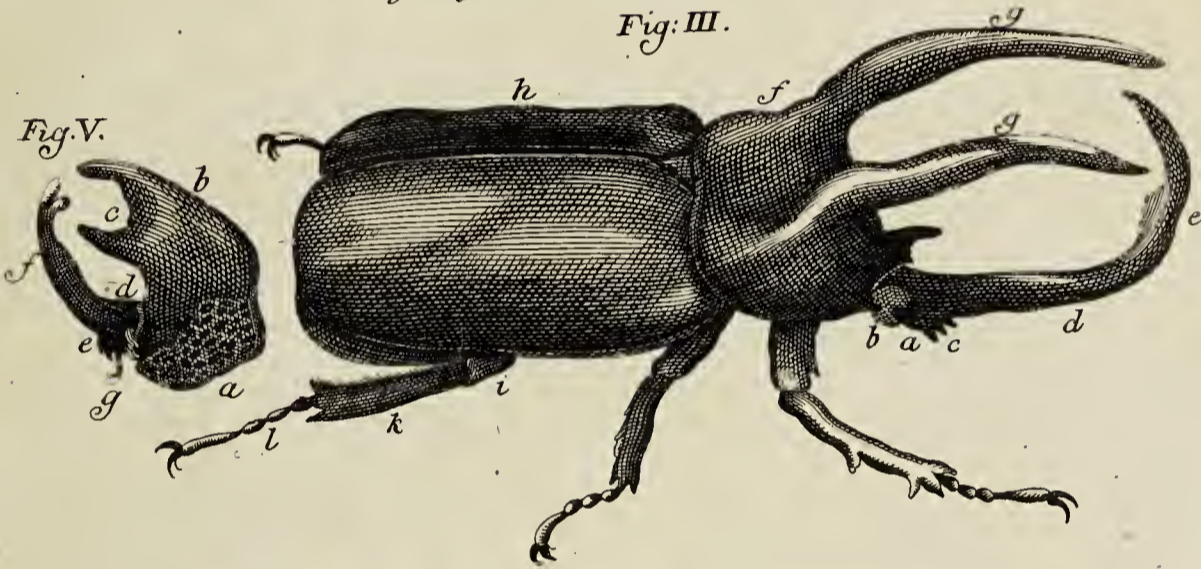


Fig. V.



Fig. VI.

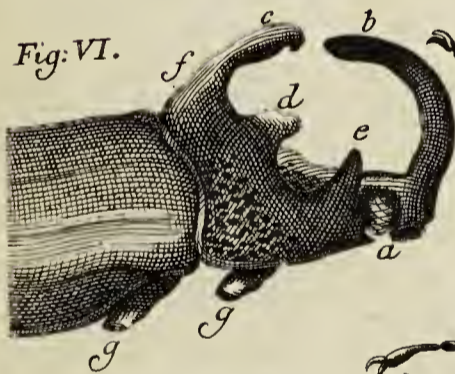


Fig. IV.

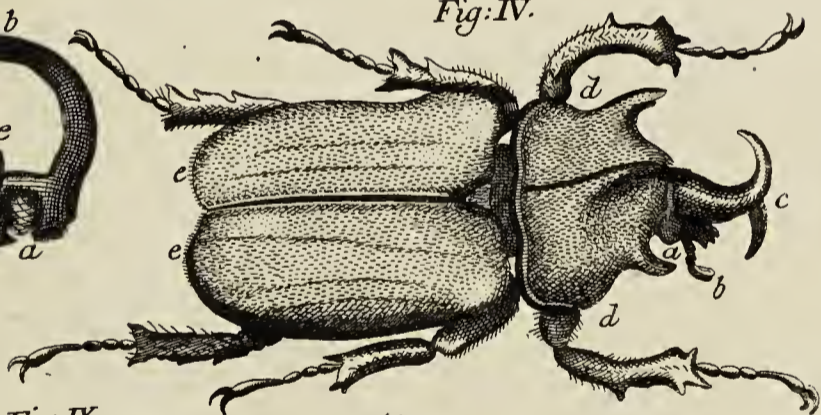


Fig. VIII.

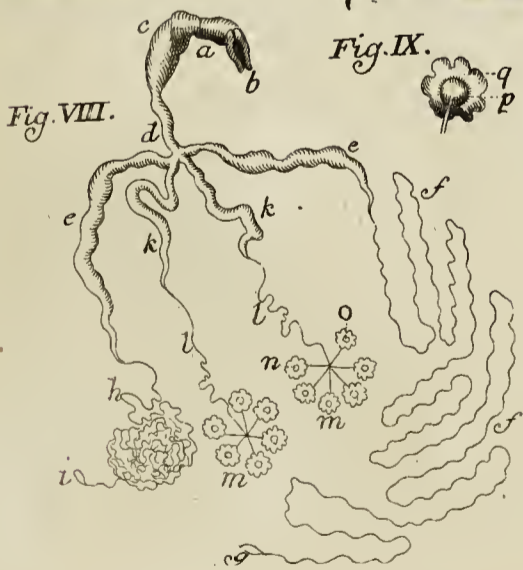
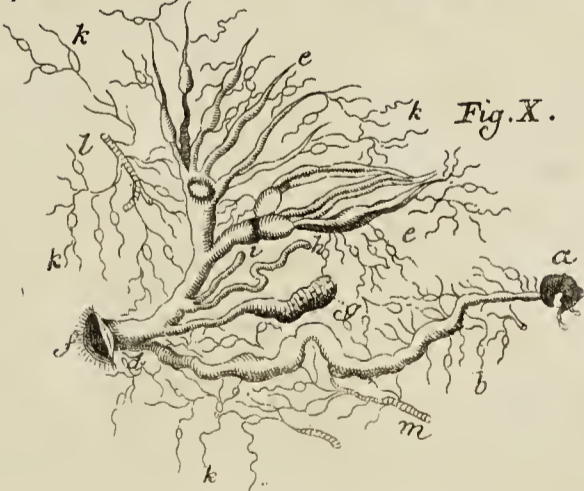


Fig. IX.



Fig. X.







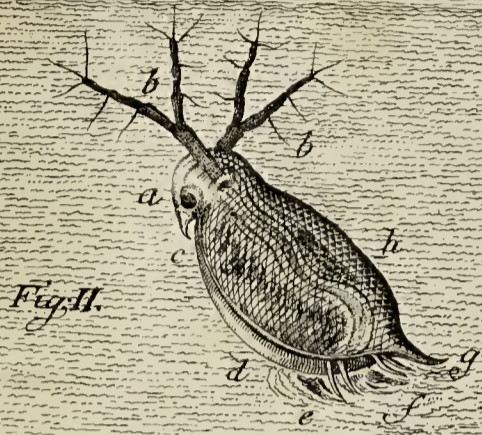


Fig. I.

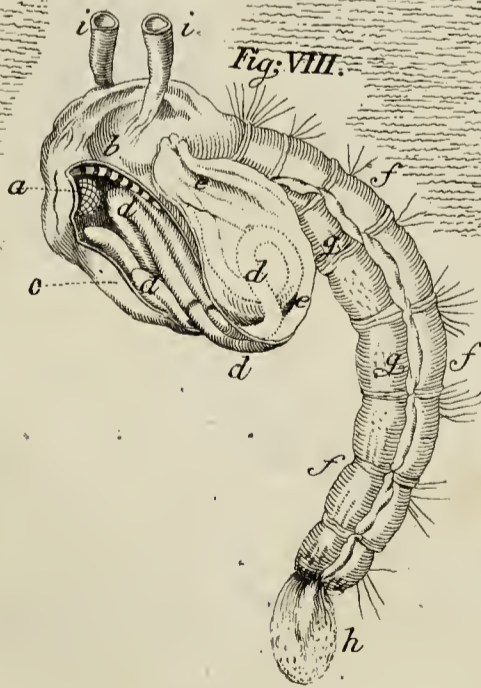
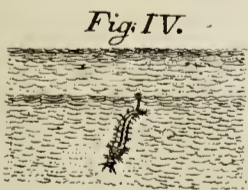
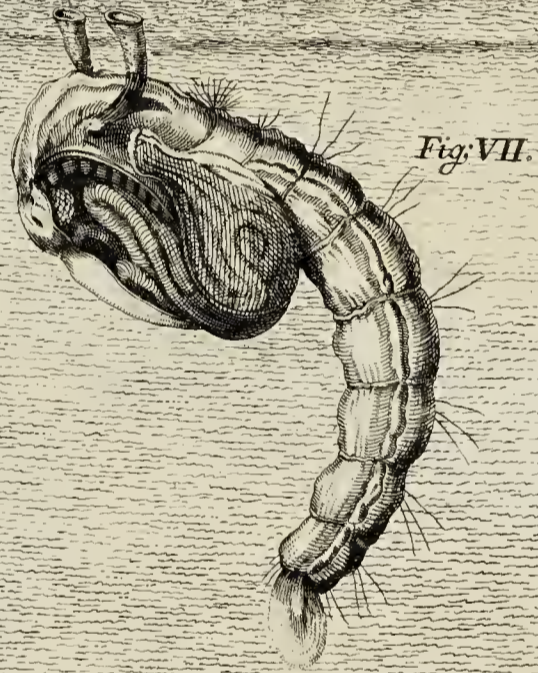
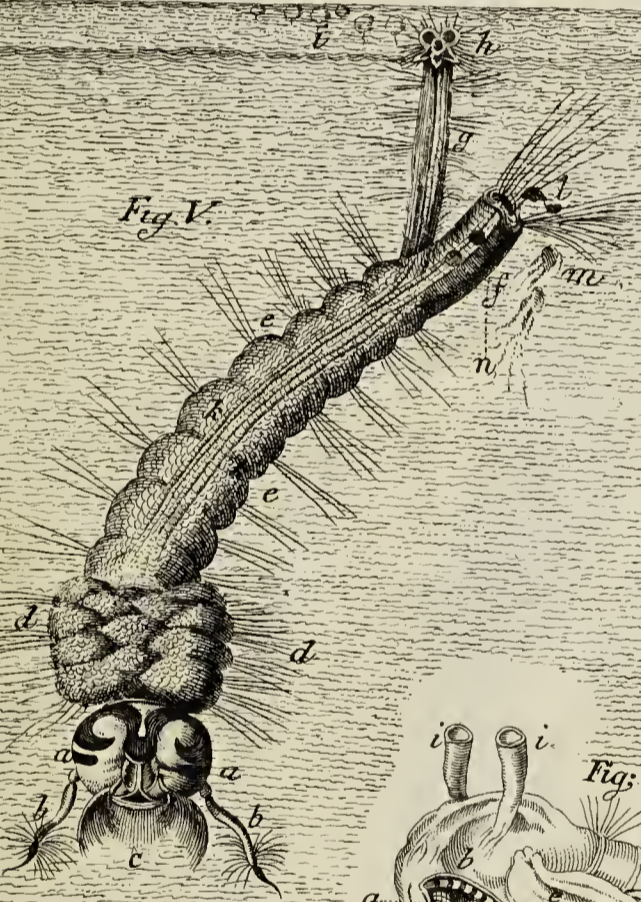
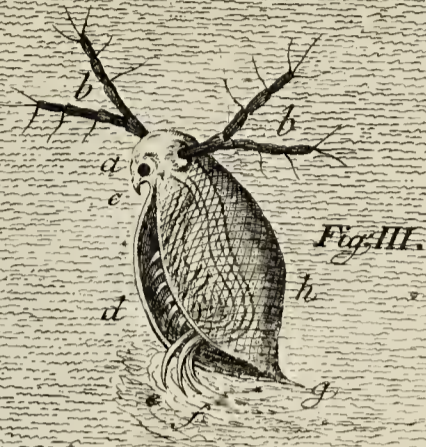






Fig. II.

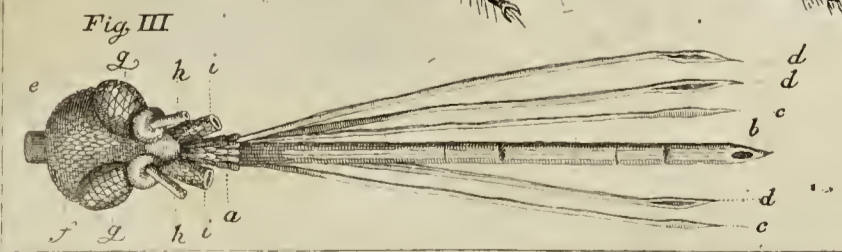
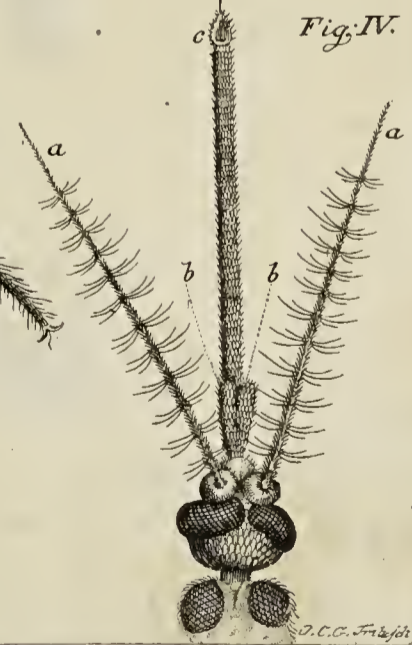


Fig. III.

J. C. C. F. sculp.



Order the Third  
Nymph Chrysalis or Aurelia

TAB. XXXIII.

Fig. I.

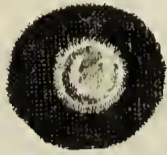


Fig. III.



Fig. II.

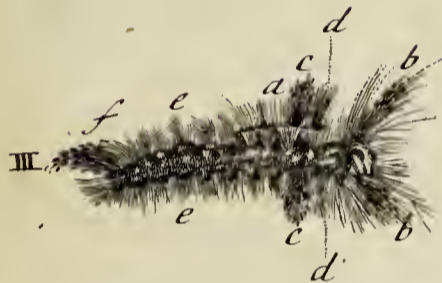
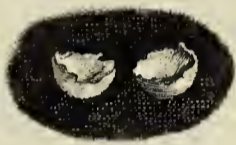


Fig. VIII.



Fig. IV.



Fig. V.

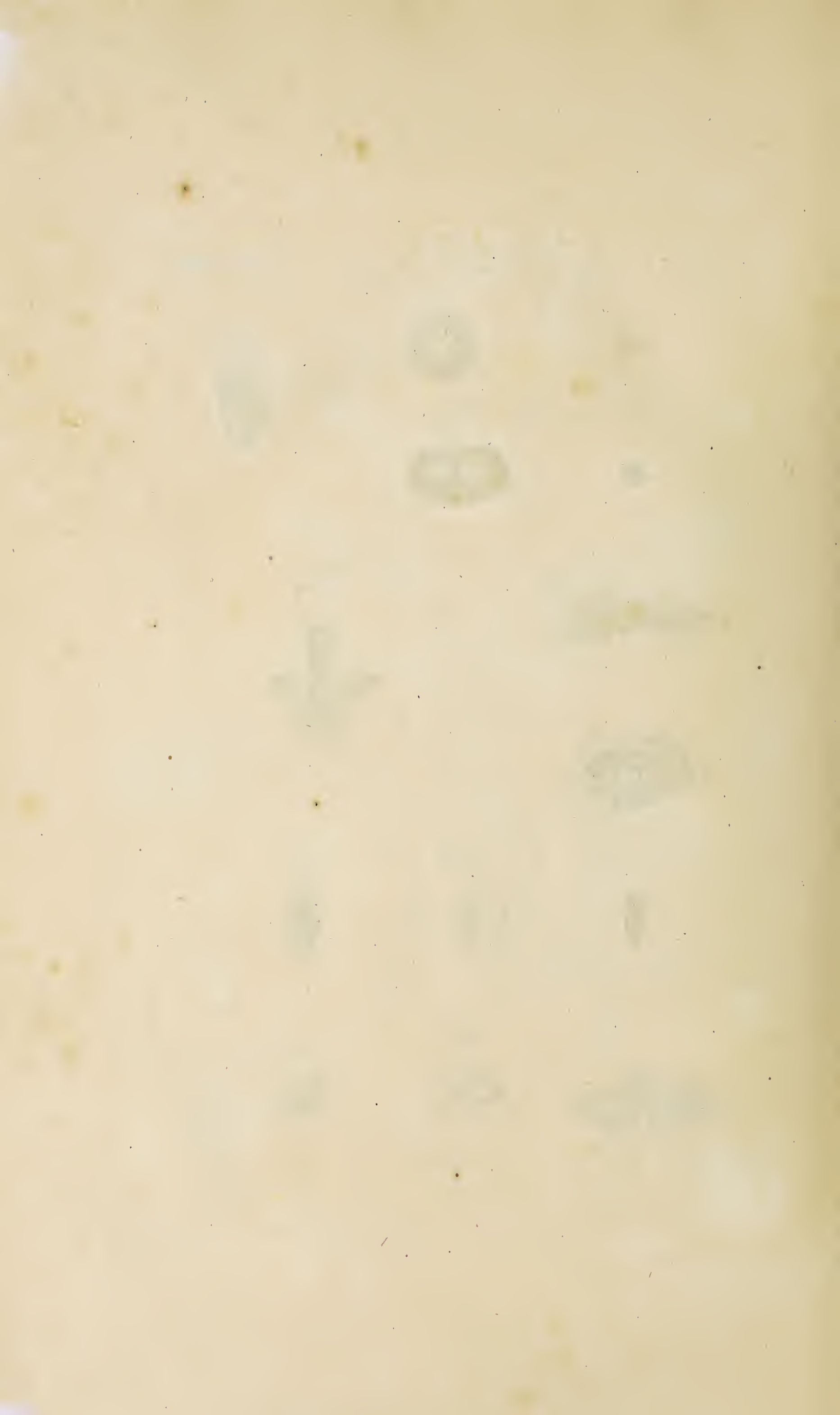


Fig. VI.



Fig. VII.





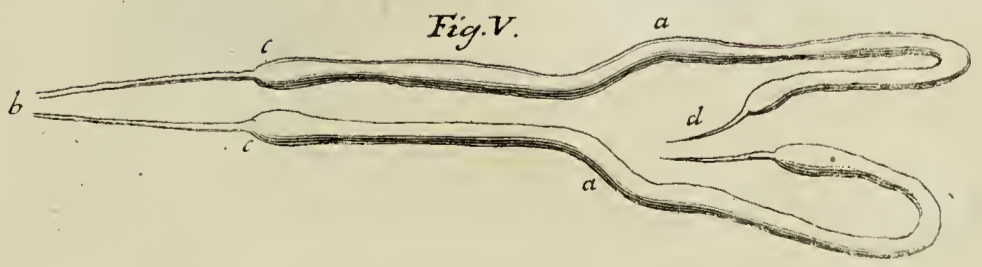
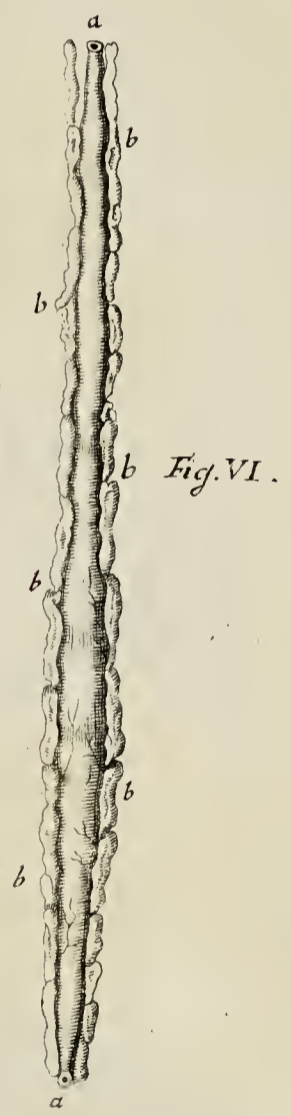
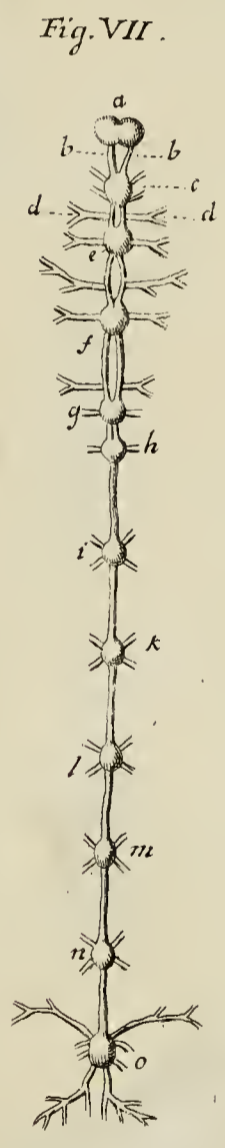
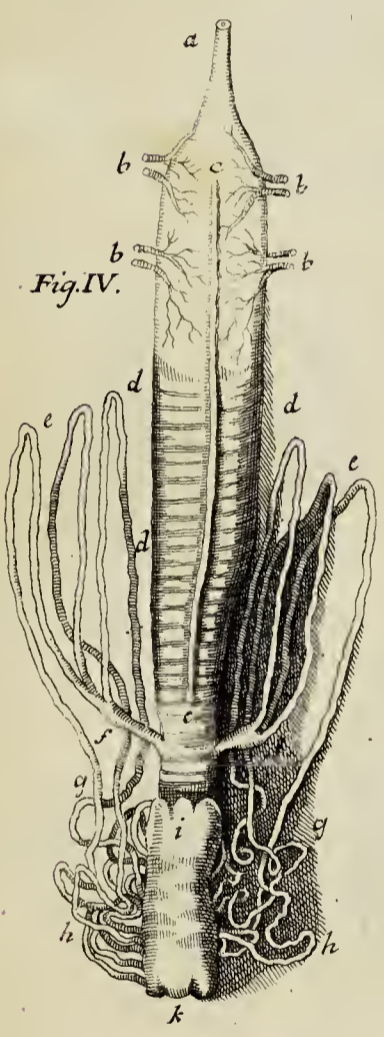
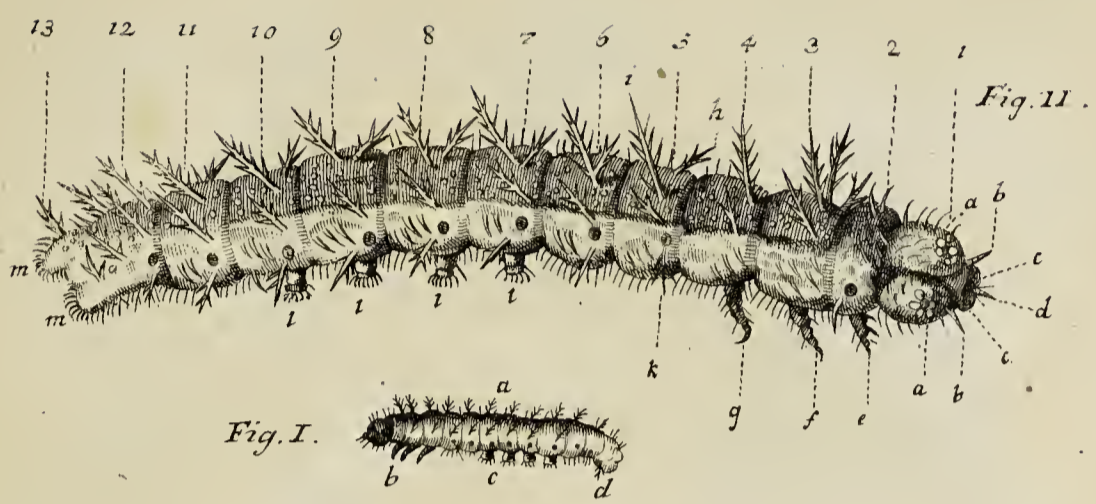






Fig. I.



Fig. II.



Fig. VII.

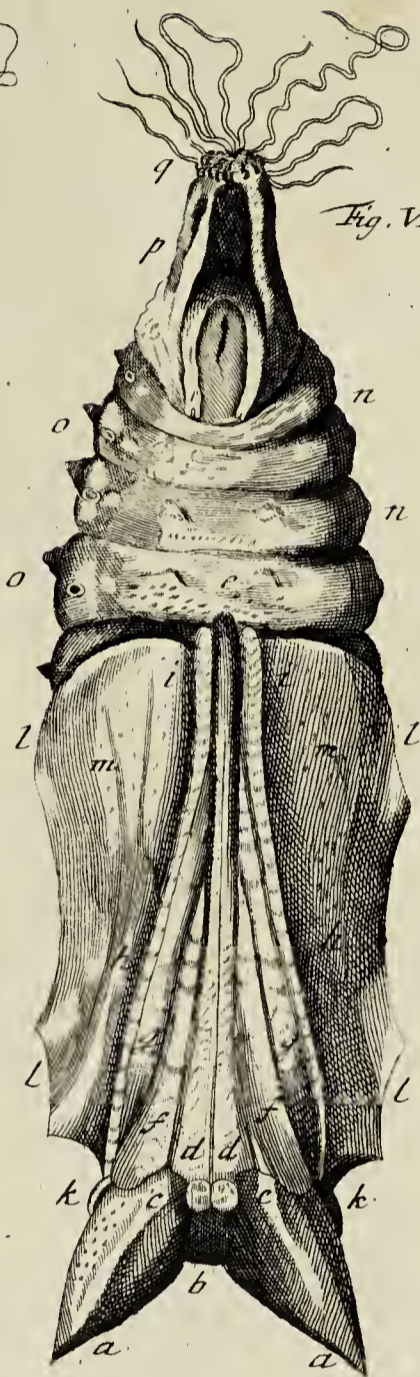


Fig. III.

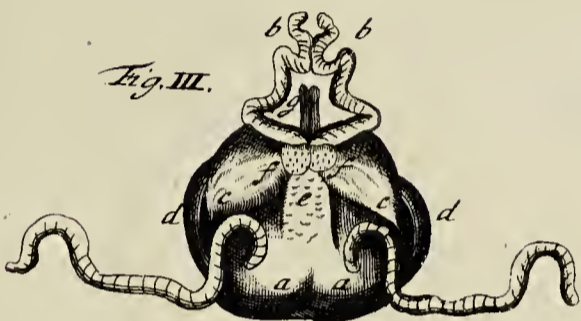


Fig. VI.



Fig. V.



Fig. IV.



Fig. X.



Fig. IX.



Fig. VIII.



Fig. XI.



Fig. XII.

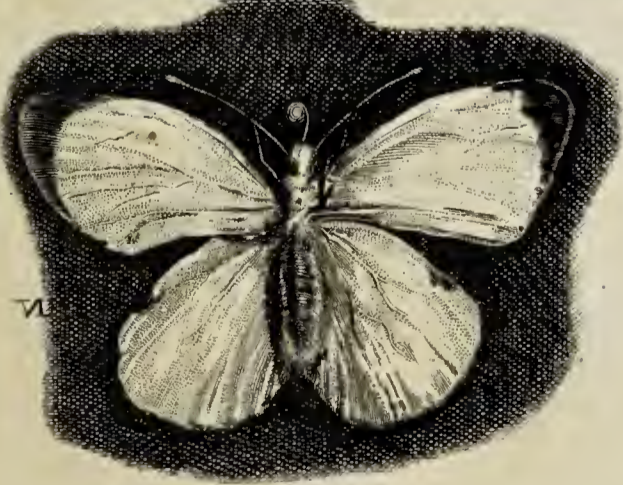
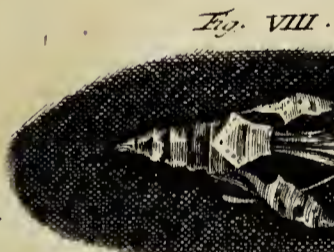
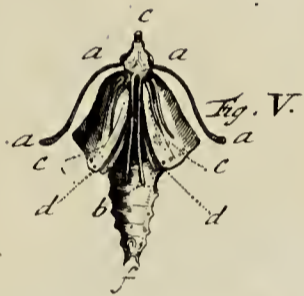
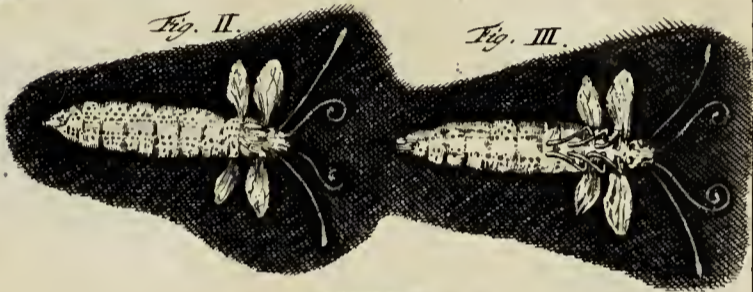
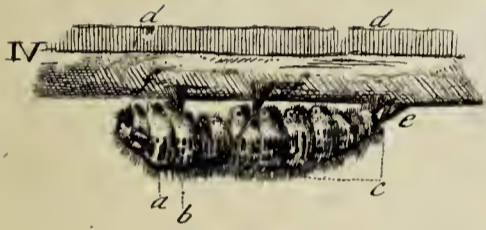
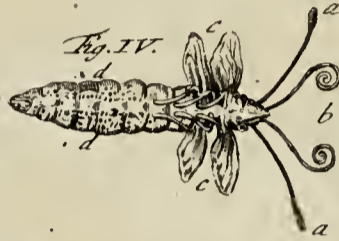








I  
II





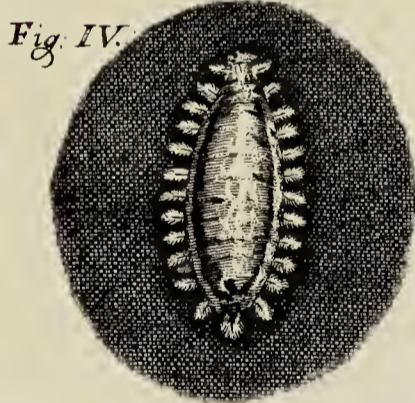
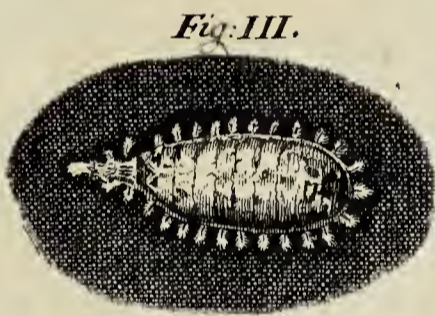


Fig. V.



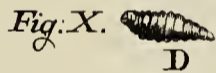
A



B



C



D



E



Fig. VI.



Fig. VII.



VI

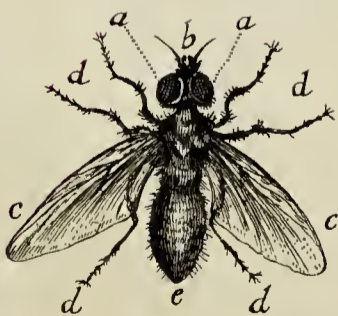


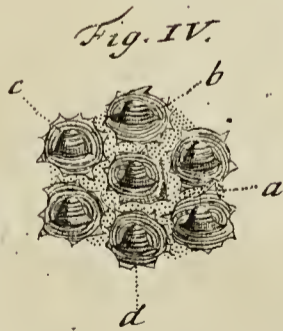
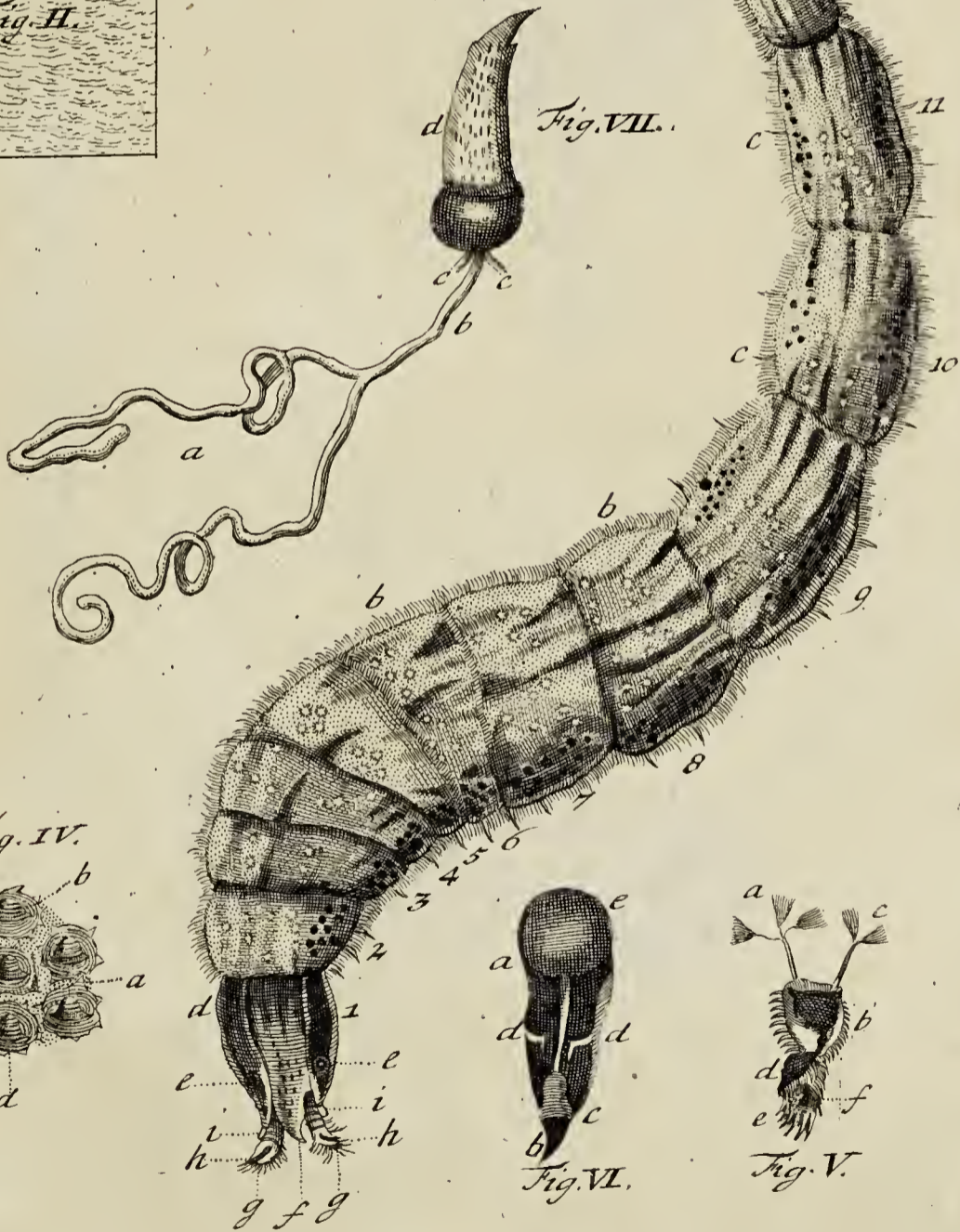
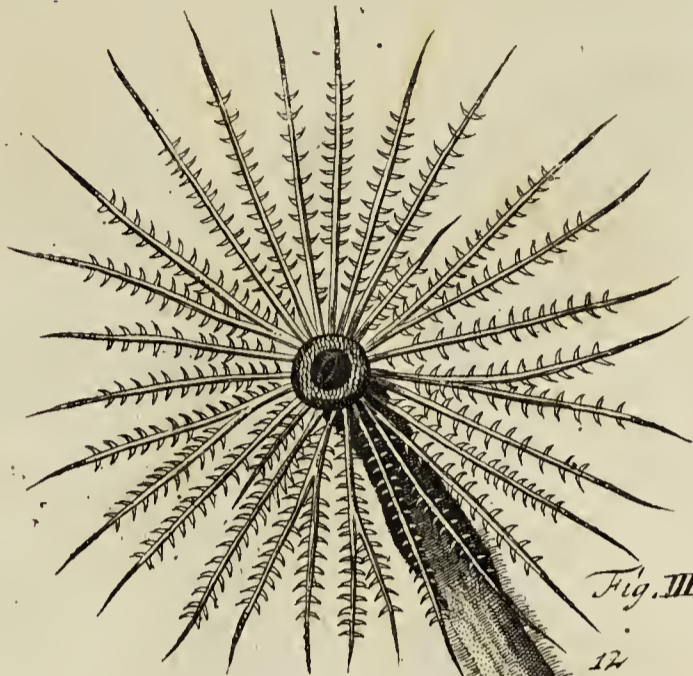
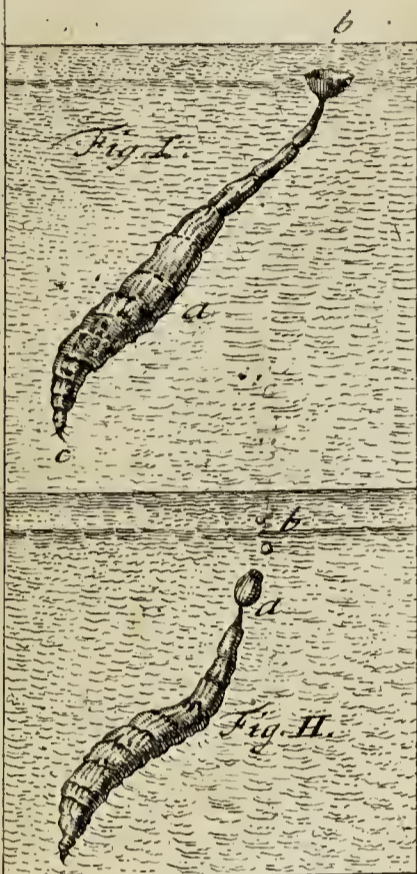
Fig. VIII.



F









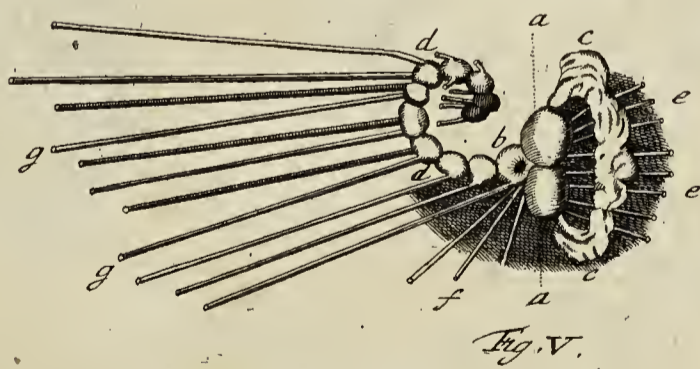
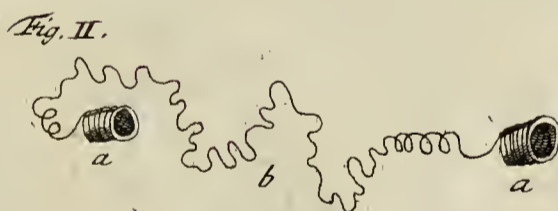
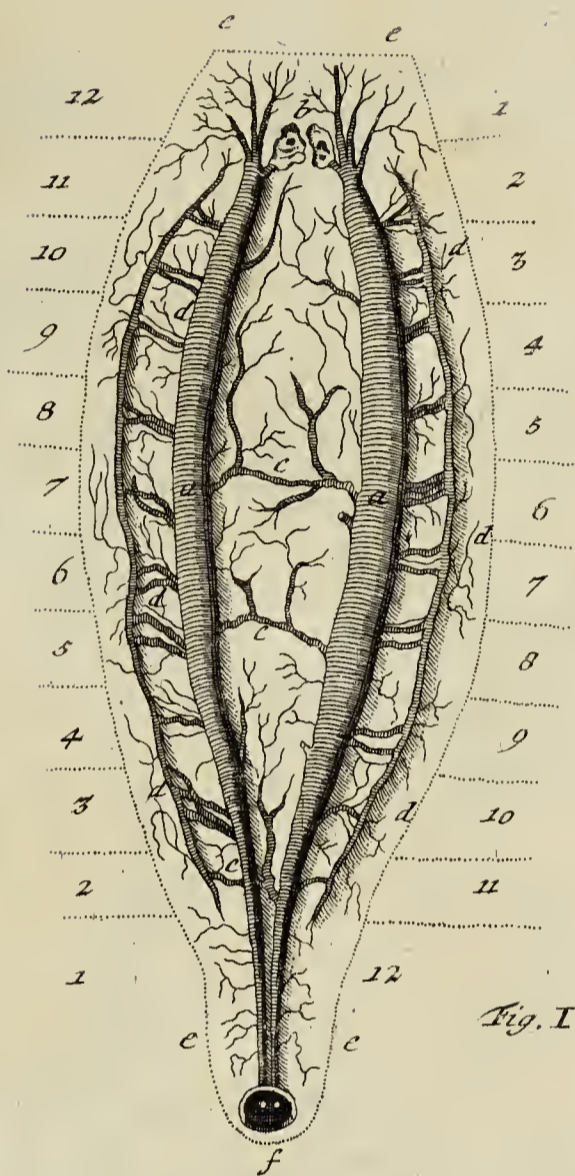
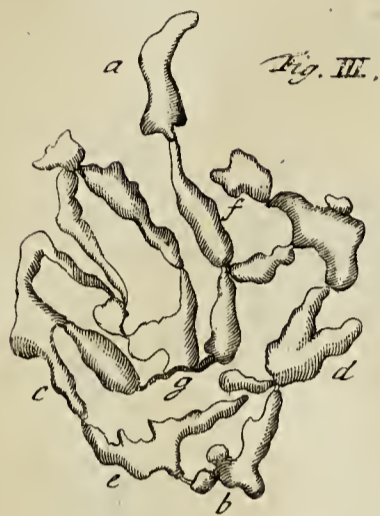




Fig. I.

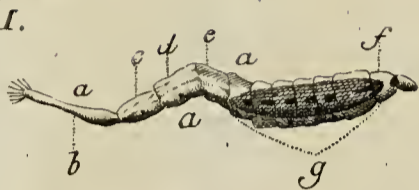


Fig. II.

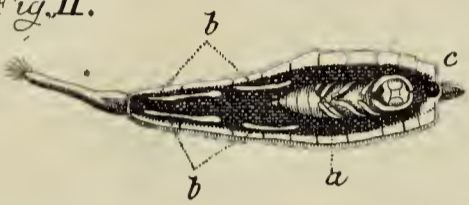


Fig. III.



Fig. V.



Fig. VI.

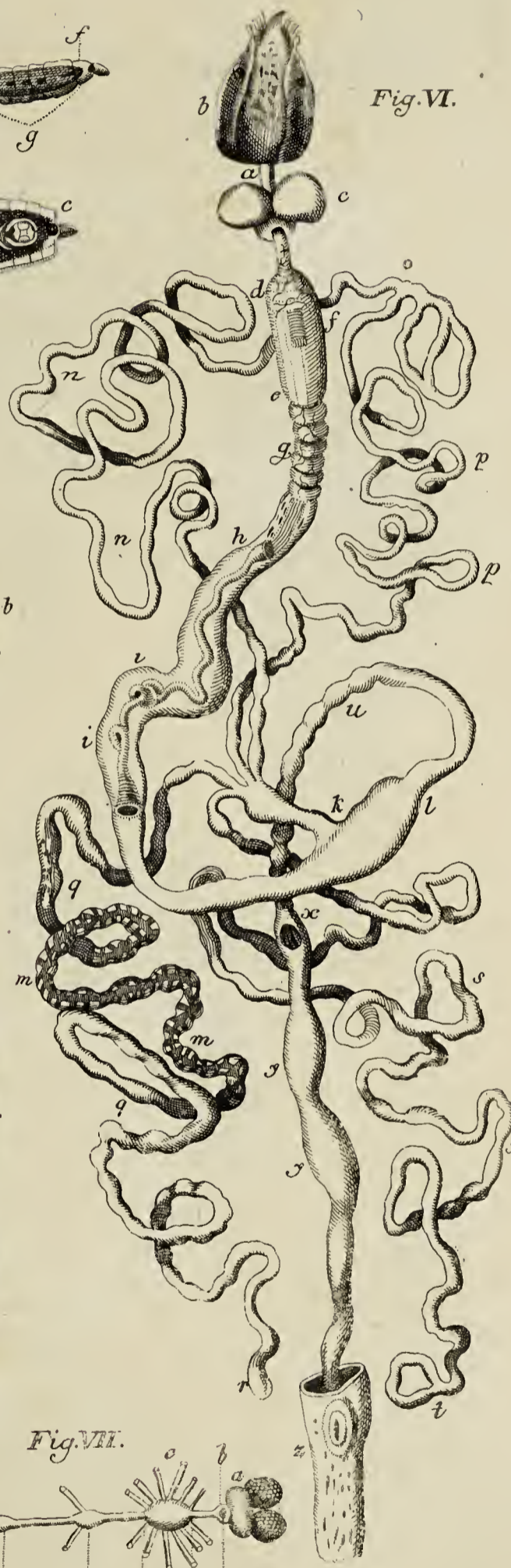
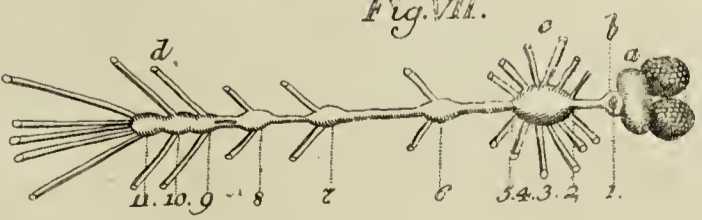
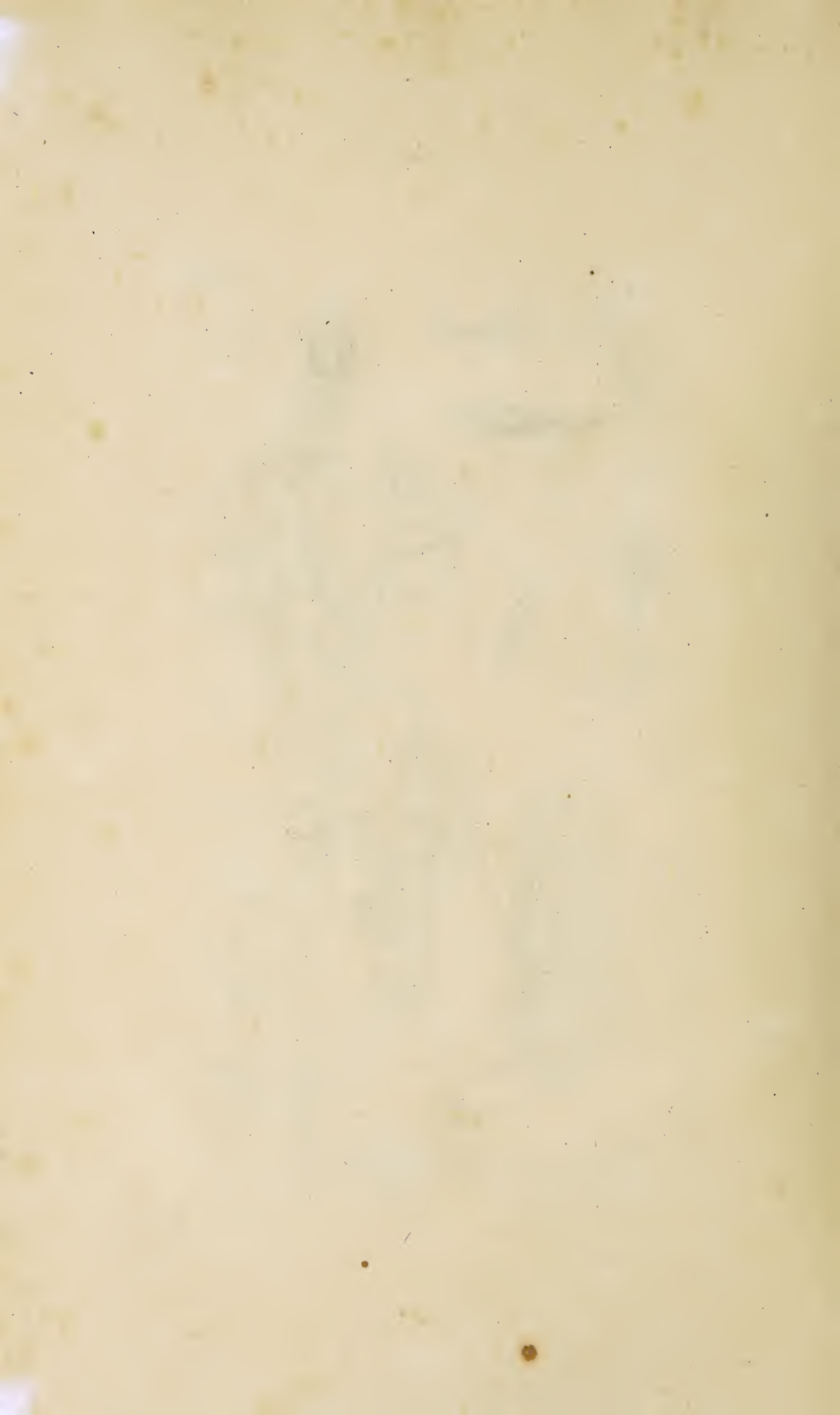


Fig. IV.

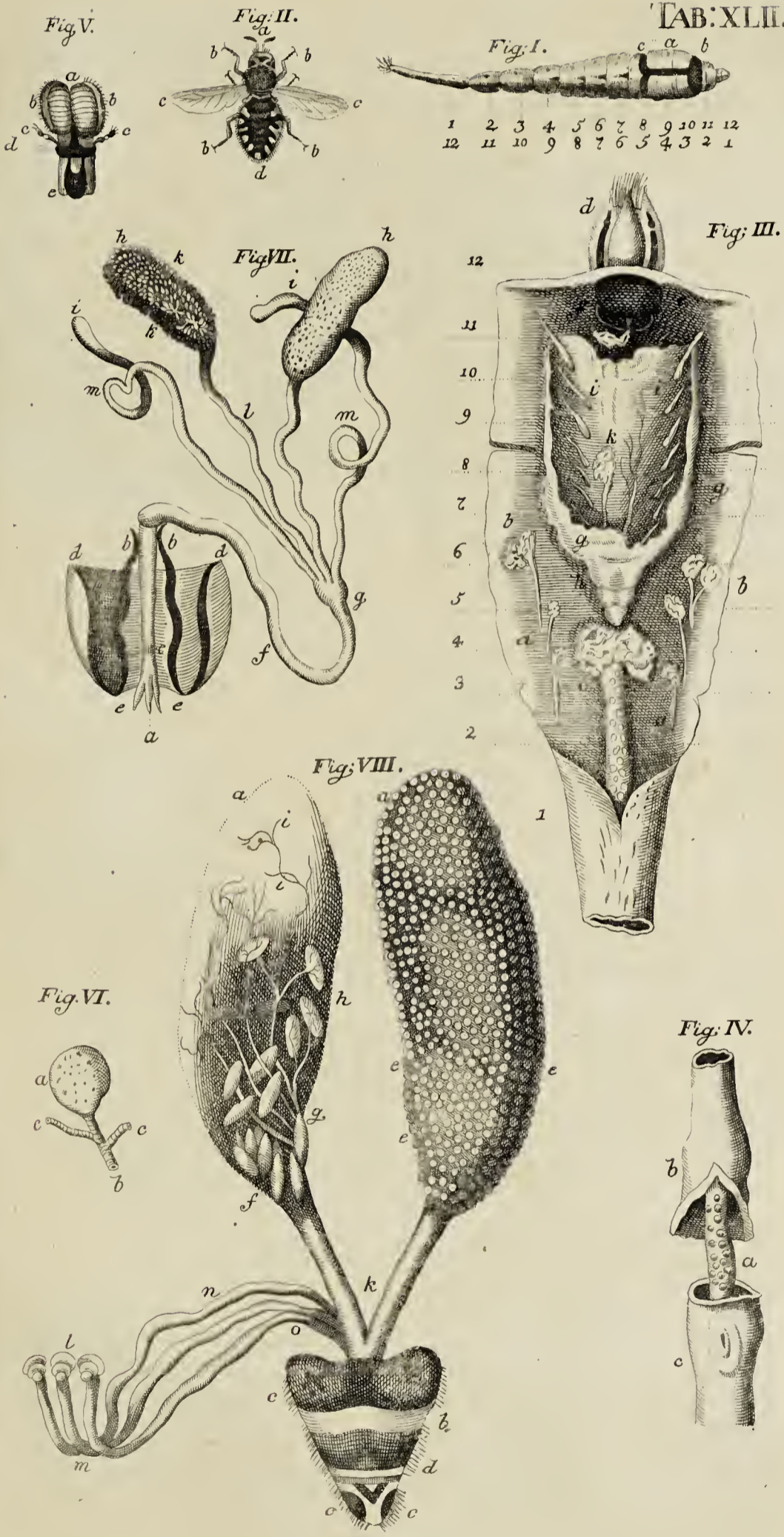


Fig. VII.





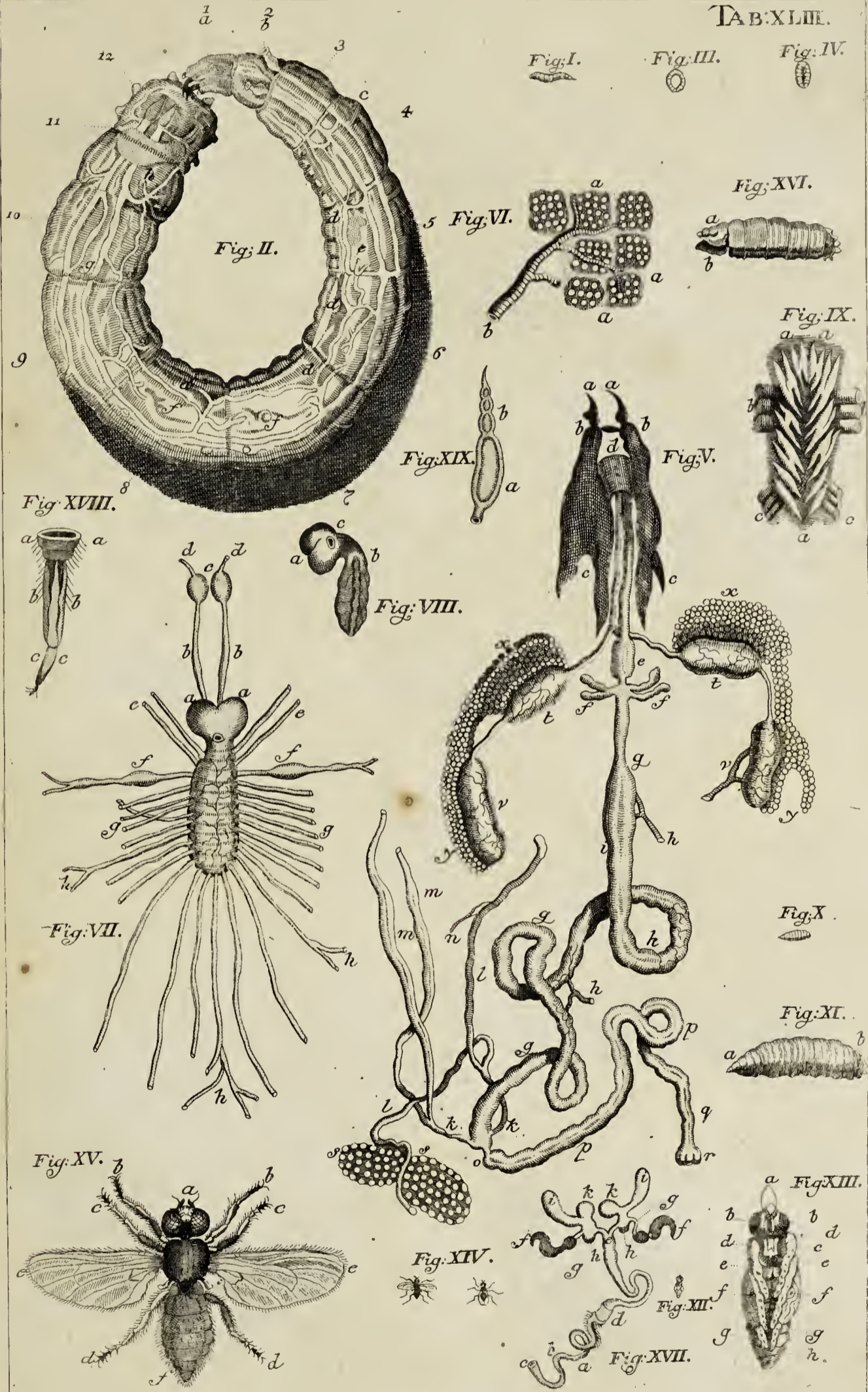
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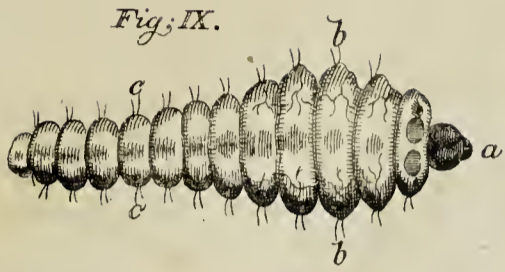


Fig. VIII.

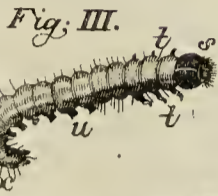


Fig. VII.

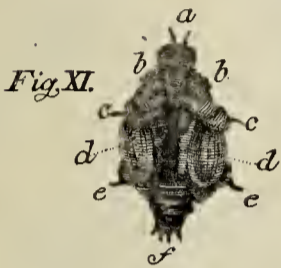


Fig. X.



Fig. XII.



Fig. XIII.



Fig. II.



Fig. IV.

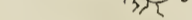


Fig. XIV.



Fig. VI.

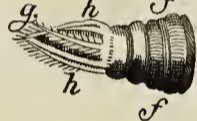


Fig. XV.



Fig. XVI.



Fig. XVII.



Fig. XVIII.

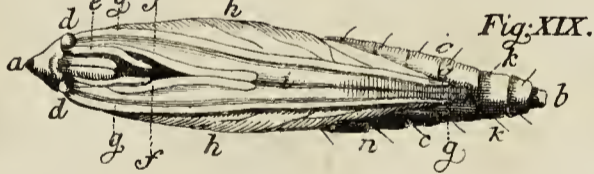


Fig. XIX.

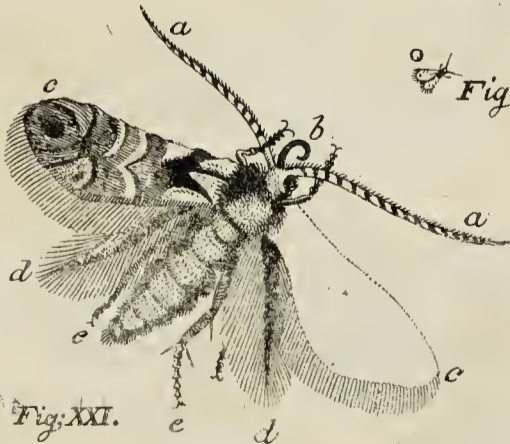


Fig. XXI.

Fig. XX.



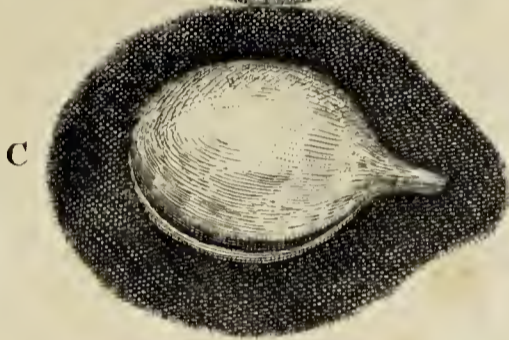
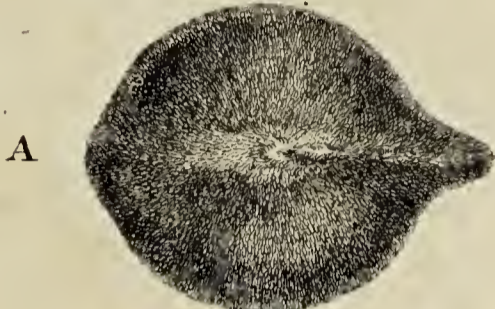
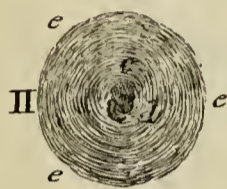
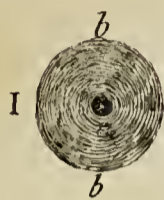




Frogs

Slow Encrease

Clove July flowers



I

II

B

III

IV

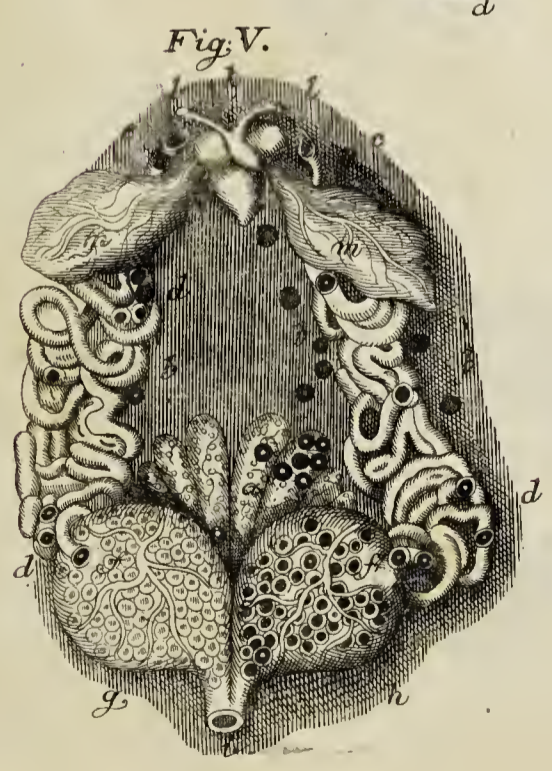
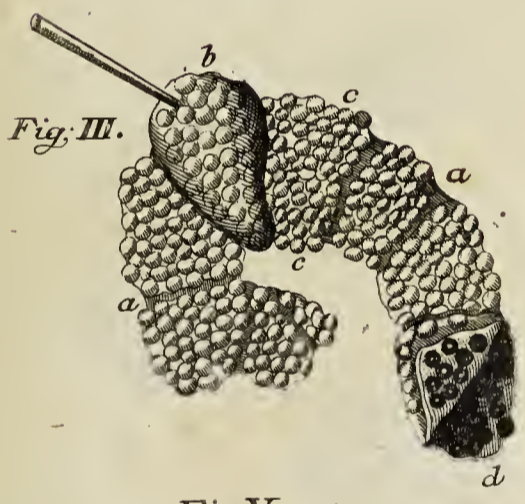
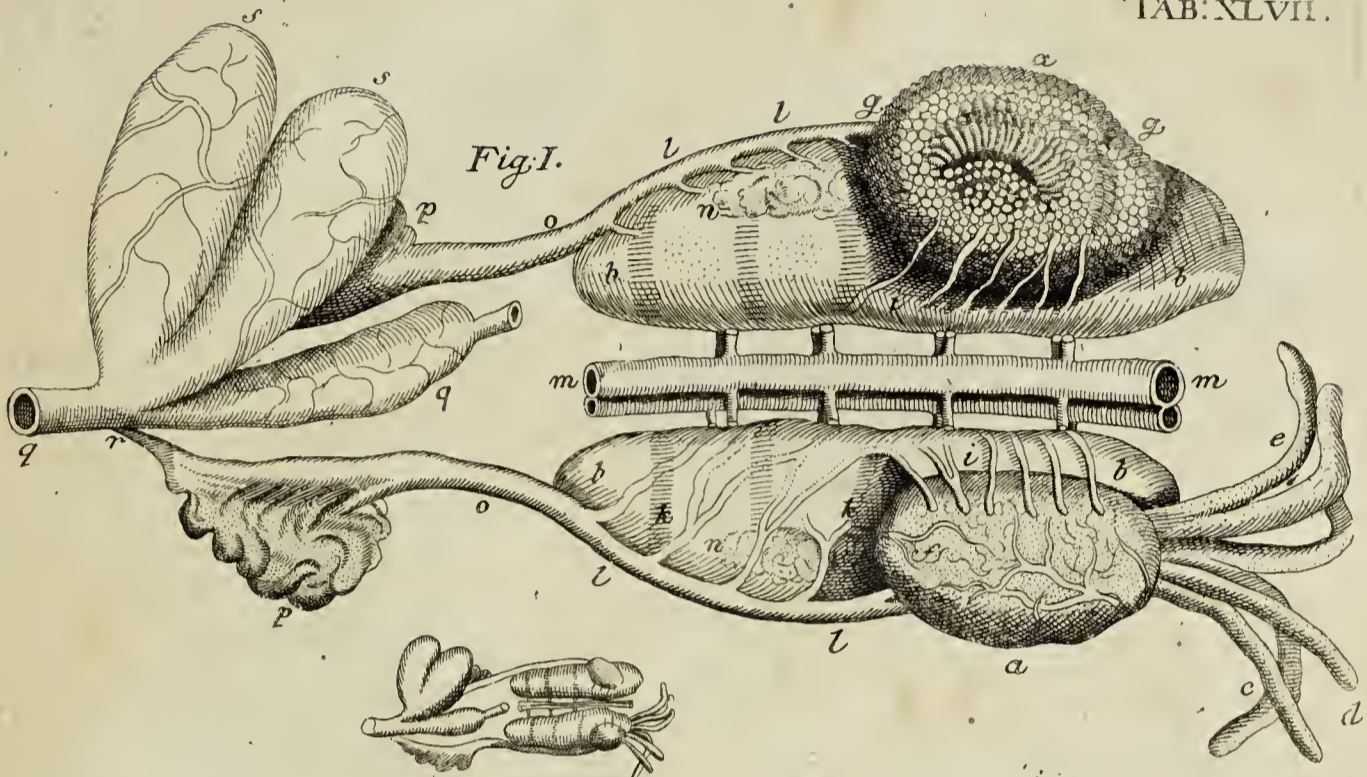
V

VI











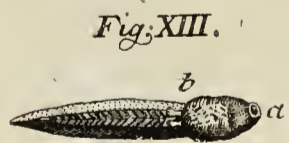
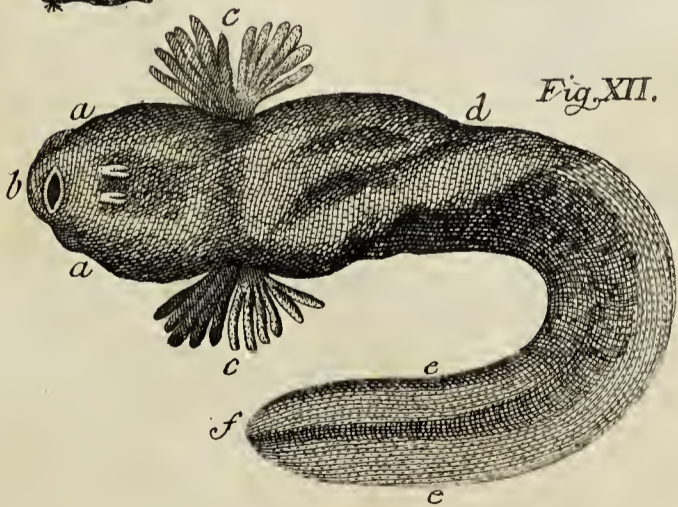
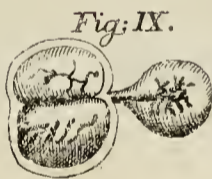
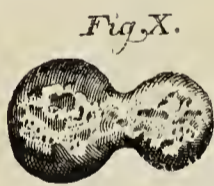
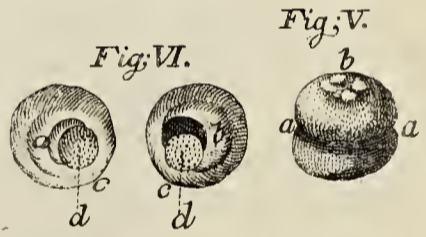
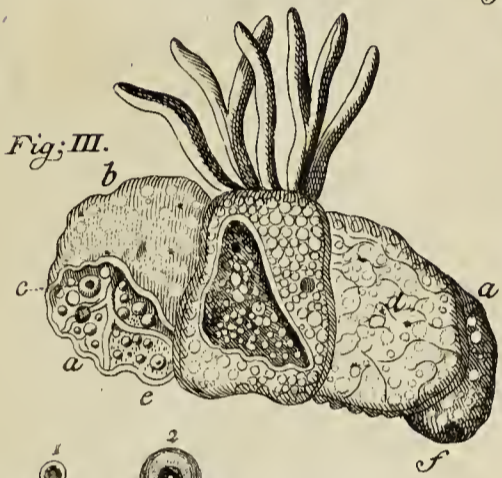
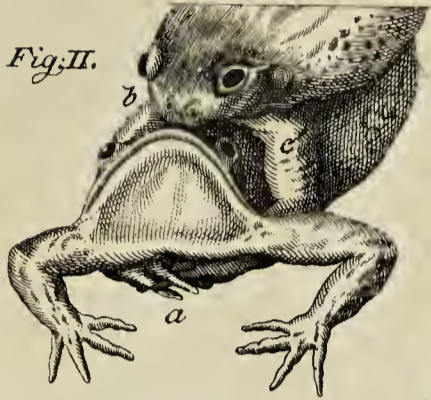




Fig. I.



Fig. II.

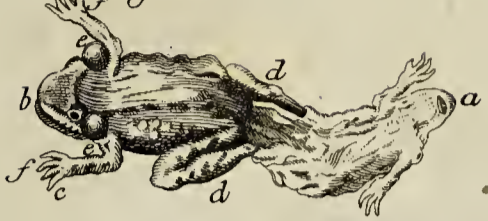


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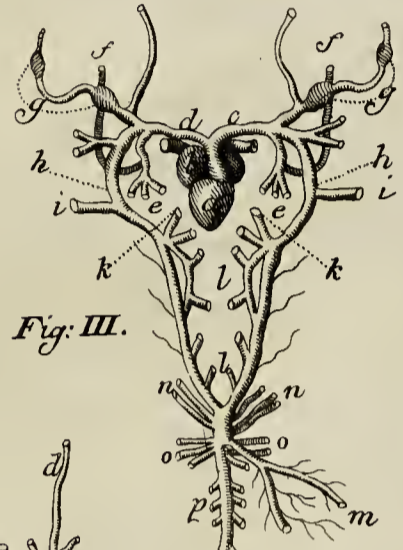


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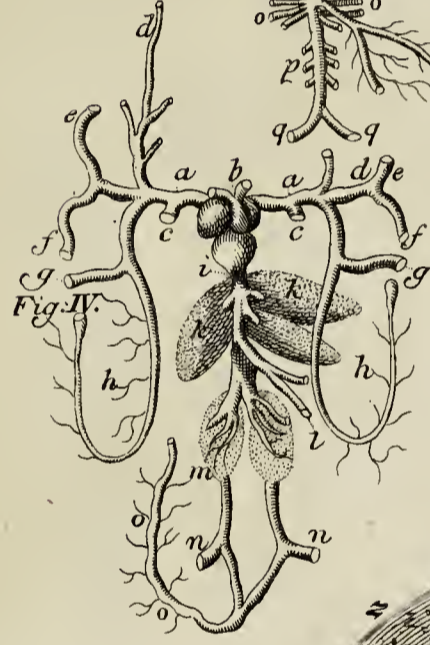


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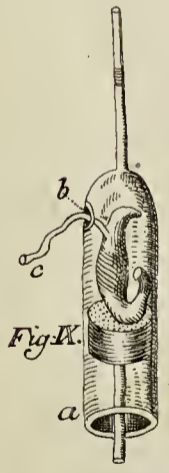


Fig. VI.

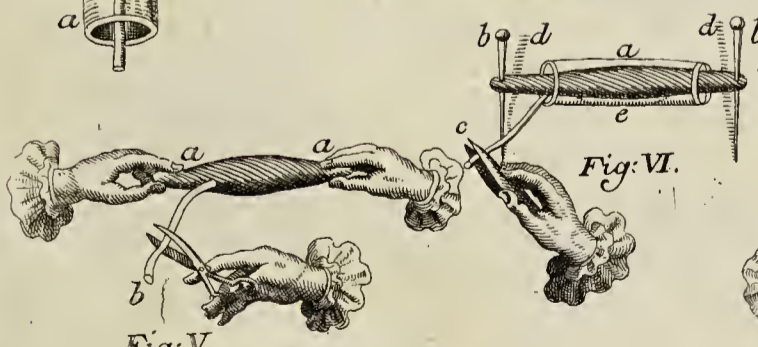


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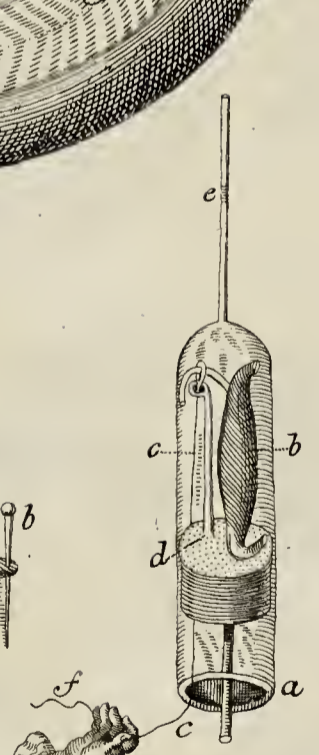
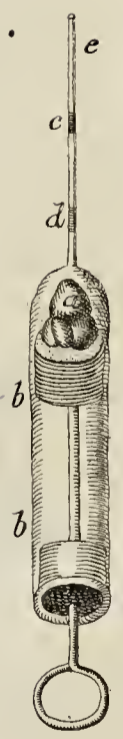
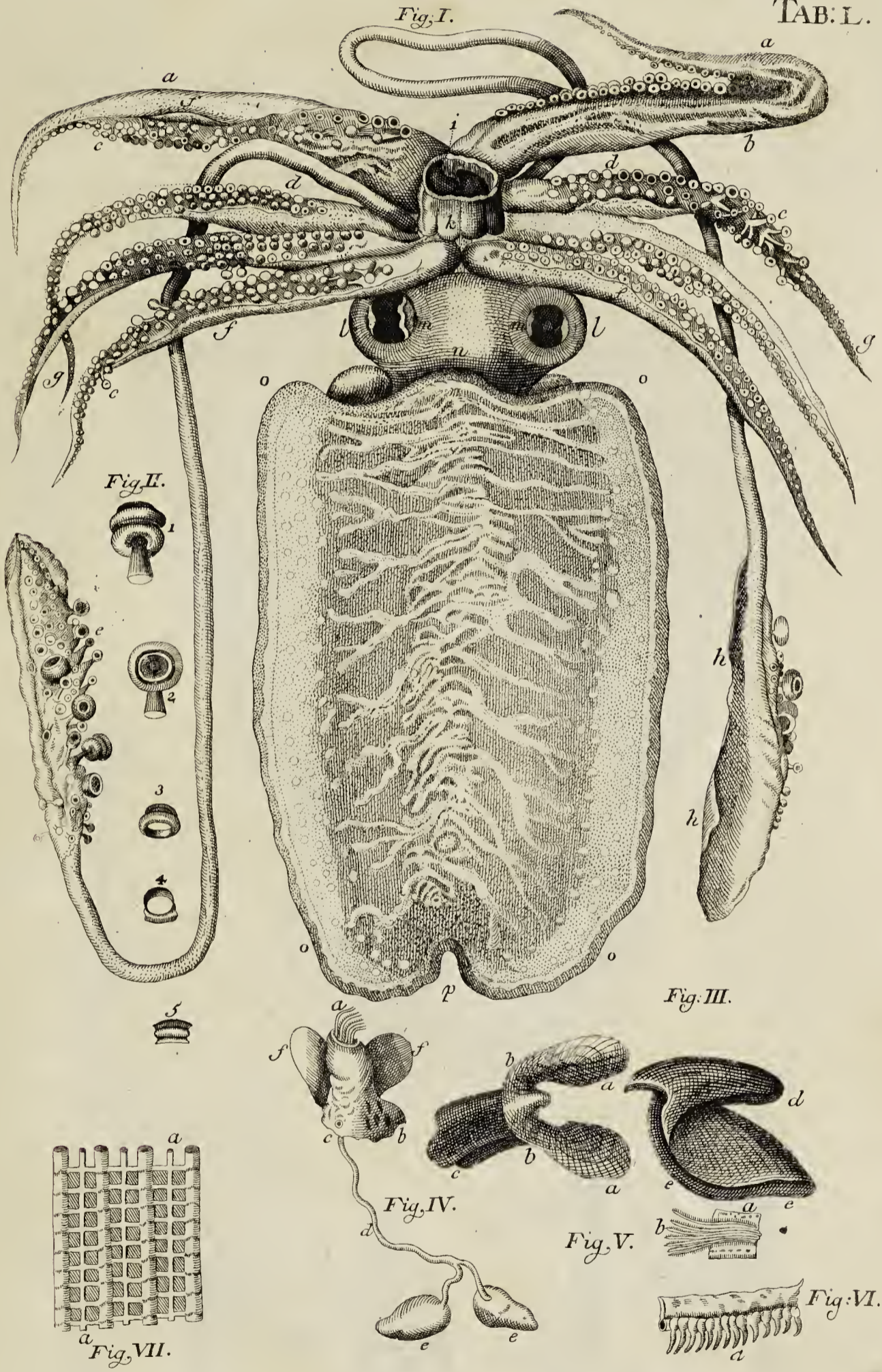


Fig. VII.

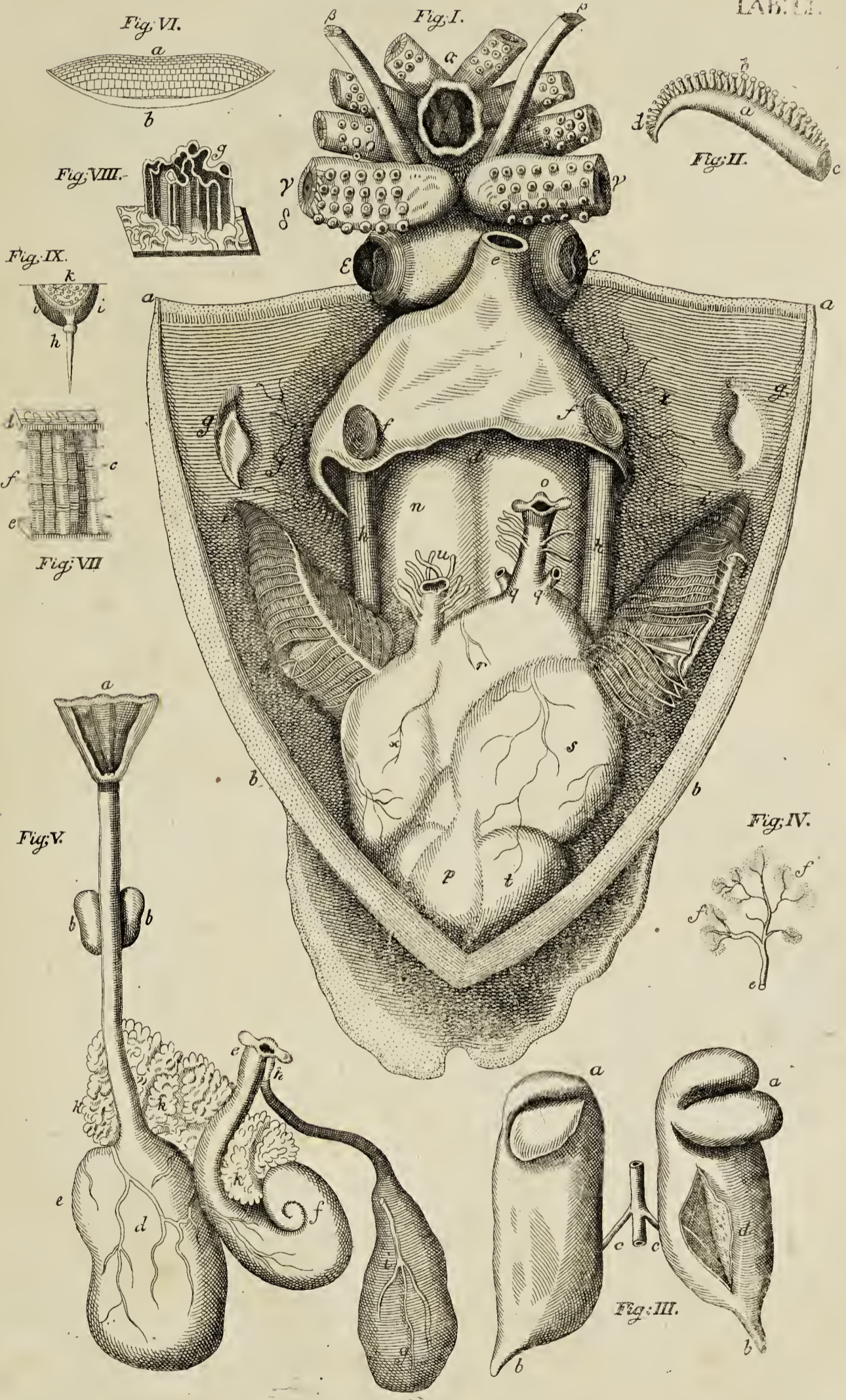




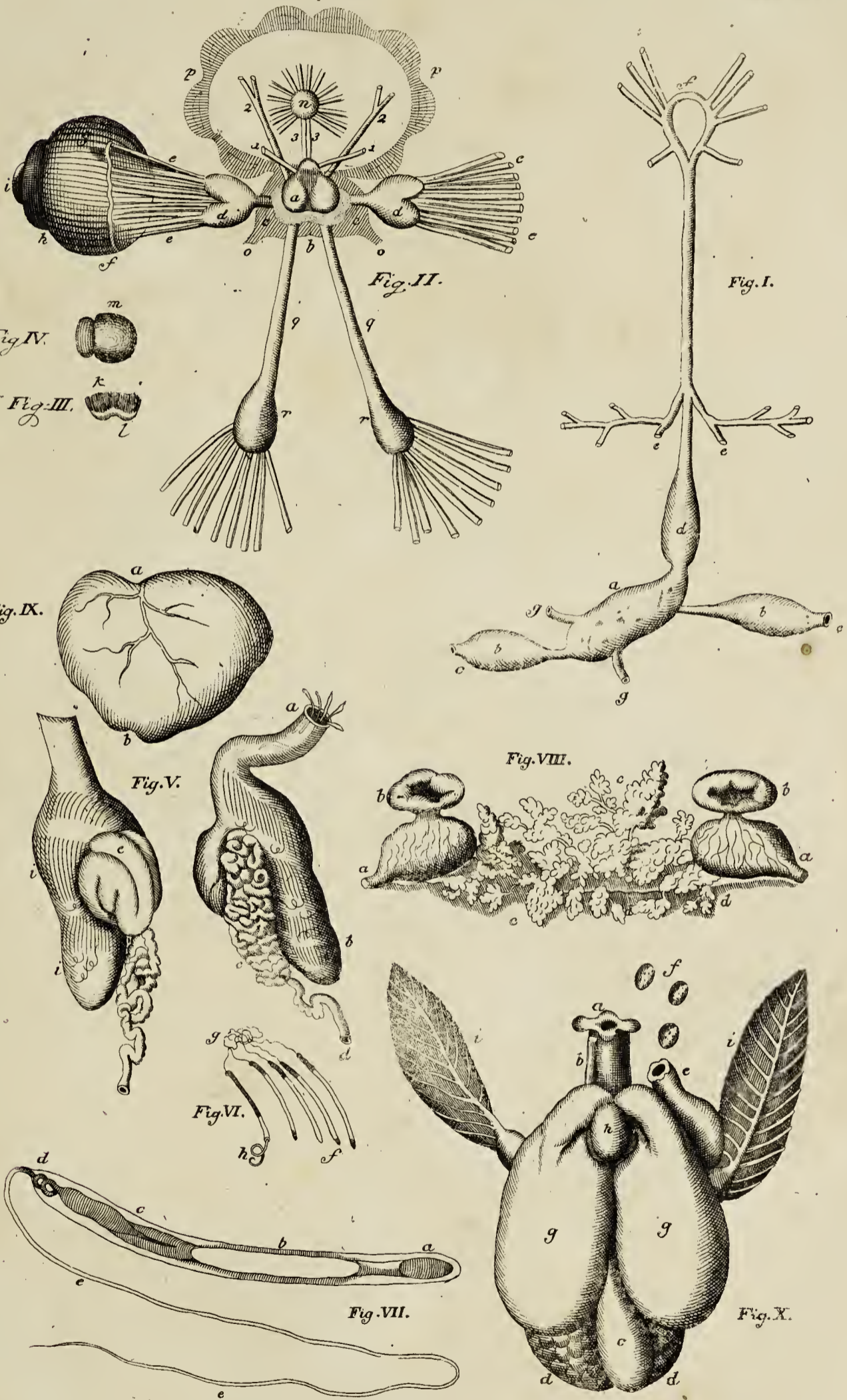




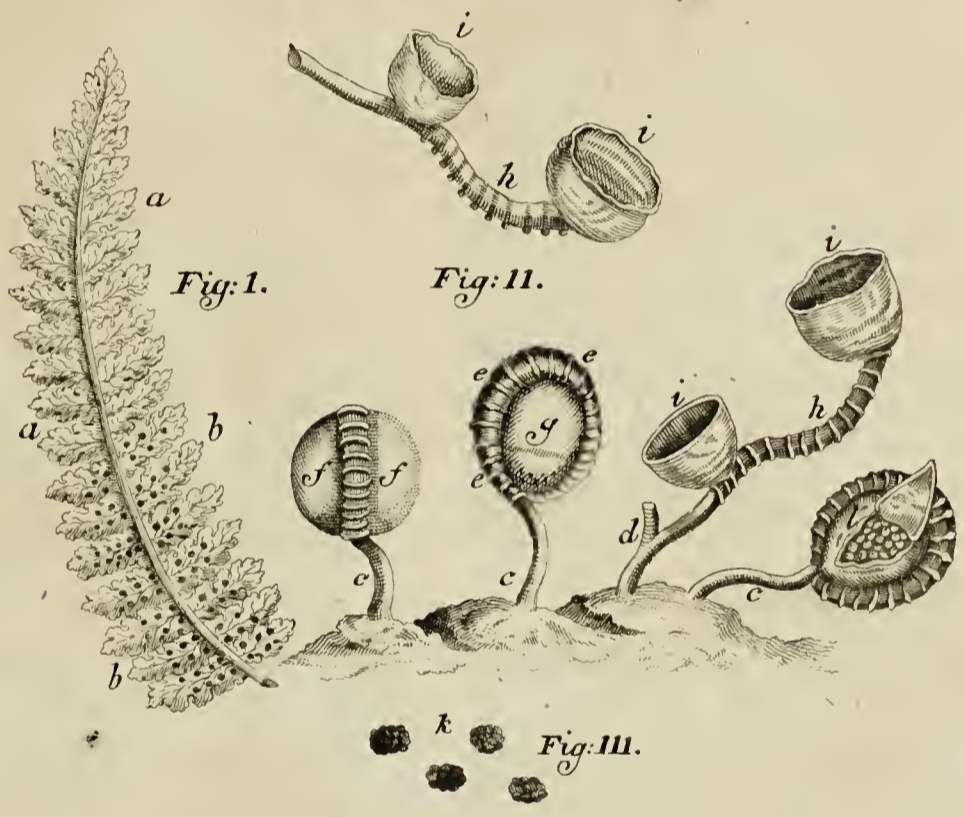




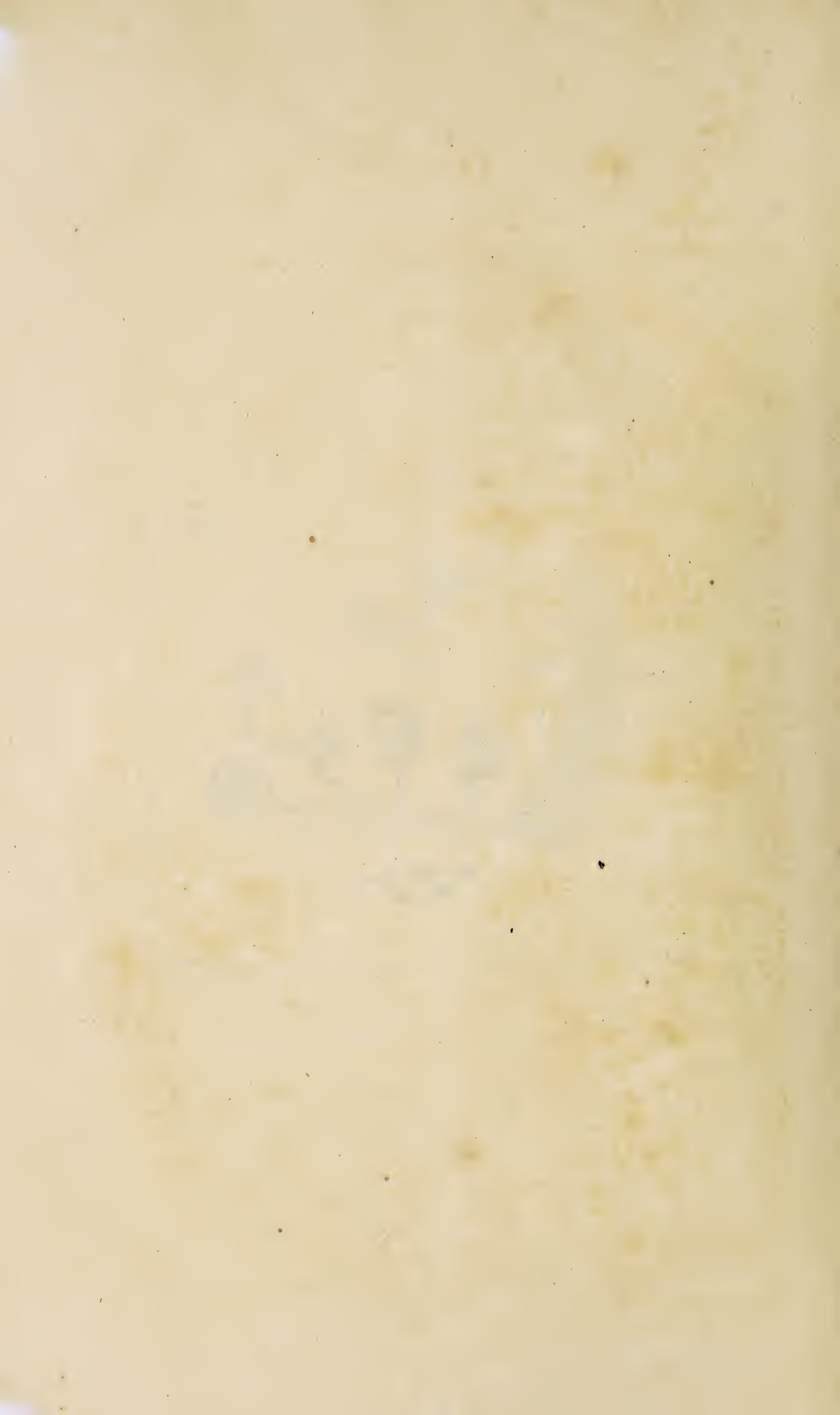








J.C.G. Fritschel. f. sculp.



# I N D E X.

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## X

**X** YLOPHTHORI of Aldrovandus, what kind of Worms P. II. 38

# T H E E N D.

The Reader is desired to excuse and correct the following ERRATA.

Page Col. Line	<i>Instead of</i>	<i>please to read</i>
31-2-3	like a point	like a point <i>b</i>
32-1-44	of those rings	of those rings <i>f</i>
39-2-47	pidgeons	Pigeons.
46-2-34	stomach	stomach <i>b</i>
52-2-37	operculum	operculum Tab. IV. Fig. III. <i>m</i>
53-2-45	a little dilated,	a little dilated <i>g</i>
56-2-33	differens, which opens	defferens <i>b b</i> which opens
57-1-18	penis <i>e</i>	penis Fig. XX. <i>e</i>
60-1-54	the brain	the brain <i>c</i>
61-1-44	bones	bone
63-1-45	Tab. IV.	Tab. VI.
65-2-29	halitations	habitations
67-1-1	Stenon	Steno
67-1-56	stretched out,	Stretched out <i>f</i>
69-1-4	two upper ones	two upper <i>c c</i> ones
73-1-8	divided skin	divided skin <i>c</i>
76-1-36	tube	tube <i>z</i>
77-2-31	uterus	uterus <i>e</i>
77-2-31	ridge	ridge <i>b</i>
90-2-40	observed <i>b</i> several	observed several
98-1-50	Fig. I.	Fig. I. <i>a</i>
98-2-11	wings	wings <i>d d</i>
100-2-54	Fig. VII.	Fig. VII. <i>a</i>
101-1-2	belong	belongs

Page Col. Line	<i>Instead of</i>	<i>please to read</i>
102-1-1	entraneous	extraneous
102-2-48	middle <i>e</i> ,	middle <i>c</i> ,
104-1-29	1661	1671
108-1-5	exuberant,	extuberant
108-2-21	Fig. IV.	Fig. IV. <i>f f</i>
109-2-58	this,	this <i>f</i>
122-1-44	Panopes,	Panorpes,
132-1-51	Tab. XVII.	Tab. XXVII.
132-1-40	varous	various
135-1-29	hairs,	hairs <i>f</i>
136-1-37	Tab. XVII.	Tab. XXVII.
138-2-8	the nerves	the nerves <i>d d d</i>
139-1-21	knot	knot <i>f</i>
140-1-last	teeth	teeth <i>d d</i>
152-1-	after Fig. V. and VI.	blot out <i>b c</i> and <i>d</i>
163-1-7th line from the bottom	Delphos	Delft
P. II.		
11-1-33	head <i>a</i>	head and
53-1-8	Hornius	Horne
141-1-8	Stento	Steno
146-1-13	with	with
149-2-26	fibres,	fibres <i>f</i> ,

The Copper Plates are to be placed between the Explanation of the Tables and the Index.







