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THE

ANCESTRY OF INSECTS.

CHAPTER XIII OF

"OUR COMMON INSECTS."

BY

A. S. PACKARD, JR.

SALEM.

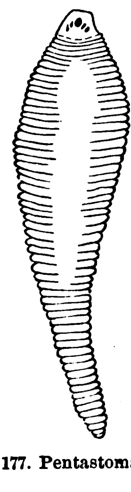
NATURALISTS' AGENCY.

1873.

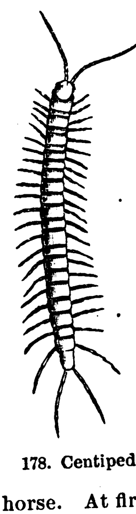
CHAPTER XIII.

HINTS ON THE ANCESTRY OF INSECTS.

THOUGH our course through the different groups of insects may have seemed rambling and desultory enough, and pursued with slight reference to a natural classification of the insects of which we have spoken, yet beginning with the Hive bee, the highest intelligence in the vast world of insects, we have gradually, though with many a sudden step, descended to perhaps the most lowly organized forms among all the insects, the parasitic mites. While the Demodex is probably the humblest in its organization of any of the insects we have treated of, there is still another mite, which some eminent naturalists continue to regard as a worm, which is yet lower in the scale. This is the Pentastoma (Fig. 177, P. tænioides), which lives in the manner of the tape worm a parasitic life in the higher animals, though instead of inhabiting the alimentary canal, the worm-like mite takes up its abode in the nostrils and frontal sinus of dogs and sheep, and sometimes of the horse. At first, however, it is found in the liver or lungs of various animals, sometimes in man. It is then in the earliest or larval state, and assumes its true mite form, being oval in shape, with minute horny jaws adapted for boring, and with two pairs of legs armed



177. Pentastoma.

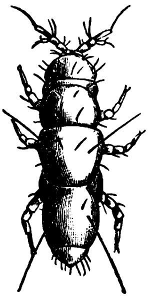


178. Centipede.

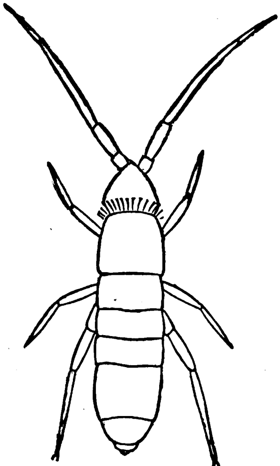
with sharp retractile claws. Such an animal as this is little higher than some worms, and indeed is lower than many of them.

We should also not pass over in silence the Centipedes (Fig. 178, Scolopocryptops sexspinosa) and Galley worms, or Thousand legs and their allies (Myriopods), which by their long slender bodies, and great number of segments and feet, vaguely recall the worms. But they, with the mites, are true insects, as they are born with only three pairs of feet, as are the mites and ticks, and breathe by tracheæ; and thus a common plan of structure underlies the entire class of insects.

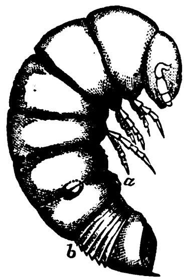
A very strange Myriopod has been discovered by Sir John



179. Young Pauropus.



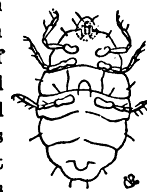
180. Spring-tail.



181. Young Julus.

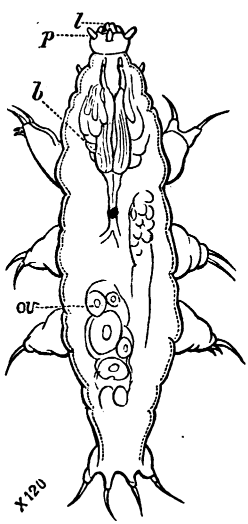
Lubbock in Europe, and we have been fortunate enough to find a species in this country. It is the Pauropus. It consists, when fully grown, of nine segments, exclusive of the head, bearing nine pairs of feet. The young of Pauropus (Fig. 179) is born with three pairs of feet, and in its general appearance reminds us of a spring-tail (Fig. 180) as may be seen by a glance at the cut. This six-legged form of Pauropus may also be compared with the young galley worm (Fig. 181).

Passing to the group of spiders and mites, we find that the young mites when first hatched have but three pairs of feet, while their parents have four, like the spiders. Figure 182 represents the larva (Leptus) of the red garden mites; while a figure of the "water bear," or Tardigrade (Fig. 183), is introduced to compare with it, as it bears a resemblance to the young of the mites, though their young are born with their full complement of legs, an exception to their nearest allies, the true mites. Now if we compare these early stages of mites and myriopods with those of the true six-footed insects, as in the larval Meloë, Cicada, Thrips and Dragon fly, we shall see quite plainly that they all share a common form. What does this mean? To the systematist who concerns him-



182. Leptus.

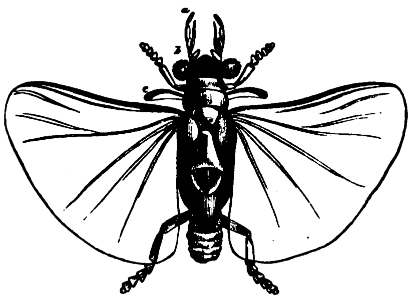
self with the classification of the myriads of different insects now living, it is a relief to find that all can be reduced to the comparatively simple forms sketched above. It is to him a proof of the unity of organization pervading the world of insects. He sees how nature, seizing upon this archetypal form has, by simple modifications of parts here and there, by the addition of wings and other organs wanting in these simple creatures, rung numberless changes in this elemental form. And starting from the simplest kinds, such as the Poduras, Spiders, Grasshoppers and May flies, allied creatures which we now know were the first to appear in the earlier geologic ages, we rise to the highest, the bees with their complex forms, their diversified economy and wonderful instincts. In ascending this scale of being, while there is a progress upwards, the beetles, for instance, being higher than the bugs and



183. Tardigrade.

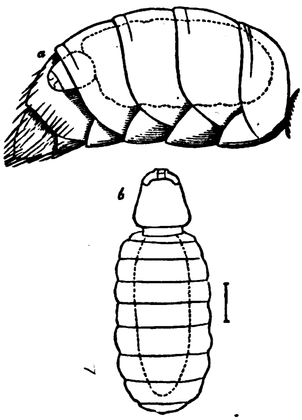
grasshoppers; and the butterflies and moths, on the whole, being more highly organized than the flies; and while we see the hymenopterous saw-flies, with their larvæ mimicking so closely the caterpillars of the butterflies, in the progress from the saw-flies up to the bees we behold a gradual loss of the lower saw-fly characters in the Cynips and Chalcid flies, and see in the sand-wasps and true wasps a constant and accelerating likeness to the bee form. Yet this continuity of improving organizations is often broken, and we often see insects which recall the earlier and more elementary forms.

Again, going back of the larval period, and studying the insect in the egg, we find that nearly all the insects yet observed agree most strikingly in their mode of growth, so that, for instance, the earlier stages of the germ of a bee, fly or beetle, bear a remarkable resemblance to each other, and suggest again, more forcibly than when we examine the larval condition, that a common design or pattern at first pervades all. In the light of the studies of Von Baer, of Lamarck and Darwin, should we be content to stop here, or does this ideal archetype become endowed with life and have a definite existence, becoming the ancestral form of all insects, the prototype which gave birth to the hundreds of thousands of insect forms which are now spread over our globe, just as we see daily happens where a single aphis may become the progenitor of a million offspring clustering on the same tree? Is there not something more than analogy in the two things, and is not the same life-giving force that evolves a million young Aphides from the germ stock of a single Aphis in a single season, the same in kind with the production of the living races of insects from a primeval ancestor? When we see the Aphis giving origin in one season to successive generations, the individuals of which may be counted by the million, it is no less mysterious than that other succession of forms of insect life which has peopled the globe during the successive chapters of its history. While we see in one case the origin of individual forms, and cannot explain what it is that starts the life in the germ and so unerringly guides the course of the growing embryo, it is illogical to deny that the same life-giving force is concerned in the production of specific and generic forms.



184. Male Stylops.

Who can explain the origin of the sexes? What is the cause that determines that one individual in a brood of Stylops, for example (Fig. 184, male; Fig. 185, grub-like female in the body of its host), shall be but a grub, living as a parasite in the body of its host, while its fellow shall be winged and as free in its actions as the most highly organized insect? It is no less mysterious, because it daily occurs before our eyes. So perhaps none the less mysterious, and no more discordant with known natural laws may the law that governs the origin of species seem to those who come after us. Certainly the present attempts to discover that law, however fatuitous they may seem to many, are neither illogical, nor, judging by the impetus already given to biology, or the science of life, labor altogether spent in vain. The theory of evolution is a powerful tool, when judiciously used, that must eventually wrest many a secret from the grasp of nature.



185. Female Stylops.

But whether true or unproved, the theory of evolution in some shape has actually been adopted by the large proportion of naturalists, who find it indispensable in their researches, and it will be used until found inadequate to explain facts. Notwithstanding the present distrust, and even fear, with which it is received by many, we doubt not but that in comparatively few years all will acknowledge that the theory of evolution will be to biology what the nebular hypothesis is to geology, or the atomic theory is to chemistry. While the evolution theory is as yet imperfect, and many objections, some seemingly insuperable, can be raised against it, it should be borne in mind that the nebular hypothesis is still comparatively crude and unsatisfactory, though indispensable as a working theory to the geologist; and in chemistry, though the atomic theory may not be satisfactorily demonstrated to some minds until an atom is actually brought to sight, it is yet invaluable in research.

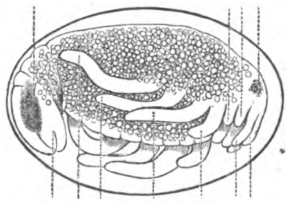
Many short sighted persons complain that such a theory sets in the back-ground the idea of a personal Creator; but minds no less devout, and perhaps a trifle more thoughtful, see the hand of a Creator not less in the evolution of plants and animals from prëexistent forms, through natural laws, than in the evolution of a summer's shower, through the laws discovered by the meteorologist, who looks back through myriads of ages to the causes that led to the distribution of mountain chains, ocean currents and trade winds, which combine to produce the necessary conditions resulting in that shower.

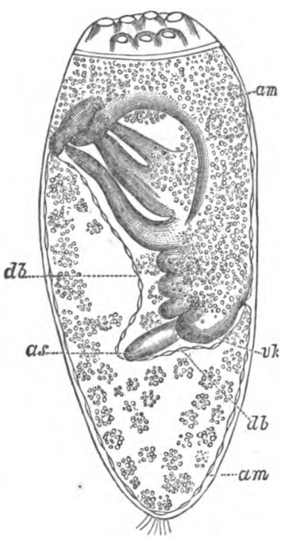
Indeed, to the student of nature, the evolution theory in biology, with the nebular hypothesis, and the grand law in physics of the correlation of forces, all interdependent, and revealing to us the mode in which the Creator of the Universe works in the world of matter, together form an immeasurably grander conception of the order of creation and its Ordainer, than was possible for us to form before these laws were discovered and put to practical use. We may be allowed, then, in a reverent spirit of inquiry, to attempt to trace the ancestry of the insects, and without arriving, perhaps, at any certain result, for it is largely a matter of speculation, point out certain facts, the thoughtful consideration of which may throw light on this difficult and embarrassing question.

Without much doubt the Poduras are the lowest of the six-footed insects. They are more embryonic in their appearance than others, as seen in the large size of the head compared with the rest of the body, the large, clumsy legs, and the equality in the size of the several segments composing the body. In other characters, such as the want of compound eyes, the absence of wings, the absence of a complete ovipositor, and the occasional want of tracheæ, they stand at the base of the insect series. That they are true insects, however, we endeavored to show in the previous chapter, and that they are neuropterous, we think is most probable, since not only in the structure of the insect after birth do they agree with the larvæ of certain neuropters, but, as we have shown in another place * in comparing the development of Isotoma, a Poduran, with that of a species of Caddis fly, the correspondence throughout the different embryological stages, nearly up to the time of hatching, is very striking. And it is a

* Memoirs of the Peabody Academy of Science, II. Embryological Studies on Diplax, Perithemis, and the Thysanurus genus Isotoma. Salem, 1871.

remarkable fact, as we have previously noticed, that when it begins to differ from the Caddis fly embryo, it begins to assume the Poduran characters, and its development consequently in some degree retrogrades, just as in the lice previous to hatching, as we have shown in a previous chapter, so that I think we are warranted at present in regarding the Thysanura, and especially the family of Podurids as degraded neuropters. Consequently the Poduras did not have an independent origin and do not, perhaps, represent a distinct branch of the genealogical tree of articulates. While the Poduras may be said to form a specialized type, the Bristle-tails (Lepisma, Machilis, Nicoletia and Campodea) are, as we have seen, much more highly organized, and form a generalized or comprehensive type. They resemble in their general form the larva of Ephemerids, and perhaps more closely the immature Perla, and also the wingless cockroaches.

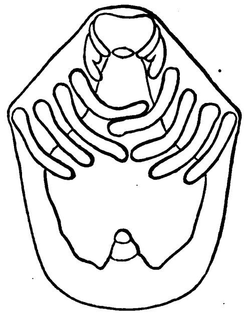

186. Embryo of Diplax.



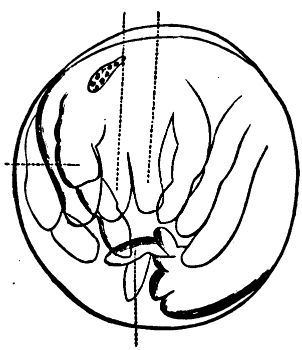
187. Embryo of Louse.

Now such forms as these Thysanura, together with the mites and the singular Pauropus, we cannot avoid suspecting to have been among the earliest to appear upon the earth, and putting together the facts, first, of their low organization; secondly, of their comprehensive structure, resembling the larvæ of other insects; and thirdly, of their probable great antiquity, we naturally look to them as being related in form to what we may conceive to have been the ancestor of the class of insects. Not that the animals mentioned above were the actual ancestors, but that certain insects bearing a greater resemblance to them than any others with which we are acquainted, and belonging possibly to families and orders now extinct, were the prototypes and progenitors of the insects now known.

Though the study of the embryology of insects is as yet in its infancy, still with the facts now in our possession we can state with tolerable certainty that at first the embryos of all insects are remarkably alike, and the process of development is much the same in all, as seen in the figure of Diplax (Fig. 186), the louse (Fig. 187), the spider (Fig. 188) and the Podura (Fig. 189), and we could give others bearing the same likeness. We notice that at a certain period in the life of the embryo all agree in having the head large, and bearing from two to four pairs of mouth organs, resembling the legs; the thorax is merged in with the abdomen, and the general form of the embryo is ovate. Now this general embryonic form characterizes the larva of the mites, of the myriopods and of the true insects. To such a generalized embryonic form to which the insects may be referred as the descendants, we would give the name of *Leptus*, as among Crustacea the ancestral form is referred to Nauplius, a larval form of the lower Crustacea, and through which the greater part of the Crabs, Shrimps, Barnacles, water fleas, etc., pass to attain their definite adult condition. A little water flea was described as a separate genus, Nauplius, before it was known to be the larva of a higher water flea, and so also Leptus was thought to be a mature mite. Accordingly, we follow the usage of certain naturalists in dealing with the Crustacea, and propose for this common primitive larval condition of insects the term Leptus.

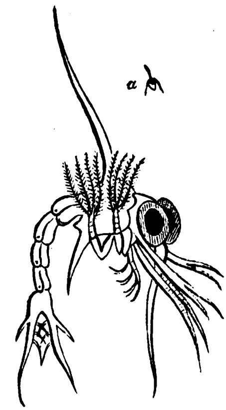


188. Embryo of Spider.



189. Embryo of Podura.

The first to discuss this subject of the ancestry of insects was Fritz Müller, who in his "Für Darwin,"* published in 1863, says, at the end of his work, "Having reached the Nauplius, the extreme outpost of the class, retiring farthest into the gray mist of primitive time, we naturally look round us to see whether ways may not be descried thence towards other bordering regions. * * * But I can see nothing certain. Even towards the nearer provinces of the Myriopoda and Arachnida I can find no bridge. For the Insecta alone, the development of the Malacostraca [Crabs, Lobsters, Shrimps, etc.] may perhaps present a point of union. Like many Zoëæ, the Insecta possess three pairs of limbs serving for the reception of nourishment, and three pairs serving for locomotion; like the Zoëæ they have an abdomen without appendages; as in all Zoëæ the mandibles in Insecta are destitute of palpi. Certainly but little in common, compared with the much which distinguishes these two animal forms. Nevertheless, the supposition that the Insecta had for their common ancestor a Zoëa which raised itself into a life on land, may be recommended for further examination" (p. 140).



190. Zoëa.

Afterwards Hæckel in his "Generelle Morphologie" (1866) and "History of Creation," published in 1868, reiterates the notion that the insects are derived from the larva (Zoëa, Fig. 190) of the crabs, though he is doubtful whether they did not originate directly from the worms.†

It may be said in opposition to the view that the insects came

* Translated in 1869 by Mr. Dallas under the title "Facts for Darwin."

†"Whether that common stem-form of all the Tracheata [Insects, Myriopods and Spiders] which I have called Protracheata in my 'General Morphology' has developed directly from the true Annelides (Cœlelminthes), or, the next thing to this (*zunachst*), out of Zoea-form Crustacea (Zoepoda), will be hereafter established only through a sufficient knowledge and comparison of the structure and mode of growth of the Tracheata, Crustacea and Annelides. In either case is the root of the Tracheata, as also of the Crustacea, to be sought in the group of the true jointed worms (Annelides, Gephyrea and Rotatoria." He considers the first insect to have appeared after the Silurian period, viz., in the Devonian.

originally from the same early crustacean resembling the larva of a crab or shrimp, that the differences between the two types are too great, or, in other words, the homologies of the two classes too remote,* and the two types are each too specialized to lead us to suppose that one was derived from the other. Moreover, we find through the researches of Messrs. Hartt and Scudder that there were highly developed insects, such as May flies, grasshoppers, etc., in the Devonian rocks of New Brunswick, leading us to expect the discovery of low insects even in the Upper Silurian rocks. At any rate this discovery pushes back the origin of insects beyond a time when there were true Zoëæ, as the shrimps and their allies are not actually known to exist so far back as the Silurian, not having as yet been found below the coal measures.

The view that the insects were derived from a Zoëa was also sustained by Friedrich Brauer, the distinguished entomologist of Vienna, in a paper† read in March, 1869. Following the suggestion of Fritz Müller and Hæckel, he derives the ancestry of insects from the Zoëa of crabs and shrimps. However, he regards the Podurids as the more immediate ancestors of the true insects, selecting Campodea as the type of such an ancestral form, remarking that the "Campodea-stage has for the Insects and Myriopods the same value as the Zoëa for the Crustacea." He says nothing regarding the spiders and mites.

At the same time‡ the writer, in criticising Hæckel's views of the derivation of insects from the Crustacea (ignorant of the fact that he had also suggested that the insects were possibly derived directly from the worms, and also independently of Brauer's opinions) declared his belief that though it seemed premature, after the discovery of highly organized winged insects

* The Zoea is born with eight pairs of jointed appendages belonging to the head, and with no thoracic limbs, while in insects there are but four pairs of cephalic appendages and three pairs of legs. Correlated with this difference is the entirely different mode of grouping the body segments, the head and thorax being united into one region in the crab, but separate in the insects, the body being as a rule divided into a head, thorax and abdomen, while these regions are much less distinctly marked in the crabs, and liable in the different orders to great variations. The great differences between the Crustacea and insects are noticeable at an early period in the egg.

† Considerations on the Transmutation of Insects in the Sense of the Theory of Descent. Read before the Imperial Zoological-botanical Society in Vienna, April 3, 1869.

‡ American Naturalist, vol. 3, p. 45. March, 1869.

in rocks so ancient as the Devonian, and with the late discovery of a land plant in the Lower Silurian rocks of Sweden,* to even guess as to the ancestry of insects, yet he would suggest that, instead of being derived from some Zoëa, "the ancestors of the insects (including the six-footed insects, spiders and myriopods) must have been worm-like and aquatic, and when the type became terrestrial we would imagine a form somewhat like the young Pauropus, which combines in a remarkable degree the characters of the myriopods and the degraded wingless insects, such as the Smynthurus, Podura, etc. Some such forms may have been introduced late in the Silurian period, for the interesting discoveries of fossil insects in the Devonian of New Brunswick, by Messrs. Hartt and Scudder, and those discovered by Messrs. Meek and Worthen in the lower part of the Coal Measures at Morris, Illinois, and described by Mr. Scudder, reveal carboniferous myriopods (two species of Euphorberia) more highly organized than Pauropus, and a carboniferous scorpion (Buthus?) closely resembling a species now living in California, together with another scorpion-like animal, Mazonia

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* See Prof. Torell's discovery of Eophyton Linnæanum, a supposed land plant allied to the rushes and grasses of our day, in certain Swedish rocks of Lower Cambrian age. The writer has, through the kindness of Prof. Torell, seen specimens of these plants in the Museum of the Geological Survey at Stockholm. Mr. Murray, of the Canadian Geological Survey, was the first to discover in America (Labrador, Straits of Belle Isle) this same genus of plants. They are described and figured by Mr. Billings, who speaks of them as "slender, cylindrical, straight, reed-like plants," in the "Canadian Naturalist" for August, 1872.

Should the terrestrial nature of these plants be established on farther evidence, then we are warranted in supposing that there were isolated patches of land in the Cambrian or Primordial period, and if there was land there must have been bodies of fresh water, hence there may have been both terrestrial and aquatic insects, possibly of forms like the Podurids, May flies, Perlæ, mites and Pauropus of the present day. There was at any rate land in the Upper Silurian period, as Dr. J. W. Dawson describes land plants (Psilophyton) from the Lower Helderberg Rocks of Gaspe, New Brunswick, corresponding in age with the Ludlow rocks of England.

We might also state in this connection that Dr. Dawson, the eminent fossil botanist of Montreal, concludes from the immense masses of carbon in the form of graphite in the Laurentian rocks of Canada, that "the Laurentian period was probably an age of most prolific vegetable growth. * * * Whether the vegetation of the Laurentian was wholly aquatic or in part terrestrial we have no means of knowing." In 1855, Dr. T. Sterry Hunt asserted "that the presence of iron ores, not less than that of graphite, points to the existence of organic life even during the Laurentian or so-called Azoic period." In 1861 he went farther and stated his belief in "the existence of an abundant vegetation during the Laurentian period." The Eophyton in Labrador occurs above the Trilobite (Paradoxides) beds, while in Sweden they occur below.

Woodiana, while the Devonian insects described from St. John by Mr. Scudder, are nearly as highly organized as our grasshoppers and May flies. Dr. Dawson has also discovered a well developed milleped (Xylobius) in the Lower Coal Measures of Nova Scotia; so that we must go back to the Silurian period in our search for the earliest ancestor, or (if not of Darwinian proclivities) prototype, of insects."

Afterwards* the writer, carrying out the idea suggested above, "referred the ancestry of the Myriopods, Arachnids, and Hexapodous insects to a Leptus-like terrestrial animal, bearing a vague resemblance to the Nauplius form among Crustacea, inasmuch as the body is not differentiated into a head, thorax and abdomen [though the head may be free from the rest of the body] and there are three pairs of temporary locomotive appendages. Like Nauplius, which was first supposed to be an adult Entomostracan, the larval form of Trombidium had been described as a genus of mites under the name of Leptus (also Ocypete and Astoma) and was supposed to be adult."

In the same year Sir John Lubbock† agrees with Brauer that the groups represented by Podura and Campodea may have been the ancestors of the insects, remarking that "the genus Campodea must be regarded as a form of remarkable interest, since it is the living representative of a primæval type from which not only the Collembola (Podura. etc.) and Thysanura, but the other great orders of insects, have all derived their origin."

The comparison of the Leptus with the Nauplius, or pre-Zoëal stage of Crustacea, is much more natural. But here we are met with apparently insuperable difficulties. While the Nauplius (Fig. 191) has but three pairs of appendages, which become the two pairs of antennæ and succeeding pair of limbs of the adult, in the Leptus as the least number we have five pairs, two of which belong to the head (the maxillæ and mandibles) and three to the thorax; besides these is a true head, distinct from the hinder region of the body. It is evident that the Leptus fundamentally differs from the Nauplius and begins life on a higher plane. We reject, therefore, the Crustacean origin of the insects. Our only refuge is in the worms, and how to account

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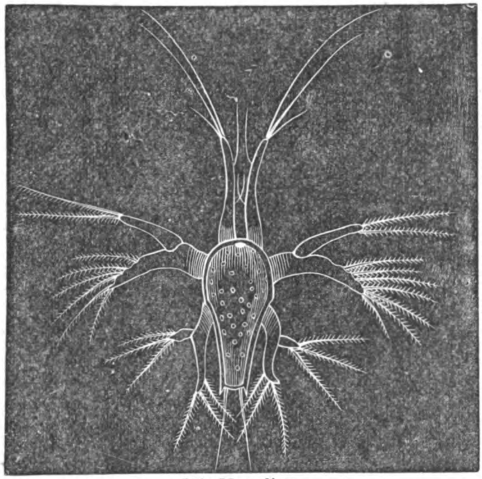
*In a communication made to the Boston Society of Natural History, Oct. 17, 1870 (see also "American Naturalist" for Feb. and Sept., 1871).

†On the Origin of Insects, a paper read before the Linnæan Society of London Nov. 2, 1871, and reported in abstract in "Nature," Nov. 9, 1871.

for the transmutation of any worm with which we are at present acquainted into a form like the Leptus, with its mandibulated mouth and jointed legs, seems at first well nigh impossible. We have the faintest possible indication in the structure of some mites, and of the Tardigrades and Pentastoma, where there is a striking recurrence, as we may term it, to a worm-like form, readily noticed by every observer, whatever his opinion may be on the developmental theory. In the Demodex we see a tendency of the mite to assume under peculiar circumstances an elongated, worm-like form. The mouth-parts are aborted (though from what we know of the embryology of other mites, they probably are indicated early in embryonic life), while the eight legs are not jointed, and form simple tubercles. In the Tardigrades, a long step lower, we have unjointed fleshy legs armed with from two to four claws, but the mouth-parts are essentially mite in character. A decided worm feature is the fact that they are hermaphrodites, each individual having ovaries and spermaries, as is the case with many worms.

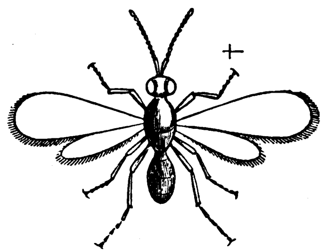


191. Nauplius.

When we come to the singular creatures of which Pentastoma and Linguatula are the type, we have the most striking approximation to the worms in external form, but these are induced evidently by their parasitic mode of life. They lose the rudimentary jointed limbs which some (Linguatula especially) have well marked in the embryo, and from being oval, rudely mite-like in form, they elongate, and only the claws or simple curved hooks, like those of young tape worms, remain to indicate the original presence of true jointed legs.

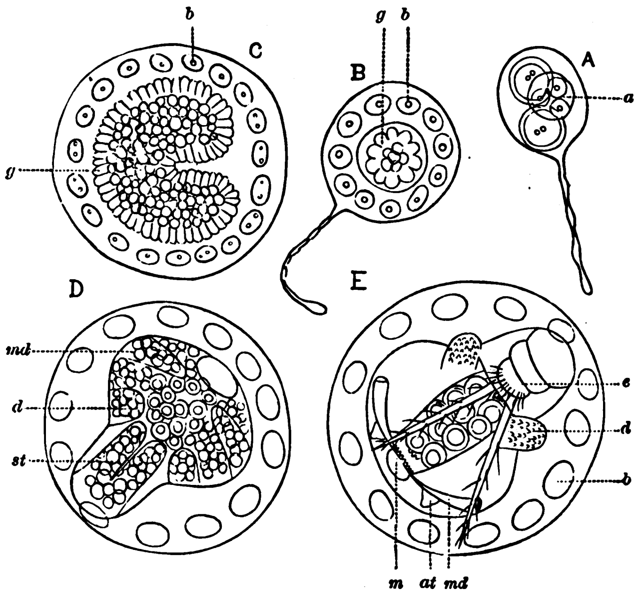
In seeking for the ancestry of our hypothetical Leptus among the worms, we are at best groping in the dark. We know of no ancestral form among the true Annelides, nor is it probable that it was derived from the intestinal worms. The only worm below the true Annelides that suggests any remote analogy to the insects is the singular and rare Peripatus, which lives on land in warm climates. Its body, not divided into rings, is provided with about thirty pairs of fleshy tubercles, each ending in two strong claws, and the head is adorned with a pair of fleshy tubercles. It is remotely possible that some Silurian land worm, if any such existed, allied to our living Peripatus, may have been the ancestor of a series of types now lost which resulted in an animal resembling the Leptus.

We may, however, as bearing upon this difficult question, cite some remarkable discoveries of Professor Ganin, a Russian naturalist, on the early stages of certain ichneumon parasites, which show some worm features in their embryonic development. In a species of Platygaster (Fig. 192, P. error of Fitch), which is a parasite on a two-winged gall fly, the earliest stage observed after the egg is laid is that in which the egg contains a single cell with a



192. Platygaster error.

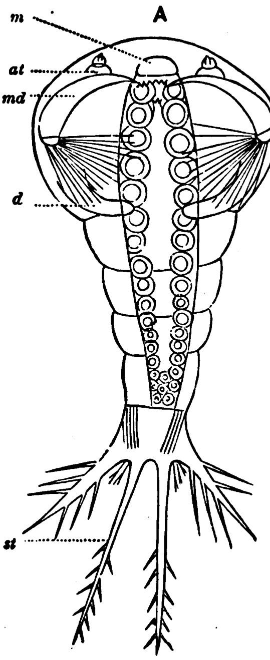
nucleus and nucleolus. Out of this cell (Fig. 193 *A*, *a*) arise two other cells. The central cell (*a*) gives origin to the embryo. The two outer ones multiply by subdivision and form the embryonal membrane, or "amnion," which is a provisional envelope and does not assist in building up the body of the germ. The central single cell, however, multiplies by the subdivision of its nucleus, thus building up the body of the germ Figure 193 *B*, *g*, shows the yolk or germ just forming out of the nuclei (*a*) and *b*, the peripheral cells of the blastoderm skin, or "amnion." Figure 193 *C* shows the yolk transformed into the embryo (*g*), with the outer layer of blastodermic cells (*b*). The body of the germ is infolded, so that the embryo appears bent on itself. Figure 193 *D* shows the embryo much farther advanced, with the two pairs of lobes (*md*, rudimentary mandibles; *d*, rudimentary pad-like organs, seen in a more advanced stage in *E*), and the bilobate tail (*st*). Figure 194 (*m*, mouth; *at*, rudimentary antennæ; *md*, mandibles; *d*, tongue-like appendages; *st*, anal stylets; the subject of this figure is of a different species from the insect previously figured, which, however, it closely resembles) shows the first larva stage after leaving the egg. This strange form, the author remarks, would scarcely be thought an insect, were not its origin and farther development known, but rather a parasitic Copepodous crustacean, whence he calls this the Cyclops-like stage. In this con-



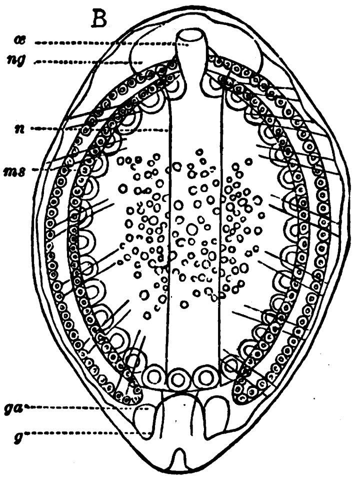
193. Development of Platygaster.

dition it clings to the inside of its host by means of its hook-like jaws (*md*), moving about like a Cestodes embryo with its well known six hooks. The tail moves up and down, and is of but little assistance in its efforts to change its place. Singularly enough, the nervous, vascular, and respiratory systems (tracheæ) are wanting, and the alimentary canal is a blind sac, remaining in an indifferent, or unorganized state. How long it remains in this state could not be ascertained.

The second larval stage (Fig. 195; *œ*, œsophagus; *ng*, supra-œsophageal ganglion; *n*, nervous cord; *ga*, and *g*, genital organs; *ms*, band of muscles) is attained by means of a moult, as usual in the metamorphoses of insects. With the change of skin the larva entirely changes its form. So-called hypodermic cells are developed. The singular tail is dropped, the segments of the body disappear, and the body grows oval, while within begins



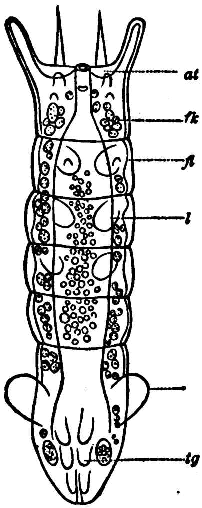
194. First Larva of Platygaster.



195. Second Larva of Platygaster.

a series of remarkable changes, like the ordinary development of the embryo of most other insects within the egg. The cells of the hypodermis multiply greatly, and lie one above the other in numerous layers. They give rise to a special primitive organ closely resembling the "primitive band" of all insect embryos. The alimentary canal is made anew, and the nervous and vascular systems now appear, but the tracheæ are not yet formed. It remains in this state for a much longer period than in the previous stage.

The third larval form only a few live to reach. This is of the usual long, oval form of the larvæ of the ichneumons, and the body has thirteen segments exclusive of the head. The muscular system has greatly developed and the larva is much more lively in its motions than before. The new organs that develop are the air tubes and fat bodies. The "imaginal disks" or rudimentary portions destined to develop and form the skin of the adult, or imago, arise in the pupa state, which resembles that of other ichneumons. These disks are only engaged, in Platygaster, in building up the rudimentary appendages, while in the flies (Muscidæ and Corethra) they build up the whole body, according to the remarkable discovery of Weismann.



196. Third Larva of Polynema.

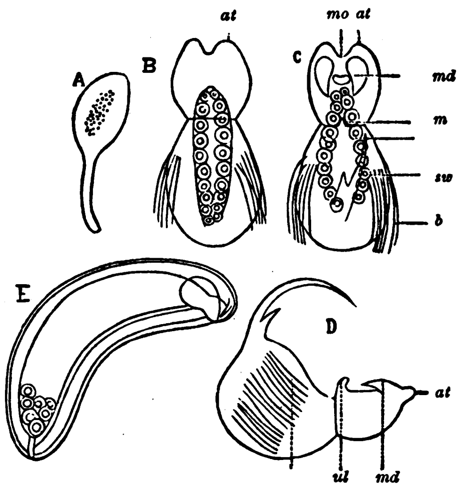
Not less interesting is the history of the development of a species of Polynema, another egg-parasite, which lays its eggs (one, seldom two) in the eggs of a small dragon fly, Agrion virgo, which oviposits in the parenchyma of the leaves of water-lilies. The eggs develop as in Platygaster. The earliest stage of the embryo is very remarkable. It leaves the egg when very small and immovable, and with scarcely a trace of organization, being a mere flask-shaped sac of cells.* It remains in this state five or six days.

In the second stage, or Histriobdella-like form, the larva is, in its general appearance, like the low worm to which Ganin compares it. It may be described as bearing a general resemblance to the third and fully developed larval form (Fig. 196, *tg*,

* This reminds us (though Ganin does not mention it) of the development of the embryo of Julus, the Thousand legs, which, according to Newport, hatches the 25th day after the egg is laid. At this period the embryo is partially organized, having faint traces of segments, and is still enveloped in its embryonal membranes and retains its connection with the shell. In this condition it remains for seventeen days, when it throws off its embryonal membrane, and becomes detached from the shell.

three pairs of abdominal tubercles destined to form the sting; *l*, rudiments of the legs; *fk*, portion of the fatty body; *at*, rudiments of the antennæ; *fl*, imaginal disks, or rudiments of the wings). No tracheæ are developed in the larva, nor do any exist in the imago. (Ganin thinks, that as these insects are somewhat aquatic, the adult insects flying over the surface of the water, the wings may act as respiratory organs, like gills.) It lives six to seven days before pupating, and remains from ten to twelve days in the pupa state.

The origin of the sting is clearly ascertained. Ganin shows that it consists of three pairs of tubercles, situated respectively on the seventh, eighth, and ninth segments of the abdomen (Fig. 196, *tg*). The labium is not developed from a pair of tubercles, as is usual, but at once appears as an unpaired, or single organ. The pupa state lasts for five or six days, and when the imago appears it eats its way through a small round opening in the end of the skin of its host, the Agrion larva.



197. Development of Egg-parasites.

The development of Ophioneurus, another egg-parasite, agrees with that of Platygaster and Polynema. This egg-parasite passes its early life in the eggs of Pieris brassicæ, and two or three live to reach the imago state, though about six eggs are deposited by the female. The eggs are oval, and not stalked. The larva is at first of the form indicated by figure 197 *E*, and when fully grown becomes of a broad oval form, the body not being divided into segments. It differs from the genera already mentioned, in remaining within its egg membrane, and not assuming their strange forms. From the non-segmented, sac-like larva, it passes directly into the pupa state.

The last egg-parasite noticed by Ganin, is Teleas, whose development resembles that of Platygaster. It is a parasite in the eggs of Gerris, the Water Boatman. Figure 197 *A* represents the egg; *B*, *C*, and *D*, the first stage of the larva, the abdomen (or posterior division of the body) being furnished with a series of bristles on each side. (*B* represents the ventral, *C* the dorsal, and *D* the profile view; *at*, antennæ; *md*, hook-like mandibles; *mo*, mouth; *b*, bristles; *m*, intestine; *sw*, the tail; *ul*, under lip or labium.) In the second larval stage, which is oval in form, and not segmented, the primitive band is formed.

In concluding the account of his remarkable discoveries, Ganin draws attention to the great differences in the formation of the eggs and the germs of these parasites from what occurs in other insects. The egg has no nutritive cells; the formation of the primitive band, usually the first indication of the germ, is retarded till the second larval stage is attained; and the embryonal membrane is not homologous with the so-called "amnion" of other insects, but may possibly be compared with the skin developed on the upper side of the low, worm-like acarian, Pentastomum, and the "larval skin" of the embryos of many low Crustacea. He says, also, that we cannot, perhaps, find the homologues of the provisional organs of the larvæ, such as the singularly shaped antennæ, the claw-like mandibles, the tongue- or ear-like appendages, in other Arthropoda (insects and Crustacea); but that they may be found in the parasitic Lernæan crustaceans, and in the leeches, such as Histriobella. He is also struck by the similarity in the development of these egg-parasites to that of a kind of leech (Nephelis), the embryo of which is provided with ciliæ, recalling the larva of Teleas (Fig. 197 *B*, *C*), while in the true leeches (Hirudo) the primitive band is not developed until after they have passed through a provisional larval stage.

This complicated metamorphosis of the egg-parasites, Ganin also compares to the so-called "hyper-metamorphosis" of certain insects (Meloe, Sitaris, and the Stylopidæ) made known by Siebold, Newport and Fabre, and he considers it to be of the same nature.

He also, in closing, compares such early larval forms as those given in figures 193 *E* and 194, to the free swimming Copepoda. Finally, he says a few words on the theory of evolution, and remarks "there is no doubt that, if a solution of the questions arising concerning the genealogical relations of different animals among themselves is possible, comparative embryology will afford the first and truest principles." He modestly suggests that the facts presented in his paper will widen our views on the genetic relations of the insects to other animals, and refers to the opinion first expressed by Fritz Müller (Für Darwin, p. 91), and endorsed by Hæckel in his "Generelle Morphologie," that we must seek for the ancestors of insects and Arachnida in the Zoëa form of Crustacea. He cautiously remarks, however, that "the embryos and larvæ observed by me in the egg-parasites open up a new and wide field for a whole series of such considerations; but I will suppress them, since I am firmly convinced that a theory, which I build up to-day, can easily be destroyed with some few facts which I learn to-morrow. Since comparative embryology as a science does not yet exist, so do I think that all genetic theories are too premature, and without a strong scientific foundation."

The writer is perhaps less cautious, but he cannot refrain from making some reflections suggested by the remarkable discoveries of Ganin. In the first place, these facts bear strongly on the theory of evolution by "acceleration and retardation." In the history of these early larval stages we see a remarkable acceleration in the growth of the embryo. A simple sac of unorganized cells, with a half-made intestine, so to speak, is hatched, and made to perform the duty of an ordinary, quite highly organized larva. Even the formation of the "primitive band," usually the first indication of the organization of the germ, is postponed to a comparatively late period in larval life. The different anatomical systems, *i.e.*, the heart with its vessels, the nervous system and the respiratory system (tracheæ), appear at longer or shorter intervals, while in one genus the tracheæ are not developed at all. Thus some portions of the animal are accelerated in their development more than others, while others are retarded, and in some species certain organs are not developed at all. Meanwhile all live in a fluid medium, with much the same habits, and surrounded with quite similar physical conditions.

The highest degree of acceleration is seen in the reproductive organs of the Cecidomyian larva of Miastor, which produces a summer brood of young, alive, and living free in the body of the child-parent; and in the pupa of Chironomus, which has been recently shown by Von Grimm, a fellow countryman of Ganin, to produce young in the spring, while the adult fly lays eggs in the autumn in the usual manner. This is in fact a true virgin reproduction, and directly comparable to the alternation of generations observed in the jelly fishes, in Salpa, and certain intestinal worms. We can now, in the light of the researches of Siebold, Leuckart, Ganin and others, trace more closely than ever the connection between simple growth and metamorphosis, and metamorphosis and parthenogenesis, and perceive that they are but the terms of a single series. By the acceleration in the development of a single set of organs (the reproductive), no more wonderful than the acceleration and retardation of the other systems of organs, so clearly pointed out in the embryos of Platygaster and its allies, we see how parthenogenesis under certain conditions may result. The barren Platygaster larva, the fertile Cecidomyia larva, the fertile Aphis larva, the fertile Chironomus pupa, the fertile hydroid polype, and the fertile adult queen bee are simply animals in different degrees of organization, and with reproductive systems differing not in quality, but in the greater or less rapidity of their development as compared with the rest of the body.

Another interesting point is, that while the larvæ vary so remarkably in form, the adult ichneumon flies are remarkably similar to one another. Do the differences in their larval history seem to point back to certain still more divergent ancestral forms?

These remarkable hyper-metamorphoses remind us of the metamorphosis of the embryo of Echinoderms into the Pluteus- and Bipinnaria-forms of the starfish, sea urchins and Holothurians;* of the Actinotrocha-form larva of the Sipunculoid worms;

It is a suggestive fact that these deciduous forms give way through histolysis to true larval forms, just as in some flies (Musca vomitoria) the true larval form goes under, and the adult form is built up from the imaginal disks of the larva. In an analogous manner the deciduous, pluteus-condition of the young Echinoderm perishes and is absorbed by the growing body of the permanent adult stage. This deciduous stage of the ichneumon may accordingly be termed the prelarval stage. Now as we find insects with and without this prelarval stage, and in the radiates quite different degrees of metamorphoses, the inquiry arises how far these differences are correlated with, and consequently dependent upon, the physical surof the Tornaria into Balanoglossus, the worm; of the Cercaria-form larva of Distoma; of the Pilidium-form larva of Nemertes; and the larval forms of the leeches; as well as the mite Pentastomum, and certain other aberrant mites, such as Myobia.

While Fritz Müller and Dohrn have considered the insects as having descended from the Crustacea (some primitive zoëa-form), and Dohrn has adduced the supposed zoëa-form larva of these egg-parasites as a proof, we cannot but think, in a subject so purely speculative as the ancestry of animals, that the facts brought out by Ganin tend to confirm our theory, that the ancestry of all the insects (including the Arachnids and Myriopods) should be traced directly to the worms. The development of the degraded, aberrant Arachnidan Pentastomum accords, in some important respects, with that of the intestinal worms. The Leptus-form larva of Julus, with its strange embryological development, in some respects so like that of some worms, points in that direction, as certainly as does the embryological development of the egg-parasite Ophioneurus. The Nauplius form of the embryo or larva of nearly all Crustacea, also points back to the worms as their ancestors, the divergence having perhaps originated, as we have suggested, in the Rotatoria.

While the Crustacea may have resulted from a series of prototypes leading up from the Rotifers (Fig. 198), it is barely

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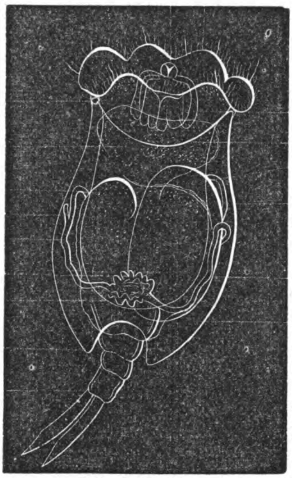
roundings of these animals in the free swimming condition. Merely to point out the differences in the mode of development of animals is an interesting matter, and one could do worse things, but the philosophical naturalist cannot rest here. He must seek how these differences were brought about.

* Leuckart, in his great work, "Die Menschlichen Parasiten," p. 700, after the analogy of Hirudo, which develops a primitive streak late in larval life, ventures to consider the first indications of the germ of Nemertes in its larval, Pilidium form as a primitive streak. He also suggests that the development of the later larval forms of the Echinoderms is the same in kind.

Moreover, nearly twenty years ago (1854) Zaddach, a German naturalist, contended that the worms are closely allied in their mode of development to the insects and crustaceans. He compares the mode of development of a leech (Clepsine) and certain bristle-bearing worms (Sænuris, Lumbriculus and Uaxes), and we may now from Kowaleusky's researches (1871) add the common earth worm (Lumbricus), in which there is no such metamorphosis as in the sea Nereids, to that of insects; the mode of formation of the primitive band in the leeches and earth worms being much like that of insects. This confirms the view of Leuckart and Ganin, who both seem to have overlooked Zaddach's remarks. Moreover, the rings of the harder bodied worms, as Zaddach says, contain chitine, as in the insects. Zaddach also enters into farther details, which in his opinion ally the worms nearer to the insects than many naturalists at his time were disposed to allow. The singular Echinoderes has some remarkable Arthropod characters.

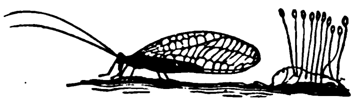
possible that one of these creatures may have given rise to a form resulting in two series of beings, one leading to the Leptus form, the other to the Nauplius. For the true Annelides (Chætopods) are too circumscribed and homogeneous a group to allow us to look to them for the ancestral forms of insects. But that the insects may have descended from some low worms is not improbable when we reflect that the Syllis and allied genera of Annelides bear appendages consisting of numerous joints; indeed, the strange Dujardinia rotifera, figured by Quatrefages, in its general form is remarkably like the larva of Chloëon. It has a quite distinct head, bearing five long, slender, jointed antennæ, and but eight or nine rings to the body, which ends in two long, many jointed appendages exactly like the tentacles. Quatrefages adds, that its movements are usually slow, but "when it wishes to move more rapidly, it moves its body alternately up and down with much vivacity, and shoots forwards by bounds, so to speak, a little after the manner of the larvæ of the mosquito" (Histoire Naturelle des Annelés, Tome 2, p. 69). The gills of aquatic insects only differ from those of worms in possessing tracheæ, though the gills of the Crustacea may be directly compared with those of insects.



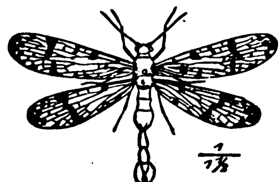
198. A Rotifer.

But when once inside the circle of the class of insects the ground is firmer, as our knowledge is surer. Granting now that the Leptus-like ancestor of the six-footed insects has become established, it is not so difficult to see how the Poduræ and finally a form like Campodea appeared. Aquatic forms resembling the larva of the Ephemeræ, Perlæ and, more remotely, the Forficulæ and white ants of to-day were probably evolved with comparative suddenness. Given the evolution of forms like the earwigs (Forficula), cockroaches and white ants (Termes), the latter of which abounded in the coal period, and it was not a great step forward to the evolution of the Dragon-flies, the Psocus, the Chrysopa, the lice or parasitic Hemiptera, together with Thrips, thus forming the establishment of lines of development leading up to those Neuroptera with a complete metamorphosis, and finally to the grasshoppers and other forms of Orthoptera, together with the Hemiptera.

We have thus advanced from wingless to winged forms, *i. e.*,

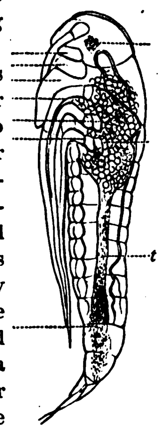


199. Chrysopa.



200. Panorpa.

from insects without a metamorphosis to those with a partial metamorphosis like the Perlas; to the May flies and Dragon flies, in which the adult is still more unlike the larva; to the Chrysopa (Fig. 199) and Forceps Tails (Panorpa, Fig. 200) and Caddis flies, in which, especially the latter, the metamorphosis is complete, the pupa being inactive and enclosed in a cocoon.



201. Embryo of Diplax.

Having assumed the creation of our Leptus by evolutional laws, we must now account for the appearance of tracheæ and those organs so dependent on them, the wings, which, by their presence and consequent changes in the structure of the crust of the body, afford such distinctive characters to the flying insects, and raise them so far above the creeping spiders and centipedes. Our Leptus at first undoubtedly breathed through the skin, as do most of the Poduras, since we have been unable to find tracheæ in them, nor even in the prolarva of a genus of minute ichneumon egg parasites, nor in the Linguatulæ and Tardigrades, and some mites, such as the Itch insect and the Demodex, and other Acari. In the Myriopod, Pauropus, Lubbock was unable to find any traces of tracheæ. If we examine the embryo of an insect shortly before birth, as in the young Dragon fly (figure 201, the dotted line *t* crosses the rudimentary tracheæ), we find it to consist of two simple tubes with few branches, while there are no stigmata, or breathing holes, to be seen in the sides of the body. This fact sustains the view of Gegenbaur* that at first the tracheæ formed two simple tubes in the body-cavity, and that the primary office of these tubes was for lightening the body, and that their function as respiratory tubes was a secondary one. The aquatic Protoleptus, as we may term the ancestor of Leptus, may have had such tubes as these, which acted like the swimming bladder of fishes for lightening the body, as suggested by Gegenbaur. It is known that the swimming bladder of fishes becomes developed into the lungs of air-breathing vertebrates and man himself. As our Leptus adopted a terrestrial life and needed more air, a connection was probably formed by a minute branch on each side of the body with some minute pore (for such exist, whose uses are as yet unknown) through the skin, which finally became specialized into a stigma, or breathing pore; and from the tracheal system being closed, we now have the open tracheal system of land insects.

The next inquiry is as to the origin of the wings. Here the question arises if wingless forms are exceptional among the winged insects, and the loss of wings is obviously dependent on the habits (as in the lice), and environment of the species (as in beetles living on islands, which are apt to lose the hinder pair of wings), why may not their acquisition in the first place have been due to external agencies; and, as they are suddenly discarded, why may they not have suddenly appeared in the first place? In aquatic larvæ there are often external gill-like organs, being simple sacs permeated by tracheæ (as in Agrion, Fig. 129, or the May flies). These organs are virtually aquatic wings, aiding the insect in progression as well as in aërating the blood, as in the true wings. They are very variable in position, some being developed at the extremity of the abdomen, as in Agrion, or along the sides, as in the May flies, or filiform and arranged in tufts on the under side of the body, as in Perla; and the naturalist is not surprised to find them absent or present in accordance with the varying habits of the animal. For example, in the larvæ of the larger Dragon flies (Libellula, etc.) they are wanting, while in Agrion and its allies they are present.

*Vergleichende Anatomie, 2te Auflage, 1870, p. 437. I should, however, here add that I am told by Mr. Putnam that some fishes which have no swim-bladder, are surface-swimmers, and *vice versa*.

Now we conceive that wings formed in much the same way, and with no more disturbance, so to speak, to the insect's organization, appeared during a certain critical period in the metamorphosis of some early insect. As soon as this novel mode of locomotion became established we can easily see how surrounding circumstances would favor their farther development until the presence of wings became universal. If space permitted us to pursue this interesting subject farther, we could show how invariably correlated in form and structure are the wings of insects to the varied conditions by which they are surrounded, and which we are forced to believe stand in the relation of cause to effect. Again, why should the wings always appear on the thorax and on the upper instead of the under side? As this is the seat of the centre of gravity, it is evident that cosmical laws as well as the more immediate laws of biology determine the position and nature of the wings of an insect.

Correlated with the presence of wings is the wonderful differentiation of the crust, especially of the thorax, where each segment consists of a number of distinct pieces; while in the spiders and Myriopods the segments are as simple as in the abdominal segments of the winged insect. It is not difficult here to trace a series leading up from the Poduras, in which the segments are like those of spiders, to the wonderful complexity of the parts in the thoracic segments of the Lepidoptera and Hymenoptera.

In his remarks "On the Origin of Insects,"* Sir John Lubbock says, "I feel great difficulty in conceiving by what natural process an insect with a suctorial mouth like that of a gnat or butterfly could be developed from a powerfully mandibulate type like the Orthoptera, or even from the Neuroptera." Is it not more difficult to account for the origin of the mouth-parts at all? They are developed as tubercles or folds in the tegument, and are homologous with the legs. Figure 186 shows that the two sorts of limbs are at one time identical in form and relative position. The thought suggests itself that these long, soft, finger-like appendages may have been derived from the tentacles of the higher worms, but the grounds for this opinion are uncertain. At any rate, the earliest form of limb must have been that of a soft tubercle armed with one, or two, or many terminal

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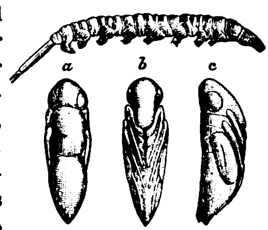
* Reported in "Nature" for Nov. 9, 1871.

claws, as seen in aquatic larvæ, such as Chironomus (Fig. 202), Ephydra (Fig. 203 *a*, *b*, *c*, pupa) and many others. As the Protoleptus assumed a terrestrial life and needed to walk, the rudimentary feet would tend to elongate, and in consequence need the presence of chitine to harden the integument, until the habit of walking becoming fixed, the necessity of a jointed structure arose. After this the different needs of the offspring of such an insect, with their different modes of taking food, vegetable or animal, would induce the diverse forms of simple, or raptorial, or leaping or digging limbs. A peculiar use of the anterior members, as seen in grasping the food and conveying it to the mouth (perhaps originally a simple orifice with soft lips, as in Peripatus), would tend to cause such limbs to be grouped together, to concentrate around the mouth-opening, and to be directed constantly forwards. With use, as in the case of legs, these originally soft mouth-feet would gradually harden at the extremities, until serviceable in biting, when they would become jaws and palpi. Given a mouth and limbs surrounding it, and we at once have a rude head set off from the rest of the body. And in fact such is the history of the development of these parts in the embryo. At first the head is indicated by the buds forming the rudiments of limbs; the segments to which they are attached do not form a true head until after the mouth-parts have attained their jaw-like characters, and it is not until the insect is about to be hatched, that the head is definitely walled in.


202. Foot of Chironomus.



203. Ephydra.

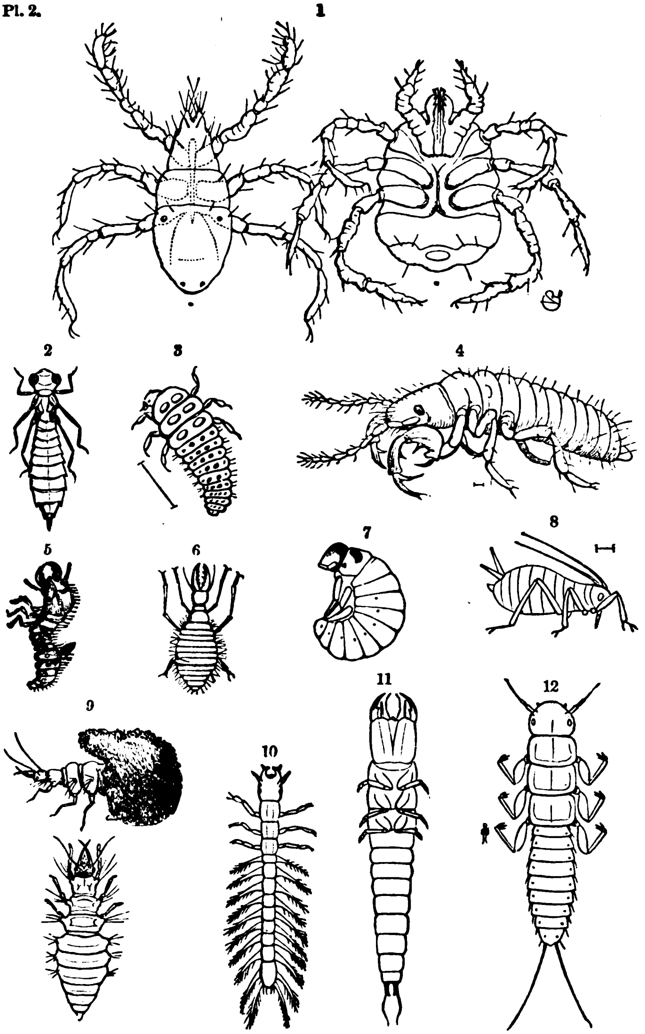
We have arrived, then, at our Leptus, with a head bearing two pairs of jaws. The spiders and mites do not advance beyond this stage. But in the true insects and Myriopods, we have the addition of special sense organs, the antennæ, and another pair of appendages, the labial palpi. It is evident that in the ancestor of these two groups the first pair of appendages became early adapted for purely sensory purposes, and were naturally projected far in advance of the mouth, forming the antennæ.

Before considering the changes from the mandibulate form of insects to those with mouth parts adapted for piercing and sucking, we must endeavor to learn how far it was possible for the caterpillar or maggot to become evolved from the Leptus-like larvæ of the Neuroptera, Orthoptera, Hemiptera and most Coleoptera. I may quote from a previous article* a few words in relation to two kinds of larvæ most prevalent among insects. "There are two forms of insectean larvæ which are pretty constant. One we call *leptiform*, from its general resemblance to the larvæ of the mites (Leptus). The larvæ of all the Neuroptera, except those of the Phryganeidæ and Panorpidæ (which are cylindrical and resemble caterpillars), are more or less leptiform, *i. e.*, have a flattened or oval body, with large thoracic legs. Such are the larvæ of the Orthoptera and Hemiptera, and the Coleoptera (except the Curculionidæ; possibly the Cerambycidæ and Buprestidæ, which approach the maggot-like form of the larvæ of weevils). On the other hand, taking the caterpillar or bee larva, with their cylindrical, fleshy bodies, in most respects typical of larval forms of the Hymenoptera, Lepidoptera and Diptera, as the type of the *eruciform* larva, etc. * * * The larvæ of the earliest insects were probably leptiform, and the eruciform condition is consequently an acquired one, as suggested by Fritz Müller."† It seems that these two sorts of larvæ had also been distinguished by Dr. Brauer in the article already referred to, with which, however, the writer was unacquainted at the time of writing the above quoted article. The similar views presented may seem to indicate that they are founded in nature. Dr. Brauer, after remarking that the Podurids seemed to fulfil Hæckel's idea of what were the most primitive insects, and noticing how closely they resemble the larvæ of Myriopods, says, "specially interesting are those forms among the Poduridæ which are described as Campodea and Japyx, since the larvæ of a great number of insects may be traced back to them"; but he adds, and with this view we are unable to agree, "while others, the caterpillar-like forms (Raupenform), resulted from them by a retrograde process, and also

*The Embryology of Chrysopa, and its bearings on the Classification of the Neuroptera, "American Naturalist," vol. v. Sept., 1871.

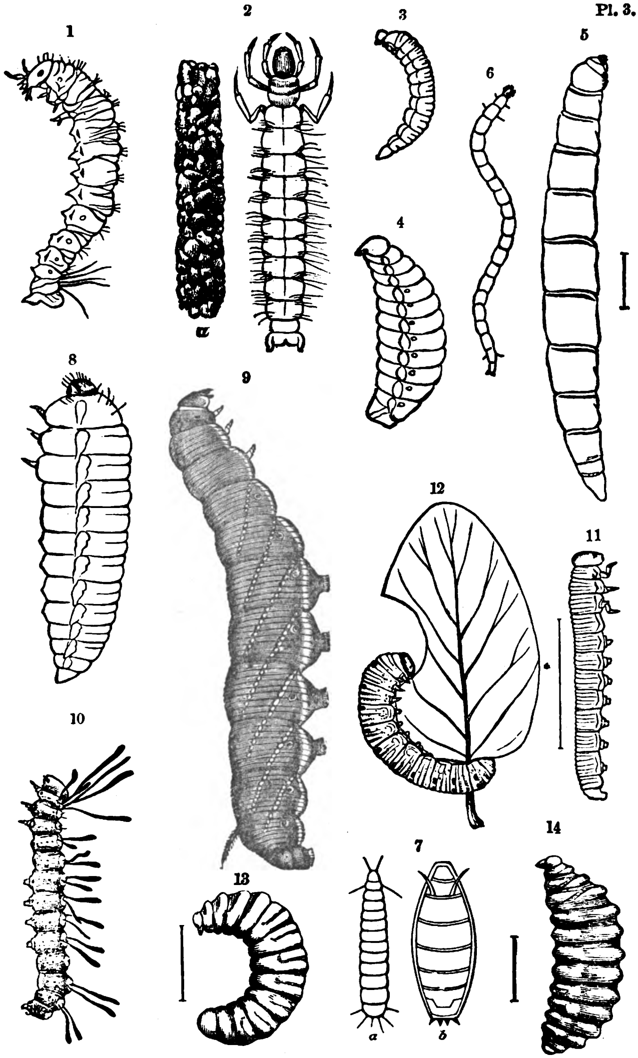
†"It is my opinion that the 'incomplete metamorphosis' of the Orthoptera is the primitive one, *inherited* from the original parents of all insects, and the 'complete metamorphosis' of the Coleoptera, Diptera, etc., a subsequently acquired one." *Fuer Darwin*, English Trans., p. 121.

Pl. 2.



EXAMPLES OF LEPTIFORM LARVÆ.

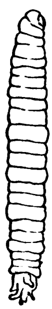
EXPLANATION OF PLATE 2. Figure 1, different forms of Leptus; 2, Diplax; 3, Coccinella larva; 4, Cicada larva; 5, Cicindela larva; 6, Ant Lion; 7, Calligrapha larva; 8, Aphis larva; 9, Hemerobius larva; 10, Gyrinus larva; 11, Carabid larva; 12, Meloe larva.



EXAMPLES OF ERUCIFORM LARVÆ.

EXPLANATION OF PLATE 3. Figure 1, Panorpa larva; 2, Phryganea larva; 3, Weevil larva; 4, third larva of Meloe; 5, Chionea larva; 6, Carpet Worm; 7, Phora larva; 8, Wheat Caterpillar; 9, Sphinx Caterpillar; 10, Acronycta? larva; 11, Saw Fly larva; 12, Abia Saw Fly larva; 13, Halictus larva; 14, Andrena larva.

the still lower maggot-like forms. While on the one hand Campodea, with its abdominal feet, and the larva of Lithobius are related, so on the other the Lepismatidæ, which are very near the Blattariæ, are nearly related to the Myriopods, since their abdominal segments often bear appendages (Machilis). The Campodea-form appears in most of the Pseudoneuroptera [Libellulids, Ephemerids, Perlids, Psocids and Termes], Orthoptera, Coleoptera, Neuroptera, perhaps modified in the Strepsiptera [Stylops and Xenos] and Coccidæ in their first stage of development, and indeed in many of these at their first moult." Farther on he says, "A larger part of the most highly developed insects assume another larva-form, which appears not only as a later acquisition, through accommodation with certain definite relations, but also arises as such before our eyes. The larvæ of butterflies and moths, of saw flies and Panorpæ, show the form most distinctly, and I call this the caterpillar form (Raupenform). That this is not the primitive form, but one later acquired, we see in the beetles. The larvæ of Meloë and Sitaris in their fully grown condition possess the caterpillar form, but the newborn larvæ of these genera show the Campodea form. The last form is lost as soon as the larva begins its parasitic mode of life. * * * The larger part of the beetles, the Neuroptera in part, the bees and flies (the last with the most degraded maggot form) possess larvæ of this second form." He considers that the caterpillar form is a degraded Campodea form, the result of its stationary life in plants or in wood.

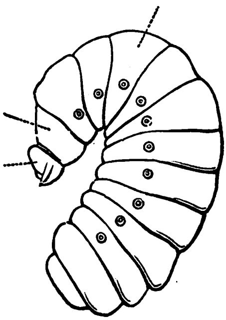


204. Tipula Larva.

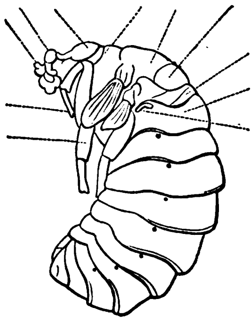
For reasons which we will not pause here to discuss, we have always regarded the eruciform type of larva as the highest. That it is the result of degradation from the Leptus or Campodea form, we should be unwilling to admit, though the maggots of flies have perhaps retrograded from such forms as the larvæ of the mosquitoes and crane flies (Tipulids, Fig. 204).

That the cylindrical form of the bee grub and caterpillar is the result of modification through descent is evident in the caterpillar-like form of the immature Caddis fly (Pl. 3, fig. 2). Here the fundamental characters of the larva are those of the Corydalus and Sialis and Panorpa, types of closely allied groups. The features that remind us of caterpillars are superadded, evidently the result of the peculiar tube-inhabiting habits of the young Caddis fly. In like manner the caterpillar-form is probably the result of the leaf-eating life of a primitive Leptiform larva. In like manner the soft-bodied maggot of the weevil is evidently the result of its living habitually in cavities in nuts and fruits. Did the soft, baggy female Stylops live exposed, like its allies in other families, to an out-of-doors life, its skin would inevitably become hard and chitinous. In these and multitudes of other cases the adaptation of the form of the insect to its mode of life is one of cause and effect, and not a bit less wonderful after we know what induced the change of form.

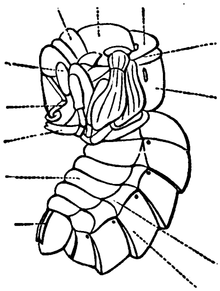
Having endeavored to show that the caterpillar is a later production than the young, wingless cockroach, with which geological facts harmonize, we have next to account for the origin of a metamorphosis in insects. Here it is necessary to disabuse the reader's mind of the prevalent belief that the terms larva, pupa and imago are fixed and absolute. If we examine at a certain season the nest of a humble bee, we shall find the occupants in every stage of growth from the egg to the pupa, and even to the perfectly formed bee ready to break out of its larval cell. So slight are the differences between the different stages that it is difficult to say where the larval stage ends and the pupa begins, so also where the pupal state ends and the imago begins. The following figures (205–208) will show four of the most characteristic stages of growth, but it should be remembered that there are intermediate stages between. Now we have noticed similar stages in the growth of a moth, though a portion of them are concealed beneath the hard, dense chrysalis skin. The external differences between the larval and pupal states are fixed for a large part of the year in most butterflies and moths, though even in this respect there is every possible variation, some moths or butterflies passing through their transformations in a few weeks, others requiring several months, while still others take a year, the majority of the moths living under ground in the pupa state for eight or nine months. The stages of metamorphosis in the Diptera are no more suddenly acquired than in the bee or butterfly. In all these insects the rudiments of the wings, legs, and even of the ovipositor of the adult exist in the young larva. We have found somewhat similar intermediate stages in the metamorphoses of the beetles. The insects we have mentioned are those with a "complete metamorphosis." We have seen that even in them the term "complete" is a relative and not absolute expression, and that the terms larva and pupa are convenient designations for states varying in duration, and assumed to fulfil certain ends of existence, and even then dependent on length of seasons, variation in climate, and even on the locality. When we descend to the insects with an "incomplete" metamorphosis, as in the May fly,



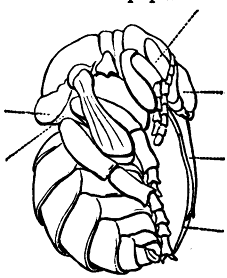
205. Larva.



206. Semi-pupa.



207. Advanced Semi-pupa.



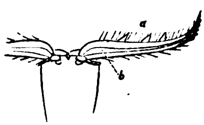
208. Pupa.

EARLY STAGES OF THE HUMBLE BEE.

we find that, as in the case of Chloëon, Sir John Lubbock has described twenty-one stages of existence, and let him who can say where the larval ends and the pupal or imaginal stages begin. So in a stronger sense with the grasshopper and cockroach. The adult state in these insects is attained after a number of moults of the skin, during each of which the insect gradually draws nearer to the final winged form. But even the so-called pupæ, or half winged individuals known not to be adult, in some cases feel the sexual impulse, while a number of species in each of the families represented by these two insects never acquire wings.

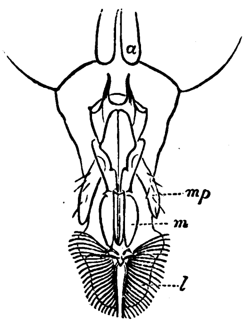
Still how did the perfect metamorphosis arise? We can only answer this indirectly by pointing to the Panorpa and Caddis flies, with their nearly perfect metamorphosis, though more nearly allied otherwise to those Neuroptera with an incomplete metamorphosis, as the lace-winged fly, than the insects of any other suborder. If, among a group of insects such as the Neuroptera, we find different families with all grades of perfection in metamorphosis, it is possible that larger and higher groups may exist in which these modes of metamorphosis may be fixed and characteristic of each. Had we more space for the exposition of many known facts, the sceptic might perceive that by observing how arbitrary and dependent on the habits of the insects are the metamorphoses of some groups, the fixed modes of other and more general groups may be seen to be probably due to biological causes, or in other words have been acquired through changes of habits or of the temperature of the seasons and of climates. Many facts crowd upon us, which might serve as illustrations and proofs of the position we have taken. For instance, though we have in tropics rainy and dry seasons when, in the latter, insects remain quiescent in the chrysalis state as in the temperate and frigid zones, yet did not the change from the earlier ages of the globe, when the temperature of the earth was nearly the same the world over, to the times of the present distribution of heat and cold in zones, possibly have its influence on the metamorphoses of insects and other animals? It is a fact that the remains of those insects with a complete metamorphosis (the bees, butterflies and moths, flies and beetles) abound most in the later deposits, while those with an incomplete metamorphosis are fewer in number and the earliest to appear. Again, certain groups of insects are not found in the polar regions. Their absence is evidently due to the adverse climatic conditions of those regions. The development of the same groups is striking in the tropics, where the sum of environing conditions all tend to favor the multiplication of insect forms.

It should be observed that some insects, as the grasshopper, for example, as Müller says, "quit the egg in a form which is distinguished from that of the adult insect almost solely by the want of wings," while the freshly hatched young of the bee, we may add, is farthest from the form of the adult. It is evident that in the young grasshoppers, the metamorphoses have been passed through, so to speak, in the egg, while the bee larva is almost embryonic in its build. The helpless young maggot of the wasp, which is fed solely by the parent, may be compared to the human infant, while the lusty young grasshopper, which immediately on hatching takes to the grass or clover field with all the enthusiasm of a duckling to its native pond, may be likened to that young feathered mariner. The lowest animals, as a rule, are at birth most like the adult. So with the earliest known crustacea. The king crabs, and in all probability the primeval trilobites, passed through their metamorphoses chiefly in the egg. So in the ancient Nebaliads (Peltocaris, Discinocaris and Ceratiocaris), if we may follow the analogy of the recent Nebalia, the young probably closely resembled the adult, while the living crabs and shrimps usually pass through the most marked metamorphoses. Among the worms, the highest, and perhaps the most recent forms, pass through the most remarkable metamorphoses.

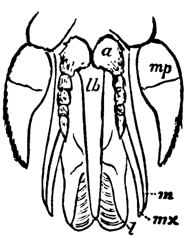


209. Jaws of Ant Lion.

Another puzzle for the evolutionist to solve is how to account for the change from the caterpillar with its powerful jaws, to the butterfly with its sucking or haustellate mouth-parts. We shall best approach the solution of this difficult problem by a study of a wide range of facts, but a few of which can be here noticed. The older entomologists divided insects into haustellate or suctorial, and mandibulate or biting insects, the butterfly being an example of one, and the beetle serving to illustrate the other category. But we shall find in studying the different groups that these are relative and not absolute terms. We find mandibulate insects with enormous jaws, like the Dytiscus, or Chrysopa larva or ant lion, perforated, as in the former, or enclosing, as in the latter two insects, the maxillæ (*b*), which slide backward and forward within the hollowed mandibles (*a*, Fig. 209, jaws of the ant lion), along which the blood of their victims flows. They suck the blood, and do not tear the flesh of their prey. The enormous mandibles of the adult Corydalus are too large for use and, as Walsh observed, are converted in the male into simple clasping organs. And to omit a number of instances, in the suctorial Hemiptera or bugs we have different grades of structure in the mouth-parts. In the biting lice (Mallophaga) the mouth is mandibulate, in the Thrips it is mandibulate, the jaws being free, and the maxillæ bearing palpi, while the Pediculi are suctorial, and the true bugs are eminently so. But in the bed bug it is easy to see that the beak is made up of the two pairs of jaws, which are simply elongated and adapted for piercing and sucking. Among the so-called haustellate insects the mouth-parts vary so much in different groups, and such different organs separately or combined perform the function of sucking, that the term haustellate loses its significance and even misleads the student. For example, in the house fly the tongue (Fig. 210 *l*, the mandibles, *m*, and maxillæ, *mp*, are useless), a fleshy prolongation of the labium or second maxillæ, is the sucker, while the mandibles and maxillæ are used as lancets by the horse fly (Fig. 211, *m*, mandibles, *mx*, maxillæ). The maxillæ in the butterfly are united to form the sucking tube, while in the bee the end of the labium (Fig. 212) is specially adapted for lapping, not sucking, the nectar of flowers. But even in the butterfly, or more especially the moth, there is a good deal of misapprehension about the structure of the so-called "tongue." The mouth-parts of the caterpillar exist in the moth. The mandibles of the caterpillar occur in the head of the moth as two small tubercles (Fig. 213, *m*). They are aborted in the adult. While the maxillæ are as a rule greatly developed in the moth, in the caterpillar they are minute and almost useless. The labium or second maxillæ, so large in the moth, serves simply as a spinneret in the caterpillar. But we find a great amount of variation in the tongue or sucker of moths, and in the silk moths the maxillæ

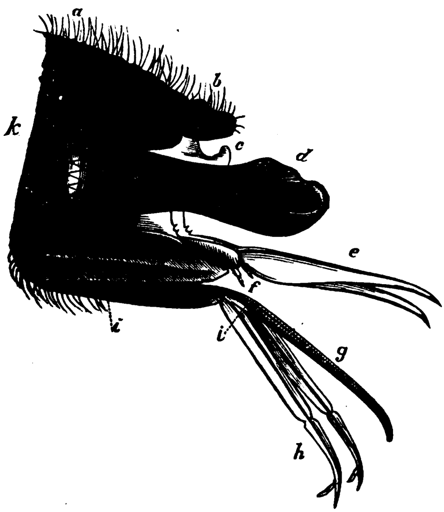


210. Mouth-parts of the House fly.



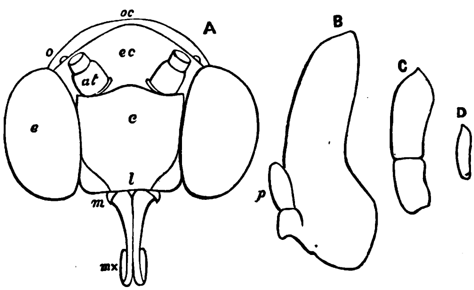
211. Mouth-parts of Horse fly.

are rudimentary, and there is no tongue, these organs being but little more developed than in the caterpillar. Figure 213, B, shows the minute blade-like maxilla of the magnificent Luna moth, an approximation to the originally blade-like form in beetles and Neuroptera. The maxillæ in this insect are minute, rudimentary, and of no service to the creature, which does not take food. In other moths of the same family we have found the maxillæ longer, and touching at their tips, though too widely separate at base to form a sucking tube, while in others the maxillæ are curved, and meet to form a true tube.



212. Head of Humble bee.

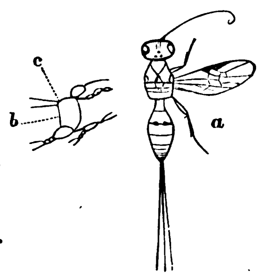
In the Cecropia moth it is difficult to trace the rudiments of the maxillæ at all, and thus we have in the whole range of the moths, every gradation from the wholly aborted maxillæ of the Platysamia Cecropia, to those of Macrosila cluentius of Madagascar, which form a tongue, according to Mr. Wallace, nine and a quarter inches in length, probably to enable



213. Mouth-parts of Moths.

their owner to probe the deep nectaries of certain orchids. These changes in form and size are certainly correlated with important differences in habits, and the evolutionist can as rightly say that the structural changes were induced by use and disuse and change of habits and the environment of the animal, as on the other hand the advocate of special creation claims that the two are simply correlated, and that is all we know about it.

Another set of organs, placed on quite another region of the body, unite to form the sting of the bee, or its equivalent the ovipositor of other hymenopterous insects, such as the Ichneumon fly (Fig. 214), the "saw" of the saw fly, and the augur of the Cicada. These are all formed on the same plan, arising early in the larval stage as three pairs of little tubercles, which ultimately form long blades, the innermost constituting the true ovipositor. We have found that one pair of these organs forms the "spring" of the Podura, and that in these insects it is three jointed, and thus is morphologically a pair of legs soldered together at their base. We would venture to regard the ovipositor of insects as probably representing three pairs of abdominal legs, comparable with those of the Myriopods, and even, as we have suggested in another place, the three pairs of jointed spinnerets of spiders. Thus the ovipositor of the bee has a history, and is not apparently a special creation, but a structure gradually developed to subserve the use of a defensive organ.



214. Ichneumon Fly.

So the organs of special sense in insects are in most cases simply altered hairs. The hairs themselves are modified epithelial cells. The eyes of insects, simple and compound, are at first simply epithelial cells, modified for a special purpose, and even the egg is but a modified epithelial cell attached to the walls of the ovary, which in turn is morphologically but a gland. Thus Nature deals in simples, and with her units of structure elaborates as her crowning work a temple in which the mind of man, formed in the image of God, may dwell. Her results are not the less marvellous because we are beginning to dimly trace the process by which they arise. It should not lessen our awe and reverence for Deity, if with minds made to adore, we also essay to trace the movements of His hand in the origin of the forms of life.

Some writers of the evolution school are strenuous in the belief that the evolution hypothesis overthrows the idea of archetypes, and plans of structure. But a true genealogy of animals and plants represents a natural system, and the types of animals, be they four, as Cuvier taught, or five, or more, are recognized by naturalists through the study of dry, hard, anatomical facts. Accepting, then, the type of articulates as founded in nature from the similar modes of development and points of structure perceived between the worms and the crustacea on the one hand, and the worms and insects on the other, have we not a strong genetic bond uniting these three great groups into one grand subkingdom, and can we not in imagination perceive the successive steps by which the Creator, acting through the laws of evolution, has built up the great articulate division of the animal kingdom?