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II.

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THE

STUDENT'S DARWIN.

BY

EDWARD B. AVELING, D.Sc.,

Fellow of University College, Lond.

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Vol. I.—"MIND IN ANIMALS." By Professor LUDWIG BÜCHNER. Translated by ANNIE BESANT. Price 5s.

INTRODUCTION.

IT is given to but few men or women to possess genius, though the word, like the word "love" and the name "poet," is unfortunately far too freely used. Even if the well-known definition of genius as "an immense faculty for taking pains" be regarded as exhaustive, the list of those possessing genius, in the course of a century, would not be a very lengthy one. If we regard the definition given above as far from complete, and recognise that the word implies something more and something rarer even than indomitable perseverance, those worthy of the title are few indeed.

That rarer and more important something beyond perseverance is, in many cases at least, the faculty of generalising. The man of genius sees the bearing of many facts one upon the other, recognises the one fundamental idea running through and connecting them all. To him the single fact is no solitary, isolated from its fellows. It is one of a vast brotherhood, having common origin, and genius, recognising this community of nature, proclaims it to the ordinary world, and directs the slow eyes of common folk towards this one great truth. As the sudden-seeing eyes of genius behold these great principles its voice in clear accents announces them to those who listen. But alas! clear, unmistakable as is the utterance, ears are deaf and hearts are dull. The awful voice of the great thinker goes echoing on, and is dying away in the distance ere the ordinary man has even heard its sound. Then is it the duty of him that has been more fortunate to re-echo the utterance of his master, to repeat his thoughts many, many times, that the joy that has fallen upon the life of this fortunate one may pass into the lives of many, that the intellectual light that has fallen upon his eyes may dawn upon the vision of his fellows.

Few are they to whom the high-sounding, much-meaning name of "genius" can be applied. But it is given to most people to admire genius. Between these two classes, the intellectual giants and the innumerable folk of ordinary mental stature, is an intermediate class—the students. These are men and women in whose lives duty and inclination have happily combined to the one great end—the acquisition of knowledge. The students are intellectual middle-men. It is their duty, as it is their privilege, to receive great truths from those on the heights above them, and to transmit them to the multitudes toiling below. Thus is the great mass of mankind raised slowly, but surely, up the steep hill of knowledge towards a serener air.

Of the men of genius produced by England, few stand higher than Charles Darwin. In him the immense faculty for taking pains exists to the fullest. To this the extraordinary number of his recorded observations and experiments, the wide field over which they extend, the long list of new facts he has given us, bear witness. But he is something more than a mere observer or recorder of facts. He is not of those who regard as the chief end of science an ever-lengthening list of species and varieties. There is something higher even than the collection of facts—that is, the making of generalisations from those facts. The object of the recordal of multitudinous small truths is the arrival at some one great truth. That is the true scientific mind which, never neglecting observation and experiment, yet is ever looking for the single generalisation to be induced from the mass of details. Whether we look at the number of general truths enunciated by Darwin, or at the magnitude and importance thereof, we are constrained to acknowledge that in this loftier attribute of genius he has few rivals.

It is the purpose of this book, coming from one of the student class, to tell something of this man's work to those who have neither time nor opportunity to investigate it fully for themselves. The most usual summing-up of his labors, his writings, his very life, is: "Darwin? Oh, yes! Says we come from apes!" This epitome of his words and deeds is as unjust as it is summary. Yet the large majority of even educated people have no other idea than this connected with the name of Darwin. It is necessary therefore to insist upon the fact that, independently of his theories, the author of "The Origin of Species" has done more for the extension of our knowledge than perhaps any other man living; that two of the most carefully elaborated biological subjects have been worked out by him; that in minuteness and accuracy of observation, as well as in wideness of generalisation, Darwin stands first among the scientific men of England—I had almost written of the world.

Especially is it necessary that more of us should know the true meaning of the word "evolution." In an age when, according to a distinguished authority, young ladies in gilded saloons "prattle Atheism about protoplasm," it is not wonderful that the word "evolution" should be on many lips. But the word to the general only connotes the development of man from some lower form of animal. The principle of evolution involves much more than that. If only to show to some readers more clearly what it does involve, and to impress upon them the fact that man's origin is comparatively of secondary importance, it were well perhaps that these pages should be written. Especially, therefore, will it be my aim to state clearly the full meaning of the theory of evolution now almost universally accepted by scientific thinkers, the arguments for and the arguments against that hypothesis. With no light consciousness of unworthiness, but with great longing to be of some service to the many, I would stand as intellectual middle-man between one man and the many, as interpreter between the bulk of readers and one of the foremost men of this age.

The general plan of this work will be as follows. The published works of Charles Darwin will be one by one recorded, analysed, epitomised. Attention will be called to the chief discoveries noted, the chief theories broached in each. The books will not be taken exactly in their chronological order. The first to be considered will, however, be also the first in point of time. (I.) "The Naturalist's Voyage round the World" will form, by its general treatment of scientific questions, an excellent introduction to the more special treatises that follow. (II.) For some time Mr. Darwin seems to have paid special attention to geology, and the works on "Coral Reefs" on "Volcanic Islands," and on "The Geology of South America," will next occupy our attention. (III.) The series of observations on plants comprised in the volumes on "Climbing Plants," "The

Orchids," "Insectivorous Plants," "Cross and Self Fertilisation," "Forms of Flowers," and "Movement in Plants," will be noticed next. (IV.) An account of the one exhaustive treatise on a purely zoological subject, "The Monograph of the Cirripedia," will follow. (V.) Finally, the series of works bearing more immediately on the great question of evolution will be studied — viz., "The Origin of Species," "Animals and Plants under Domestication," "The Descent of Man," "The Expression of the Emotions."

It is earnestly hoped that this work may be of use to students themselves. Even those who have read, and read carefully, the writings in question may find the perusal of this summary of value to them, as they find the re-reading of their lecture-notes of use as recalling the experiments and statements of their lecturer. For them will be made that which, in truth, each should make for himself, a complete analysis of Darwin's works. It may be said that nothing is worth reading that is not worth analysing. It may be said that no idea of another man's is ever in reality understood by the student until it has been expressed in the student's own words. Surely, then, the writings of the man perhaps most worthy to be read at the present day, the writings of the man whose ideas are the most necessary to become ours, are worthy of analysis.

But, as was stated above, the work may be of value to the ordinary reader. As the translations of classical authors in "Bohn's Library" are read and studied by those unacquainted with the Greek and Latin tongues, as thus the great thoughts of the old world thinkers are rendered intelligible to those unable to understand them in the originals, so it is thought that the many who have neither the time nor the technical skill required to read the whole of the great master's works may yet become acquainted with some of their contained wonders and beauties by the perusal of these pages. It is well that all of us should know at least the outline of the work that has been done by this man. For as the name of Chaucer marks the fourteenth, and the name of Shakspere the sixteenth century, so probably will the name of Charles Darwin mark the nineteenth century in the years to come.

I.—THE NATURALIST'S VOYAGE ROUND THE WORLD.

CHAPTER I.

ON the 27th of December, 1831, a ten-gun brig, the "Beagle," sailed from Devonport. The object of the expedition was to survey certain parts of South America, and to put a girdle round the earth in the shape of chronometrical measurement. On the 2nd of October 1836, the "Beagle" made the coast of England once again. To the Englishman, with the old love of battle not quite dead within him, the "Victory" and the "Arethusa" are historical names among ships; but to the student far more highly ranks the name of the ten-gun brig "Beagle," for during that period of nearly five years the vessel was accompanied by Charles Darwin. "The Naturalist's Voyage Round the World" is an account in the form of a diary of the most interesting facts that came under the observation of the writer during that time.

Among the memories of our boyhood not the least vivid is the recollection of two quaint, long-haired men, who told us, in language of beautiful simplicity, two stories that never failed to fascinate. They are stories that will last as long as there are boys to read them. About their name hangs an indefinable charm, such as that which lies in the word "home," in the portrait of one long passed away, in the scent of a flower that one's mistress was wont to twine in her sunny hair. The names of these two writers are Daniel De Foe and John Bunyan. Next to "Robinson Crusoe" and "The Pilgrim's Progress," I know of no book so likely to take firm hold of a boy's mind as "The Naturalist's Voyage Round the World."

The outcry against fairy tales for boys and girls should be left to Mr. Gradgrind. The rest of the world must confess to a passionate admiration for "Jack the Giant-Killer," and a passionate adoration of "Cinderella," and is never tired of hearing of gnomes, and pixies, and kelpies. On the other hand the terrible outcry made by some good folks against giving facts to children is a little incomprehensible. It seems to be forgotten that to our little ones all they read and hear is true. Hop-o'my-Thumb, Friday, Mr. Greatheart, are real beings to them. They *know* that the wonderful beanstalk grew to that portentous height. They *know* that Cassim's bones are still lying in the robbers' cave. They *know* that Aladdin's lamp is somewhere in the world, if they could but find it. Let the children have the beautiful old fairy tales, but let them have, moreover, such books as this whereof we speak. They will learn for themselves sufficiently soon what is romance.

And indeed "The Naturalist's Voyage Round the World" reads very much like a fairy tale. It takes us into wonderful regions, where vampire bats flit through the night, where man's path lies across beds of sensitive plants, and a broad track is left behind him marked by the drooping of the tender leaf-stalks, where peach-trees are used for firewood, where hail falls that kills cattle, where showers of butterflies come like summer rain. From the first page to the last the book is crowded with facts as dazzling as any inventions of the most brilliant fancy.

No special knowledge is required to enjoy this most fascinating work. Its statements will, of course, have a deeper meaning to anyone possessed of a little scientific lore; but some of the most enthusiastic admirers of the book are readers of the ordinary class, without the faintest suspicion of technical knowledge.

And yet Mr. Darwin's style can hardly be called a popular one. He is not an elegant writer. Some of his sentences, indeed, are at times almost clumsy, but the exquisite charm of the new series of facts he tells us atones for any peculiarities of style. We forget how he talks to us: we are so delighted with what he says. If he had written nothing else this volume alone would have stamped its author as one of the first among contributors to general scientific knowledge.

Pre-eminently in this work shine out Mr. Darwin's extraordinary powers of observation. He seems well-nigh omniscient. Nothing escapes him. Dust in the air, color in the sea, the habits of a spider, a cuttle-fish, an ostrich, an Indian, he notices all. But whilst this, his first great work, is specially a collection of facts, it is not that alone. Again and again are encountered instances of his capacity for abstracting from a large number of small truths the one great truth running through them all. In these pages the reader of riper mind will linger over many passages that the boys and girls will skip—passages embodying wide generalisations, pregnant with interest. Especially will the student be impressed with the numerous occasions whereon he will meet hints and suggestions of the line of thought so fully worked out in later years in "The Origin of Species." In this first publication are the germs at least of the views enunciated in the "Magnum Opus."

It will be well to consider—A. The nature of the facts communicated to the world in "The Naturalist's Voyage:" B. The nature of the chief generalisations contained in the volume. It is especially difficult to separate fact from generalisation with Darwin, but the attempt will be made. C. The foreshadowings of later theories.

A. *An account of some of the most important facts contained in "The Naturalist's Voyage Round the World."*

(1.) On the 6th of December, 1834, on the island of San Pedro, off the coast of Chili, were to be seen two English naval officers engaged in taking a round of angles with a particular astronomical instrument known as the theodolite. Upon this island of San Pedro at that time resided a certain fox, who on the day and at the hour in question was indulging in his customary evening stroll. Beholding the strangers in the course of his peregrinations, the perambulating animal stopped, and took a cautious survey of them. His curiosity was aroused. He grew deeply interested in these men performing such strange antics with such a queer-looking instrument. He became absorbed in contemplation. On the rocks behind him, a naturalist, ever on the look-out for new specimens, happened to be walking. *He* became absorbed in contemplation of the rare animal before him. The animal was curious in two senses of the word. The interest of the scientific fox took the passive form of close observation. The interest of the scientific man took the active form of cautious advancing. The former stood wrapt in wonder. The latter drew near, and smote a deadly blow with a geologist's hammer on the head of the observing one. The name of the fox, whose remains are to be seen to this day in the museum of the Zoological Society, was *Canis fulvipes*. The name of the naturalist was Charles Darwin.

The earth is one great battle-field. Between the innumerable races of animals dwelling on the bosom of that which is the mother of them all endless struggles occur. No mere skirmishes are these contests, as a rule, but battles, wherein death is the penalty of defeat. "Væ victis!" is the cry of all nature. No matter of surprise is it, therefore, that in "The Naturalist's Voyage Round the World" stories such as the above are not infrequent. No wonder is it that some of the most fascinating parts of the book are those wherein are recorded the life and death struggles of the animal creation. We read with deepest interest, whereunto something of horror lends a zest, of the weird, ghoul-like wasps that sting spiders or caterpillars, not to death but half way thereto, and then store up their victims till such time as the wasp larvæ, emerging from the eggs, devour at their leisure the inert yet living bodies of their prey. We watch eagerly the fight between wasp and spider, the wounding of the latter, its temporary escape, the wondrous, systematic hunt for it by its unrelenting foe, the discovery, and finally, after much artful manœuvring, the deadly stab that narcotises the unfortunate Arachnid. It is with a pleased sense of that poetic justice, so dear to us all when it is dealt out to other people, that we read, on the other hand, of the terrible spider which wraps round and round the miserable wasp entangled in its web, a fatal mesh, then, inflicting the death-bite, waits with a fearful patience till the poison has done its work, and the blood of the victim may be sucked from the lifeless corpse.

There are endless tales, moreover, for those who object to sup even lightly of horrors. The very spider mentioned immediately above, when disturbed, has all kinds of ways of saving itself from peril. Now it runs from one side of its huge web through a central passage to the other, now it drops into the dense thicket beneath, often letting fall a fine rope previously, down which it lowers itself with marvellous rapidity; now, standing in the middle of the web, it jerks the gossamer circles backwards and forwards with such speed that, in the rapid vibration, the outline of the creature's body becomes indistinct and lost.

Amongst curious animals tortoises again rank high. Some met with in Chatham Island weighed respectively more than fourteen stone. These huge monsters, suggestive of antediluvian beings, when encountered usually fall to the ground as if dead, with a deep hiss, and a sudden and alarming disappearance of head and limbs. A few taps on their shells will reassure them, and rising they march sedately onwards, even with a man standing erect on their backs. Very sedate, in truth, are their movements. Some six yards per minute was all that could be accomplished by one of average speed, even when not suffering from the pressure of a superimposed naturalist. A very powerful attachment to water is characteristic of these Chelonia and near the springs are to be seen two sets of the reptiles, the one hastening with outstretched necks and longing aspirations towards their watery elysium, the other returning calm and composed, with all the complacent though somewhat irritating equanimity of satiety. In this way they tread out broad, well-beaten paths from the coast inland, paths which led to the first discovery of the watering-places by the Spaniards.

These beings live, apparently, to an exceedingly venerable age. Slow in living they seem to be equally so in dying, generally terminating their lives by a fall from a precipice or some other accident. In connexion with this same subject of death, a curious fact is recorded in relation to certain parasites on birds that reminds us forcibly of the half-mythological tales of rats deserting a ship doomed to destruction. For several hours before the death of a huge condor—one of the carrion fowl of America—the parasites upon it were seen crawling to the outside feathers.

(2.) Amongst the multitudinous epigrams that flowed from the facile pen of Alexander Pope, versifier, the one most frequently quoted is the epigram that tells us that "the proper study of mankind is man." It is as true as are most epigrams. With the swiftly attractive and noticeable germ of truth contained in the phrase is bound up so much of exception, and the condensed brilliancy of the witty saying has to be toned down by so much of the shadowing off that results from after-reflection, that the statement is a veritable epigram. The habit of condensing much thought into a short phrase is worthy, but not unattended with danger. The complex relationships of our modern life are not easily summed up in one neatly turned remark, and during the condensation of an idea into a pithy sentence evaporation may occur, and something of accuracy be sacrificed to the desire for brilliancy. Despite all this, not the least interesting genus we can study is the genus *Homo*. For all mankind, metaphysics and history, the two sciences that treat of man himself, possess a fascination quite peculiar to themselves, a fascination whose like is scarcely to be found in any of the studies that investigate forms of matter other than that known as human.

An observer so acute as our greatest naturalist, during five years spent in foreign climes, could not fail to note many a fact of interest concerning the men he encountered. They were men not infrequently whose structure would force him to place them in the same order and genus with himself, but whose mental and moral natures were separated widely indeed from his own.

We could scarcely place in this latter category, however, General Rosas, despotic ruler, in fact if not in name, of the wild Gauchos of the Rio Colorada. This remarkable man seems to have been a kind of South American Cnut. He kept two fools, like a baron of the middle ages. His laugh was a dreaded sign of punishment impending, and his method of punishment was to stretch a man between four stakes, like a hide that is to be dried. He had been chosen General because he was able to sit on a cross-bar under which wild horses rushed at full speed, to drop thence on one of the animals, and without aid of saddle or bridle not only to ride the creature but to bring it back to the place whence it started.

Almost as interesting a study are the Fuegians. Three of these were in the "Beagle." They were returning to their native land, whence Captain Fitzroy had brought them four or five years previously. A most amusing boy was Jemmy Button, whom the Captain had purchased in his former voyage for the immense sum of one pearl button. A chubby lad was he, with a quite abnormal fondness for cleanliness and gloves, peculiarly acute sight, and a great belief in his own country, wherein he firmly maintained that necessary appendage of civilisation, the devil, was nonexistent. Notable was the difference between him and the Fuegians who had received none of these advantages. These were stunted, greasy wild beasts, with hideous features bedaubed with entangled hair, with harsh, grating voices, a repulsive habit of ape-like mimicry, and scarcely a suspicion of clothing. They had no belief in a future state, no rites that the wildest imagination could twist into religious ceremonies, and in times of scarcity would hold their old women over the fire-smoke, and then devour them, before they sacrificed their very dogs. Yet were these of the same race as this decent, well-dressed, well-behaved, and as things go now, tolerably moral youth. He was simply one of these horrible savages *plus* education.

The incessant cry of these beings was, "Yammerschooner!" which being interpreted means, "Give me!" Everything down to the very coat-buttons, with the one significant exception of the guns, did they point to with the cry, "Yammerschooner!" With young and old, women and men, it was the same, the last, if they failed on their own account, pointing first to the object of their desire, then to their wives or children, with the like eternal cry. It has been suggested that something very like "Yammerschoonering" is to be seen in more civilised realms than Tierra del Fuego.

As one reads the account of these low forms of man, and of others their allies, it is possible to see how one question is already moving in the mind of their observer. Reading between the lines it is not difficult to observe this inquiry suggesting itself: Are these creatures created in the likeness of a perfect being, or are they evolved from those animals that I see around them, and that I behold living lives almost as lofty as theirs? To that question, even thus early I say, moving within the mind of the young writer, he was destined in the after-years to give no uncertain reply.

(3.) But of course the most interesting man in "The Naturalist's Voyage Round the World" is its writer. In novels and plays we always want the author's personality to be merged into that of his characters In a diary we look for that personality to be vivid, distinct. At first one is inclined to say that the journal is disappointing in this respect. It seems to be full of a thousand facts, a hundred speculations, but to contain too little of Dr. Darwin himself. A little reflection dispels this idea. We recognise that these facts, these speculations, *are* Dr. Darwin, that the observation of things, the construction of hypotheses, are part and parcel of his very nature.

We obtain some glimpses also into the inner life of this remarkable man. We see in him a grim sense of humor, a love for all his kind—above all that charming modesty and freedom from aggressive and dogmatic assertion which have ever distinguished his works.

In these days, moreover, when the sweeping condemnation of such gifts as nature provides for moderate consumption is too rife—in these times when people are to be found who have so low an opinion of human nature as to imagine there can be no temperance without abstinence, I confess to a feeling of pleasure in speaking that a man of such extraordinary attainments as Dr. Darwin openly expresses his delight in a good dinner and a good cigar. In these days, also, when clergymen at Church Congresses can advise hearers to abjure entirely all kinds of light reading, every species of public amusement, it is right pleasant to find one who has done more work and better work than any man of his time speaking of a theatre not as a hotbed of vice, but as a place of rational entertainment. It is well for us to recognise (and to insist on others recognising) that amusement is as essential to man as work. It is time that such puerilities as the absolute condemnation of all amusements should be treated with the scorn that we should lavish on one who, passing to the opposite extreme, stated that life should consist solely of entertainment, to the exclusion of all honest labor. It is those who do not know the meaning of real, warm, hearty world-work that speak thus. The thorough men and women do not echo such cry, and open their clear honest eyes widely in wonder when it makes its moan. The true workers are the true players. He that is most man in his hours of labor is most child in his moments of sweet doing nothing. The heart that aches for humanity is, in order that it may work the better for its mistress, the most lightsome at times. The eyes that are for the most part stern in resolve, or pity-laden, are most full of the brightest mirth when the time for mirth is, and the voice that can exhort, warn, comfort, threaten, has the fresh, hearty ring of the laughter of childhood when it sounds cool and clear over the waters of the seaward-flowing river in the summer-time.

CHAPTER II.

B. *Chief Generalisations.*

CHARLES DARWIN has the power of observing facts. So numerous and acute are his observations that nobody can deny him the possession of that part of genius which consists in the immense faculty of taking pains. But he has that higher attribute of genius which enables the few to look into the very heart of multitudinous facts, and see the great truth that underlies them all. He is able to make generalisations. Even as early in his career as when "The Naturalist's Voyage Round the World" was written, we find Charles Darwin interspersing with his record of facts suggestions and hypotheses. These hypotheses have, almost without exception, passed long ere the present day from the region of hypotheses into that of general truths.

(1.) As early as the eighth page of the journal occurs a passage wherein is recorded the fact "that all the many small islands, lying far from any continent, in the Pacific, Indian, and Atlantic Oceans, with the exception of the Seychelles and one other little point of rock, are composed either of coral or erupted matter." This is at once connected with the statement that the majority of active volcanoes are either on islands or hard by sea-coasts.

(2.) Visiting the Galapagos Archipelago, a group of islands between five and six hundred miles to the west of America, the naturalist is struck with the remarkable fact that the different islands are to a considerable extent inhabited by a different set of beings. The islands are not more than fifty miles apart, have the same geological formation and similar climates, yet they are tenanted by different varieties of the same species of animals, so that the Vice-Governor could at once tell from which island a particular tortoise was brought.

(3.) When Columbus landed in America after the immortal voyage, no horses were known in the country. From the observations of the "Beagle" naturalist, aided by those of others since the year 1833, has resulted the establishment of the hugely important fact that in South America, centuries agone, an aboriginal horse existed—that in the process of time, in the great battle of life, it was slowly forced out of existence, to be succeeded in the after years by its fellows, descended from those introduced by the Spaniards.

(4.) Siberia and Patagonia are regions not apparently presenting much in common. In the volume under discussion a striking resemblance between the two, at least as far as their remarkable salt lakes are concerned, is established. Both countries appear to have been recently raised above the level of the sea. Both present plains with shallow depressions filled with salt water. In both the muddy borders of these depressions are black and fœtid. In both, besides common salt (sodium chloride), Epsom salts (magnesium sulphate) and gypsum (calcium sulphate) are found in connexion with the salt lakes. Finally the salt lakes of both countries are the habitat of multitudes of small Crustacea and the haunts of the flamingo.

(5.) Dealing with the past history of the wonder-laden continent, our author broaches the probability of stranded icebergs grooving and smoothing rocks over which they passed, after the fashion of glaciers. This suggestion is worked out more fully in the ninth volume of the *Geographical Journal*. It is pleasant to record that this original idea of Charles Darwin's is now accepted as true by geologists.

(6.) The general assumption that the large animals of past times must have required, for their food, plants of corresponding size, that the mastodons, megatheriums, and deinotheriums must have browsed upon vegetation colossal in its dimensions, had been handed down from text-book to text-book. It was reserved for the author of "The Naturalist's Voyage round the World" to establish a generalisation the precise converse of the above. A mental glance, on one side, at South America, with, as its largest quadrupeds, tapirs, deer, and capybaras, and with its world of forests stretching hundreds of miles in all their wealth of wood and foliage and flower and fruit—a glance, again, to Africa, with its elephant, giraffe, rhinoceros, elan, and hippopotamus, and its infinite stretches of desert country, will help in the comprehension, and, indeed force upon us a conviction as to the truth of Charles Darwin's hypothesis that the gigantic mammals of present and of past times have fed upon a vegetation that has been sparse rather than luxuriant.

(7.) Perhaps one of the most daring of hypotheses is that as to the formation of great mountain chains, such as the Cordilleras. Combating the view that these Titanic wrinkles on the breast of Mother Earth are the result of one single upheaval, he suggests that they are the consequence of repeated ejections of volcanic matter from the interior of the earth. These masses of fluid rock cast out of the earth's interior have been successively injected into a kind of hollow mould of the mountain chain, formed primarily by an upheaval of the land surface. These ejections from the earth, and injections into the hollow raised mould, must have occurred at sufficiently long intervals to allow of the cooling and solidifying of each layer before the next one beneath was upcast. In short, he holds that the upheaval of a mountain chain is not the result of one single enormous action, but of a series of such actions. The wrinkles on Mother Earth's bosom are not due to one struggle, but to the continued action of the hard taskmistress Time.

(8.) Perhaps the best-known and most extensively applied of the large truths enunciated in the first work of Darwin is his well-known theory of the subsidence of the base of the Pacific Ocean. Indeed, this, even in the year 1835, was not a theory. Thus, at pages 172, 321, 344, 369, 370, and 475, actual proofs of the subsidence are given. Our naturalist shows that the majority of oceanic living beings flourished, to use the phrase of the old historians, in comparatively shallow water. In comparatively shallow water, if the bottom remain stationary, no sedimentary deposit of any depth and extent is conceivable. Such a sedimentary deposit, of notable thickness and extent, is necessary for the preservation of organic forms as fossils. Yet, in connexion with the Pacific Ocean are found fossiliferous deposits of enormous extent and of great thickness, wherein are treasured the durable remains of organic beings, such as shells, that were, according to all evidence, inhabitants of comparatively shallow water. As the inferior layers, at least, of these mighty deposits are at great depths, the only hypothesis that binds together these many facts is that as the sedimentary deposits took place the bed of the ocean slowly sank. Each layer, therefore, is formed in no great depth of water, stores up the shells of its time, and then slowly sinks, ever deeper, deeper, deeper, as future strata form upon it. This hypothesis is the hypothesis of Charles Darwin.

(9.) Lastly, the application of this same theory of subsidence to the explanation of the arrangement of coral reefs will be investigated in a special chapter, as the author has written on the subject a special book.

CHAPTER III.

C. *The Foreshadowing of Later Theories.*

IT is on record that that most didactic of English versifiers, William Wordsworth, gave utterance to the remark "the child was father to the man." As it is interesting to notice in the child the looks, the gestures, the habits that are destined to become part of the stock in life of the man, so is it interesting to notice how, in the earlier works of certain authors, there are faint adumbrations of ideas that are to be worked out more fully in their later writings. Such a study is of especial value in the case of Darwin. All the world knows that his fame is principally founded on the hypothesis as to the origin of the different species of plants and animals. In his first work, "The Naturalist's Voyage round the World," passages frequently occur, hinting at, faintly shadowing forth, the views enunciated in the "Origin of Species," supported by numberless facts in "Animals and Plants under Domestication," and elaborated in the "Descent of Man" and the "Expression of the Emotions." To call attention to some at least of the passages in his first work, where such foreshadowings occur, is the object of the present chapter.

(1.) At pp. 131, 132 a series of facts are given to show that North and South America, within a comparatively recently geological period, were much more closely related in the character of the animals inhabiting them than they are at the present day. There is no suggestion yet of the evolution of these animals from certain common primordial forms under the varying external conditions to which those primordial forms have been subjected in the two parts of the continent.

(2.) P. 315. The qualities of the mule as compared with those of its parents are noticed. Its superiority to both parents in reason, in memory, in muscular endurance, in affection, and, to the consolation of some of us let it be added, in obstinacy, is suggested as instancing a case where art has outdone nature. This reflection, to those who remember how the account of artificial selection precedes the introduction of the theory of natural selection in the crowning work, will not be devoid of interest.

(3.) Upon pp. 379 and 380 of "The Naturalist's Voyage Round the World" a dissertation is introduced upon the beaks of a particular genus of birds. The careful investigation of so apparently small a matter as the beaks of one special genus of the class Aves, and a somewhat elaborate account of the results of such investigation, might seem work of supererogation at first sight. But he that studies the writings of our foremost Naturalist and the literature of Evolution generally, will learn that it is by the patient study of minute details of such kind as this, by the accumulation of numberless small facts, that the large ideas of Evolution have been suggested and supported. In the pages of the work at present under consideration certain pictures are given of the heads of certain birds. Three of the birds belong to the genus *Geospiza*. A fourth that is also represented is a member of another genus, *Certhidia*. The first species of the genus *Geospiza* (γη, the earth, σπιζω I chirp) is one known as *magnirostris*, or great billed. The third species whose head is represented is *Geospiza parvula* (*parvulus* = little). Its beak is small and of shape differing from that of its large-billed congener. Between these two forms of beak there are six gradations insensibly passing into each other. Only one of these six is shown in the book, the beak of *Geospiza fortis* (*fortis* = strong). This ranks as nearly as possible midway between the two extreme forms encountered within the limits of this single genus of birds. When comparison is made of these eight beaks and that of one of the birds belonging to the closely allied genus Certhidia is placed along with them, a regular gradation is to be noticed in the organs under consideration from a beak as large as that of a hawfinch to one about the size of the bill of a chaffinch. One passage referring to this subject is so remarkable viewed in the light of later writings from the same pen, that not without advantage it may be quoted here in its entirety. "Seeing this gradation and diversity of structure in one small intimately-related group of birds, one might really fancy that from an original paucity of birds in this archipelago, one species had been taken and modified for different ends."

(4.) On p. 82 occurs a discussion on the Toxodon, a huge land animal, whose remains are found in company with those of the Megatherium, the Megalonyx, the Mylodon, and other giant mammals of the past, immersed in the plains of mud and sand encountered upon certain parts of the Eastern coast of South America. Our naturalist takes cognizance of the size of the Toxodon like any ordinary observer, but his acute scientific vision sees that which is invisible to the eye of the many. He is impressed with the blending in this one animal of bygone ages of the characters, not of distinct species, not of distinct genera, but of distinct orders of animals now extinct. In size the Toxodon reminds us of the Proboscidea or elephant order; in its dental structure, of the Rodentia or rat order; in many details of anatomical arrangement, of the Ungulata or hoofed order; in the position of its sense organs, of the Sirenia, the order including the herbivorous aquatic mammals. The sentence following the enunciation of these facts is interesting from an ethical point of view. It commences with the phrase "How wonderfully" and ends with a note of astonishment. Sentences akin to this are frequently encountered in the pages of Dr. Darwin's earlier works. They are not often seen in the productions of his later years. It savors of truism to say that the writings of younger men are more full of strong adjectives and adverbs, that their pages are more plentifully besprinkled with interjectional marks and remarks than are those of their elders. The first line in Shelley's first poem, the much abused and unequal *Queen Mab*, is "How wonderful is Death!" As years advance, in writing, as in all things, the hyper-enthusiasm of youth yields to the calmer judgment of maturer years.

(5.) In this, his first work, the word "created" occurs in connexions wherein it would certainly not be encountered in the present writings of our author. It is true that it is not accompanied by the word "specially," nor does he, to the knowledge of the present writer, use the phrase "special creation;" but two passages at least that will now be quoted show that in the year 1835 he still employed the phraseology that his own labors have since done so much to render antiquated. P. 289, "finding, as in this case, animals which seemed to play so insignificant a part in the great scheme of nature, one is apt to wonder why they were created." P. 391, "at the Galapagos Archipelago we have a halting place, where many new forms have been created."

(6.) As we read the young Naturalist's description of different animals, it is evident that the possibility of the evolution of higher forms from lower is growing upon him. Even in dealing with the highest of all animals, the genus Homo, it is clear that this possibility is very present with him. The grades of human-kind seen in his travels ranged over a very wide intellectual area. Indeed, some of the races he portrays hardly admit of the employment of the adjective "intellectual" in connexion with them. It is in the account of these lowest specimens of humanity that the most striking phrases occur to assure us that his mind is even then pondering on the question, whether, from a form of being that was the parent of these stunted wretches, by courtesy called men, could be evolved in the course of time peoples that should number among them a Shakspere and a Goethe. One reference in support of the above passage may be made to the description on pp. 205 and 206 of the savages who were so far in advance of many of their fellows encountered by him at Tierra del Fuego.

(7.) In the "Origin of Species" occurs very frequently the word "reversion." Reversion signifies the abnormal appearance in an animal, or a plant, of some peculiarity that was possessed by one of its ancestors, but is not possessed by its fellows. The word presupposes that the species of plants and animals at present in existence have originated from a few primordial forms, and are not the work of special creation. Gardeners frequently meet with plants differing in some detail from their fellows. They call them "sports." Similar sports occur in the animal kingdom. Many of these sports are explained by Charles Darwin as cases of temporary reversion to a condition that was permanent in the ancestral type. To take a time-honored illustration, horses are occasionally born with stripe marks upon them. It is hardly necessary to call to the reader's mind the zebra, in order to point the moral of this occurrence.

In "The Naturalist's Voyage Round the World" the theory of reversion is not actually enunciated any more than the theory of natural selection. But reference thereto is made. Thus, on p. 505, mention is made of the fascination that hunting exercises over almost all mankind, and not a few of womankind, and the delight that is felt in living in the open air, when one does it from choice and not from necessity. The love of the chase is a relic of the old conditions of existence when the chase was essential. It carries us back to the early times when savage man, skin-clad and armed with spear and bow, in primeval forests slew for very livelihood the beasts that were almost his fellows. The love of travel and the delight that the strong man feels in sleeping with the earth for bed and star-crowded sky for canopy carry us back to nomadic ages when houses and cities were not. So that the modern picnic, with its paraphernalia of champagne cup, lobster salad, indifferent amateur waiters and cooks, flirtations, and colds in the head, is but a case of the reversion of society to the habits of its dead-and-gone ancestors.

(8.) One passage in the book under consideration suggests the general principle upon which so many anatomical and physiological variations that occur first 'accidentally,' have become permanently fixed in the races of beings presenting them. Such a principle is, of course, of enormous importancce in the study of evolution, or the development of many species from a few primordial forms. The passage referred to deals with the development of the habit of man-fearing in wild birds. Thus the birds at Bourbon in 1571 were perfectly tame; at the present day they are wild enough. After noting this fact follows the passage in question. The wildness of birds with regard to man is a particular habit directed against *him*, and not dependent on any general degree of caution arising from other sources of danger; secondly, it is not acquired by individual birds in a short time, even when much persecuted, but in the course of successive generations it becomes hereditary.

(9.) Hints occur in the pages of this first production of a principle much enlarged upon in later works. This is the principle of the struggle for existence. On p. 175 we read: "Some check is constantly preventing the too rapid increase of every organised being left in a state of nature." And again: "Causes generally quite inappreciable by us determine whether a given species shall be abundant or scanty in numbers." This idea, like most of those broached in "The Naturalist's Voyage Round the World," is discussed more fully in the succeeding volumes.

(10.) Finally, I purpose referring to four or five passages in which the attentive reader can trace a still further foreshadowing of what is to come. They are passages that contain hints of the line of thought along which our greatest naturalist has worked during the last forty years. On p. 378 is the phrase, "That mystery of mysteries, the first appearance of new beings on this earth." To the elucidation of that mystery none has contributed so largely as the writer of that phrase. On p. 176 we read: "If, then, as appears probable, species first became rare and then extinct; if the too rapid increase of every species, even the most favored, is steadily checked, as we must admit, though how and when it is hard to say, and another closely allied species is in the same district, why should we feel such great astonishment at the variety being carried a step further to extinction?" This is from the pen of the author of "The Origin of Species." P. 173: "This wonderful relationship in the same continent between the dead and the living will, I do not doubt, hereafter throw more light on the appearance of organic beings on our earth and their disappearance from it than any other class of facts." Here is reference to the value of the study of fossils in any inquiry into the origin of living beings. But the most interesting part of the quotation is the intrinsic evidence it affords that this inquiry will be prosecuted by the writer in after time. A passage previously quoted on account of the word "created" therein, is worth requoting in this connexion with its context. P. 289: "When finding animals which seem to play so insignificant a part in the great scheme of Nature, one is apt to wonder why they were created. But it should always be recollected that, in some other country, perhaps, they are essential members of society, or at some former period may have been so." Lastly, on p. 192, is one of the most characteristic passages in the book, involving a distinct suggestion of the survival of the particular variation in a contest with other kindred variations. It is not precisely an enunciation of the survival of the fittest, but certainly contains the germ of the theory of natural selection: "It is interesting thus to find the once domesticated cattle breaking into three colors, of which some one color would in all probability ultimately prevail over the others, if the herds were left undisturbed for the next several centuries."

II.—GEOLOGICAL WORKS.

During those early years when the "Beagle" was flitting from place to place in the wonder-world of the western half of the globe, multitudes of geological observations were made by its naturalist. These are in the main embodied in two volumes to-day. The one is that on "The Geology of Volcanic Islands and South America;" the other is on "Coral Reefs."

A.—Geological Observations on Volcanic Islands and on Parts of South America.

CHAPTER IV.

(1.) *Volcanic Islands.*

(*a.*) ST. JAGO.

DARWIN visited part of this island, one of the Cape de Verde Archipelago, and found its structure to be briefly as follows. The island is composed of central mountains several thousand feet high, rising from a plain whose boundary is a broken ring of cone-shaped hills. Another plain, broken here and there with other isolated hills, slopes from the cone-shaped hills to the sea cliffs.

The lowermost strata of the sea cliffs are basaltic and of sub-marine origin, and are identical with the tops of the hill ring. Overlying this basaltic stratum is a calcareous one of late tertiary age, the lowermost part whereof often passes into conglomerate sandstone or earthy tuff. It contains fossils characteristic of shallow seas. On this calcareous formation is another sub-marine basaltic formation, a lava flood long since cooled, the streams of which can be traced back through the valleys that separate the hills of the hill ring as far as the central plain. The detached hills of the coast-plain are of more recent date. They were volcanoes, and their streams of lava, imperfectly mixed with earthy lime derived from the calcareous strata underneath, may be traced flowing over the basalt coast-plain, and in some instances precipitating themselves over the sea-cliffs formed by its edges. The hills of the hill ring, like the lowermost strata of sea cliffs, are composed of basalt resting on trachyte. The central mountains which Darwin did not visit are, possibly, of trachyte. In this case the island would have throughout a trachytic basis, like Ascension and many others.

It would therefore appear that the history of the island is somewhat as follows. Apparently, *on the whole*, persistent upheaval has taken place. From the central region of the island, the oldest basalt lavas, forming the tops of the hill ring and the lowest strata of the coast, have flowed over the lowermost rocks constituting the island basis, while the latter were submerged beneath the waves. Upheaval of the land has then taken place in such a manner that the central seat of volcanic agency has been lifted up out of the water to a less height than its periphery. An island whose cliff line was the present "hill ring" was thus produced. A period, such as that of to-day, of comparative freedom from volcanic disturbance seems to have succeeded, during which the sea wore out in the cliffs gullies that are now the valleys of the "hill ring," and deposited the calcareous stratum.

Through the gorges thus worn out into the sea, passed the second basaltic flood. Upheaval again succeeded, turning the new sea bottom into a new coast plain, the edges of which the sea has eaten away, forming the cliffs of to-day. Comparatively recent disturbances succeeding another period of rest, have produced the isolated hills with their lava streams of the third basaltic series.

Such is the history of St. Jago, and such in principle that of Mauritius, St. Helena, and Ascension, repetition of like changes succeeding regularly. After the present period of rest at St. Jago, with its sea now presenting a calcareous floor, like the old calcareous strata of the island—who shall say that a fifth basalt flood may not be poured forth to ring in again the old changes? An instance noticeable enough this, of how the record of the past may be interpreted in the language of the present!

(*b*.) MAURITIUS.

In this island we find an oval ring of high basalt mountains enclosing a central plain of a second more recent basalt, which has overflowed through the gap-like gorges of the ring to form the encircled basalt plain. The sea has worn the edges of this plain into the present cliffs. This coast plain is of submarine basalt, and bears evidences, such as the presence of stranded coral reefs and the fact of its being overlaid by a calcareous stratum, of recent elevation. Whether we have here a huge crater which has fallen in as Bailey suggests, or whether the central part of the island is an upheaved region whose periphery has been elevated to a greater extent than its centre, Darwin does not decide, though he, while admitting the possibility of Bailey's view, decidedly inclines to the latter suggestion.

(*c*.) ASCENSION.

The basis of this island is trachytic rock, which forms the central and south-eastern regions of the island. The trachytic series present the usual conical hills with truncated summits, the latter often cut off obliquely and sloping towards the south-east, the quarter whence the trade wind blows. This structure is due to the fact that the ejected ashes and fragments of eruptions are blown towards one side more than another. Nearly the entire circumference of the island is covered by basalt, which can be traced to the central trachytes, and sometimes to the now long quiescent volcanoes themselves.

This basalt seems to have had but little fluidity, as it has frequently heaped itself up, as it were, on arriving at a place affording opposition to its regular flow. Its surface, on a stupendous scale, therefore, is in places like that of a brook traversing a pebbly watercourse. Numerous remarkable appearances result from this cause, and are examined in detail by Darwin. One of these is the solidification of the ends of lava streams into lofty walls or cliffs of basalt.

The beach in many parts is largely composed of broken shells and corals. These are perpetually being comminuted by the waves, the sea thus becoming saturated with carbonate and sulphate of calcium. This the waves of the sea again precipitate either as a very remarkable frondescent incrustation on the volcanic rocks round the shore, or in the interstices of the shell beach, cementing the shells and the stones of the beach into rocks of various degrees of hardness, some compact enough to be quarried for building stones, and some with a density as great as that of Carrara marble. This fact is very remarkable considering the absence of heat and pressure.

(*d*.) ST. HELENA.

This island of many memories has an extremely interesting geological history.

We find our old friend the basaltic ring again coming to the fore. This time it forms cliffs, from a few hundred to 2,000 feet in height, around the island. As the coast is low on the south side of the island, the cliffs form a "horseshoe ring" open towards the south. Under this visible basalt is a basal formation of the same material still older and submarine, and over it a series of much metamorphosed feldspathic rock. Nevertheless some of these were originally lavas, whilst most of them were derived from scoriæ and ashes. So great, however, is the geological age of everything in this island that the lavas can no longer be traced, as at Ascension, to their craters. Yet Darwin discovered in the central mountainous region of the island the last remains of a great crater three miles long by a mile and a half broad, whose feldspathic lavas had filled up the trough between its outer side and the basaltic periphery. The trough was an oval space nine miles by four.

On the top of the central curved ridge, the last remnants of the tip of the crater, there still remain fragments of a wall or parapet which is perfect on Cotopaxi, the Peak of Teneriffe. At the Galapagos Islands a similar less perfect wall presents from a distance, the appearance of a small cylinder placed on a truncated cone.

Again, on the inward sides of this cold crater, are flat ledges left by the cooling lava, as during its shrinking its height decreased, "like ice round a pool from which the water has drained." So great have been the changes since the old crater poured forth its last feldspathic charge, that in places these very lava floods have been tilted to greater heights than that from which they originally flowed. Into the rents which such mighty convulsions have caused rock masses, while liquid, have been injected. These have taken the mould most faithfully, have cooled, have afterwards become exposed by denudation, and project at the present day in a hundred different grotesque forms. The whole forms a fine instance, as Darwin remarks, of the manner wherein the structure of volcanic districts may become obscure and finally obliterated. The basalt cliffs tell the same tale. Portions of the ring, two or three miles in length, by one or two in breadth, and from one to two thousand feet in height, have been worn away by the Atlantic swell. Even the more rapid erosion of the wind side of the island tells its tale after many centuries.

Among other interesting features of St. Helena are certain calcareous beds composed of minute equal-sized round particles of shells. These are found in some of the valleys several hundred feet above the sea, but protected from the prevalent winds. In vain are calcareous beds searched for around the modern coast to yield a dust whose sifted particles blown up the valleys by the wind might form such a deposit. We must therefore look back to a period when, before the land was worn into the present precipices, a shelving coast, like that of Ascension was favorable to the accumulation of shelly deposits.

(*e*.) GALAPAGOS ARCHIPELAGO.

This group of islands is, from a geological point of view, singularly uninteresting. All the islands are volcanic. In two of them, craters have been seen in operation, and some of the lava streams exhibit a recent appearance. Many of the craters appear to have been submerged during the time they were active, as Stromboli is submerged to-day. This is the explanation of the scarcity of ashes. As usual many of the craters are filled with solidified basalt. In some again are lakes of brine, evidently the result of elevation of submerged craters, and consequent concentration of the sea-water contained therein. The craters, of which there are many thousands in the Archipelago, appear to arrange themselves pretty definitely in parallel lines, and there is an absence of any one great vent in the group.

(*f*.) DISTRIBUTION OF VOLCANIC ISLANDS.

With the exception of St. Paul's Rocks, Falkland Islands, Seychelles, New Caledonia, and Georgia, and the Continental Island group (Australia, New Zealand, &c.), all the islands of the Pacific, Indian, and Atlantic are volcanic. This is evidently an extension of that law, and the effect of those same causes, whether chemical or mechanical, from which it results that a vast majority of the volcanoes now in action stand either as islands in the sea or near its shores.

To smooth away the apparent discrepancy of mountain chains being generally non-volcanic, while oceanic islands are volcanic, Charles Darwin suggests that volcanic eruptions reach the surface more readily through fissures formed during the first stages of the conversion of the ocean bed into dry land. In all volcanic archipelagos, the islands are arranged in one, two, or three somewhat curved but fairly parallel volcanic rows. This phænomenon, Charles Darwin considers as in close relation to the formation of parallel volcanic chains, such as the Cordilleras of South America. The two cases are but different instances of the same general action.

Finally, the connexion between contemporaneous elevation and volcanic eruptions is entered into in the "Structure and Distribution of Coral Reefs," to be hereafter discusssed.

In considering these various accounts of islands we must be impressed by the great similarity of their structures. Almost always is there a trachytic basis, overflowed by basaltic lava of various ages and natures, flowing, in almost all cases, from "craters of elevation."

The absence of sedimentary rocks, with the exception of the calcareous deposits, renders the reference of these islands to definite geological periods nearly impossible. Even the calcareous stratum yields but few fossils, and these not of a very satisfactory nature; and, again, the Atlantic region of the earth seems to have continued to deposit calcareous matter in greater or less quantity from the chalk age down to the present time.

CHAPTER V.

(2.) *Geology of South America.*

THE first geological work of Charles Darwin that came under our consideration dealt with the geological structure of certain islands, at which the ship bearing the illustrious naturalist made pause. As the stoppages of the "Beagle" were not infrequently of but short duration, many of Darwin's accounts of these places are necessarily somewhat imperfect. In dealing, however, with that part of the New World south of the Tropic of Capricorn, he had time to make fuller investigation. The result is a most interesting and eminently suggestive work known as "Observations on the Geology of South America."

It is, then, with the geology of that part of America which lies south of the Tropic of Capricorn that we have in this particular chapter to deal. A careful study of the volume in question demonstrates that, whilst from the first page to the last the subject matter is of great interest, certain topics are dealt with that stand out from their fellows as of paramount import. Each of these is of moment, because in connexion with it there has been large accumulation of facts; but yet more, because of the generalisations induced by the acute mind of Charles Darwin from these several sets of facts.

(*a.*) The elevation of the Coasts of South America. As the Humber, upon the eastern coast of England, is nothing more than an estuary formed by the flowing together of the Trent, the Don, the Ouse, and the Swale, so the Rio de la Plata, upon the eastern coast of South America, is nothing more than an estuary formed by the flowing together of the rivers Paraguay and Uruguay. Examination of the shores of the Rio de la Plata, an examination extending some distance inland on either side of the estuary itself, reveals the presence of the shells of many Mollusca (soft-bodied animals). These shells are identical with the shells of Mollusca that are alive at the present hour. But while the shells whose inhabitants and builders are dead are found imbedded in the land and in close proximity to fresh water, the shells of to-day with their living denizens are encountered in the *salt* waters of these latitudes.

Investigation by our naturalist of various other points on the eastern coast, to the south of the La Plata, revealed the same peculiarity of shell-bearing living beings in the sea, and of empty shells identical in nature with those in the ocean imbedded in the land, far from any water that was otherwise than fresh. Bahia Blanca, S. Blas, Port Antonio, S. Joseph, Port Desire, Santa Cruz, Tierra del Fuego, all yield similar results. It is a legitimate inference, therefore, that the whole coast will present this remarkable phænomenon.

Further, in Patagonia, where South America is almost at its narrowest, and but a thin strip of land bars the Pacific from the Atlantic, the structure of the "steppe plains," viewed side by side with the distribution of the shells upon this eastern coast, is very suggestive. Patagonia presents many level steppe-formed plains rising in steady succession one above the other. Each plain is covered with an irregular bed of gravel. This gravel is of the same kind as the gravel of the sea-shore to-day, and the lines of escarpment, that run longitudinally through Patagonia parallel with the sea shore, and separate the plains one from another, are of the same nature as the sea cliffs of to-day. Not only are these tiers of plains traceable along lines parallel to the sea coast, presenting the appearance of a colossal staircase, trodden by the foot of some gigantic Titan of the past as he stepped seawards, but at times, when in their course southwards they would strike into some river bed, they suddenly sweep inland and trace the course of the river, back and ever back towards the place where the huge stream was born of the embrace of tropical thunder clouds and the crags of the Andes. The Rio Santa Cruz presents an instance of this phænomenon. The river therefore flows through a plain that is bounded laterally by tier above tier of other plains. Each of these plains, running parallel to the river, is continuous at the mouth of the river with one of those running parallel to the sea. From the study of this river, and others of like nature, Charles Darwin is led to believe that the Pacific and Atlantic Oceans were connected by two or three straits other than those of Magellan.

It has been said that the geological structure of these plains of Patagonia is identical with that of the sea shore, and that the structure of the escarpments bounding the plains is identical with that of the sea cliffs. Let it be added that the organic remains encountered in these plains are identical with those encountered in the sea. No question can exist therefore as to the identity of nature, and probably of origin of these inland structures and of the coast formation. But there is question as to the method whereby what were once marine have now become terrestrial. Two theories have been suggested. An account of them will be interesting, not only in connexion with the present subject, but as showing one of the chief thought-differences between the naturalists of yesterday and to-day. The old school was always on the look out for that which was startling and sudden. The modern school seems to see that the gradual, the imperceptible, the accumulative are more frequent. The former believed in special creation, the latter in evolution. The former looked upon Nature as working by cataclysms, the latter looks upon her as working by every day means, but ceaselessly and imperturbably until a new order of things has slowly unfolded itself from the old.

Hence D'Orbigny and the old geologists saw in the escarpments of the terrace plains the result of a sudden and violent upheaval of a sea beach of the past. They saw in the plain itself the result of a long period of quiescence. But Charles Darwin could find no marks of volcanic agency. He found, moreover, that the plains were not perfectly level. They sloped gradually upwards from the brink of one escarpment to the foot of the next. Therefore he has been led to believe that the formation of these plains, in the past and at the present, has been and is due to the elevation of the land out of the sea; and that this elevation has been most rapid during the periods when escarpments were in the process of formation, slowest during the years when the plains were a-building. As a test that may fairly be called crucial, of the greater accuracy of one or the other of these hypotheses, Charles Darwin brings forward, in his usual quiet fashion, one of his suggestions, at once simple and most admirable. He points out that in the bed of ocean there is a very irregular arrangement of stone fragments according to size. Thus, the largest stones are always met with in the shallowest water, and the smallest are always present in the floor of the sea, where the sea is at its greatest depth. There is a regular decrease in size of the pebbles with the increase of the depth of the water. Therefore, if these plains were due to sudden elevation of a large area of the sea floor we should expect to find their pebbles of very variable size. But the pebbles of the plains present a most striking sameness as to dimensions, and this is easily reconcileable with a slow elevation of the land. For if the beach rose inch by inch out of the sea, only those pebbles near high-water mark would be slowly rescued from the waves. They would then be removed and their place would be occupied by others. These would be still the pebbles about high-water mark. Therefore in size they would be similar to their predecessors, and thus also would it be with succeeding layers of stone fragments, as the sea slowly sank away from the land.

A like elevation of the western coast of this continent of wonders has also been demonstrated by our naturalist. And indeed South America seems to have been the Venus Anadyomene among earth's great tracts of land. Like the goddess it has risen from the sea, like her it is beautiful, and like her, there is something of the terrific and the fatal in its beauty. The stupendous importance of this elevation can scarely be over estimated. An area of the earth's surface 1,180 miles long on the east coast of South America, 2,075 miles long on the western side, with a breadth in the south equal to the breadth of Patagonia added to the breadth of the sea as far as the Falkland Islands, equal in the north region possibly to the breadth of La Plata, has risen very slowly to heights varying from 100 feet (La Plata) to 1,300 feet (Valparaiso). This elevation has taken place during the period of existing shells, and geologists will tell us that the existing shells were preceded by others their allies, also lasting through countless ages. And from the history of this little fragment of earth some very faint conception may be formed of the cycles upon cycles upon cycles of ages during which earth, sweeping in her orbit round the central sun, has added her voice to the solemn music of the spheres.

(*b*) The Salt Beds. (i.) Near Iquique, in Peru, is the famous deposit of sodium nitrate, whereof even the geography books make mention. This nitre bed is some thirty miles from the sea. Between it and the sea lies a tract of land rich in common salt (sodium chloride) and gypsum, or alabaster, (calcium sulphate). The nitre bed itself extends for a distance of 120 to 150 miles along the western margin of a plain raised 3,300 feet above the level of the sea. Its average thickness is between two and three feet, and it is of such hardness that it has to be blasted by gunpowder. The bed rests on sand that contains vegetable remains and sea shells. Vegetable remains and sea-shells of kindred nature occur in the deposit itself. Overlying the nitre bed is a superficial deposit of sand, in nature closely allied to the sand on the salt-bearing tract that lies between the nitre bed and the sea. In reference to this remarkable deposit our author writes as follows : "With respect to the origin of this saline mass, from the manner in which the gently inclined compact bed follows for so many miles the sinuous margin of the plain, there can be no doubt that it was deposited from a sheet of water : from the fragments of imbedded shells, from the abundant iodic salts, from the superficial saligerous crust occurring at a higher level and being probably of marine origin. . . . there can be little doubt that this sheet of water was at least originally connected with the sea."

To Charles Darwin, therefore, the great nitre bed means this. A portion of the great sea that at one time overflowed this land became shut off in a basin-like valley as the main body of water retreated. Gradual evaporation of this isolated water took place with ever increasing concentration of such salt-containing water as was left. That is, the evaporation of pure water would leave the residual brine more and more "salt" in its nature. At last the solution would become so concentrated, that the less soluble salts would begin to crystalize out. These would be common salt (sodium chloride) and the salts of calcium. Deposits of these therefore will be found high up the sides of the basin, nearest its rim, at a level most remote from the centre of the sea-water lake. Then will follow the crystallizing out of the more soluble salts and the formation of the nitre beds.

(ii.) Beside the nitre beds South America abounds in other saline deposits. Most notable among these are those of sodium sulphate or Glauber's salt. This salt occurs in mud banks. The mud banks are often in direct continuity with mud banks still rising from the sea. The Glauber's salt is mixed with common salt, and the nearer the deposit is to the sea, and therefore the more recent it is, the greater is the quantity of the common salt. Finally, the mud abounds in chalky matter, that is, calcium carbonate. Before stating Darwin's explanation of these chemical phænomena it were well to give an account of that which was observed at San Lorenzo. On the coast cliffs of this island are ledges filled with shells which are, of course, in the main calcium carbonate. These shells are cemented together by sodium chloride. The sodium chloride is the result of the evaporation of the sea spray. On the higher and older ledges a white powder is found, composed chiefly of calcium chloride, sodium sulphate, and the two other salts encountered on the cliffs below, namely, calcium carbonate and sodium chloride. And now we come to Charles Darwin's explanations. First, it is known that a moistened mixture of calcium carbonate (the shells) and sodium chloride (from the sea), results in mutual decomposition, and the formation of calcium chloride and sodium carbonate. Therefore the two original salts will be found close to the sea, the two ultimate salts in the upper cliff levels and in the mud banks. The great difficulty, however presented, is the absence of the sodium carbonate, and the presence of sodium *sulphate* in the more inland regions. It would seem therefore that the common salt (sodium chloride) in soaking through the mud, becomes first sodium carbonate, and then sodium sulphate. This last stage of the conversion of sodium carbonate into sodium sulphate presents difficulties even to Charles Darwin. It may be suggested that the necessary sulphuric acid for such change might result from the oxidation of the sulphur occurring in decomposing animal and vegetable matters that would be certain to be present in such geological formations.

(*c*.) The Pampas. The continent of America is the continent of vast plains. In each division of that continent exists a gigantic expanse that is larger than the whole of Europe. Parts of the great plain in North America are known as prairies, from the French word for meadow, or as savannahs, from the Spanish *sabana*, a sheet. Parts of the great plain in South America are known as llanos, whilst other regions are called pampas. Llanos (levels or plains) are encountered in the northern region of the southern division of the New World. Pampas is the native name for the treeless plains of the southern part of South America.

The prairies or savannahs are fertile seas of grass that go billowing onwards from your feet to the very horizon. The llanos are now fertile, richly clad with tall, strong, green grass—now dry, sterile, baked by the vertical rays of a tropical sun to a rock-like hardness. South of 34° S. lie the pampas. From 34° to 40° S. they are the pampas of Buenos Ayres; from 40° S. southwards those of Patagonia. These plains are almost always dry. Upon them "the gentle rain from heaven" rarely falls. Much of them is grass-covered, but over wide areas stretch sandy deserts, and in the extreme north lies a waste of salt, 30,000 square miles in extent, called Las Salinas. The investigation of Charles Darwin into the nature of the remarkable formations known as pampas is our next subject of consideration. Following him as leader—and, for my part, I know none worthier—I shall consider the extent, the structure, the theories as to the origin of the pampean formation.

(i.) The extent. Longitudinally and laterally the pampas have huge extent. In length this strange region has been traced by Darwin himself from the river Colorado, almost at the southernmost part of the Argentine Republic, as far north as Santa Fé de Bajada, placed on the river Parana and nearly in the midst of the far-reaching district of Argentina. For some 250 miles further north than even Santa Fé, D'Orbigny was able to trace the form of earth-structure characteristic of the pampas. From side to side the extent varies. Measure it at the latitude of the Rio de la Plata and a width of between 300 and 400 miles is encountered. Even if this width be regarded as above the average, the whole extent is at the very least equal to that of France. It is probably nearer the truth to say it is twice or thrice as great as the area of that country. Thus much for its superficial extent. Vertically the pampean formation varies in thickness from 20 to 100 feet, and at Buenos Ayres the boring for an Artesian well revealed a depth of 210 feet as that of the strata characteristic of this special region.

(ii.) The structure. In the southern parts of the pampas the upper layers of the earth show some traces of having been deposited in successive strata. They consist of hard rock known as Tosca rock. Below lies the peculiar pampean mud, dull-red of hue, slightly hardened, and of clay-like nature. This mud is generally traversed by horizontal lines that are of chalk. The mud does not, however, contain any traces of calcium carbonate, no matter how close to the concretions of chalk is the mud whereof examination is made. The Tosca rock also contains calcium carbonate as concretions, and in finely divided form, resulting from the comminution of shells and coral. Whence comes this enormous mass of mud? The answer of the naturalist is that the mud of the pampas is traceable to the rocks of Brazil. These rocks are of granite nature. They have in the dim past suffered abrasion and disintegration. They have been turned into a red, gritty, clay-like mass that has formed the "mud." To-day the Rio de la Plata sweeping towards the South Atlantic waters bears with it large quantities of mud. In the past ages, in all probability, mud was drifted in a course running more directly south, for it travelled as far southward as Colorado. The fossils of this formation comprise corals, barnacles and Mollusca still existent, certain rodent or gnawing animals, and the great-toothed Machairodus of the Carnivora or flesh-eaters. To name the other animals is to name the majority of the gigantic, sloth-like, herbivorous quadrupeds whose very names sound huge. Megatherium, Megalonyx, Mylodon, Glyptodon, Equus, Scelidotherium, Mastodon, all the mighty brutes that made earth shake as they moved in their slow, ponderous, dreamy fashion over its surface in the time that was but yesterday, and yet was ere man lived, are here entombed.

It is noteworthy, moreover, that the evidence is strong in favor of the view that, at the epoch of formation of the pampean region, the animals of the north and those of the south halves of the continent were similar, if not identical.

(iii.) Theories. Speculation has been rife concerning the origin of the pampean formation. Three theories have been broached. In studying them we shall once more see that the suggestion of Charles Darwin leads us in the direction of the quiet, long-continued, imperturbable action of nature as opposed to her performance of work by cataclysmic change.

(α) Of D'Orbigny. D'Orbigny is, as usual, on the side of the startling. A great catastrophe suddenly cast hecatombs of the mud, to-day called pampas mud, somewhence. The mud entombed myriads of living beings that happened to be in the way. To this mud winding sheet theory Darwin objects that there is distinct evidence of the formation having been at least partially deposited in layers, an arrangement not possible on the D'Orbigny theory; that it is difficult to conceive the formation, storing-up, and sudden use of material enough to cover an area 750 miles by 400, to a depth of from 20 to 100 feet; that on this view a mass of mud without one single pebble has been carried under the sea over the wide surface of the pampas, while by the same or a similar cataclysm Patagonia was covered, not by mud, but by gravel.

(β) Of Sir W. Parish. That the pampean formation is due to the throwing down of mud upon low marshy plains by the rivers of South America, when they flowed in courses other than those they traverse at the present hour. Objections to this view urged by Charles Darwin, in his usual sedate, irresistible fashion, are the composition of the deposit, the way wherein it slopes up the primary ranges, the nature of the strata beneath, the *sea*-shells on the surface, the sandstone beds that at certain places overlie the pampas formation, the non-discovery of a single skeleton of a mammal in the erect position that would be probable had it been overwhelmed with a fatal mud wave.

(γ) Of Charles Darwin. That the pampean deposit was slowly accumulated at the mouth of the former estuary of the Rio de la Plata and in the adjoining sea. All that has been stated in the preceding paragraphs in favor of this idea is indeed only understandable upon acceptance thereof. And to the evidence already adduced the patient accumulator adds yet other, until even he, most reluctant to give assent to any theory of his own, unless supported by all fact, is sure.

(*d.*) The Patagonian formation. South of Argentina lies the country of the giants, Patagonia. The land is of stupendous nature. Its shores are washed by the Atlantic wave. Its rocks are allied to those of the realm that lies to its north, but great lava-rivers have flowed over them from the awful Cordilleras that creep solemnly down into its northern lands. The immense formation known as the Patagonian reaches from the Colorado on the north to Santa Cruz and even further south. To the north of the river Colorado it underlies the pampean formation, coming to the surface again at Banda Oriental. Its eastern boundary is the ocean. Its western is the mountains. Its thickness, vertically, at the coast is 800 feet. Consider this formation and that of the pampas. Are they not colossal? It is as if from the Straits of Gibraltar to the southern coast of Iceland stretched one continuous line of structure, not in one single observed instance unequally tilted or dislocated by a fault. The whole has been slowly, steadily, evenly upraised from the sea.

The Cordilleras are quiet now. The Titans beneath them are at rest to-day. But whilst this huge formation was a-building the Cordilleras were active enough. Travel up the rivers from the mouth. Sixty-seven miles inland streams of basalt meet you, frozen now, once on a time hot, flowing lava. Follow them up on the north side of the river valley 100 miles: note that this deluge of lava is from 130 to 300 feet in thickness; see how two or three streams have flowed side by side, and at places have flowed one over the other; see the clear demarcation of each stream by the vesicular layer on its summit where the up-struggling bubbles of steam have been caught: remember that this, the largest lava-stream in the world, has been formed beneath the sea in the dead ages, and has fought its slow way onwards against the resisting pressure of huge water-masses, and here once again you will have borne in upon your mind that this is in truth the continent of wonders.

(*e.*) The absence of extensive shell deposits in the South America of to-day. The fortunate unfortunate to whose lot falls the attempt to explain to the many the principles of Evolution is over and over again met with the inquiry: "Where are the missing links?" The believer in the theory of special creation and the man who without any actual belief in any theory as to the origin of the many species of plants and of animals now existing is afraid of Evolution, these alike constantly cry: "You say that the species of the Now are the result of gradual development from the species of the Then. Where are the forms of living beings that represent the transition stages between the plants and animals now existent and their ancestral forms?" To this ever-repeated question there are replies and replies. In connexion with our present object of study only one of those replies need be quoted: "Lost through the imperfection of the Geological record."

Of old it was thought that every organic being of the dead past, as it became one of the dead past, was preserved in fossil condition to be for a lesson unto man. It was thought that Earth held hidden in her breast all forms that broad and bounteous bosom had ever borne. It was believed that in the rocks were lying the records of all that had lived. Would it were true! The longer Geology is at work the more clearly does it demonstrate that the record of the past preserved to be read by the eager eye of man is but a fragment. Myriads of plants, myriads of animals have been born, have lived and have passed away, whose very structure has been of such nature that their preservation in the museum of the rocks was impossible. Again, years, centuries, cycles, æons have passed during which the earth-conditions were such that no possibility was of the storing-up of such living things as had structure that admitted of preservation. The naturalist who has most clearly demonstrated this all-important fact is Charles Darwin. The 10th chapter of the "Origin of Species" is devoted to the Imperfection of the Geological Record. Those who are interested in the study of rudimentary, of embryonic forms, those who like to see the germ of new thought and to compare it with its fuller, riper growth will do well to compare the thoughts on the absence of shell-deposits in South America in the volume we now investigate with the 10th chapter of the great book.

The sub-division of the Kingdom Animalia whereof the Cuttle-fish, Snail, Oyster are types, with its soft-bodied, shell-clad animals is known as the sub-kingdom Mollusca. It is known that Mollusca live within a sea-depth of 100 fathoms: that the number and variety of Mollusca existing at the present day upon the coast of America is very great: that in geological periods not very remote, as the history of this old, old earth goes, there was enough and to spare of the sediment needed for the preservation of Molluscan remains. And yet, the vast deposits upon the South American coast are very nearly devoid of Molluscan shells. Let us, following our master, try to understand how this state of things came about.

First, it is clear that if any deposit is to remain as a record of the past it must be of great extent and of great longevity. It must have been accumulating during a vast space of time, for its thickness represents the amount of sinking of the neighboring land. And in the special case under consideration matters are intensified, for these creatures live not in depths greater than 100 fathoms. Hence only to the margins of slow-building formations can shells of Mollusca be added.

Next, let us consider what are the conditions that determine the size of the shell-bearing zone, whether it shall be large or small. Charles Darwin has shown that everything depends upon the relative condition of the bed of the sea, during the deposition of the shells. The bed of the sea may be still, the bed of the sea may rise, the bed of the sea may fall. Hence three cases may present themselves. (i.) Where the floor of the sea whereon the shells are being deposited is through long time at rest. Clearly in this case the shell layers can only accumulate to a thickness equal to the maximum depth within which the shell-formers can live, *i.e.*, to a thickness of not more than 100 fathoms. Such layers could only form to any great width upon very gently sloping coasts. So shallow would the sea be that the water pressure upon the rocks formed out of the shells would be very slight and the consolidation of the rocks but feeble. In this first case therefore the best conditions for obtaining the maximum of shell-bearing formation do not exist. The formation would be small in extent, and when raised into dry land would afford but little resistance to the denudating action of the sea-waves. (ii.) When the floor of the sea whereon the shells are being deposited is through long time slowly rising. Slow but persistent upheaval occurs. This is the condition that Charles Darwin has shown to have obtained in byegone times on the shores of South America. This case resembles case (i.) in the main, adding, however, to the difficulties in the way of shell-bearing deposit under case (i.) the fact that the shells would have to undergo the ordeal of the beach. The tendency of the beach-waves is to wear down and disperse all things exposed to their action. (iii.) Where the floor of the sea whereon the shells are being deposited is through long time slowly sinking. Here at last we have the best conditions for the formation of shell-bearing deposits. The sea is slowly encroaching upon the land, and the land thus conquered is forming a shell-bed beneath the waters. The shell-bed is constantly pushed slowly out seawards, is constantly renewed upon its shoreward edge. Here thickness of far more than 100 fathoms is possible. Here extent even of many miles is possible. Here hardness that can resist wave-action is possible. In short, here are the best conditions for the formation of shell-bearing deposits. But here are *not* the conditions met with on the coast of South America, or indeed for the most part anywhere upon earth. Therefore organic remains, at least of this particular kind, will not be preserved.

The old idea that wherever sediment is falling present life is undergoing preservation for future observation must therefore be abandoned. Three essentials are each of rare occurrence and the conjunction of the three most rare. They are long continued supply of sediment, an extensive shallow area, the slow subsidence of this area to a great depth. To quote our author: "In how few parts of the world probably do these conditions at the present day concur." Looking at the shore of the continent of America as it is to-day, Charles Darwin sees that but a little while hence those who live upon this earth will find no more record of the shells of our time than we can find of those of the recent past, unless the existing conditions of coast-elevation be altered. And yet the series of shells is incalculable in number and is of a nature peculiar to South America. In the hereafter a huge gap will be in the series of organic forms, due to the non-preservation of these South American Mollusca of to-day.

It is impossible for the earnest student of Charles Darwin's works to leave this subject without a word upon the result of these suggestions to scientific thinkers. It would indeed be a distinct omission upon the part of one who strives, unworthily enough, to point out in some measure the nature of the genius of this remarkable man. These suggestions as to the imperfection of the geological record were published in 1846. To-day they form part of the accepted creed of scientific thinkers. Only thirty-four years and the man who produced the new thought still amongst us! To those who know how very, very slow is the comprehension and extension of new ideas that overthrow a score of antique notions and remorselessly slay a hundred old-fashioned, orthodox, eminently respectable falsities; to those who remember how few of the great have beheld with their own patient eyes their own greatness in some faint degree recognised during their own lives, their own thoughts accepted as true guide by the thoughtful, assuredly there is cause for comfort here.

The arguments of the tenth chapter of the "Origin of Species" would now be questioned by no competent geologist. Now-a-days one reads with a half-smile the quotation from Professor H. D. Rogers and the solemn, diffident way wherein Charles Darwin utters his criticism thereanent. Professor Rogers, addressing the American Association of Geologists had said: "I question if we are at all aware how completely the whole history of all departed time lies indelibly recorded with the amplest minuteness of detail in the successive sediments of the globe, how effectually in other words every period of time has written its own history, carefully preserving every created form and every trace of action." Very gravely, with that gentle doubt of his own power of reasoning that is always the accompaniment of his genius, Charles Darwin replies; "I think the correctness of such remarks is more than doubtful." And multitudes of thinkers set a-thinking by his words have so observed, reflected and spoken that it is to-day for an assured thing that the history of the dead years is in no sense completely recorded and that there have been, alas! long periods of time when living forms rose into being and passed away into the mineral products of their decay, leaving no vestige of a trace of what they were during their life-journey.

(*f.*) The Structure of the Cordilleras. Of the great topics considered by Charles Darwin in this the second of his purely geological works, the last and not the least interesting is the structure of the vast mountain chains known as the Cordilleras. The Andes run uninterruptedly through South America from north to south. They are always close to the western coast of the continent. So near are they to the Pacific waves in Southern Chili and in Patagonia that their rugged heights are the sea cliffs. One hundred miles is the greatest distance they are ever found inland. This occurs about the middle of Chili. Save in the south the Andes form for the most part a double range, or even in some regions a triple one, and between the lines of mountains stretch long valleys. Thus at about 19° S. latitude the range is double. Between its two divisions, at the height of 13,000 feet, lies a large table-land embosoming a lake. The mountain boundaries of this table-land are the Cordilleras or girdles, lying east and west and moving into each other once again at 13° S. Volcanoes are many and busy in the Cordilleras. There is food therefore for reflexion in the structure of these huge ranges. Of old the belief was that their origin was wholly cataclysmic: that the giants were cast skywards in one paroxysmal throe of earth's agony. It will be found that our great teacher, after patient observation and patient reflexion has arrived at a conclusion other than this. Once more he is upon the side of gentle and long combined action rather than upon that of the forcible and the sudden.

(i.) Facts. The observations of Charles Darwin were in the main conducted upon two of the passes that seam the Cordilleras. These twain were the Peuquenes or Portillo pass and the Cumbre or Uspallata pass. Both of these lie in the region of South America between Santiago and Mendoza. The Peuquenes range in the one pass and the Cumbre in the other are to the west and nearer the sea. The Portillo range in the one and the Uspallata in the other are to the east and lie more inland. Crossing the Cordilleras by these two passes Charles Darwin observed accurately the structure of the mountain ranges. He gives record of his observations thus. The lower layers of rock are partly of the kind known as igneous or Plutonic as opposed to sedimentary or Neptunian. That is, they have been formed by the sudden action of volcanic agency, not by slow deposit of material from suspension in water. With these are associated clay-slate and other rocks. Overlying these basal strata of the Cordilleras are great masses and thick layers of the rocks known as porphyries. Intercalated with these are layers of slaty rock that all evidence shows were once on a time so many layers of mud. Above these again are the rocks named by our naturalist the gypseous formation. This formation presents a series of rocks fairly well supplied with fossils. The rocks are at times of sand structure, at times give indication of formation from materials of volcanic origin, but most frequently are of chalk. Vast deposits of gypsum, one form of calcium sulphate, form a characteristic feature of this part of the Cordilleras, point to its origin in the vicinity of volcanic disturbances, and give it the name mentioned above. These three chief regions of rock, the igneous and the clay slate, the porphyries and the slates, the gypseous formation are encountered in both the passes and would seem to be characteristic of the whole length and breadth of the Andes.

When it is borne in mind that the very summits of the highest mountains are of the gypseous formation, and that the summits of the less lofty parts of the range also present this structure, it would be expected that the strata have been tilted and twisted in a myriad different ways. Such expectation would be realised. Finally, subsequently to the period of the formation of the gypsum deposits an immense mass of conglomerate was formed, filling up the valley that lies between the western and the eastern range of mountains in the Peuquenes Pass, whilst in its fellow pass, between the Cumbre and the Uspallata chains, trees buried but still upright bear witness to changes of level of many thousand feet.

(ii.) Theories. After this array of facts that must be, I fear, to the non-technical reader rather uninteresting, let us ask what explanations have been suggested as to the structure of this gigantic mountain-range. There is first the old view hinted at above, that the Cordilleras are the result of one huge upheaval of rock. But Charles Darwin is a sore disperser of old theories, forasmuch as he has a rare power of observing facts and the rarer power of reflecting upon them until some general truth dawns upon him: a truth new to the world of thought until he has enunciated it—a truth old often as the world that has been waiting these many ages to be first seen of these deep-searching eyes. Opposed, therefore, to the old cataclysmic view is the second explanation that is found in the book now under discussion.

The Darwinian view as to the origin of the great mountain system is as follows. The basal igneous rocks though volcanic in origin were formed beneath the waves of the sea. On to the bed of this ancient sea from many an orifice of eruption beneath the waters was ejected a mighty flood of porphyritic fluid that became anon solid rock. This flood has stretched multitudes of miles in extent, and in central Chili is more than a mile in thickness. That it was ejected at very great depths below the surface of the sea seems more than probable. Finally, when the eruptions producing these rocks had nearly or quite ceased, from the sea-water was deposited as a sediment the gypseous formation. In the words of Darwin himself: "If we picture to ourselves the bottom of the sea rendered uneven in an extreme degree with numerous craters, some few occasionally in eruption, but the greater number in the state of solfataras, discharging calcareous (chalky), silicious (flint), ferruginous matter (matter containing iron), with sulphuric acid to an extent surpassing perhaps even the existing sulphurous volcanoes of Java, we shall probably understand the circumstances under which this singular pile of varying strata was accumulated. The shells appear to have lived at the quiescent periods when only limestone or calcareo-argillaceous matter (chalk and clay) was depositing."

A period of subsidence over an area at least 400 miles in length, probably of far greater extent, now occurred. This is indicated by the presence in certain places of strata 7,000 feet in thickness capping the gypsum formation over a long range of miles. Elsewhere during this time upheaval had taken place and certain islands of granite, notably in the neighborhood of Copiapo, had emerged from the sea and upon them were growing fir-trees.

Next came upheaval following upon the subsidence, and the Cumbre and Peuquenes ranges came into being. Again was this upheaval succeeded by a slow subsidence. Of this last movement proofs are found in the trees buried in an upright position at Uspallata, buried formerly under thousands of feet of strata in the conglomerate of the valleys thousands of feet in thickness, yet in structure and in its fossils giving clear proof of having been formed in shallow water.

Finally there is strong evidence showing that at the beginning of the Tertiary period the South American continent stood at about its present height out of the sea and then for the third time slowly subsided several hundred feet to be once more raised to its present level.

It can thus be seen how opposed is this complicated history of series of changes slowly effected to the view that regards this great mountain system as formed at one blow. And further, remembering how many have been these changes, through what long series of years each of them was at work, we have once more borne in upon us the fact of the stupendous age of earth. And let it not be forgotten that this era of mountain formation is not yet completed.

Truly is this the continent of wonders. Think only of the main points it has been considered well to consider here: remember that these are but a selected few out of many, and you will agree with the writer whom we are studying, that "in South America everything has taken place on a grand scale, and all geological phænomena are still in active operation. . . . I know not whether the spectacle of its immense valleys, with mountain-masses of once liquified and intrusive rocks now bored and intersected, or whether the view of those plains, composed of shingle and sediment hence derived, which stretch to the borders of the Atlantic Ocean, is best adapted to excite our astonishment at the amount of wear and tear which these mountains have undergone."

B.—On the Structure and Distribution of Coral Reefs.

CHAPTER VI.

(1.) *On Coral.*

FROM our earliest years the remarkable substance known as Coral is of more than ordinary interest. Its association with those earliest years, the fact that it is almost the first thing after the mother's face that grows out of the dim world environing us, and becomes a tangible, recognisable part of our "shadow-peopled infancy," its lovely color, strange smoothness, fantastic shape, its use as the gracefullest of ornaments in later life, its connexion with the remote and the unknown, its strange sea-sojourn, its suggestion of far-off islets in southern seas where palm-trees lazily sway in the warm tropical air and the waves fall upon the low-lying land with a restful sound that is more a sigh than a murmur, the tales or fables we have heard of the lives of those that seek for coral beneath the waters—all these things unite to render coral a substance that combines in one the beautiful, the wonderful, and the mysterious.

Travelling, as we have seen, through the regions of Earth where this remarkable growth is most rife, our great naturalist has as usual observed, and has as usual arrived, after much observation, at a large generalisation. The results of his observations, and the great theory whereunto he has been led, are enunciated in the work now under discussion. This, the last of his purely geological works, has for full title the name at the head of this page. For the sake of brevity I shall for the future speak of the book as Charles Darwin's work on "Coral Reefs."

The first edition of the "Coral Reefs" was issued in 1842. It is pleasant to find that its author, writing a preface to a new edition thirty-two years later, is able to show, in his usual quiet and modest fashion, that some at least of the naturalists who have made corals their objects of study have accepted his conclusions. Still more pleasant is it to be able to record that he has, after his customary manner, quite underestimated the amount of adhesion to his views in respect to coral reefs on the part of scientific men. Such adhesion is as general to-day as the acceptance of his yet greater generalisation as to Natural Selection, that is, it is well-nigh universal.

I venture to think it were well for the behoof of the general reader to give, before consideration of the "Coral Reefs," a brief account (*a*) of the general distribution of coral islands (*b*) of the nature of coral itself. This latter point is not touched upon by Charles Darwin himself, and the former is rather told in the commencement of his book by means of a map than in words. And, indeed, a map will tell far better than mere words. Best of all, perhaps, is combination of map and words. I would, therefore, very earnestly ask those who may honor me by reading these pages to follow that which is now to be said with an atlas before them.

(*a*) If two horizontal lines be drawn round the earth, the one 30° south and the other 30° north of the equator, the whole of the coral formations of the world will lie between these lines. Laterally the extent of coral formation extends as far westward as 30° E. longitude, as far to the east as 60° W. longitude. Thus, a traveller passing down the Red Sea, skirting the eastern coast of Africa as far to the south as Mozambique, passing athwart the northern end of Madagascar, striking in a north-easterly direction across the Indian Ocean to Ceylon, thence to Sumatra, threading his way first northwards and then southwards, amongst the crowds of islands clustered round the north of New Holland and studding the Pacific Ocean to the east of that huge island, finally striking again to the north until the West Indian Islands were reached, would have traversed the area upon the earth's surface where coral structures most do congregate.

(*b*) Coral is the product of numberless minute animals living in colonies. Let me proceed to disabuse all readers of one popular idea. It is the thankless yet essential office of the students of nature in all her forms to do that constantly. There is no such thing as a coral *insect*. It is sincerely to be hoped that this iconoclastic statement, that shatters at once one of our earliest and most cherished beliefs, and removes for ever from our vocabulary one of our most respectable and time-honored phrases, will not shock too deeply. True is it that generations of men have spoken of coral insects, have had faith in coral insects: true is it that the phrase has been good enough for our forefathers, and therefore, after the reasoning of some amongst us, is good enough for us: true is it that, in taking away that phrase, we are loosening humanity from its old moorings, and that some, alas! may only recognise the negative and not see that, in place of fixed anchorage to one phrase, there is offered them a new sea of thought, whereon to move in stately fashion towards lands yet unknown, but as beautiful as those whereby even now we sail. But the truth is great, and shall prevail in this as in larger matters. Let us then away with the old stereotyped phrase that has concealed the ignorance of the past, and looking once again into the steadfast eyes of nature, who waits to teach us better things, learn of her.

There is no coral insect. Coral is formed by multitudes of minute animals, each whereof in its essential structure is a Sea-Anemone. Let us wander down on a still summer evening when the day is sliding away westward in a regretful farewell of amber and crimson clouds that lie, island fashion, in a still sea of blue: let us move lightly down toward the far-retreating sea that is following the far-off sun in the very love of it: let us leave the garish town with its white houses and clamber here in the cool evening over moist rocks that are making love to the little water pools they have caught as the waves slipped seaward. Is it not still? The evening is quiet, and those sunset clouds are at rest, and the strident voice of the distant town is now a lullaby, and the sea is slumbering, and the wide air is asleep by the side of the sea, and the tossing heart of man even is at peace for a time, and as calm and clear and reposeful as this little lake of sea-water caught in the embrace of the strong brown rock. And see! In the pellucid wavelet thus imprisoned float lovely filaments of rainbow hue as bright thoughts grow in the still heart of man. They are the tentacles of the Sea-Anemone.

A strangely-colored body fixed by its base to the rock. If you took it home and hardened it in chromic acid (does not that seem cruel to-night?), and dissected it, you would find it is a bag within a bag. Within that soft body wall hangs another bag that is the stomach of the Sea-Anemone. Its mouth is there in the very midst of the lazily-floating tentacles. Were you a piece of Sea-Anemone food, after you had passed through that mouth into that suspended stomach, you would drop into the great body-cavity below. Then you would have choice enough of routes, for the space between the wall of the body and the stomach is divided by vertical partitions into many rooms, and into any one of these you, food particle, may pass. You have found your way into one of them, and are in a room bounded below by the base of the creature, right and left by two of the partitions, inwards by the wall of the stomach, outwards by the body-wall. There is no outlet but upwards. The roof of the room wherein you are stretches far away and is indeed a tentacle, and as you slowly pass upwards you find you are growing smaller and ever smaller, yielding to your surroundings of living matter all that is of good in you, until your useless residue passes out through the opening at the top of the tentacle to be lost in the great sea. You have done your work and helped others.

This body wall of the Sea-Anemone is not quite so simple as it seems. Not only does it enclose a stomach-cavity, not only do partitions run inwards and join it with the outer wall of the stomach, but this body-wall itself is twofold. It has an outer and an inner layer. They are known as ectoderm and endoderm respectively. Now mark the power of these layers of the body-wall. They have power over the huge sea wherein they live. Dissolved in that sea are salts of different metals. Calcium salts are there, and the allies of this mysterious Sea-Anemone have the strange power of separating (secreting the wise it call) from the sea-water the salts dissolved therein, and placing them once more in solid form in these soft tissues.

Imagine Sea-Anemone budding off Sea-Anemone. Imagine a great colony thus formed. Imagine all these many colonists members of one great colony separating from the blue sea that bathes them hard salt matter. Imagine the beings that have done this dying as to their soft, unlasting parts, but leaving behind them these durable memorials of themselves that are to benefit the world coming after them and you have coral.

CHAPTER VII.

(2.) *On Coral Reefs.*

THIS first fundamental proposition must be laid down. Coral formers can only live within shallow water—*i.e.*, within a depth of not more than twenty fathoms. This fundamental fact must be thoroughly grasped for comprehension of what follows.

(*a*) Reefs. Three distinct arrangements of reefs of coral are known. There are but three forms encountered over all the large area where coral abounds. These are lagoon-islands or atolls, barrier or encircling reefs, fringing or shore reefs.

(i.) The atoll or lagoon-island is a ring of coral, often of vast size and enclosing many square miles of sea. The ocean outside the ring restless as of old, beats ceaselessly upon the coral girdle. But within the ring the sea is at rest. A calm expanse of water lies asleep there, bright green in hue, many fathoms in depth and undisturbed as a rule by so much as a wavelet. Often upon the circular reef small islands or islets are formed differing frequently in shape and in size upon different sides of the same reef. These lagoon-islands or more accurately coral rings enclosing a central expanse of water and bearing islets upon their free surfaces will be spoken of hereafter by the shorter name of "atolls."

(ii.) Barrier reefs do not enclose clear spaces of water destitute of land. They encircle small islands, sometimes one island, sometimes many. Some of them are gigantic. Not content with encircling islands of ordinary size, they run parallel with the shores of islands that are continental. Such are the mighty barrier reefs of Australia and of New Caledonia. That of New Caledonia runs along the western coast of the huge islands for 400 miles. Long after the northern extremity of New Caledonia is reached the reef runs northward. It ploughs its way through oceanic depths for 150 miles beyond the extreme north of the island. Had you to swim out to the reef from the south of New Caledonia you would have to pass over sixteen miles of sea. But for many leagues the reef is only half that distance from the shore. The barrier reef of the great continent-island, Australia, has length over 1,000 miles. Its average distance from the land is between twenty and thirty miles. At some points the land and the reef are from fifty to ninety miles asunder. The great sea-space included between Australia and its barrier reef is never less than ten fathoms in depth. Between ten and twenty-five is the average. Down south the depth is increased to forty fathoms, and in some parts to more than sixty. These and all barrier reefs then are related to land. They skirt shores. But the distance between them and the islands they environ is expressed in miles, and the depth of water lying between land and reef is expressed in fathoms.

(iii.) Fringing reefs are shore reefs. They are close to the island or the continent they fringe. The water between them and the land is shallow. The reefs near the shore of the island of Mauritius and those adjacent to the eastern coast of Africa are fringing reefs. The distance of the reef skirting the island of Mauritius from the shore varies from half a mile to three miles. In some places a man can wade from island to reef, whilst the extremest depth of the water lying between the Mauritius and its fringing reef is twelve feet. The distance from land of the reef that skirts the continent of Africa on the east is, on the average, a little over a mile. The channel between the reef and Africa is from six to twelve feet deep. The distance between these reefs and the land they environ is expressed in yards, and the depth of water lying between land and reef is expressed in feet.

To sum up. A circular ring of coral enclosing a still peaceful lagoon of pellucid water is an atoll. A reef miles out to sea with many fathoms depth of water between it and the land is a barrier reef. A reef near the shore with only a shallow channel between it and the land is a fringing reef.

(*b*) Facts. (i.) The atolls are considered first, and a very full description is given of Keeling atoll as a fairly typical one. This atoll lies in the Indian Ocean 12° 5′ S., 90° 55′ E.

The width of the lagoon is nine and a half miles at its greatest. The width of the reef itself that encircles the sea-lake within is from 250 to 500 yards. 2,200 yards out to sea from the coral ring the depth is so great that a line one and a half miles long found no bottom. The submarine slope of this coral formation is, therefore, far steeper than that of any known volcano. Sounding within the reef every time the lead sank lower than twenty fathoms the floor of the sea was sand. At a less depth than twelve fathoms the bottom was always coralline. Islets are noticeable on the reef both on its windward and leeward side. But the former are much higher out of the water than the latter.

The rest of the first chapter upon atolls is devoted to the consideration of these structures in general, and to the establishment of the position that in the main they are identical with the typical instance of Keeling atoll that had been fully described. To quote our author: "There appears to be scarcely a feature in the structure of Keeling atoll which is not of common, if not of universal, occurrence in other atolls." Especially is this demonstrated in respect to Maldiva Archipelago, lying to the south-west of Hindustan, stretching from north to south 470 miles, with a breadth of fifty miles on the average. It is a string of atolls, in each whereof a disc rises from the unfathomable sea fringed with many oval basins of coral rock, each with its little lake of clear salt water. Especially is this demonstrated also in respect to the great Chagos Bank, that lies directly south of the Maldiva Archipelago. This also is neither more nor less than a "half-drowned atoll."

(ii.) In the second chapter of the Coral Reefs there is consideration as to the nature of the Barrier Reefs or those stretches of coral that run parallel with the shore of some large land, and are separated therefrom by a wide expanse of fairly deep water. These reefs are of great depth, and present, therefore, difficulty of explanation when it is remembered that coral formers can only live within a certain limited depth. In the sudden dip of these reefs into the unfathomable depths of sea on their outer sides, in the nature of the corals whereby they are formed, in the nature of the lagoon-channels lying between them and the mainland, in the number and distribution of the islets upon the reefs, in the position and the depth of the breaches in the barrier reef, in their form, size and grouping these barrier reefs so exactly reproduce the dip, the corals, the lagoons, the islets, the breaches, the form, size and grouping of the atolls, that it is perfectly fair to say that there is not one essential point of difference between barrier reefs and atolls, save in position.

What are the theories that have been broached anent these reefs? (α) That the sea had eaten deeply into the coast of the encircled land, and thus had left a broad submarine ledge on the margin whereof the corals grew. But upon this view the island shore ought not to slope down to the lagoon-channel as it does, and the great distance of the reef and great depth of the intervening channel are inexplicable. (β) That the barrier reefs have risen from banks of sediment. It is difficult to conceive the possibility of a bank of sediment extending in unbroken ring round an island. (γ) That these reefs result from the fact that reef-building animals can only live at a considerable distance from the land. But this view is contradicted by the observed fact that they only live close to land. (δ) That these mighty reefs are founded on the edges of the craters of submarine volcanoes. Stupendous phænomena of nature as without doubt volcanoes are, it requires a very imaginative mind to believe in the existence of a volcano 1,000 miles long. The rejection of these theories once more leaves but one view open to us—viz., the view of Darwin (ϵ) that the coral reef has been slowly built up to the level of the sea-waves as their foundation, the sea-floor, has slowly subsided.

(iii.) In the chapter upon fringing reefs—*i.e.*, those reefs that are near the shores of the islands they skirt and are separated therefrom by comparatively shallow water, it is shown that these reefs differ from barrier reefs in no one main particular. The reefs are somewhat narrower and the islets on the reefs less frequent, but in all essentials they are like the barrier reefs and like the atolls. Hence we are forced to conclude that one explanation must suffice for all three of these structures, and that any view only affording explanation of one or even of two kinds of reefs cannot be considered so satisfactory as a theory that, whilst it is in accordance with all known facts, explains all kinds of reefs, and indeed connects them one with another.

(d) Their Growth. Before passing finally to the enunciations of his great theory Darwin devotes one chapter to the growth of coral reefs. He considers (i.) their distribution and the conditions that favor their increase: (ii.) the rate of their formation: (iii.) the depths whereat they grow.

(i.) As usual he first slays the volcanic theory. Not even is the proximity of volcanic land favorable to the formation of coral. Still less is it essential. On the other hand he shows that the greater the exposure of the corals to the action of the surf the stronger is their growth, the more massive are the formations resulting from them. It is the old story of the strengthening influence of difficulties once again. The recoil of the sea from the steep shore tells against the growth of coral, whilst where the waves break over a bank, the reefs grow apace. Large quantities of sediment, especially if accumulated at places where they are likely to undergo much shifting to and fro under the action of the waves, are unfavorable to coral growth.

(ii.) He combats the notion that the growth of coral is so slow as has been generally supposed, proves to demonstration the formation of huge masses of coral in the Pacific Ocean, and quotes the interesting experiments of Dr. Allan, of Forres, on the actual growth of certain masses of coral placed in favorable circumstances and under actual observation. In these experiments each mass of coral weighing 10lbs. and placed on a sand-bank which at low water was three feet deep was found within six months to have extended in length several feet, to be quite immovable and to have grown upwards nearly three feet. Thus is he led to the conclusion that almost the only condition under which a quick upward growth of the whole surface of a reef could occur is the slow subsidence of the ocean bed that formed its basis.

(iii.) Much evidence is adduced in support of the view enunciated at the very outset of the analysis of this book as to the comparatively slight depths within which coral-building animals can exist. The conclusion is that in ordinary cases reef-building animals do not live at greater depths than between twenty and thirty fathoms and rarely at greater depths than fifteen fathoms.

CHAPTER VIII.

(3.) *Theories.*

AND now all the main facts in relation to coral reefs and the habits of their minute builders having been stated it remains to discuss the explanations by various observers that have been offered as to these remarkable structures. This is done in the sixth chapter. All the views other than that of Charles Darwin are stated as clearly as if they were his own and refuted by appeal to facts as impartially as he would refute a theory that was his if he found the facts were opposed thereto.

(*a*) The volcanic theory, that all these three kinds of reef are founded upon submarine volcanic craters. Against this are (i.) the shape of some atolls, five times as long as they are broad: (ii.) the immense number of such craters that must be crowded together under the sea: (iii.) the difficulty of conceiving that these many craters lie nearly all at the same level.

(*b*) Chamisso's theory that the more massive corals love the surf and therefore the outer portions of a reef will reach the surface first and form a ring. Against this are (i.) the necessity upon this theory for every basis to consist of a flat bank: (ii.) as lagoons are often more than forty fathoms deep, corals at a depth where the waves have ceased from tossing and the corals are at rest, must grow more vigorously on the edges than on the centre of a bank: (iii.) the number of atolls each requiring on this view a submerged bank.

(*c*) The theory that banks of sediment have afforded the required basis for the coral. Against this are (i.) the form and disposition of the atolls: (ii.) that far away from the land, where the dark blue color of the pellucid wave is pure as a maiden's eyes, piles of sediment are assumed to have fallen. Even if the bases are to be rocky in their nature, looking at sub-aerial mountain ranges is it possible to believe in submarine mountain ranges extending for hundreds of miles and yet having broad summits, all lying between 120 and 180 feet from the level of their basis?

(*d*) That elevation has been at work. Against this is the want of evidence and difficulty of imagination that so many points of sea-floor, so widely separated have been raised to a certain definite level and no one has been raised above that level. The consideration and rejection of these various hypotheses leads at length to his own view (*e*) that the foundations of many atolls have slowly sunk downwards to their present level.

Theory after theory, therefore, has been broached in the desire to explain and to connect the various forms of coral reefs. Theory after theory has had to be rejected as inconsistent with, or even as contradictory to, observed facts. One theory remains to be considered. It is that enunciated by Charles Darwin. It is the hypothesis that to-day is accepted by the totality of scientific thinkers, as best helping to explain the phænomena of coral growths. The view held by the great naturalist is that the bed of the Pacific Ocean has over certain regions slowly sunk, and that as it sank the coral-builders have, working without ceasing, built up the reefs to the level of the sea.

Once more, and for the last time, let me state that whereof explanation is demanded. Huge expanses of ocean without any high land present the three forms of reef, all of which are formed by animals only capable of living within comparatively shallow water. These reefs are fringing-reefs near the shores, with little depth of water lying between them and the adjacent land: barrier-reefs far out to sea, separated by wide deep stretch of sea from the skirted coast: atolls with circular rings holding nothing enclosed in their embrace save a portion of the sea itself. No theory save that of the subsidence of the base of the Pacific Ocean appears satisfactory for explanation of all these.

Proofs of such subsidence are first offered. Buried under strata whose thickness is expressed in thousands of feet are found trees standing erect. The whole investigation of South America as detailed in other books by Charles Darwin, and noted in former parts of this work, reveals such evidence of elevation that we are forced to believe in the inevitable concomitant of such elevation, subsidence in other regions. Islands have been swept away by storms. Earthquakes are rife in those districts of the earth. Islands described fifty or sixty years agone do not present to-day the same extent of rise above the level of the sea. The Island of Pouynipète, in the Caroline Archipelago, has a town in ruins, whose houses in 1835 had their very doorsteps washed by the sea-waves. There is evidence enough of change to render the theory of subsidence not impossible, not improbable.

Then follows the daring and successful attempt to explain the three forms of reef by this hypothesis of subsidence. The fringing-reef presents no difficulties, for its depth is not greater than that whereat coral-formers are known to live. Imagine an island skirted by a fringing-reef. If subsidence of the floor of the ocean take place, subsidence of the floor whereon island and fringing-reef alike rest, the water will begin to grow upon the island. The land will be gradually submerged, the island become of smaller and ever smaller dimensions. But as the ocean-bed sinks and the original summit of the fringing-reef sinks also the unwearied coral-formers ceaselessly at toil build up the reef to the level of the water. Further, as the sinking island is encroached upon by the slow-rising sea and as the fringing-reef sinking as to its base is building vertically upwards, the space between land and reef must widen and deepen. Island sinking, reef sinking, but the coral-creatures still busy, water-sweep between them widening and deepening, behold after a time the space between island and reef is no mere shallow, narrow armlet of the sea, but a deep, wide expanse of water, and the fringing-reef of yesterday is the barrier-reef of to-day.

But the barrier-reef of to-day is doomed to be the atoll of the morrow. Let the sinking of ocean-bed continue. Still the sea grows upon the sinking island. Still its waves lap stealthily, irresistibly higher. Still the reef, always built up to the water-level by the coral-formers building for dear life, seems to recede further and further from the land by whose side once on a time it was. Still the channel between them grows wider and deeper, though their deep bases that are the memories of the long-ago are as close together as they must ever be. And the island sinks and the reef struggles upwards and the channel between deepens and widens until the land slips beneath the waters, the first wave ripples softly over the crest of the buried palm-trees, and the barrier-reef holding in its arms naught but the sea and its secrets is a strange circular reef in mid-ocean that the sailors call an atoll.

Sinking atolls may be converted into many smaller ones. If the reef-builders die they may become banks of dead rock. These last again subsiding yet further and affording basis for deposit of sediment pass into the condition of level banks wherein no eye other than that of the skilled naturalist would detect evidence of the time when these were reefs alive with a million of busy toilers.

(4) Distribution. The last chapter of this work is devoted to a consideration of "the distribution of coral reefs with reference to the theory of their formation." Its conclusions are remarkable. The atolls and barrier-reefs, confessedly alike and passing through similar histories on the hypothesis of subsidence of the base of ocean, are constantly found near each other. Where they exist, moreover, there is dearth of volcanoes. "There is not a single active volcano within several hundred miles of a group, even a small group, of atolls." Atolls further, as if to insist upon their past history being rightly understood, have the most striking resemblance in shape to the outline of the islands amongst which they occur. The islands unto which they were once upon a time fringing, and yet more recently barrier-reefs, had more than possibly a shape similar to that now possessed by their neighbors that are as yet unsubmerged. It might be anticipated that the atolls would have shape similar to that of the islands amongst which they are, and such anticipation is realised. The atolls and barrier-reefs are found also within areas where the evidence as to subsidence of the base of ocean is strong.

Turning to the fringing-reefs, these seem to occur universally in regions where steadfastness or far more frequently *elevation* of the sea-floor has been the recent rule. Volcanoes are frequent enough in the vicinity of fringing-reefs and upon the shores near them are found multitudes of organic remains. Indeed Charles Darwin himself, on page 187 of the volume under consideration, holds that "the most important generalisation to which the study of coral reefs has indirectly led" him is that volcanoes are often to be encountered in areas where elevation has lately occurred or is even now occurring, and are absent where subsidence is or recently has been.

And now, after study of the great thinker's works upon volcanic islands, upon South America, upon coral islands, we are, under his careful and most delightful guidance, able to arrive at some conception of the gigantic changes of level that are affecting certain vast areas of the surface of earth. Away to the east of the coral-haunted district lies America. Away to its west lies Africa. These mighty continents, the boundaries of the coral seas, are slowly rising out of the waters. Between America and Africa lie the oceans known as the Pacific and the Indian. The beds of these twain are slowly subsiding at least over the larger part of their area. Scattered over these expanses of water, quiet now from all volcanic outburst, are a myriad fringing reefs, barrier reefs, atolls. These, as the foundations of the great seas sank, have glided one into the other, and to-day the circular atolls over whose summit the mariner beholds the crests of white waves breaking are the monuments of islands dead and buried. Upon each of them the eyes of him that thinks can read, "Hic jacet."

III.—BOTANICAL WORKS.

A.—Introductory.

CHAPTER IX.

(1.) *Classification of Sciences.*

THE additions to the storehouse of geological facts made by Charles Darwin have been demonstrated as multitudinous. The generalisations thence deduced are many and of great importance. Yet, in turning from his geological works to those that deal with biological subjects, the feeling that possesses me is akin to that of one who, after toiling along a narrow lane that has not been destitute of flowers, finds the narrower path suddenly opening out upon a vast plain stretching to the horizon. The odors of the blossoms and grasses are more varied; the sky seems loftier and of a richer blue, and the great expanse undulating from our feet gives promises of yet undiscovered regions in the unseen beyond. This may be due to the nature of the subjects upon the study whereof we now enter. They are subjects that, to some of us, seem to be of moment even greater than that possessed by the studies that deal with inanimate objects. Or the feeling may be due to the consciousness that, in the branches of thought that have to do with plants and animals, the discoveries of Charles Darwin have been so numerous and so important that there is no exaggeration in saying that, as an investigator of animate structures, he stands alone. Other men may bave given to their fellows new facts and new generalisations in connexion with the rocks as momentous as those he presents to us, but very surely none other has so added to our knowledge, or so widened our field of thought in respect to plants and animals, as the author of "The Fertilisation of Orchids" and "The Descent of Man."

That the non-technical reader may be able to follow without difficulty the investigations of the writings of our great naturalist now to be entered upon, it seems well at the outset to explain certain general terms that will be found to be of frequent recurrence, and the comprehension whereof is essential to the complete comprehension of the analysis now to be made.

From the birth hour, the child born of woman is surrounded by a world of beauty and of mystery. In this world, and of it, the little one begins to drink in impressions. Through all its sense-avenues, from those that are its wide-opened, innocent-looking eyes down to the touch that responds to the softness of velvet or the sweeter softness of the lips that whisper "My darling," it drinks in impressions from the vast universe whereof it is a fragment. At first all is loveliness and wonder. But ere long the same or similar impressions recur, and soon the recognition of like and of unlike dawns. The child begins to recognise that whilst the universe is varied there are likenesses, and its impressions fall into groups. Wandering by the sea, music-voiced, or playing with the worn stones at last at rest after the tossing of the many waves: roaming up the glens where the streamlet dropping seaward has carved its way through the myriad-shaped, many-colored rocks: clambering up the mountain sides and over stone after stone after stone, old as sorrow the child meets Nature in her stillness. She is here at rest, imperturbably at rest. No movement, no growth. If the rock-fragment be hurled from its resting place, where it falls it lies, seeming to say "Let me be. I am old." The very waters that move it are not animate. They are passing towards the sea, drawn by an irresistible force over which they have no mastery, and will rest in its bosom. But in the sea and the streamlet move multitudes of beings. In the sand of the seashore crawls the worm. Upon the moist rock the Sea-Anemone waves its tentacles. Through the glen flits the insect, and the perfume of many flowers makes a gladness in the air; and the child soon learns to distinguish between the inanimate and the animate. Its elders have even gone so far as to name the collection of facts referring to the living things. *βιος* is the Greek word for life; λογος is our old schoolday friend, and means, roughly, "Science or knowledge." Hence comes Biology or the science that deals with living beings.

But of living beings two great kinds are. Delicate odors sweetly burden the air. Exquisite shapes charm the eye. Colors that move you like a deep-toned voice, combinations of them so graceful and harmonious that they set you a-thinking of your mistress, greet you, and the world of plants is before you. Or the dog that leaps upon you, the horse that carries you king-like over hill and dale, the brother that will take your hand and lead you very silently to the side of the stream and show you the speckled trout lying under the floating rushes, all remind you that living beings of even greater beauty and greater wonder than the plants exist. And thus dawns upon the child the perception of the two forms of living things—plants and animals.

The Greek word for a plant is *βοτανη*. The Greek word for an animal is *ζωον*. Hence Biology has its two divisions: Botany the study of plants, Zoology the study of animals. The facts that are learnable as to plants or as to animals are many. Yet they also fall under definite heads. The oak has its wood arranged in rings. Man has a backbone. These are facts of structure. All such facts are comprised under the head of Anatomy (from *ανατεμνο* I cut up). The oak forms yellow dust or pollen that ripens its seeds. Man uses muscles for the purpose of movement. These are facts of function. All such facts as these are comprised under the head of Physiology (from *φυσις* nature and *λογος*.) The oak has many points of similarity with the hazel, the beach, and the edible chestnut, and is placed in the order Cupuliferæ with these and other kindred trees. Man has many points of similarity with the gorilla, the orang, the marmoset, and is placed in the order Primates with these and other kindred animals. These are facts of grouping. All such facts as these are comprised under the head of Classification.

Whilst each of these three great divisions of the study of plants and of the study of animals has numberless subdivisions, the first (Anatomy, or the study of structure) has two main branches of such import that reference to them is inevitable. The oak has a tree-like stem and leaves of sinuous border. Man has four limbs and a heart of four cavities. These are facts relating to organs. All such facts as these are comprised under the head of Morphology (from *μορφη* form or organ). But the microscope tells us that the stem of the oak has cells, fibres, vessels, and that the heart of man has fibres that are strangely allied in structure to those under his control and also to those that are beyond that control. These are facts relating to tissues. All such facts as these are comprised under the head of Histology (from ἱστος, a web or tissue).

To make these terms yet more clear to the reader I append them finally in a tabular form, with earnest appeal to all to make effort to master completely the meaning and the position in relation to others of every one of the terms used in the table now appended.

Biology	Vegetable = Botany	Anatomy	Histology.
			Morphology.
		Physiology.	
		Classification.	
	Animal = Zoology	Anatomy	Histology.
			Morphology.
		Physiology.	
		Classification.	

CHAPTER X.

(2.) *Botanical Terms.*

THE botanical writings of Charles Darwin have to do with the structure, the functions, the grouping of plants. The comprehension of these products of his genius on the part of the non-technical reader will be rendered easy by acquaintance with one or two ordinary terms used in the study of plants. I ask for the patience of my readers while I try to explain the very few words whose meaning should be mastered by all who desire to obtain fair grasp of the thoughts contained in the flower-books of Charles Darwin.

These terms shall be arranged under the heads Anatomy, Physiology, Classification. (*a*) ANATOMY or the study of structure. This has two aspects. It may investigate the minute structure, by aid of microscope, and is then Histology. Or it may investigate the build of the general, palpable organs of the plant, studying the shape of leaves or the number of petals in the flower. This branch of Anatomy is Morphology. (i.) *Histology* or the study of tissues. Four principal terms are worthy to be mastered here. (α) *Cell.* The microscopic bag which, in conjunction with thousands of its fellows, makes up the whole of the young plant and the softer parts of the older plant. The cells are closed, very minute bags with exceedingly delicate walls. The walls are made of (β) *Cellulose.* A substance closely allied to starch, containing the three chemical elements, carbon, hydrogen, oxygen, and forming the wall of the plant cell. (γ) *Protoplasm.* From $\pi\rho\omega\tau o\varsigma =$ first, and $\pi\lambda\alpha\sigma\mu\alpha =$ formative matter. The contents of the cell when young. Protoplasm is semi-fluid, granular or dotted in appearance, not clear, not pellucid, is made up of the four chemical elements, carbon, hydrogen, oxygen, and nitrogen, has the power of contracting itself into smaller dimensions and has the capacity for being formed into other substances. But plants are not all soft-parted and succulent. Many of them form hard, strong organs, needing something more for their composition than delicate thin-walled protoplasm-filled cells. The hard stem of the forest-tree presents (δ) *Fibres.* These are cells that have been much elongated and have had their walls strengthened by thickenings of woody tissue. The elongated thick-walled cells known as fibres have generally as companions certain long tubes that often run for many inches, or even feet, up the stem of the plant possessing them. These, of far greater length than fibres, are vessels. They are formed by the walls of many cells that lie one above the other disappearing and all the cells running into each other. Imagine one cell, then, growing in length and having its wall strengthened by deposit of woody matter and you have a fibre. Imagine many cells ranged in vertical series and the intervening partitions disappearing and you have a vessel. The walls of these long vessel-tubes are generally strengthened by woody deposit, and as that deposit often takes the form of a spiral running round on the inner side of the original cellulose wall the vessels are often met with as spiral vessels.

(ii.) *Morphology.* The plants that we know best have roots, stems, leaves, flowers. (α) Of the root as an organ of the plant nothing need be said. (β) As to the stem, two words of importance call for explanation. The point on the stem whence the leaf takes origin is called the *node* (from nodus = a knot). The part of the stem lying between two successive nodes is an *internode* (inter = between). (γ) Most leaves present a stalk or *petiole* (from pes = a foot) and a blade or *lamina* (lamina = a plate). (δ) Flowers call for more detailed notice. If possible, let the reader now examine some ordinary flower, say a primrose or a hyacinth. In the former he will find green outer leaves joined together, pale-yellow inner leaves joined together. Opening this yellow cup, he will find on its inner face some yellow threads, and deep down in the very base of the flower a little green structure like a flask, presenting a swollen base crowned by a slender stalk that is in its turn surmounted by a small cap. In the hyacinth certain white leaves are joined together. Opening this white cup, the student will find on its inner face some yellow threads, and deep down in the very base of the flower a little green structure like a flask, presenting a swollen base crowned by a slender stalk that is in its turn surmounted by a small cap. Of the structures common to the two flowers the yellow threads are the male organs. Collectively they form the *andrœcium* (ανηρ = man, οικος = house). Individually the threads are known as stamens. Each has three parts—(1) a threadlike stalk or *filament* (filum = a thread); (2) a head or *anther* containing (3) yellow dust or *pollen.* Of the structures common to the two flowers the little green structure like a flask is the female organ or *gynœcium* (γυνη = woman, οικος = house. If you cut across its swollen base horizontally, you will find that swollen base or *ovary* contains unripe seeds or *ovules.* Both these words are derived from ovum, an egg.

(*b*) Physiology, or the study of function. The function of the fibre is to carry sap; of the vessel to carry air; of the root, to fix the plant in the ground, to take in food, to give out unrequired materials; of the stem, to support leaves and flowers and to carry by means of its fibres and vessels sap and air; of the leaves, to breathe and to feed upon the gases of the air; of the green outer leaves or sepals of the primrose, of the yellow inner leaves or petals of the primrose, of the white leaves of the hyacinth, to protect the male and the female organs of the flower, and to attract the flower insects. The functions of the male and the female part of the flower need more detailed account. The pollen or yellow dust in the anther of the stamen is the fertilising agent of the flower. Unless it reach the unripe seeds, there will be no ripe seeds, no reproduction. In the swollen base of the gynœcium, or female organ, are unripe seeds or ovules, waiting to be made seeds. How is this to be effected? By the pollen. Unless the pollen from an anther of the same flower reach the ovule of a plant, or unless (and this is far more frequently the case) *the pollen from an anther of another flower of the same species* reach the ovule, that ovule or unripe seed will never become a ripened seed.

(*c*) Classification. He that desires to understand the work that lies before us will do well to understand the following simple facts of classification. All plants either have not or have these palpable yellow threads, pollen-bearing and constituting the male organ or andrœcium, together with the ovule-enclosing body known as the female organ or gynœcium. Thus in the sea-weeds, the moulds and mushrooms, the grey lichens encrusting the tombstones leaning to the leeward, the mosses and the ferns, these structures are not, and these plants and their allies are called flowerless plants or Cryptogamia (κρυπτος = hidden, γαμος = marriage). The higher plants are flowering plants or Phænogamia (φαινεω = I appear). These latter present two divisions of import to the general reader. A hyacinth has leaves whose veins run parallel and has the number 3 running through its flower. It represents a great class of flowering plants, the Monocotyledones. The primrose has leaves whose veins form a net-work and has the number 5 running through its flower. It represents a great class of flowering plants, the Dicotyledones.

I am aware these are dry details. But if the reader will struggle once for all with them, will read this chapter not once but many times, will master the terms and definitions here introduced, he will fit himself for the full understanding of the works of Charles Darwin that have to do with plants.

B.—Climbing Plants.

CHAPTER XI.

On Climbing Plants.

THE sweet-pea, the bryony, the clematis, the vine, the ivy, the hop, the passion-flower, the sarsaparilla, the deadly nightshade, the virginian creeper are but a few of the plants, whose graceful forms will rise in imagination before every observer of Nature at the bidding of the title of the first of the botanical works of Charles Darwin. Two questions rise most naturally to the lips of each observer. What advantage do these plants derive from climbing, and how do they climb? Of the advantages derived by plants from this habit other writers have spoken. To be able to reach the light and to expose green surfaces to its action and to that of the air is of distinct value to the plant. But to the inquiry as to how this desirable end has been attained no answer in any sense fully satisfactory had been given until in 1865 the journal of the Linnæan Society was honored by containing an essay subsequently enlarged into the book known as "Darwin's Climbing Plants."

Herein, as everywhere in his writings, the naturalist is found to be very keenly alive to the beautiful adaptations encountered in Nature. But with him there is no talk of design or of the wisdom of the impalpable. Throughout the 206 pages of this book the word god never once occurs. When he sees a beautiful adaptation of some organ to some end he asks what is the advantage in the life-struggle to the possessor of that organ of the end attained, and through what slow steps of gradual change has the organ passed to its complete adaptation. They are to be found, these intermediate steps to-day. Witness in the common grape-vine the series of gradations between the ordinary flower-stalks and that extreme modification of a flower-stalk known as the tendril of the vine. Witness in the common garden berberry the series of gradations between the ordinary leaves and the extreme modification of a leaf known as a spine. And the acute mind of a Darwin recognises in the plants to-day many more of these intermediate steps, and sees ever the growing evidence that there has been no leap, no hiatus, but an unbroken series connecting the primal plants with those that throng our fields, woods, and gardens at this hour.

Climbing plants present four divisions. (1) Those climbing by the aid of rootlets, as the ivy. (2) By aid of hooks, as some few roses, one species of *Rubus (R. australis)* and the yellow bedstraw. (3) Twining plants, as the convolvulus or the hop. (4) Plants with sensitive organs that coming into contact with any structure, clasp it, as the clematis or the vine.

(1) Rootlet Climbers. Only a few pages are devoted to these plants. The ivy has nothing of the power possessed by other plants that will be described anon of moving either towards or from the light. Its rootlets allowed to press against glass adhere very slightly thereto and secrete a small amount of yellowish matter. A particular kind of fig, upon close investigation by Darwin, gave evidence that led to the belief that its rootlets first secrete a viscid fluid, absorb the watery part thereof (the fluid will not dry on exposure to the air even for many days) and leave behind a cement. These rootlets, when allowed to press against glass, left upon removal atoms of yellowish matter like that formed by the ivy rootlets.

(2) Hook-Climbers also call for but passing notice. They show no spontaneous revolving movement, if they are simply hook-climbers. Very frequently, however, hooks are developed upon the twining and tendril bearing plants. To these last, as of far greater interest, I now pass.

(3) Twining Plants. When the stem of a hop-plant comes out of the ground its first two or three internodes (the portions of the stem intervening between the points of insertion of successive leaves) grow up erect. Then even though none other plant and no beneficently-placed hop-pole be near, the young internode that is now formed at the top of the growing stem bends slowly and gracefully to one side and travels steadily round to every point of the compass, describing a complete circle, as the

minute hand of a watch moves over the face. Two hours eight minutes is the average length of time that each swing round occupies, and as each internode of the stem grows older and younger ones are formed upon its summit it ceases to revolve. Thirty-seven of revolutions such as these were performed by one carefully-observed internode of a hop-plant ere it suddenly became motionless. This number of revolutions performed by only one internode of the plant, considered in conjunction with the number of internodes successively developed, will give some idea of the admirable chance the plant will have of striking in its revolutions against some support and then revolving round that support. For as soon as the revolving stem, wandering round and round, strikes some support, it will necessarily cease to grow at the point of contact but as the free projecting part beyond continues to revolve the point of contact will become a line and the hop will twine round the hop-pole.

The twining plants in our temperate climate are only able to grow round stems of moderate thickness. They cannot compass huge stems. The power to do so would be injurious to them, for, as they are only annual plants, in one year they could not if they twined round trees of great circumference struggle up into the light. On the other hand, the twiners of tropical forests are able to work round trunks of trees and for them this is well. Amidst the dense luxurious growth of the tropical forest, were they destitute of this power, plants of many years' duration could never hope to grow up into the light at all. Thus is the great truth of Natural Selection once more to the fore with an explanation.

It has been mentioned above that many twiners have hooks developed at the end of the shoots. These serve to seize the support and also enable the shoot to obtain a much closer hold upon that support and thus prevent the ever-present possibility of the shoot being blown away from its support by the wind from becoming actual.

Finally comes the inquiry into the reason of this remarkable revolution of plants. The reply to this inquiry is due to other thinkers than our greatest. None has, however, made greater or more legitimate use of the principle about to be enunciated than the author of "Climbing Plants."

Not only is light not necessary to growth—it is injurious. Plants grow better in the dark, as some people seem to think children do, judging from their method of punishment. They *feed* better in the light. The side of a stem therefore remote from the light will grow more rapidly than the side of the stem turned towards the light. Thus plants grow lightwards. Thus the vagrant vines go "seeking the sunshine." These strange revolutions of the twining stems are due to greater growth upon the side of the stem that is away from the centre of the circle described by the twining plant, and when that plant catches a support the arrest of growth upon the side of the stem next the support and the continuance of the growth upon the side of the stem away from the support will cause the twiner to grow round and round the body upon which it rests.

(4) Plants with sensitive organs. Of the true climbing plants as distinct from mere twiners or from those that climb by means of hooks or by means of rootlets; of those plants that climb by the help of organs that undergo movement when they are touched two divisions exist. These are (*a*) leaf-climbers, (*b*) tendril bearers. These will be considered in the present chapter. (*a*) Leaf-climbers. (i.) The earliest condition of those sensitive plants, whose sensitiveness leads to the remarkable movements known as "climbing," is encountered in a plant closely allied to our English Snapdragon. In this plant the peduncles or stalks of the flowers revolve in a feeble fashion, and are slightly sensitive to a touch. As yet, however, these flower stalks are not turned into true tendrils, and we have here only the very earliest stage of a true climbing plant. (ii.) The next condition is met with in the Gloriosa, a member of the lily order. In this plant the leaf actually becomes a sensitive organ, having for function the help of the plant in its upward growth, lightwards. But it is only just the tip of the leaf that is modified. (iii.) The petioles or leaf-stalks next take on the functions of revolution, of sensitiveness, of clasping and climbing. Of this no better illustration can be than the familiar Clematis. The upper, younger internodes of most species of Clematis go wandering, after the manner of the twining plants, round and round in slow circles. Thus the leaves run good chance of coming into contact with stems or twigs, or even the trellis-work that the hand of man has erected at the southward-looking porch of the country home. Such objects as are thus encountered are seized slowly but

surely by the petioles or leaf-stalks of those leaves that are borne into collision with these objects of support. For the petioles of the Clematis are sensitive, and the moment they come into contact with any object they begin to grow less vigorously upon the side thus touched, whilst upon the side that is free they continue to grow as strongly as before. Hence the leaf-stalk winds slowly round the supporting body holding it in ever closer and more extensive embrace. Internodes at the upper part of the stem slowly swinging round in circles: contact of the petioles of the leaves with other bodies: the sensitive petioles growing in less degree upon the side of contact than upon the side that is free; slow winding of the petiole round and round the supporting body and your Clematis is a climbing plant. These three stages, then, have been observed. (i.) The plant allied to the snapdragon, with its feeble revolutions and its feeble sensitiveness; (ii.) the Gloriosa with its sensitive, clinging leaf-tip; (iii.) the Clematis with its sensitive petioles. Even between these gradations are yet others. In evolution it is veritably "wheels within wheels." Thus in the different species of Clematis a remarkable set of gradations present themselves between the very limited sensitiveness of *Clematis montana* and the far more general sensitiveness of *Clematis viticella.* It is very interesting to watch in the various plants the responsive power to touch spreading over larger and larger areas with constantly increasing advantage to the plant. And again in the Tropæolum of our gardens, more commonly known as the Indian cress or as the nasturtium or "sturtian" of the gardener, many stages are seen between certain threads with just a suspicion of flattening at the free end and perfect leaves. Of this plant Darwin writes.—

"Until the plant grows to a height of two or three feet, requiring about a month from the time when the first shoot appears above ground, no true leaves are produced, but, in their place, filaments colored like the stem. The extremities of these filaments are pointed, a little flattened, and furrowed on the upper surface. They never become developed into leaves. As the plant grows in height new filaments are produced with slightly enlarged tips; then others, bearing on each side of the enlarged medial tip a rudimentary segment of a leaf; soon other segments appear, and at last a perfect leaf is formed, with seven deep segments. So that on the same plant we may see every step, from tendril-like clasping filaments to perfect leaves with clasping petioles. After the plant has grown to a considerable height, and is secured to its support by the petioles of the true leaves, the clasping filaments on the lower part of the stem wither and drop off; so that they perform only a temporary service."

(*b*) Tendril climbers. A tendril is a structure that is sensitive to touch and is used for climbing. These thread-like organs with their ready response to any contact and their notable power of twining round and clinging to objects, are the loftiest stage encountered in the study of climbing plants. We have seen rootlet climbers and hook climbers; we have seen plants climbing by aid of *part* of their leaves, as the tip or the stalk. Now we come to plants that climb by means of special structures that are modifications of complete organs, not of parts of organs, and are known as tendrils. Let us consider (i.) the organs transformed into tendrils (ii.) two or three special plants that are tendril bearers (iii.) the adhesive structures seen at the free ends of certain tendrils (iv.) the spiral contraction of these organs after they have caught their supports (v.) the causes of their revolution.

(i.) These tendrils are formed out of various organs. Thus the tendril of the passion-flower is a whole branch transformed: that of the vine is a flower-peduncle: that of the ordinary pea is a modification of certain of the leaflets: that of the sweet-pea of the whole of the blade of the leaf: that of the sarsaparilla plant or of the cucumber and its allies arises from the alteration of the little leaf-like bodies seen at the base of the petiole in some plants—*e.g.*, the rose, and known as stipules.

(ii.) If anyone will examine the tendril of the grape-vine he will find the following arrangement. From the main stem comes off a common peduncle that soon divides into two parts. Of these two parts one bears flowers, the other becomes the tendril. The common peduncle does not respond to a touch or a rub at all: the one of its two divisions carrying flowers is feebly sensitive: the true tendril is excessively sensitive. Sometimes the division that bears flowers carries only a few blossoms. In those cases it is very interesting to notice that this division is then far more sensitive, and has indeed taken on more of the character of a true tendril. The whole apparatus of common peduncle, flower-bearing division and true tendril, is capable of slow spontaneous movement, that affords to the tendril every chance of coming into contact with some object of support.

The bignonia, species of which can be seen at Kew, has tendrils that are modified leaves. It is a plant of especial interest on account of its remarkable habit of searching, as it were, for holes or crevices wherein to insert the extremities of its tendrils. The tendril will travel slowly over the surface of a woody stem until some hole is reached, when the end of the tendril straightway passes into the aperture. Sometimes the tendril is fastidious, and, not satisfied with the particular hole it has first encountered, will draw itself out again and insert itself into another more to its liking. Such a habit would naturally be of value to a plant growing upon trees with many noticeable irregularities of surface, and the bignonias affect especially trees that are covered with moss or lichens.

Of the Cucumber order one very remarkable climber is known by the somewhat lengthy appellation of *Echinocystis lobata.* As the tendril revolves at an angle of about 45° with a horizontal line, suddenly at one part of its course it stiffens and straightens itself so as to become for a little time nearly or quite vertical. If this strange temporary straightening did not occur, the free revolving end of the tendril would without doubt strike against the extremity of the plant, and the tendril would be arrested in its movement by the plant itself. This is prevented by the temporary straightening of the tendril, and as soon as by this device the end of the climbing organ has passed beyond the end of the stem of the plant that forms the obstacle in its way the tendril falls again into its old inclined position.

(iii.) The development of adhesive masses at the free ends of tendrils demands especial notice. The well-known Virginian creeper, so often seen covering the sides of houses to-day, a plant belonging to the same order as the vine, presents such structures. Soon after the tendrils of the Virginian creeper have laid themselves down, as it were, upon a wall the tips swell, become red and form little disks or cushions. These envelope "every minute and irregular projection, insinuate themselves into every crevice," and also appear to secrete a resinous and adhesive cement, reminding us of the ivy among the root climbers. Some of the bignonias and certain members of the cucumber order present the same peculiarity.

(iv.) When tendrils have clasped a support they undergo a general spiral contraction that necessarily shortens their length, and confers upon them a very distinct elasticity. The contraction begins from half-a-day to two or three days after the tendril has caught its support. This spiral contraction is of the utmost value to the plant. If the shoot is inclined, the shortening of the tendril draws it up and lifts the leaves yet more fully into the light. If the shoot is vertical, the shortening of the tendril is of use, for but for that shortening as the main stem grew, the shoot would be left slack, were it not for the spiral contraction which draws up the stem as its length increases. Again, the tendrils being thus rendered highly elastic, the strain due to the weight of the supported plant is distributed over many branches, not concentrated too greatly at one point. Further, a tendril that has seized upon a support, always becomes twisted in one direction in one region of its length, in the opposite direction in another region of its length, whilst between the two regions of opposed twisting intervenes a straight portion. But for this curious reversal of the twist of the tendril that organ would during the process of spiral contraction now under study become ruptured. Those who have noticed a draper winding up a piece of ribbon as he says, "And the next article, please?" or those who have ever flown kites, will understand the value of this reversal of the twist of the tendril.

(v.) Finally the causes of the revolution of tendrils. Probably these are of nature similar to the causes of the movements of the twining plants. There is increased growth along a special line of the tendril: a longitudinal line that travels slowly round the organ and bows successive parts to the opposite side. This growth is of course upon the side opposite to that which becomes concave. Charles Darwin is also of opinion that along with this increased growth upon the convex side there is contraction of the cells along the concave side. By both these means the sensitive tendril will be made to grow slowly round the object of support, fulfilling its functions as the most specialised organ met with among the climbing plants.

C.—Insectivorous Plants.

CHAPTER XII.

(1.) *Plants and Animals.*

WE were taught in our schooldays that three great kingdoms existed in Nature: the Mineral, Vegetable, and Animal. We were taught, moreover, that these great kingdoms were very markedly distinct one from another, and that the possibility of confusion between minerals, vegetables, and animals was almost inconceivable. This is still the belief of many. But the researches of scientific thinkers during the past few years have shown that the old hard and fast lines between the three great groups of things cannot be drawn, and that the three kingdoms glide imperceptibly one into the other. All such researches and their results once more strengthen the belief in evolution rather than in special creation. Especially has the line of demarcation between plants and animals faded away under closer investigation. Aforetime, to determine whether a living thing were vegetable or animal was supposed to be an easy task. The task is still easy if the higher kinds of each kingdom are studied. Nobody would hesitate as to the position of an oak-tree or of a man. But when the lowly members of the two great kingdoms of living things are studied difficulties present themselves. The minute microscopic living things puzzle. It is often impossible to say positively whether they are vegetables or of higher nature. The two groups of organic beings, widely asunder in their loftiest conditions, approach each other ever more closely in their lower and lower forms, until at last and at lowest they glide into each other and are one. So thoroughly is this fact recognised to-day that the great German biologist Haeckel has suggested a group-name for those organisms whose exact nature it is difficult to determine. He proposes to call the dwellers in this biological no-man's land, Protista ($\pi\rho\omega\tau o\varsigma =$ first).

But, further, the distinctions between plants and animals that were wont to be given do not hold even in respect to beings that would be without hesitation named by any ordinary observer as clearly either plant or animal. The distinctions usually given in the past were the following. (*a*) The tissues of plants contain the three chemical elements, Carbon, Hydrogen, Oxygen: those of animals contain the four chemical elements, Carbon, Hydrogen, Oxygen, Nitrogen. But, first, Nitrogen is found in plant tissues and to a very considerable extent; and, second, in the body-walls of certain animals the structure supposed to be distinctive of plants, cellulose, has been encountered. (*b*) Plants have no power of sensation or of movement, whilst animals can feel and move. But many plants do respond to stimuli, as the study of climbing plants demonstrated, and as the name "Sensitive plant" reminds us. Nowadays, moreover, there is demonstration of the effects of such stimuli being transmitted through vegetable structures in definite directions, and evidence is not wanting of certain actions in particular plants that deserve the application to them of the adjective "nervous." Again, plants have undoubtedly the power of movement. Tendrils climb, the leaves of the Mimosa alter their position, the flower opens and closes, the stamen of the Berberry when touched springs forwards on to the body touching it or on to the stigma, the spores of the lower plants flit across the field of the microscope and the strange protoplasmic masses of some Fungi crawl slowly over decaying matter. In many plants there is more movement than can be observed in a Sea-anemone or a Barnacle. It is almost unnecessary to point out that the distinction cannot be maintained by insertion of the adjective 'voluntary' before the word movement, as the movements of many animals very clearly never rise to the level of movements that are under the control of the will. (*c*) Plants do not take their food into any internal cavity, and their food is of an inorganic or mineral nature; animals do take their food into an internal cavity, and their food is organic—that is, either vegetable or animal. But many undoubted animals have no true digestive cavity. The Tape-worm, whom no one would credit with vegetable proclivities, has no alimentary canal. The second part of this third distinction was that to which men clung the longest, and was the last to vanish in the light of investigation. For recently many plants have been shown to feed largely upon matter other than mineral. Thus there is a large group of plants whose food is derived from decaying organic matter that has certainly not passed to its ultimate destination, *i.e.*, the mineral condition represented by carbonic acid, water, and ammonia. These plants, feeding not upon inorganic things nor upon organic substances, but upon the latter during their slow decay or passage into the former, are called Saprophytes (σαπρος = decayed, φυτον = plant). Amongst them are some of our English orchids, and certain allies of our heaths and of our foxgloves. Again, plants exist whose food is derived from the prepared fluids of other plants, and not from the mineral kingdom directly. These, growing upon other plants, are known as parasites. Mistletoe, broom-rape, dodder, are examples of these breakers of the unjust "law" that states that the food of plants is inorganic, that of animals organic. But, finally, certain remarkable plants have of late years been under close investigation that have received, as result of that investigation, the name of carnivorous or insectivorous plants. It is to the study of the work of Charles Darwin that deals with these strange members of the vegetable kingdom that we now turn.

Other thinkers had been busy with the animal-eating plants before him. As far back as 1782 a patient German had studied the little sun-dew. Trécul in France, Nitschke in Germany, Mrs. Treat in America, and Mr. Alfred Bennett in England had been at work upon the same plant. At Belfast, in 1874, Dr. Hooker, as president of the British Association, set society into a fashionable flutter, and gave rise to quite a little chorus of "Remarkables! Dear me's! Very extraordinary's!" by reading an address upon Carnivorous Plants. But it was reserved for a greater than any of these to complete their work, and to complete it so very thoroughly that it would almost seem as if nothing were left to reward the toils of future laborers. In truth, no other of Charles Darwin's works shows better than this one the notable thoroughness of the man. The minute investigation, the infinite patience, the endless making of experiments and careful recordal of results, the attention to innumerable minutiæ, the doggedly persistent repetition of observations and trials, the steady accumulation of details before any attempt is made at a generalisation, are perhaps almost more observable in this book on the insectivorous plants than in any other of his works. In addition comes out very clearly herein his intense desire to get at truth and truth only. Preconceived notions are not for him. He states the arguments for the conclusions that would strengthen the position of the great theory of Evolution only less clearly than he states those that tell against that theory. No man was ever more of judge than he; no man was ever less of advocate. Of his calm, dispassionate method of weighing evidence with but the one desire to arrive at what is true actuating him, a typical instance is furnished in the third chapter of this very book, where the proximate causes of the protoplasmic aggregation in the cells of the sun-dew are under consideration.

The obligations of Charles Darwin to other workers in the same field as himself are always paid with a cordiality and courtesy that must be as gratifying to them as they are natural to him. It is pleasurable to find in the work now under consideration, as in many others from the same hand, that of those fellow-workers some bear his honored name. The references to the help by pen and pencil rendered by the sons of the great naturalist to their illustrious father become invested with a deeper interest to us all when we remember that to-day the names of his children are becoming famous, not alone for the father's sake, but on account of the good work done in the very branches of knowledge wherein he has built for himself an everlasting name.

In the attempt to interpret between the investigator of the insect-eating plants and the student, the plan followed will be substantially one with that of the book itself. The sun-dew itself will be considered as one of the most remarkable types of flesh-eating plants. The curious Venus' fly-trap will be studied. Certain plants allied to these last twain will be noticed. The bladder-wort and its congeners will constitute the last set of organisms calling for attention under the head of Insectivorous Plants.

CHAPTER XIII.

(2.) *The Sun-Dew.*

A TINY plant growing in peaty soil with lowly mosses for its companions, a plant that would be inconspicuous but for the frequent glisten of the sunlight upon its drop-studded leaves: these same leaves, not more than six in number, growing out horizontally close to the ground, their length somewhat less than their breadth, and their faces covered with small stalks that end in rounded heads, each whereof is surrounded by a large drop of viscid fluid: that is the Sun-Dew or Drosera. Let us, following the Master, call the small stalks "tentacles," the rounded heads that form and are bathed in the viscid fluid, glands.

Let us watch the Sun-Dew. It grows in the barrenest of soil. Around it are vegetating a few spare Sphagnums or bog-mosses. These gather their food from the air rather than from the soil wherein they grow. In very truth, this last would yield but little supply. The Sun-Dew is in the same condition. From the soil it can derive little or no food. Its supply must come from the air. And as you watch the little plant, lo! the food comes. A fluttering insect moves with vague, irregular flight through the warm air over the barren land. Its flutterings carry it hither and thither, and at last against the motionless leaves of the Sun-Dew. It touches with vibrating wing or dependent feet the glistening spots that have possibly allured it from afar, and its flight is for ever at an end. The gland that has caught the hapless one secretes more and more fluid, and the victim is more and more hopelessly entangled. And now other tentacles begin slowly to bend towards the place where the captive still struggles faintly. From all parts of the leaf they move inwards remorselessly, until their glands are in contact with the insect, and are at work upon it. As the glands of tentacles that were at first remote touch the living food the amount of the secretion increases. The fluid that is thus poured out alters moreover in quality. It becomes acid. The insect thus caught, thus surrounded by scores of fatal claspers, struggles. But its struggles grow feebler as it becomes weaker. The clammy moisture clogs its breathing pores, and stifles it. Its strength fails, its life ebbs away. But a little while, and that which a few minutes agone was a flash of bright color on a sunny day, and the very emblem of gaiety and care-freedom, is an inert soiled mass imbedded in the fluid of the Sun-Dew. And again a little while, and the tentacles slowly move back to their old places, the leaf is as it was before, and a gust of wind blows away a fragment or two of dust, that is all that is left of the captured insect. The rest has been digested by the plant.

The movements of these strange tentacles have been subjected to an analysis by Charles Darwin searching and complete. The results of this patient investigation we now study.

(*a*) Movements of the tentacles due to the contact of solid bodies. The body must touch the glands. It is not enough for it to rest on or even in the fluid secreted by them. Absolute contact (as it is called) must take place. Mere transitory touches are of little or no value as causing inflexion of the tentacles on the Sun-Dew leaf. A slight pressure is far more effective than a very vigorous touch. This peculiarity is of service to the plant, as often in the wind-stirred marshes swaying grasses or fragments blown from far-away plants and caught by the eddying wind must roughly brush against the leaves, and in these cases inflexion of the tentacles would be useless. But it is of advantage that the pressure of the minute feet of a struggling insect on the glands should cause the tentacles on distant parts to move towards the place where the insect is. Drops of water falling upon the leaves produce no effect, and the importance of this negative result will be patent to those who remember the rainy nature of the districts where Sun-Dews most do congregate.

The excessive smallness of the solid particles that will cause inflexion is most remarkable. Thus, a particle weighing only $\frac{1}{78740}$ grain or ·000822 milligram caused inflexion. But, in connexion with this subject, perhaps the most remarkable thing is the indirect inflexion. That a tentacle whose own gland is touched should bend is strange enough. That tentacles remote from those actually touched should have transmitted to them through the tissues of the leaf some influence that causes them to bend and the glands on their summits to secrete more fluid and more acid fluid is yet more strange. The fact, to those who remember how in the animal kingdom nerves will transmit an influence to glands and modify the nature of their secretion, is of deepest significance.

(*b*) Aggregation of protoplasm. The cells of the tentacles are full of protoplasm. Before a touch has made impression on the glands the contents of the cells are a purple fluid, quite homogenous—that is, continuous and similar throughout and bounded by colorless protoplasm externally. This protoplasm, it will be observed, lies between the cell-wall and the homogenous purple fluid. *After* contact of a solid body the purple matter is found no longer continuous but broken up into variously-shaped masses that are suspended in a colorless fluid. Once again the smallness of the particles causing this change is notable. Absorption by a gland of $\frac{1}{134400}$ grain or ·000482 milligram causes aggregation of the protoplasm in the cells of the tentacles.

The process is not the result of the inbending of the tentacles. It precedes this movement. If the glands of the tentacles on the centre of the leaf are touched they send influence to the glands on the marginal tentacles, and these in turn send influence down their supporting stalks, for the aggregation works from above downwards. Again the student of animal physiology is impressed with the remarkable suggestion involved herein. When a nerve-ending in the hand is impressed, and the impression is transmitted up the nerve to the brain so that we feel, our belief is that some actual change occurs in the very structure of the nerve as the transmission takes place. Here in the Sun-Dew we actually *see* a change of structure take place under our very eyes as influence that it is almost impossible not to call nervous is transmitted.

(*c*) The effect of heat. Heat, light, electricity, magnetism, life seem all to be but modes of vibration of particles of matter almost inconceivably minute. As investigation proceeds the connexion between all these forms of movement of minute atoms grows constantly more evident to us. We are yet but in the infancy of our knowledge of this subject. What we do know is nevertheless full of deepest interest. Notice the curious gradation of effects of rising temperature upon our Sun-Dew leaves. (i.) With a temperature between 48° and 51° C. there is quick inflexion and the leaf survives. (ii.) With a temperature about 54° there is no inflexion but the leaf survives. (iii.) With a temperature of 65° the leaf is not inflected and dies.

(*d*) Action of various fluids upon the leaves. (i.) Organic fluids. Fluids taken from the animal and vegetable kingdoms are roughly divided into those containing only carbon, hydrogen, oxygen (non-nitrogenous), and those containing carbon, hydrogen, oxygen and nitrogen (nitrogenous). The former have no effect upon the leaves of Drosera : the latter invariably cause inflexion. The little plant seems to be able to tell with unfailing accuracy whether nitrogen be present or not in a fluid that is submitted to it. Here is a remarkable test as to the presence or absence of nitrogen in organic fluids that hitherto has not been known to fail. (ii.) Salts of ammonium. Ammonia is a compound containing three atoms of hydrogen and one atom of nitrogen. Dissolved in water and then combined with acids ammonia gives rise to a series of salts called ammonium salts. These all, of course, contain nitrogen. Solutions of these salts were found by Charles Darwin to affect the leaves, causing both inflexion of the tentacles and aggregation of the protoplasm in their cells. They do not effect these changes, however, if their solutions are taken in after the ordinary fashion by the roots. Ammonium carbonate causes a certain amount of inflexion, ammonium nitrate causes more, ammonium phosphate most. This succession is not without interest. Nitrogen and phosphorus are especially animal elements, far more largely present in animal structures than in vegetable. As the quantities of these increase in the salts under consideration the effect of solutions of the salts upon the Sun-Dew increases also. Thus, ammonium carbonate contains $29\frac{1}{6}$ parts by weight of nitrogen in 100 parts of the salt, ammonium nitrate contains 35 in 100, ammonium phosphate $28\frac{28}{149}$ of nitrogen and $20\frac{120}{149}$ of phosphorus in 100. Of this last salt $\frac{1}{200000000}$ grain absorbed by a gland of Drosera causes some impulse to be sent down the whole length of the supporting tentacle, an impulse resulting in the bending of the tentacle through an angle of more than 180°. (iii.) Salts generally. The outcome of many experiments is that the nature of the metal in the salt is of much more importance than the nature of the acid, and in this result there is once more affinity with animals. Again, salts of sodium cause inflexion and the plant lives. Salts of potassium kill the Sun-Dew. Sodium salts can be introduced in small quantities into the blood of animals without any ill result following. Potassium salts are fatal. (iv.) Poisons. Under the action of strychnine and nicotine, poisons fatal to animals because of their effect on the nervous system, Drosera dies. But under the action of morphia, belladonna, alcohol, curare, poisons fatal to animals because of their effect on the nervous system, Drosera does not die. As to these last, however, the observation may be made that they act on motor-nerves—*i.e.*, on nerves that supply muscles, and it is difficult at present to conceive of the Sun-Dew as possessing representatives of these.

(*e*) The digestive power of Drosera. Drosera, or the Sun-Dew, has remarkable power of recognising, under any disguise the presence of the element nitrogen in most compounds submitted to its action. The results of certain other of the experiments of Charles Darwin confirming this view may with advantage be given here. (i.) Action on food stuffs. Of substances producing no effect upon the plant when they were submitted to the action of its leaves were gum arabic, sugar, starch, dilute alcohol, olive oil, tea. The chemical composition of the first four of these is as follows :

Gum Arabic...	$C^6 H^{10} O^5$
Sugar	$C^{12} H^{22} O^{11}$
Alcohol...	$C^2 H^6 O$
Olive Oil	$(C^3 H^5)^2 (C^{18} H^{32} O)^3 O^3$

i.e., gum consists of 6 atoms of carbon, 10 of hydrogen, 5 of oxygen, and so on. The action of tea, or rather its non-action, is somewhat remarkable. For tea, as a plant, contains albuminous matter, and that contains nitrogen. Possibly in the drying of the leaves of the tea plant the albuminous matter they may have contained is rendered insoluble. But this is not a sufficient explanation, as when the alkaloid principle of tea, called theine, is applied to the leaves, still no result follows. The formula of theine is $C^8 H^{10} N^4 O^2$. It contains nitrogen, but does not cause the tentacles to inflect.

Of substances producing effect upon the plant when they were submitted to the action of its leaves were milk, urine, albumen, infusion of raw meat, mucus from the throat, saliva, isinglass. Milk contains casein, whose composition is C. 53·8, H.7, N. 15·8, O. 22·4, S. 1 per cent. Urine contains uric acid, $C^5 H^4 N^4 O^3$, and also salts of ammonium. Albumen has composition, C. 53·8, H. 7, N. 15·5, O. 22·5, S. 1·2. Meat contains large quantities of albuminoids. The action of mucus seems due to the admixture of albuminous matter from the food, or of saliva. Isinglass is the substance of the swim-bladder or rudimentary lung of the sturgeon, and is rich in nitrogen.

(ii.) Secretion. The digestive power of the secretion next comes under consideration. That the leaves of the Sun-Dew absorb was very early rendered beyond doubt. The next inquiry was as to whether they did something more than absorb. Were they capable not only of absorbing, but of digesting? Digestion implies the preparation of food for tissue-forming, and this preparation involves at least the rendering of that food soluble. The result of many laborious and carefully recorded experiments is the important generalisation that the digestive action of Drosera is as nearly as possible identical with that of the fluid poured into the stomach of the higher animals. That digestive fluid of the higher animals, known as gastric juice, had for much time been regarded as specially "vital" in its working, and men were not wanting who were ready to declare that nothing in imitation of its action or of any other "vital" action could ever be effected by man. But man has not merely imitated, but performed not a few actions that were once called "vital" in his laboratory, and amongst others this function of digestion can be performed—artificially, but thoroughly—in the laboratory to-day. All this is good news to the evolutionist and to him that believes in man's advancing power, and this good news is strengthened yet again by the announcement that by Drosera, by a little marsh plant not very high in the scale of plants, a function nearly identical with that of the digestion of animals is performed.

For those who have made no special study of the physiology of animals it may be stated that in the gastric juice of the higher animals two principal things are present. One is a ferment called pepsin. This, like ferments generally, is organic, nitrogenous, able, existing in small quantity, to work change in much substance of the body to be acted upon. With this pepsin is associated an acid, very generally hydrochloric acid (H Cl). In the secretion of the leaves of the Sun-Dew a ferment is present. With this ferment is associated an acid, apparently one of that great series of fat acids, of which formic acid, once obtained from the *Formica* or ant, and acetic acid or vinegar, are the first two members. Just as the introduction of an alkali, such as potash, soda, or ammonia, into the acid gastric juice of the stomach of a higher animal, causing neutralisation of the acid, stops the action of the gastric juice upon the food materials, so the introduction of an alkali, such as potash, soda, or ammonia, into the acid secretion of the Drosera, causing neutralisation of the acid, stops the action of the secretion of the leaves upon the food materials.

(iii.) Comparison with animals. To trace out yet further the striking analogy or likeness of function obtaining between the Drosera fluid and that of the stomach of man, let us see what substances are digested by both fluids under favorable conditions, what substances are not affected by them. (*a*) Those acted upon by the secretion formed by the glands of the Sun-Dew leaves and by the gastric juice of animals. They are albumen or the white of egg, cubes whereof very soon after their immersion in the leaf-fluid had their angles and edges gradually rounded off (this rounding off of edges and points is highly characteristic of the action of gastric juice upon albumen): meat after it had been cooked; fibrin or the material of the clot of blood, slow in its action because from some cause it fails to excite other glands remote from the place of contact, and therefore does not cause so much inflexion nor secretion; syntonin or muscle-fibrin, very rapid in its action; areolar or connective tissue, quickly digested but not causing excitement of the leaves to any great extent; cartilage, fibro-cartilage, bone, in acting whereon the acid secretion first attacks the salts and especially the calcium phosphate of bone, and does not make digestive inroads upon the more animal part of bone until the mineral is no longer attacked; gelatin slowly attacked, as it is by animals, ordinary casein, not affected to any great extent, that casein which is artificially prepared, much affected; in this double action upon the natural and artificial casein resembling once again the gastric juice of man. Gluten prepared from wheat does not, nitrogenous and nutritious as it is, submit to the action of the secretion formed by the leaves of the Drosera, but as it is a very powerful substance it is at least possible that it is strong enough to poison the leaf and prevent any action at all.

(β) In its negative action, as to digestion, upon various substances the fluid formed upon this remarkable leaf again strikingly resembles that fluid secreted by the stomach. Human nails and hair, bird's feathers, all epidermic in their origin, fibro-elastic tissue, mucin from mucous membranes, pepsin the ferment itself, urea ($C\ H^4\ N^2\ O$) a refuse product of animal decay, chitin the hard part of the coats of insects, cellulose or the material constituting the wall of the vegetable cell, chlorophyll or the green color matter of plants, fats, oils, and starch are not affected by the fluid secreted by the leaves of Drosera. But also none of these is acted upon by gastric juice. Negatively, therefore, as well as positively, is likeness in function or analogy between these two fluids established; the one fluid formed by the tiny glands on the tiny tentacles on the leaves of a tiny plant, the other formed by the peptic glands in the walls of the stomach of a man.

(f) The Sensitiveness of the Leaves and the direction of transmission of motor impulse. (i.) The sensitive part. Many experiments establish the fact that only the glands and the very summits of the tentacles are sensitive, and that the amount of excitement undergone by the leaves depends upon the nature and the quantity of the substance applied, the number of times it is made to touch the leaf, the number of glands touched. (ii.) Transmission of impulse. In every case when a gland on the top of a tentacle is touched, a moving impulse must travel thence to the basal part of the tentacle and cause inflexion of that basal region, and this journey of the motor impulse down the tentacle is performed at velocity much greater than that at which the impulse travels from tentacle to tentacle across the leaf. When that impulse has reached the point of junction of a central

tentacle and the leaf-blade, it spreads centrifugally in every direction and the nearest tentacles bend first. But when the tentacle earliest affected is marginal though that tentacle bends first, it is not until after its bending has carried its gland, food-laden, into contact with a central gland that the marginal tentacles close to the first are affected. They seem to depend for their movement upon impulse radiated from the central tentacles after these last have been stimulated by contact with the gland first affected. The transmission of this strange influence across the blade of the leaf is much slower than its transmission lengthways, a fact to be borne in mind anon. The action is not reflex. There does not appear to be in any case, as far as transmission of motor impulse is concerned, the flow in one direction and then the flow in another direction more or less opposed to the former that is always implied in reflex action. The impulse to movement passes directly from tentacle to tentacle. But in the succession of aggregation of protoplasm in individual cells before referred to, there is a curious imitation of or identity with reflex action in animals. A gland of the centre is stimulated. Its cells show aggregation of their protoplasmic contents from above downwards. From the tentacle whereof these cells consist impulse moves outwards to other tentacles. These contract at their bases as soon as the stimulus reaches them. But the aggregation of the protoplasm in the cells of these distant tentacles begins in the upper cells, not in the lower. The stimulus, influence, what you will, travels from the first tentacle athwart the leaf to the base of another tentacle, ascends that and then is reflected downwards, causing aggregation of the protoplasm of individual cells from above downwards. (iii.) The tissue that transmits. Three tissues present themselves in the Sun-Dew leaf: the fundamental or cellular, the fibro-vascular or the veins, the epidermal on the exterior. After many minutely laborious experiments Charles Darwin has demonstrated that the first of these three is the real transmitter of motor impulse. This fact explains two or three others. It explains the pause in the process of aggregation of protoplasm in successive cells. The delay appears to be due to the stoppage of the transmission of influence by the intervening cell-walls. It explains the more rapid transmission down the tentacles as compared with the transmission across the blade, for in the former the cells are longer than elsewhere, and there is a sort of confinement of the influence within the tentacle for a time. It explains the more rapid transmission along the tentacle than athwart the leaf, as the cells of the fundamental tissue are four times as long as broad. It explains the incurving of the tentacles, as the cells of the leaf-blade converge towards the tentacle base, and transmitting accumulated influence thither, cause inbending. The strange history of the Sun-Dew has been told. Its fellows equally remarkable will be studied next.

CHAPTER XIV.

(3.) *Venus' Fly-trap and its allies.*

a. *DIONŒA MUSCIPULA.* In the eastern region of North Carolina lives the Venus' fly trap, whose scientific name is *Dionœa muscipula.* i. Structure. The interest of this plant to us centres in its leaves. The petiole or leaf-stalk is leaflike. The blade has its right and left halves not in the same plane, but making one with the other an angle of rather less than 90°. The leaf bears the following structures: filaments, spikes, glands, octofids, hairs.

(*a*) *The filaments.*—These are six in number, three on the upper face of each half of the leaf-blade. They are exceedingly sensitive, and the slightest touch upon any one of them is followed by a sudden clapping together of the two parts of the leaf so that the two halves of the upper face thereof are brought into contact. Near the base of the filament is a joint, so that when this closure of the two halves of the lamina occurs the six filaments are bent down flat, parallel to the surface of the leaf-blade and are not broken. The filaments of the Fly-trap support no glands, form no secretion. They are exceedingly sensitive, a touch upon them causing the instantaneous closure of the leaf. And yet if drops of water are allowed to fall upon the filaments no movement takes place. This negative response to the action of water must be of value to a plant living in a rainy district and subject, therefore, to frequent percussion of falling rain-drops. It is a distinct advantage to such a plant not to close every moment upon drops of non-nutritious water. Further, if the touch upon these sensitive filaments is due to bodies of such nature as wandering grass-blades, wind-borne fragments of no nutrient value, the leaves open again almost as soon as they have closed. This also must be of value as such "accidental" contact of useless particles must often occur in its American home, and the more rapidly the leaf re-opens the more rapidly will it be ready to receive, capture, and digest more food-yielding substances. On the other hand if the body striking upon the waiting filament be nitrogenous and nitrogen-yielding the leaves remain closed for many days.

(β) *The spikes.*—These are arranged on the leaf-margin and in such fashion that when the leaf-blade closes upon itself the spikes of its two moieties interlock. But when the leaf first closes its two parts are not in close contact. There is room therefore between its two parts for movements of the captured insect, and the spikes are not yet closely interlocked. Small insects can escape through the elongated spaces between the spikes. But as the halves of the leaf come more closely together, these interspaces diminish in size and eventually become closed. A large insect once caught can never escape. A small insect does escape, and the leaf, opening again, waits for his larger fellow. This also is of advantage, as it is better for the plant to bide its time until a moderately-sized insect is caught, and to allow the smaller fry to escape ere it goes to the trouble of secreting a digestive fluid.

(γ) *Glands.*—On the upper surface, *i.e.* the same as that whereon the sensitive filaments stand, are many reddish glands. These do not habitually secret fluid, but when nitrogenous bodies come into contact with them, secretion sets in and absorption follows.

(δ) *Octofids.*—These are tiny projections consisting of eight spreading arms of red or orange color scattered over the petiole and the under service of the lamina. They are probably homologous with the papillæ on the leaves of Drosera.

(ϵ) *Hairs.*—Minute, simple, pointed hairs upon the under surface of the leaf.

(ii.) Action. Let us now consider the action of all these parts. Imagine the leaf of the Venus' fly-trap as the plant grows in its Carolina home. Leafy petiole, broad lamina with its two parts nearly at right angles one with the other, each part bearing its three sensitive filaments, the leaf margins provided with long rigid spikes, the leaf surfaces studded with purple glands. An insect alights upon the leaf and touches one of the six filaments. Instantly, with no long delay as in Drosera, the two halves of the leaf-blade close in towards each other. The spikes on the margins interlock. The insect if small escapes. But the larger insect struggles as the walls of its prison close in upon it. Its struggles stimulate the glands. They secrete their digestive fluid. The insect is crushed and soaked to death. Between the closely apposed halves of the leaf the imprisoned being dies and is digested and absorbed. Later the leaf slowly opens: the insect is gone, and with outspread tentacles its devourer awaits once more its prey. If the leaf has closed simply because a filament has been touched, say by the finger, or if the enclosed object contains no nitrogen, or if containing nitrogen, the object is dry and not damp, though the leaf-lobes close in towards each other, they do not gradually press themselves into close contact all over their surface as they do when they have seized an edible body.

As in the Sun-Dew, the strange impulse that causes in the Dionœa such sudden results is transmitted through the cellular tissue, not by way of fibres or vessels. The fact is rendered especially clear in the plant under consideration by the demonstration of the fact that no fibres or vessels enter the sensitive filaments at all.

b. Aldrovanda vesiculosa, a native of Germany and of Australia. It would seem to be a minute Venus' fly-trap, whose habitat is water. In water it floats rootless. Its curious leaves stand in the midst of certain rigid protective projections. The two halves of its leaf-blade are more closely approximated than are those of Dionœa, and thus the capture of aquatic insects is rendered more easy. The structures upon the leaf of Aldrovanda are very similar to those upon the leaf of Dionœa. They are hairs, points, glands, quadrifids. (i.) *The hairs.* These represent the filaments of the fly-trap. They are on the upper surface of the leaf, are many, long, pointed. They have two articulations, not one as in Dionœa, and thus are not broken when the two halves of the leaf close together, despite their length. (ii.) *Points.* These are upon the margins of the leaf. As the margin of the leaf is infolded the free ends of these points are turned towards the mid-rib of the leaf. They seem at first sight to prevent the escape of prey, but this function is not theirs. It seems rather that these marginal points absorb decaying organic matter. We have seen already in these insect-eating plants forms that catch, kill, and devour living creatures, and in Aldrovanda itself we shall see the same series of actions. But we shall also encounter later on plants that do not kill and then digest insects, but that commence their operations upon dead and decaying organic matter. Aldrovanda is a link between the Sun-Dew on the one hand and these last upon the other. By part of its leaves Aldrovanda catches, kills, digests: by another part it absorbs the decaying materials yielded by dead organic bodies. And this other part is the point-bearing margin. These points, therefore, have little or nothing in common with the spikes of Dionœa, save their position on the leaf-margin. (iii.) *Glands.* On the upper surface of the leaf, near the mid-rib, are many colorless glands that appear to secrete a digestive fluid after contact with organic bodies. In this again is resemblance to Dionœa rather than to Drosera. (iv.) *Quadrifids.* On the upper surface of the leaf nearer the margin are prominences carrying four radiating processes. These represent the octofids of Dionœa. Their function is that of the points upon the margin. They absorb matter already in a state of decay.

c. Drosophyllum Lusitanicum. A Portuguese plant, with tentacles and sessile or non-stalked glands. (i.) *The tentacles.* These, mushroom-shaped, have no power of movement or of causing movement. The secretion of the glands they bear is acid even before the glands are excited by contact of living matter. (ii.) *The sessile glands.* These do not secrete spontaneously. They only secrete when upon them is placed nitrogenous organic matter. They will absorb such nitrogenous matter with sufficient rapidity. The action appears to be thus. An insect attracted by the glistening secretion on the stalked glands flies to the plant. It is caught by the viscid fluid of the glands touched and of other adjacent glands. It becomes hopelessly entangled, and with clogged wings and legs sinks deeper and deeper down into a morass of viscidity. Thus it reaches the sessile glands. They secrete digesting fluid, and the dead insect is digested and absorbed.

d. Roridula, a Cape of Good Hope plant, resembles the last, but has no sessile glands, and as the upper surface of the leaf is studded with many sharp, erect hairs, this is not unnatural.

e. Byblis, of Western Australia, like Drosophyllum, has sessile as well as stalked glands.

CHAPTER XV

(4.) *The Butterwort and Bladderwort.*

WE have, under the guidance of Charles Darwin, studied the action of the Sun-Dew with its sticky glands raised on stalks and its power of bringing many glands to bear upon the captured insect: the Venus' fly-trap with its sensitive filaments and sudden close upon an intruding animal: the allies of these with the lengthy names and habits akin to those of the Drosera and Dionœa. A quartette of remarkable plants, differing from all these in their food relations, remain for consideration. *a. Pinguicula.* There is a minute plant to be found in the Highlands, in wet, boggy places, during the months of May and July. Its common name is the butterwort. Its technical name is Pinguicula. Upon the leaves of this plant are many hairs that are constantly forming a viscid, colorless fluid. These hairs are not sensitive in the same sense as are the filaments of the Fly-trap, and, indeed, the plant is not adapted for catching living insects. These may, apparently, touch the leaves with entire impunity. But dead bodies of animal nature and nitrogenous matters generally appear to act as follows. Contact with them causes an increased amount of secretion on the part of the glandular hairs. The secretion at the same time becomes acid. The margins of the leaves, always somewhat incurved towards the mid-rib upon the front face, when under the stimulus of contact with dead animal matter, move further and further in towards the mid-rib, pushing before and beneath them the exciting substance. Thus is the latter brought into contact with more and more of the glandular hairs, and these under the stimulus pour out more and more of their secretion. This in its turn digests the animal matter exposed to its action after the same fashion as does the Sun-Dew. Pinguicula, therefore, digests dead animal matter. It does not catch and kill and then digest. Nor can it be fairly urged that of such dead animal matter, the supply would be too small to be of value. Insect life is so frequent in the districts where Pinguicula dwells that insect death must be very rife. The gusts of wind must carry multitudes of fragments of dead matter in all directions, and there is much likelihood of some such fragments being borne into contact with the viscid leaves of the butterwort.

b. Utricularia. To the same natural order as Pinguicula belongs the Utricularia, the bladderwort. One species of this strange genus is aquatic, another is in the main subterranean. The aquatic form floats freely, rootless in the water of pools and ditches in Scotland and Ireland. Its leaves carry little bladders about 1-8th to 1-4th of an inch in diameter. Each leaf bears two or three bladders. These organs are full of water. Entrance into the bladder is effected through an opening at one part guarded by a valve or sort of trap-door opening inwards and sloping into the cavity. The entrance is further guarded by bristles that only allow of the passage inwards of animals not too large for the plant to deal with. Lining the interior of the bladder are many quadrifid processes. Nothing in this plant seems to be sensitive. No part shows the power of movement so remarkable in the Sun-dew and Fly-trap. It would appear that small water animals make their way into the bladder by passing between the guard bristles and forcing open the sloping valve that opens inwards. Once within the cavity exit is impossible. The valve closes again and as it opens inwards there is no escape. The imprisoned animal swims about freely for some little time within the bladder, but ere long it dies. There is no evidence of any fatal influence of the plant upon its prey. The prisoner appears to die of starvation rather than by any more positive death. There is also no evidence of any actual digestion. A true digestive fluid does not appear to be secreted. The Utricularia, like Pinguicula its ally, absorbs the decaying animal matter and makes this part of itself. The absorption is effected by the quadrifids, whose protoplasm, like that of the hairs of Pinguicula, shows after absorption the same kind of aggregation noticeable in the Sun-Dew.

c. Polypompholyx and *Genlisea.* A plant named Polypompholyx is almost identical in structure and in action with the bladderwort, and a Brazilian plant known as Genlisea ends this remarkable series of vegetable structures. In Genlisea the bladders have a very long neck, the external opening of which is provided with sharp hairs pointing downwards. These allow a small animal to pass inwards and down towards the bladder far below, but they very effectually prevent its return.

CHAPTER XVI.

(5.) *Evolution of Insect Eating Plants.*

AND now, in conclusion, after this our study of the insect-eating plants, the evolutionist is fain to ask what possibilities seem to be of the evolution of such remarkable plants as Drosera or Dionœa. They are so remarkable in their action that the temptation would be strong for a lazy thinker to say, "Oh, these have not been evolved from others. They are special creations." In truth their behavior is in many respects so widely different from that of ordinary vegetables that it does seem difficult to conceive of the possibility of their evolution from other plants. But a little patience, a little listening to the Master's voice and the difficulty is not so great.

The special peculiarities that render these organisms so distinct from other members of the same kingdom are—(*a*) sensitiveness, (*b*) movement, (*c*) aggregation of protoplasm, (*d*) digestive and absorptive power.

(a) Sensitiveness.—This property of susceptibility to stimuli is not confined to these plants. The closing of leaves and flower-leaves in the dark, their expansion under the sunlight, indicate sensitiveness. Still better illustration in this connexion is the Mimosa or Sensitive plant, for it responds to the mechanical stimulus of a touch, as the sensitive filaments of the Venus' fly-trap respond.

(b) Movement.—The examples given above are also illustrations of the motile power possessed by certain parts of certain plants. But the examples known to-day of movements in plants might be multiplied almost indefinitely. Both the kinds of motion encountered in the insectivorous plants are seen in other organisms, for the slow movement of the leaves of the Sensitive plant parallels the gradual incurving of the "tentacles" of the Sun-Dew, and the spring inwards of the stamen of the Berberry when its base is

touched, is as sudden as the leaf-closure of the Fly-trap. Further, it is to be noticed that these movements of plants and parts of plants are due to one kind of tissue only. That tissue is the fundamental or cellular tissue. Wherever motion takes places it is referable to contraction of cellular tissue. Fibres and vessels take no part in the work. The movements of the Drosera and of Dionœa are dependent upon the same cellular tissue.

(c) Aggregation of Protoplasm.—Certain plants that carry glandular hairs upon their stems and leaves appear to absorb animal matter that may be entangled in the viscid fluid secreted by the hairs. Some at least of these plants show in the cells of the hairs aggregation of protoplasm. Thus the Saxifrages, best known to the non-botanical reader through the medium of the "London Pride," the Primula, the Scarlet Geranium or Pelargonium, the Heaths, the Marvel of Peru, the Tobacco plant, all have glandular hairs. Of these the Saxifrages, Primula, Pelargonium all rapidly absorb animal matter, and the protoplasm in the cells of the hairs undergoes aggregation. The Saxifrages, which show this process best of all, are allied in structure to the Sun-Dew.

(d) Absorptive and Digestive Power.—Of the capacity for absorbing animal matter as resident in some degree in plants other than the insectivorous, mention has just been made. Whether outside those dealt with in the book now slipping from our hands plants occur able to secrete a digestive fluid is at present open to question. That many plants do secrete fluid, and a fluid in some cases of acid nature, is assured. But whether any such fluid has the power of actual digestion of organic matter is as yet doubtful. It must however be noted that all the plants we have recently studied have not the full digestive ability. In truth the gradations are gradual enough to satisfy the evolutionist's mind at least in some measure. Commencing with the absorbent, glandular hairs of Saxifraga, and the retention of dead matter by the viscid glands of Pinguicula, he observes next the capture of unwary insects in the pitchers of the pitcher plants of the East Indian and Chinese swamps, their decay and absorption. He passes then to the mechanical seizure of the like animals in the bladders of Utricularia. In all these cases he sees absorption of decaying organic matter, no killing,

and probably no true digestion. But studying Aldrovanda, he meets therein with one part of the leaf devoted to the absorption of decaying organic matter and another to the capture and the killing and the digestion of living beings. Again, in Byblis, Roridula, Drosophyllum, the power of seizing and killing and digesting alone appears. The earlier cruder form of work is gone. And through these he passes up to the final and most specialised stages of all, where the Sun-Dew with its viscid shining glands entangles, slowly seizes, and digests the insect, or the Fly-trap on a touch of its sensitive filaments closes suddenly upon its prey.

D.—On the various contrivances by which British and Foreign Orchids are Fertilised by Insects.

CHAPTER XVII.

(1.) *Structure of an English Orchid.*

THIS work, the third of those to be considered among the publications on the Vegetable Kingdom by Charles Darwin, will for the future be denoted by the briefer title, "Fertilisation of Orchids." To its consideration we now pass. One object of the book is sufficiently indicated by its title. There is design to show the varying method and complex machinery whereby the many Orchids of Great Britain and of the tropical regions are fertilised. But a yet more important object is in view. There is design to show that these methods and this machinery are of such nature that the fertilisation of the ovules of any given flower by the pollen of the same flower is very rare, and that, therefore, as a rule, cross-fertilisation occurs. It will be remembered even by the non-botanical reader that in most flowers there is a female organ, the gynœcium, within whose swollen base (ovary or seed-case) are unripe seeds or ovules. These ovules can never become seeds unless they receive the influence of the pollen or yellow dust contained in the anthers or upper caps of the male organs or stamens. This pollen is carried to the stigma or receptive part of the female structure either by the wind or by insects. Many flowers have the pollen carried to their stigmas by the wind. The grasses or plaintains, for example, with their humble, dingily colored, unscented flowers, destitute of nectar, are not attractive to insects. But their clouds of yellow pollen lodged in anthers borne loosely on the top of long, weak, swaying filaments, and their hairy stigmas, fit them to be fertilised through the agency of the wind. Such plants as these are known as anemophilous or "wind-loving" plants.

On the other hand, many flowers have the pollen carried to their stigmas by insects. The roses or the violets, for example, with their gay, brightly colored, sweetly scented, flowers, nectar-laden, are attractive to insects. Such plants as these are known as "entomophilous," or "insect loving" plants.

Nobody who has seen an Orchid could ever be in doubt as to whether it were an anemophilous or an entomophilous plant. The book under discussion not only demonstrates this fact, but records all the minute and multitudinous adaptations to one end that are encountered in the large number of strange plants that constitute the order Orchidaceæ. Many of the facts known in relation to these plants were not originally discovered by Darwin. These he records together with his own innumerable and incomparable observations, and gives us as result a book, whereof it is inadequate praise to say that it is far more interesting than any novel.

Following the plan of the author, we will study the British Orchids first, and later some of the wonders of their tropical brethren. These notes, like the book itself, will be more intelligible to those who have seen, and far more intelligible to those who have dissected, the flowers to be studied than to the ordinary reader. Yet all will be quite able to follow the account and understand the mechanism of the Orchid who will patiently strive to master the details that follow.

The flowers best known to ordinary observers present outside the male and female organs two circles of protective leaves. The outer of these is the generally green calyx or cup, of sepals. The inner is the generally brightly colored corolla, of petals. Within these are the stamens constituting the male circle or andrœcium, and within these again, in the very heart of the flower, is the gynœcium or circle of female organs. The single female organ is called a carpel. And here may be remarked with great diffidence, as illustration of the height to which looseness of phraseology may reach, that even in "The Fertilisation of Orchids" there occurs confusion more than once between the terms gynœcium (or pistil) and carpels. It is as if a man confused the conduct and nature of a regiment with the nature and conduct of its individual soldiers. The account above given of the arrangement of parts in an ordinary flower, as a rose, will not exactly serve in the description of an Orchid. Let us study together an ordinary British member of the remarkable family, such as the Spotted Orchis that makes gay the face of Sussex Downs and the summits of many a sea-cliff in the south. From a curiously swollen root rises an erect, smooth, stem. On this are several smooth, parallel-veined, spotted leaves, and the summit is crowned with a nearly pyramidal head of many purple flowers. Carefully remove one of the flowers and hold it in the same position as that assumed by it when upon the stem. Apparently, it has a greenish, twisted stalk. Cut horizontally across this supposed stalk. It is full of ovules. This greenish, twisted part is no flower-stalk therefore. It is the lowermost part of the gynœcium. It is the ovary or seed-case. Observe now the structures placed upon the top of this ovary. Arranged in a sort of double circle upon its summit are six purple leaves. These represent the sepals and petals. Their color in itself would be for a lure to insects, but one of them is of such fantastic shape and huge size that it could hardly fail to attract the attention of an insect of the most unobservant nature. This notable leaf is, as you hold the flower now, on the side of the flower nearer to you. But we saw that the greenish ovary was twisted, and a little careful looking at young and old flowers teaches that in the early state this strange leaf is on the upper side of the flower, and that it only comes to be on the lower side through the twisting of the ovary. This odd leaf has received a special name, and considering upon what very small provocation structures are labelled with polysyllabic titles by scientific men, one can hardly wonder at this strange Orchid flower-leaf having a special designation. For, in the first place, it is so much larger than its fellows. Then it has a long spur running down from it, nearly parallel to the twisted ovary. This spur you may be sure contains honey for the visiting insect, and this spur we may call the nectary. Yet, again, the large leaf or labellum is partially lobed or roughly divided into three at its upper part, and this broad, three-lobed region looks a very likely landing-stage for an insect. Nay, in many more complex orchids than the spotted one, this labellum is much more modified, and assumes the very queerest shapes. When you hear in the future of bee, or spider, or fly, or butterfly, or man orchis you may remember that the names of all these are founded upon the odd shapes assumed by their labella.

Now holding the Orchid with its labellum turned towards you, look to the opposite side of the flower within the other flower-leaves. That is, you are to look across the wide three-lobed table-land of the labellum, across the open mouth, that is the opening of the nectary. If the nectary or spur were a precipice, upon your side of the precipice is the table-land of the labellum, and on the other side of the precipice are the structures I wish now to mention. First two shiny, sticky spaces. These are, as it were, on the remote wall of the precipice, not on the very summit. Second, a little shelf projecting out over the opening into the abyss like a ledge, and right in the way of anybody or of anything that might try to pass down into the nectary. Third, towering up from this ledge a large deep-purple two-lobed structure that is the anther, and behind that the flower leaves again. The shiny, sticky spaces you will see are at the top of the twisted ovary and are the stigma. *The pollen will have to be placed upon this ere the ovules in the ovary below will become ripe.* The little shelf or ledge is of the utmost importance. It is really a part of the stigma much altered, and is called the rostellum or little beak. It not only projects over the opening into the nectary, but covers also the base of the purple anther. The anther with its two purple lobes is the last of this strange series of structures. The orchid has only one stamen. If the flower is not very young each of the two purple lobes of the anther will be found to split open along a vertical line all down its front face. Try to find out what may be concealed within those purple anther lobes. The best way to do that is to press the fine point of a pencil against the rostellum, to hold it steadily there, and to wait patiently about twenty seconds. Then draw away the pencil slowly, and if your hand was steady the pencil will be adorned with two curious bodies that you have drawn out of the anther lobes, and that are pollen-masses. Each of them is broad above, where there are many packets of pollen-grains held together by little threads. In the middle part the grains are wanting, and only a thin stalk made of the threads is present. This stalk is the caudicle or little tail. Finally, at the very base is some sticky body, or how could the whole pollinium adhere to your pencil? It may seem strange that these two pollinia were removed by means of pressing the pencil point against the rostellum. But it was noted above that this same rostellum covered the base of the anther, and the pencil rested against and really displaced it and got at the sticky bases of the pollen-masses or pollinia inside the anther lobes. *These pollen-masses must be removed, and their upper portions rich in grains brought into contact with the stigma ere the ovules can be fertilised.*

Even if you have never studied or even perhaps seen an Orchid, you may now be able to picture it to yourself in some degree. You can imagine the smooth, erect stem with the smooth parallel-veined leaves and the crown of purple flowers. You can imagine the flowers very attractive and irregular with the large, lobed, spurred labellum, the one anther with its two purple lobes, each harboring a pollinium. You can picture the pollinium with its broad upper end of packets of pollen grains, its narrow caudicle, its sticky base. There also is the rostellum covering those viscid bases and partly blocking up the entrance into the nectary, and on either side of the rostellum the viscid stigmatic surface, crowning the twisted ovary.

The working of all this complex mechanism will form our next object of study.

CHAPTER XVIII.

(2.) *Action of Parts.*

AS we study the action of the parts of the Orchid flower described in the last chapter, two things especially are to be kept in mind. Of these, one is that Charles Darwin desires to show that Orchids are entomophilous, or are aided by insects in the fertilisation of their flowers. The other is that cross-fertilisation occurs—*i.e.*, the pollen of a given flower is not placed upon the stigma of the same flower but upon that of another of the same kind.

The Orchids attract insects. The particular one selected as type attracts them by its color, its odd shape, and its nectar. Others of its fellows serve as yet more attractive lures to insects; their strangely-shaped labella assuming the very forms of insect life. Yet others of the order that open in the night rather than in the day have a powerful odor that must be as attractive to night-flying insects as are the colors and shapes of their brethren to the sunlight-haunting butterflies and bees. An insect allured to the Orchid flower lands upon the labellum or specially modified leaf on the lower side of the flower. He passes his proboscis down into the nectary or spur of the labellum, down the "precipice" of the former chapter. It will be remembered that from the wall of that "precipice" opposite to that upon whose summit the insect stands juts out a ledge, the rostellum. The head of the insect must strike against that ledge. The ledge is really a trap-door, with hinges below. It is free at the top, and on the right side, and on the left side. Only attached along its lower edge, this rostellum is depressed by the pressure of the insect head, and the head now rests against whatever may be behind that ledge. But behind the rostellum, as the "pencil experiment" showed, are the bases of the purple anther-lobes and the sticky glands of the pollen-masses. The head of the insect, therefore, rests now against these last. The sticky glands, when exposed to the air as they now are, "set." Liquid at first, contact with the air makes them turn solid and set like a cement. It will be observed that they are setting on the head of the insect. This process requires time, requires many seconds. And this required time is gained by means of a device whose discovery is due to our author entirely. If the honey of the Orchid were free in its spur, so that the proboscis of the insect at once dipped into it and drank it, he would fly away so soon that there would be no time for the sticky parts of the pollen-masses to "set." But Charles Darwin has shown that in the spotted Orchid, and in all its fellows whose glands require time to set, the honey is not free in the tube, but is lodged in the very thickness of the walls of the nectary. To get at its food-supply, therefore, the insect has to bore, perhaps more than once or twice, into the walls of the spur, and all this takes time. It is "pretty to see" that all Orchids whose sticky glands take time to set have the honey in the thickness of the walls of the nectary, and on the other hand that Orchids whose glands adhere at once to any touching body have the honey placed as it is in most flowers, *i.e.*, free in the cavity of the nectary.

Our insect, then, standing upon the broad part of the labellum, pushing down his proboscis into the spur, eating into the wall of that spur, is resting his head against the two sticky glands of the pollen-masses, and these glands are setting on his head. And now, his meal finished, he flies away, and just as your pencil, when withdrawn from the Orchid, carried with it the two pollen-masses, so does the insect head or proboscis carry away the two pollen-masses. The insect flies away bearing, as it were, two new pairs of antennæ. This is no romance. Any student who will watch a bed of Orchids in the flowering time will see them visited by insects, and if he will catch some of the insects after they have left the plants, he will find affixed to their proboscides pollinia. In the "Fertilisation of Orchids" is figured a moth with seven pairs of pollinia attached to it, and reference is made to another insect that was encumbered with no less than thirteen pairs.

Now, however, a difficulty presents itself. The two pollen-masses within their anther-lobes are parallel to each other. When they are removed from the anther-lobes and are affixed to the insect they are still parallel. Suppose our insect goes to another flower, stands again upon the labellum, seeks for nectar in the spur. As his head rests against the rostellum of this new flower, the two pollen-masses will strike against the anther-lobes, and not upon the stigma. They would be placed in exactly the same position as that whence they were removed. No fertilisation could occur.

Try the pencil experiment again. After the pollinia have been removed, watch them carefully. They do not remain in the position that was theirs at first. A slow movement, so slow that it is almost imperceptible, takes place. The broad ends of the pollen-masses, those that are made of packets of pollen-grains, begin to move outwards, downwards, forwards. This mysterious movement—not perceptible in its details, very perceptible and momentous in its results—is due to a tiny piece of membrane attached to the sticky gland, and, in truth, like that, a part of the rostellum. Now gather the full consequences of this movement outwards, downwards, forwards. Had the pollen-masses remained in their original positions, they would have struck against the anther-lobes again as the insect visited the second flower. Now, however, as the insect lands upon the labellum, investigates with his proboscis the interior of the nectary, cats into the walls, his head resting placidly against the new adhesive glands behind the depressed rostellum, the tops of the pollen-masses strike not against the anther-lobes, but against those structures lower and more away from the middle line of the flower, the stigmas. Thus, then, the pollen has been removed by an insect from the anther-lobes of one flower and borne by an insect to the stigma of another flower. This Orchid, at least, is entomophilous and is cross-fertilised.

One further minutia of arrangement. Suppose an insect juvenile, inexperienced, lands upon the labellum and investigates the interior of the nectary. Upon his proboscis, as he feeds, he feels the sticky glands setting. To the young the unusual is the terrific. The frightened insect quits feeding, and ere his repast is ended flies from the flower. He has not allowed the sticky glands sufficient time to set. He flies away pollinialess. The sticky glands of the pollen-masses have been exposed to the air and are setting uselessly? Not so. For the depressed rostellum, unlike most things when depressed, is elastic, and, springing into place again, keeps the glands of the pollen-masses from the air, and gives them the opportunity of retaining their moist condition The slimy stigma surface, moreover, is also viscid. Hence it detaches but a few pollen-grains from each pollen-mass, leaving the bulk of the grains still untouched and ready to fertilise the flower next visited.

And now, in all this exquisite adaptation of means to end, in this wondrous arrangement of atttractive flower leaves, of hidden nectar, of sticky bases of pollinia, of contractile pieces of membrane, of consequently moving pollen-masses, of elastic and depressable rostellum, and of viscid stigma, do we not see the marvellous power of nature and her no less marvellous patience ? To think that all this has slowly evolved—not magically and at a word sprung into being—has, during the course of many centuries, been developed piece by piece, taking time in its growth by the side whereof man's little life is but a moment, fills us with awe and with heartfelt longing to understand more of these regular successions of events that we name "laws." These laws, that have been at work before man or god existed, and shall endure when gods are no more, perhaps for longer time than even life itself—aye, they are worth the study.

The arrangement of parts and the working of parts just described hold true in the main, not only for the *Orchis maculata* or Spotted Orchis, but in four other species of the same genus, and also for the Man Orchis, which is placed, probably unwisely, in a separate genus. Only in the Man Orchis the two sticky glands of the pollen-masses are very close together and present an interesting gradation towards the condition met with in yet another Orchid where the two become one. And, at the risk of wearying the reader, reference must be made to another series of gradations in the stigma structure. In the Spotted Orchis this organ is single, but slightly lobed. In the *Orchis mascula* it is clearly bi-lobed. In *Orchis ustulata* it is nearly double, and in the last Orchid to be studied it is quite double. That last Orchid is the pyramidal Orchid.

In this plant the general arrangement is as in those already described, but the following points of difference obtain. The labellum has two ridges that serve as guides to the proboscis of the insect and insist upon its going straight down the nectary, turning neither to the right hand nor to the left. The two pollen-masses are united at the base in a sort of saddle-shaped structure whose *under* side is adhesive. This sticking to a proboscis, the saddle so contracts as to make the pollen-masses sweep outwards and downwards only. Then later on a second movement forwards takes place and the two masses are aptly placed to hit the stigmas As we said above, the stigma is double.

The arrangements met with in the curiously modified fly, spider, bee, and frog orchids will next claim our attention.

CHAPTER XIX.

(3.) *Other British Orchids.*

IN the British orchids that are next to be studied we have to do with members of a genus other than that last considered. The genus now to be considered is the genus Ophrys. It must be quite understood that the plants to be described are of the order Orchidaceæ, and come under the general name of Orchids, but they belong botanically to a group different from that known as the genus Orchis. That group is the genus Ophrys.

All members of the genus Ophrys have two separate rostella. No longer have the anther-lobes one common trap-door covering their bases. Each anther-lobe with its included sticky gland forming the lowest point of the pollinium, has its own covering. A double ledge, therefore, projects out over the opening leading to the nectary.

(*a*) *Fly Orchis (Ophrys muscifera).*—This plant with its strange resemblance to the insect whose name it bears, has no nectary and apparently no nectar. Still its shape must be attractive to insects, and there is evidence and to spare that insects do visit the Fly-orchis. On the labellum, just where it joins the rest of the flower, are two shiny knobs. They contain no honey, but they may be attractive to and deceptive of insects. Sprengel, a great German Botanist, believes in "false nectaries," and these may be of that ilk. The caudicle or stalk of conjoined threads of the pollen-mass is in the Fly Orchis bent twice at nearly a right angle. As a consequence the remarkable movement of the pollen-masses described in Orchis is not required here, and moreover is not encountered. The double bend is of such nature that an insect crawling along the labellum and bending towards the shiny "false nectaries" must strike the pollen-grains that form the summit of the pollen-mass against the viscid stigma.

(*b*) *Spider Orchis (Ophrys aranifera).*—The caudicle of each pollen-mass is bent twice, but not nearly so much at right angles as in the last plant. The movement of depression does take place in this case, and is necessary to bring the pollen-grains ultimately into contact with the stigma. The anther-lobes in the "Spider" are widely open, and this is an interesting gradation towards the condition met with in the next plant.

(*c*) *Bee Orchis (Ophrys apifera).*—This lovely flower, that the dwellers in Cowes, Isle of Wight, can find growing out at "Egypt," has long, weak caudicles, and its anther-lobes, intensifying that which is seen in lesser degree in the Spider Orchis, open so widely that the heavy, upper pollen-masses fall out, and while the sticky glands remain in their places below, the pollen-heads are driven by the wind against the viscid stigma in front of which they are now dangling. Here, then, is an elaborate arrangement for self-fertilisation, and yet there are in the plant, despite all this, so many arrangements that in other flowers allied to it are clearly of use for cross-fertilisation, that it seems reasonable to suppose that at least occasionally cross-fertilisation may take place. Unless this be so, the bee-like aspect, the depressable rostellum, the viscid lower parts of the pollinia, the movement of depression that does occur if they are removed, the elastic threads, the viscid stigma are in the main incomprehensible. Charles Darwin asks: "Are we to believe that these contrivances in the Bee Orchis are absolutely purposeless, as would certainly be the case if the species is perpetually self-fertilised?" Venturing to suggest for the words "contrivances" and "purposeless" the substitutes "structures" and "resultless," we may repeat the question, and the answer of those who believe in the gradual evolution of organs and organisms, and the survival only of that which is of value to the possessor, must be in the negative.

(*d*) *Musk Orchis (Herminium monorchis.)*—The name of this plant tells of its attraction to insects. The tiny flowers have a strong, musky odor. There is no nectar. The sticky gland is helmet-shaped. The head or body of the insect strikes into the hollow of the sticky gland, as the head of the warrior fits into the helmet, and removes the whole pollinium. The caudicle is fixed, not to the apex of the helmet, but to the hinder end, and there is a necessary movement of depression after removal from the anther-lobes.

(*e*) *Frog Orchis* (*Peristylus viridis*).—A very short nectary is seen in the Frog Orchis, and also two curious spots that secrete nectar. Now the opening into the nectary is very small, and is exactly in the middle line of the labellum. The two spots that form nectar drops are on the base of the labellum, one on each side of the middle line and immediately beneath the two rostella, behind which are the sticky glands. Further, running along the middle line of the labellum is a ridge that would be very uncomfortable for an insect. Hence the insect alights on the labellum to one side of this uncomfortable ridge, takes the nectar drop of that side, strikes against the rostellum of that side and removes the pollinium of that side. If, then, it goes to the opening of the short nectary in the middle line, it must strike the pollinium against the stigma, whose position is such that no movement of depression is needed. This would lead to self-fertilisation if both anther and stigma were ripe at the same time. But if the insect, disregarding any little inconvenience, went first to the richer supply of nectar in the median nectary and then to the side drops, he would carry away, whilst taking the latter, the pollen-mass of that flower to fertilise the stigma of the next one he visited.

(*f*) *Fragrant Orchid* (*Gymnadenia Conopsea*).—Sweet-smelling, nectar-laden flowers, whose sticky glands are never covered by a rostellum at all. The caudicles and pollen-grains at the summits are covered by the anther-lobes and kept from air, but the sticky bases are exposed. A moth can carry away the pollinia, therefore, but as the sticky glands never "set," the first contact of the pollen-grains with a stigma, after the caudicles now exposed to the air have moved downwards, would result in the dragging away of the whole mass. This is obviated by the elastic threads that hold together the packets of pollen-grains being very weak. They allow the removal of some of those grains without the sticky non-setting gland being removed from the head of the insect.

(*g*) *Butterfly Orchis* (*Habenaria chlorantha*).—White and of strong odor, with a long, richly laden nectary, this flower is very attractive to moths rather than to butterflies. The sticky gland in the Butterfly Orchis is not joined at once to the caudicle, as in all those hitherto studied, but has between it and the caudicle a little round stalk, shaped like a small side-drum. This serves to push the sticky part very prominently in the way of an investigating insect's head, and the necessary movement of the pollen-mass is effected, not by the caudicle, but by the drum-like stalk.

We now pass to a second tribe of the order Orchidaceæ Having considered the Ophreæ from the Spotted Orchis to the Butterfly, we turn to the Neotteæ. Here are no caudicles—*i.e.*, no little stalks of threads destitute of grains of pollen. The pollen grains of the uppermost part of the pollinia are no longer in large packets, but are held together, often in groups of four, by elastic threads. These threads finally project beyond the region of the pollen-grains, cohering with each other and generally becoming joined to the rostellum.

(h) Marsh Epipactis (Epipactis palustris).—The labellum is of two parts: (i.) the more prominent part that offers an excellent landing stage for insects and is joined on to (ii.) the basal part or nectary. In the normal position (i.) is partly enclosed within the edges of (ii.), and the entrance into the flower is minute. But even the weight of a fly will depress (i.), so delicate is the hinge between the two parts, and the insect can pass into the flower. As soon, however, as it has passed beyond the hinge the part (i.) springs up again, and our insect will have to force its way out of the flower backwards. Ere its entry, the elastic threads of the pollinia that project have become joined to the rostellum, and then the rostellum has undergone a curious movement forwards that serves to draw the pollen-masses out of their anther-lobes. Further, the front face of the rostellum has become exceedingly delicate, and at the lightest touch will rupture and present a sticky surface, whilst the very tiptop of the anther is destitute of pollen-grains and projects as a blunt point. How does all this act? An insect landing on the part (i.) of the labellum nearest to him depresses it by his weight. The entry into the flower is easy. He crawls in, and, feasting upon the nectar in part (ii.) of the labellum, the landing stage closes in behind him and he is a prisoner in the flower. When he has got all he can out of the flower

he proceeds, man-fashion, to desert it. Struggling out backwards, his head strikes the rostellum for the first time, ruptures it, exposes the sticky part, draws that away, and with it the conjoined threads and the pollen-grains to which they are attached. As he thus struggles, part of his back presses against the projecting, blunt, grain-empty top of the anther and "eases" the anther-lobes. Thus the exit thence of the pollen masses already partly withdrawn by the forward movement of the rostellum is rendered much more easy. Visiting thereafter another flower, the part (i.) of its labellum is again depressed by his weight and an easy entrance is left for him and his attendant pollen-masses. This is of value, as the pollen is so friable that were it to strike against the leaves of the flower it would be scattered and lost. As the insect enters, these pollen-masses strike upon the stigma which projects further forwards than the anther-lobes or even than the rostellum, and, once again, cross-fertilisation by insect aid is effected.

(i) Helleborine (Epipactis latifolia).—As the last, save that the blunt tip of the anther does not appear to serve the same office of "easing" the anther-lobes, as the insect's back does not appear to press against it as he backs out of the flower.

(i) White Helleborine (Cephalanthera grandiflora.)—The part of the labellum nearest an approaching insect and furthest from the stamen is hinged on to the rest. At first it is erect and keeps the flower closed. As soon as the organs of reproduction are ripe, this hinged portion bends down and affords a landing-stage for insects. Then, later on, it rises into its former position and the flower is closed again. Further, the pollen-masses in this plant, standing immediately behind the stigmas, emit certain pollen-tubes from some of the grains, that penetrate into the substance of the stigma, and doubtless serve for self-fertilisation. After this penetration by some pollen-tubes the stigma moves forwards, partially withdrawing the pollen-masses from out the anther-lobes. The erect position of the petals of the flower guards these pollen-masses from the wind, that but for the petals would infallibly blow them out of the flower.

(k) Ladies' tresses (Spiranthes autumnalis).—The labellum in this plant is channelled down the middle, and thus the

insect is guided to the opening of the nectary. It has a fringed landing-stage, at first in such a position that there is but the very narrowest aperture into the flower. Later, the labellum moves further away and leaves a wider opening. This slight movement is essential for the fertilisation of the plant. Within the rostellum is a structure exactly like a boat standing erect on end. This boat has a cargo of sticky matter, and is about 1-25th of an inch long and 1-100th of an inch broad. The front face of the rostellum quite covers over the front of the boat, and is, as it were, a vertical deck to the viscid cargo. Now the front face of the rostellum is strangely sensitive, and on the slightest touch splits in such manner as to completely free the erect boat of its cargo. Below this complex rostellum lies the stigma, and from it runs on each side a membrane up to the anther above. These two membranes protect additionally the pollen-masses and form the clinandrum (from *κλίνη*, bed) or bed of the anther. The action of all these parts is as follows. A bee visiting a flower whose anther is ready for work finds the labellum in such position that only a very narrow channel is left leading into the flower. Even as the bee's proboscis passes down this channel the rostellum must be touched. That strange, sudden rupture occurs, and the boat is free. Its viscid matter sets upon the insect head, and the pollen-masses are withdrawn as the insect flies away. Journeying to a flower a little more advanced in hours, our bee finds the labellum has shifted further away from the rest of the flower. The entrance is now easy, and the pollen-masses from the younger blossom carried into the interior of the older, now strike against the stigma. The flower is cross-fertilised by the aid of insects. The Ladies' Tresses grows in spikes of flowers, and the bees always begin at the lowest flower and work steadily upwards. The result of this constant habit is of the greatest importance. I quote from our author:—"In the early morning, when the bee starts on her rounds, let us suppose that she alighted on the summit of the spike; she would surely extract the pollinia from the uppermost and last-opened flowers; but when visiting the next succeeding flower, of which the labellum in all probability would not as yet have moved from the column (for this is slowly and very gradually effected), the pollen-masses would be often brushed off her proboscis and be wasted. But nature suffers no such waste. The bee goes first to the lowest flower, and, crawling spirally up the spike, effects nothing on the first spike which she visits till she reaches the upper flowers, then she withdraws the pollinia: she soon flies to another plant, and, alighting on the lowest and oldest flower, into which there will be a wide passage from the greater reflexion of the labellum, the pollinia will strike the protuberant stigma: if the stigma of the lowest flower has already been fully fertilised, little or no pollen will be left on its dried surface; but on the next succeeding flower, of which the stigma is viscid, large sheets of pollen will be left. Then as soon as the bee arrives near the summit of the spike she will again withdraw fresh pollinia, will fly to the lower flowers on another plant and fertilise them; and thus, as she goes her rounds and adds to her store of honey, she will continually fertilise fresh flowers, and perpetuate the race of our autumnal Spiranthes, which will yield honey to future generations of bees."

(l) (Goodyera repens.)—A rare and deeply interesting little plant found in the Highlands: interesting as a link between many different kinds of Orchids. For, placed among the tribe known as the Neotteæ, whose members are destitute of caudicles, it has rudiments of those organs. Again, it only of its tribe has the pollen-grains in packets. The breadth of the filament of the stamen allies it to Cephalanthera: the structure of its rostellum and the shape of its labellum to Epipactis: the possession of a clinandrum to Spiranthes.

Of British Orchids only two of note remain for consideration. Neither of these has the rostellum attached permanently to the pollinia.

(*m*) *Bog Orchis* (*Malaxis paludosa.*)—This is the smallest of British Orchids and one of the rarest. It differs from other members of the order in having its labellum upturned and in other leaves of the flower being bent back as if to atone for the conduct of the labellum and allow room for the insect to visit the flower. The position of the labellum on the upperside of the flower is due to the twisted ovary having twisted just twice as much as it usually does. On the crest of the rostellum is to be seen a drop of viscid matter. As the anther-lobes behind the rostellum shrivel down and leave their contained pollen-masses free, the upper ends of these are caught by this sticky drop on the crest of the rostellum. They are thus held, and are sheltered from the wind by the two membranes running from stigma to anther, one on each side, and known as the clinandrum. An insect inserting its proboscis into the flower between the labellum and the rostellum must touch the sticky drop on the crest of the rostellum and remove it and the pollinia it has caught. These pollinia are loose, and naturally, drooping from the insect head, on its visiting another flower are deposited within the "waistcoat-pocket" structure at the base of the rostellum, that is the stigma. Once more the plant is cross-fertilised by insect aid.

(*n*) *Tway-blade* (*Listera ovata.*)—The labellum is very long and bent vertically downwards. It has a furrow whose borders secrete much honey. This furrow attracts and guides the insect straight up the middle of the long labellum. When he reaches its summit his head strikes the rostellum, which is in the Tway-blade greatly arched forwards. On the back of the rostellum lie the two pollinia. The position here of rostellum and pollinia, it will be observed, is very different from that to be seen in most Orchids. In those already studied the anther, with its contained pollen-masses, was erect, and the rostellum was vertically below the anther. In Listera the rostellum is nearly horizontal, and so is the anther. The pollinia escaping from the anther-lobes lie loosely on the rostellum. Now, when the insect head strikes the rostellum the latter explodes and gives forth two drops of sticky fluid, which catch at one and the same time the pollinia and the head of the insect. The insect flies away bearing the pollinia, and passing to an older flower fertilises that. Some remarkable movements backwards and forwards of the rostellum aid and are indeed essential to the cross fertilisation thus effected. Thus, when first the pollen-masses quitting the anther-lobes rest on the back of the rostellum, the latter slowly moves downwards and thus avoids the risk of its explosion of viscid drops catching the anther as well as the pollinia. This downward movement also brings the rostellum into admirable position for the insect head to strike it. Again, after the explosion the rostellum suddenly curves yet further downwards and covers the stigma below, so as to prevent self-fertilisation, and a little later it moves back again, further back, indeed, than its former position, and leaves the stigma quite uncovered and *now* viscid to be impregnated.

CHAPTER XX.

(4.) *Foreign Orchids.*

THE various Orchids that grow in Great Britain have now been studied under the guidance of the great teacher. He leads us next to the contemplation of those Orchids known to most of us as existent in hot-houses, but growing wild and abundant in tropical lands. These natives of climes far hence, where the temperature is higher and nature in all ways more prodigal, would not be likely to be inferior in wonder and in strange structures and devices to their brethren growing beneath a cooler sky.

To understand fully that which follows it will be necessary to remember that there are in the great natural order, Orchidaceæ, seven divisions or tribes. These are:—(*a*) Malaxeæ, whose pollinia have no caudicle; one member of this tribe, the Bog Malaxis, has already been studied. (*b*) Epidendreæ, whose pollinia have caudicles that are free below and not attached to any part of the rostellum: the well-known foreign Orchid, the Cattleya, is an example. (*c*) Vandeæ, whose caudicles are attached to the rostellum but not to the sticky part or "gland" directly: there is in this tribe a sticky gland, but interposed between the gland and the caudicle or stalk of the pollen-mass is a portion of the rostellum not viscid: example, Catasetum. (*d*) Ophreæ, with caudicles attached at once to the viscid gland, with no intervening non-viscid part: our own British Orchids are illustrations. (*e*) Arethuseæ, with hinged or opercular anthers; example, Vanilla, dear to the lovers of sweets. (*f*) Neotteæ, no caudicles, anthers dorsal: example, Spiranthes. (*g*) Cypripedieæ, including only one genus, Cypripedium, differing from all others in having two stamens instead of one. Our British Orchids belong for the most part to the divisions (*d*) and (*f*), the two great tribes Ophreæ and Neotteæ. The foreign Orchids come in the main under the other five groups.

Arranging these in tabular form we have:—

ORCHIDACEÆ—			*Tribe.*	*Example.*
One stamen.	Pollen in waxy masses... ...	Without caudicles	Malaxeæ ...	Malaxis.
		With free caudicles	Epidendreæ.	Cattleya.
		Caudicles attached to rostellum ...	Vandeæ ...	Catasetum.
	Pollen powdery or with threads	Caudicles attached to glands... ...	Ophreæ ...	Orchis.
		With caudicles—anthers hinged .	Arethuseæ..	Vanilla.
		Without caudicles	Neotteæ ...	Spiranthes.
Two stamens			Cypripedieæ	Cypripedium

The two tribes Ophreæ and Neotteæ have been fully considered. Of the Arethuseæ Darwin had not up to the time of the issue of his book dissected any member. A brief account of each of the other tribes will finish the history of the individual plants of this remarkable order.

(*a*) *Malaxeæ.*—(i.) *Masdevallia fenestrata.* A strange case of a flower completely closed, save for two tiny windows in the sides. These two windows show how essential are insects to the fertilisation of Orchids. That they enter at the windows there can be little doubt. As to what they do inside the dark room where the furrowed labellum, the rostellum and the caudicles wait for them, not even Charles Darwin can tell at present.

(ii.) *Bulbophyllum.*—The labellum is joined to the rest of the flower by a very narrow elastic strap, and thus, under the influence of the lightest breeze, performs a movement so eccentric that even our great philosopher uses the word "waggle" to describe it. As the flowers are dull in color, small, inodorous, the waggling is of use in attracting insects. The rostellum becomes viscid, and insects, in withdrawing from the flower, force the viscid matter up into the anther above and catch the pollinia. These are thus borne away, and on visiting another flower *one* only of the pollinia fits exactly into the oval opening of the stigmatic room.

(iii.) *Dendrobium.*—This flower has the parts arranged from above downwards as follows: (α) An anther with a long, elastic filament compressed like a spring and pressing the anther down against (β) the sloping clinandrum: (γ) the rostellum viscid and milky: (δ) the stigma. The labellum includes and faces all these, and the part of it opposite the stigma is curiously thickened. A retreating insect forces the viscid matter from the rostellum into the anther and *generally* carries away the two pollinia. If he fails to carry them off, the elastic filament, released during the retreat of the insect, flings the anther forward over the rostellum, flings the two pollinia out of the anther-lobes on to the thickened part of the labellum, whence they rebound on to the stigma, and self-fertilisation occurs.

(*b*) *Epidendreæ*.—(i.) *Cattleya*. The rostellum above the stigma and below the anther is broad, tongue-shaped, viscid. The pollinia have caudicles that lie outside the anther-lobes and on the upper part of the rostellum. A humble bee passing into the flower of Cattleya would depress the tongue-shaped rostellum, and as the bee withdrew, the rostellum would be upturned, its viscid matter forced over edges and sides and into the anther, glueing the free, protruding tips of the pollinia to the retreating humble bee. Thus the insect would carry away the pollinia, one whereof, on its visit to the next flower, would strike the sticky stigma below the rostellum, and once again an Orchid would be cross-fertilised through insect-agency.

(*c*) *Vandeæ*. (i.) Generally. In this tribe the caudicles within the anther-lobes are attached to the sticky gland or disc through the medium of a non-sticky part of the rostellum which, following Charles Darwin, we will call the pedicel. Three parts will be removed by insects, therefore; (α) the sticky part or disc (β) the non-sticky part of the rostellum or pedicel (γ) the caudicles carrying the pollen-masses.

(α) The disc is with one exception single and not enclosed.

(β) The pedicel. Its length in many cases is exquisitely related to the depth of the stigmatic room into which the pollen-masses are to be inserted. In a few cases, however, where the pedicel is long and the stigmatic room is shallow, compensating actions are encountered. These compensating actions take these forms. 1. Depression of the pollinium forwards like that which occurs in most of our British Orchids, and due to the contraction of the viscid disc. 2. Sudden bending backwards of the *pedicel* at about its middle point (*Maxillaria ornithorhynca*). 3. Elasticity of the pedicel, which originally fastened down in a straight line with disc at one end and anther at the other, springs up on removal into a position at right angles to the disc (*Oncidium*). 4. Curving of the pedicel whereby the originally straight pedicel presents a straight portion at each end with a curved intermediate part convex upwards. This curved median portion, resting on the ledge of the deep cavity of the stigma, enables the supported pollen-masses to be easily dropped into the depths of the cavity (*Phalænopsis*). 5. Reflexion of the pollinia from the sloping sides of the rostellum on to the stigmas. This occurs in Calanthe. In this Orchid the pedicel is wanting and the pollen-masses, eight in each anther-lobe, are attached at once to and radiate from the viscid disc. After removal by insect agency from one flower, and upon introduction into another flower of the same species, these radiating pollinia, striking against the sloping sides of the rostellum, glance off on to the lateral stigmas.

(γ) The strength of the caudicles and the length to which they can be stretched without rupturing is very remarkable in many of the Vandeæ. For some little time these facts were a puzzle to our investigator, for in the Vandeæ the pollen balls have to be detached and left on the surface of the stigma as wholes, not as parts. A few grains cannot in these plants be detached at a time as they can be in our British orchids. Many experiments in which the observer introduced the pollen-masses into the stigma room, allowed them to remain there, and then slowly withdrew the disc and the pedicel, all gave the same result. There was much stretching of the caudicles, but no rupture, and no fertilisation therefore by abandoned pollen-masses. At last it struck the naturalist that an insect in quitting the flower would not fly directly upwards and lift the pollinia out of the stigmatic room. He would be more likely to fly away in a nearly horizontal direction, and drag out the pollinia over the edge of the cavity. When the experiment was made after this fashion the stretched caudicles rubbing against the edge of the stigma room ruptured, and left the pollinia behind in the depths of the room.

One special genus and one special family of the Vandeæ remain for special consideration. The genus is Acropera, and the family Catasetidæ.

(ii.) *Acropera* was for long a subject of trouble. In the first place the mouth of the stigma room was so small in all the plants examined by Darwin that the pollen-masses could only with great difficulty be forced into the chamber. On the other hand, the small disc, the long, thin pedicel, the depression of the pollinia, all indicated relationships to a large stigma cavity low down. After much anxiety, it occurred to Charles Darwin that perhaps the Acroperæ he had studied were in function unisexual and not bisexual, *i.e.*, were in function only males, and not both male and female. Careful investigation confirmed this view. The surface of the stigma was found to be scarcely at all viscid : the cells making up the substance of the stigma were empty of protoplasm. The ovules or unripe seeds on the placenta-cords in the ovary or seed-case were replaced by rudimentary structures, quite useless in the reproduction of the plant.

(iii.) *Catasetidæ.*—The most remarkable of all the members of the remarkable order Orchidaceæ. With the genus Catasetum two other genera are very closely allied, Monachanthus and Myanthus: two other genera are less closely allied, Mormodes and Cycnoches.

(*a*) *Catasetum.*—The most reptilian in aspect of all known plants. The flowers are very large, of hue partly coppery, partly orange. The labellum is proportionately large and is fringed at the free end, whilst the attached end is scooped out into a chasm-like hollow, whose walls are thick, fleshy, sweet, nutritious. The rostellum is large and protuberant, and most remarkable of all, is prolonged below into two huge curved, tapering horns, free everywhere save at their points of attachment to the main body of the rostellum. These strange horns, called by Darwin antennæ, are tubular, and through the medium of two little fringes of membrane, are in direct structural continuity with the viscid discs of the pollinia above. The left-hand one of the two antennæ bends upwards at its free extremity, so that the tip is just in the middle line and guards the entrance into the chasm-like hollow of the labellum. The tip of the right-hand antenna is turned a little outwards. The pollinia have very large viscid discs, but these discs are so placed that they cannot possibly be touched by any part of the body of any animal visiting the flower. They are turned inwards into a chamber that is homologically the stigmatic room. The pedicel attached below to the enclosed viscid disc may be traced upwards over the front face of the curved protuberant rostellum into continuity with the pollen-mass enclosed in the anther-lobe. The pedicel is, therefore, fastened down in a curved position. Before considering the action of the various parts in this complex arrangement, the statement must be made that the three species of the genus Catasetum —viz., *C. saccatum*, *callosum*, *tridentatum*—are like the Acropera, males, that Monachanthus is the female form corresponding to these males, and finally, that Myanthus is the bisexual form corresponding in other respects with both these last. In reality, therefore, these three genera are different sexual forms of the same plant. The male form is Catasetum: the female form is Monachanthus: the bisexual form, wherein both male and female organs appear and function, is Myanthus.

Let us now see how Catasetum works. An insect attracted by the lurid aspect of its flowers makes for the thick, fleshy, sweet, nutritious walls of the chasm-like hollow of the labellum. The tip of the left-hand horn of the rostellum (the antenna) must be struck by the insect's head or body. The horn is marvellously sensitive, and the moment it is touched it transmits the stimulus up through the fringe of membrane to the pollinium above. The edges of the disc under this transmitted stimulus at once rupture. The disc is now free. The curved elastic pedicel fastened down originally over the protuberant rostellum is now freed below. It jerks the heavy disc forwards out of the functionless stigmatic room with such force, that the pollen-masses are dragged out of the anther-lobes, and the two whole pollinia, consisting of viscid disc, pedicel and pollen, are thrown with the vi cid disc forward on to the insect's head or body. The in-ect flying from the male or the Catasetum visits sooner or later the female (Monachanthus), or the bisexual Myanthus. In either case the pollen will be left on the viscid surface of a functionally active stigma, and once again cross-fertilisation by insect agency will be effected.

(*β*) *Mormodes* has an arrangement of pollinia nearly identical with that of Catasetum. But no antennæ are present in Mormodes. The method in which its elastic pedicel is freed is as follows. The labellum, whose stalk is sweet to the taste, is turned upwards into an erect position, and is firmly pressed against the column formed of the stamen and gynœcium. The column is so arranged as to face the side of the flower, and not the front as in all other Orchids. Columns of successive flowers face alternately right and left. The position of parts is of great importance, as otherwise there would have been a want of space for the outthrowing of the pollinia. Lastly, there is near the top of the anther a little sensitive hinge. The action of the parts is on this wise. An insect lands on the top of the erect upturned labellum, and leans over to gnaw the sweet stalk and the equally sweet swollen bases of the other leaves of the flower. The weight and movements of the insect, and the actual pressure of his legs in his efforts after the edible, would indirectly or directly communicate pressure to the sensitive hinge of the anther, and the pollinia would be at once ejected, viscid disc foremost on to his body.

Divisions *d*, *e*, *f*, have already been considered.

(g) Cypripedieæ.—The labellum is in the Cypripedium strangely folded upon itself, and gives rise to the plant's common name of Ladies' Slipper. The one stamen of other Orchids is here rudimentary, and two others are developed. The pollen is, in this genus alone, glutinous. The rostellum is replaced by a third true stigma, and the three stigmas are rather convex and in this genus only not viscid. An insect entering the labellum by the median slit in its dorsal aspect, and seeking the more palatable parts in front, must crawl round by the side passages and over the two side anthers. In doing thus he will be smeared with the glutinous pollen. If he pursue his investigations yet further he will smear some of the pollen off upon the convex stigma, and if that organ be ripe self-fertilisation will occur. If, however, he make his exit without going the whole length of the labellum and visit another Cypripedium whose stigma is ripe, cross-fertilisation may take place.

We have now studied all the various forms of Orchids dealt with in the "Fertilisation of Orchids." One more chapter will be devoted to certain general matters in connexion with these remarkable plants, such as the honey secretion and the effect of the plants upon the insects, and then we shall pass to the consideration of yet another of the botanical works of Charles Darwin.

CHAPTER XXI.

(5.) *General facts.*

In this, the last chapter on the Orchids, and the last, indeed, upon the most remarkable of the works on Botany that have come from the pen of Charles Darwin, it is proposed to take up one or two points of general interest in regard to the structure and actions of Orchids. We have studied all the chief plants of this wonderful order, perhaps in almost too great detail. It will be well now to conclude our account of them by taking up points that concern the whole series, not individuals only. The sepals and petals, the sources of attraction to insects, the rostellum, the movements of the pollen-masses, the homologies of the different parts of the flower, these call for a few words.

(*a*) *Sepals and Petals.*—These, generally highly colored, are attractive to insects possibly at considerable distance. They protect the parts within, and in many cases are so placed that they serve as a guide to the insect visiting the flower, and ensure the insertion of the proboscis into the nectar-place. Foremost in interest amongst these flower-leaves ranks the strangely modified petal called the labellum. Fantastic enough are the shapes it assumes, and far more attractive must it be than all the rest of the flower. Broad and lobed in most cases, it not only attracts. It affords a landing-stage for insects. Often it is grooved or ridged so as to guide the proboscis. Its elasticity in some cases as Epipactis, its odd folding upon itself in others as Cypripedium, its movements from and towards the rest of the flower, all help in the fertilisation and in the cross-fertilisation of the plants.

(*b*) *The Sources of Attraction to Insects.*—We have seen that the bright colors and odd shapes of these flowers serve to excite the curiosity and to determine the direction of the flight of insects. But there are other sources of attraction.

In the night-flowering Orchids the dull, musky odor aids. Nectar and edible portions of the flower do their work in yet other members of the order. These attractive causes may be grouped thus: (i.) Shape, (ii.) Color, (iii.) Odor, (iv.) Food. The food may be liquid, as in the nectar flowers, or solid. Hence our fourth division falls again into two groups: (α) Liquid food or nectar. On the whole this honey is secreted by the labellum, and generally by some part of its base. In one genus, Coryanthes, the base of the labellum is provided with two small horns, from whose tips the secreted nectar drips down into a sort of bucket formed for its reception by the rest of the labellum. In Vanilla, the base of the ovary where it joins the stalk of the plant is sweet. In Cypripedium the honey is formed by the hairs that are on the surface of the labellum. In some of our British Orchids the fluid is loose in the tube of this remarkable organ, and can at once be devoured, and in these the "setting" of the sticky glands takes place at once. In others the nectar is in the very thickness of the walls of the tube or spur, and can only be obtained by the insect gnawing into those walls. This process takes time, and the "setting" of the sticky glands in these particular Orchids and in these alone requires time. Lastly, in Sarcanthus both these two last conditions are encountered, and nectar is found free in the spur, and also imprisoned in the substance of the walls of the spur. (β) Solid food. This is seen in the form of certain edible portions of the flower, and generally of the labellum. On the labellum of the reptilian lurid-looking Catasetum are excrescences that are sweet to the taste. On that of Calanthe is a cluster of round little warts, and in Eulophia are fringed ridges, and these warts and ridges would seem to be edible and attractive.

(c) *The rostellum.*—This organ plays a very important part in the life-history of almost all Orchids. It is the middle one of the three stigmas. The two side stigmas remain normal and receptive of pollen. The median stigma becomes modified to form the rostellum. In no other known plants is there a structure akin to the rostellum of Orchids. It secretes viscid or sticky matter. So in less degree do the two side stigmas. But whilst the two side stigmas are thus enabled to attach to themselves the pollen grains brought by insects, the sticky part of the rostellum causes the pollen masses to adhere to the body of the insect. Very various as are the aspects under which this organ presents itself, they are all connected by many minute gradations. From the tiny oval piece of membrane to which the caudicle of Orchis adheres up to the gigantic disk and pedicel and antennæ of Catasetum every gradation can be traced.

(*d*) *The movements of the pollinia.*—It will be remembered that in many cases when pollen masses have been withdrawn from the anther of a particular flower by the insect, they are in such a position as to render fertilisation of that or of any other flower out of the question. In those cases a slow movement of the pollen-masses is observed that at last places them in such a position that on the next visit to an Orchid of the same species as that whence the pollinia were taken the pollen grains are brought into contact with the viscid surface of the stigmas. The movement is always due to the contraction of a piece of the rostellum. Sometimes as in the Orchis, the piece is very minute. Sometimes, as with the huge "pedicel," drum-like in shape, of the Butterfly-Orchis a large portion undergoes contraction. The movement is in the main hygrometric (from ὑγρος, moisture, and μετρον, a measure), that is, it is due to drying up and consequent contraction of certain moist parts.

(*e*) *The homologies of the different parts of the flower.*—Homology is likeness in structure, not necessarily in function. Parts that are built upon the same model are homologous. Parts that perform similar functions are analogous. Arm and leg in man are instances of homologues. Bones, muscles, arteries, veins, nerves are alike in each. But arm and leg are not analogues. Their functions are not similar. The lungs of a man and the gills of a fish are analogues, for they perform the same office, that of respiration. They are not, however, alike in structure. The extraordinary flower of the Orchid, with its labellum and single stamen and clinandrum, presents a curious problem to the student. How to reconcile all these queer parts and arrangements with the ordinary type of flowers that belong to the same great class as the Orchidaceæ? Lilies and Irises are normal enough with their six flower-leaves, six stamens, and three carpels. Where are these parts or their homologues in the Orchid? By most patient dissection and observation Charles Darwin has answered this enquiry. To account for the six flower-leaves is not difficult. They are there, the whole six. Truly one of them is very much modified into the middle part of the labellum, but they are all to be seen. Only the middle part of this curious landing place is true petal. The two side pieces will be accounted for directly.

Let us see what has become of the six stamens that are typically present in the great class Monocotyledones. The six stamens in the Lily, the Iris and other plants are in two sets of three, an outer and an inner. Of the outer three, in Orchids one only develops into a pollen-bearing stamen. The single stamen so often mentioned belongs to this outer set of three. Its two companions are modified to form the two side-pieces of the labellum. So that the labellum really is made of one petal forming the central part of that oddly-shaped organ and of two stamens belonging to the outer trio and forming the two side-pieces of the labellum. What is the fate of the three inner stamens? Two of them are present as actual pollen-carrying stamens in Cypripedium. In other Orchids these two form the membranous sides of the clinandrum or anther-bed. In this "bed" the anther lies protected from the wind by the two membranous modified stamens. Lastly, the third stamen of this inner or second circle is represented by a little ridge that runs down the front of and strengthens the column. The three carpels are easily recognised on making a transverse section of the ovary or seed-case. Three sets of seeds are observable, attached to the inner walls of that ovary. The three stigmas are represented by the two viscid side spaces and the central rostellum.

(*f*) *Conclusions.* And now what are the conclusions arrived at by the illustrious author of this book? After all his laborious investigation of multitudinous Orchids, three great principles force themselves upon him and upon us. (i.) That insects are necessary for the fertilisation of Orchids. Pollen from anther cannot get to stigma and thence to unripe seed or ovule and impregnate that ovule save through the agency of insects. Arrangement upon arrangement is met with demonstrating the remarkable adaptation of flower to insect, and of insect to flower.

(ii.) That self-fertilisation is rare, and cross-fertilisation almost universal. Very rarely is the pollen of a given Orchid used to fertilise the ovules of the same plant. Far more generally is the pollen of a particular flower borne to the stigma and thence to the ovule of another individual of the same species. And this cross-fertilisation, not confined, as will hereafter be shown, to Orchids only, but almost universal in plants, by bringing together in the reproduction of the new being cells from two slightly different parents and not cells from the same plant, gives far more opportunity for the variation of that new individual in ever new directions.

(iii.) That these wonderful adaptations of structure are not the result of special creative acts. It is, after careful review of all the evidence, impossible to believe that each species of Orchid sprang into existence at the word of an almighty being. All these marvellous flowers, with all their minute and curious structure-modifications, and all their complex relationships of parts to one another and to insects, are the result of slow modification of parts through century upon century. By gradual evolution from simpler forms the Orchids have come into being. Every slight variation that has rendered them more fitted for the great struggle for existence, that has given them a better chance in the life-battle, has been transmitted and strengthened until we find such a wondrous arrangement as the sensitive antennæ of Catasetum, and the heavy pedicel flung out to strike with unerring aim the head of the insect. Let us end this our study of the Fertilisation of Orchids with quotation of the master's own words: "The more I study nature, the more I become impressed with ever-increasing force with the conclusion that the contrivances and beautiful adaptations slowly acquired through each part occasionally varying in a slight degree but in many ways, with the preservation or natural selection of those variations which are beneficial to the organism under the complex and ever-varying conditions of life, transcend in an incomparable degree the contrivances and adaptations which the most fertile imagination of the most imaginative man could suggest with unlimited time at his disposal."

E.—Cross and Self-Fertilisation in Plants.

CHAPTER XXII.

(1) *Introduction and* (2) *Experiments.*

FOR the full understanding alike of this work and of any account thereof, it is essential that the reader keep in mind the chief facts in connexion with the structure and functions of flowering plants, those that possess stamens and carpels. The stamens or small threads within the petals of a flower are the male organs. Within their caps or anthers is the yellow dust or pollen, of many grains. These are the fertilising structures. The carpels, generally welded together into one solid central organ of the flower, are the female organs. Within their swollen bases are the ovules or unripe seeds. These are the structures to be fertilised. Originally the fertilisation of an ovule by a pollen-grain was supposed to occur within the limits of an individual flower. Pollen of flower A impregnated ovule of flower A. And this action, whenever it does occur, is self-fertilisation. But the labors of Darwin, Gärtner, and Kölreuter, aided by the less continuous observations of others, have established that this method is a rare one. Many times more frequently the pollen of flower A impregnates the ovule of flower B of the same species. And this action is cross-fertilisation. The object of the work on plants now claiming consideration is the comparison of the effects of self and cross-fertilisation. It deals incidentally with the relative frequency of the two methods and with the means whereby each is performed, but " we are not here concerned with the means but with the results of cross-fertilisation." Speaking generally those results are advantageous to the plant in the life-battle. This work is in short " the complement of that on Orchids." In the consideration of it I shall follow the lines marked out for me by its author and deal with its introduction, the results of his experiments, the means of cross-fertilisation, the relation of insects to the process and a general summary.

(1.) *Introduction.*—This brief prelude to the main body of the work falls into four parts. (*a*) The object of the work, already discussed in the preceding paragraph. (*b*) The method of the experiments. A plant or two or three plants of the same variety was, or were, placed under a net that was not in contact with it or them. Insects were thus excluded, with the exception of one minute, experiment-disturbing being called Thrips which refused to be kept out by any net, no matter how fine were the meshes. Flowers upon this enclosed plant were fertilised, some by the pollen of their own stamens, others by pollen from the stamens in flowers on another plant of the same variety outside the net. In the former case self-fertilisation occurred: in the latter cross-fertilisation. The seeds thus produced were never gathered until they were thoroughly ripe. The seeds that were the result of self and cross-fertilisation were then allowed to germinate under exactly similar conditions. If any of the one set began to develop before any of the other, they were thrown away. But when a seed the result of the one process and a seed the result of the other began to germinate at the same time the two were planted side by side under exactly similar conditions. If any individual plant from any cause sickened in its youth, it and its companion of the opposite order were thrown away. And thus two sets of plants of the same variety, grown under exactly similar conditions, but one moiety of them the results of self-fertilisation, the other the results of cross-fertilisation, were growing side by side for comparison. Descendants of these plants of the first generation were treated as their immediate parents had been, and this process was continued even to the tenth generation in many cases. The experiments as a whole extended over a period of eleven years, a sufficiently long period to eliminate any accidental sources of error due to the circumstances of a special period of time.

(*c*) The tables. A series of elaborate tables were drawn up, month by month and year by year. In these were recorded the numbers of the flowers crossed or self-fertilised, and the heights of their offspring when measured at certain definite times from the commencement of their existence as separate individuals. The average height of the plants developed from cross-fertilised seeds was always taken as 100, and then the average height of the plants developed from self-fertilised seeds was easily comparable therewith. In any numbers I may give to afford a general idea of the results of these experiments, the 100 and its fellow numeral will be used. Not only were the heights of the flowers compared, but also the number of the ripened fruits they produced, and the number of the ripe seeds in each fruit. In all these respects, and in certain others, the plants that were the result of cross-fertilisation had, in almost every case, a very marked advantage over those the result of self-fertilisation. They were taller, they were healthier, they were stronger, they produced more fruits, they produced more seeds, they were in all ways better fitted than their fellows for the life-struggle.

(*d*) The reason of this superiority. This would seem to be that the crossed individuals possessed slight differences in their natures, as results of their having been exposed to slightly different external conditions. Those somewhat different natures have left their mark upon the reproductive structures. The pollen-grain of plant A and the ovule of plant B differ more one from the other than do the pollen-grain of A and the ovule of A, or the pollen-grain and ovule of B. With the blending of two structures somewhat different in their antecedents, and therefore in their tendencies, comes the greater possibility of further development and renewed strength. The collision of two structures thus dissimilar sets old forms of motion into stronger action, or evolves new and often unexpected forms. Hence cross-fertilisation is, moreover, of value as giving more possibility, not only of greater strength, but of variation. The whole of this important subject is dwelt upon at greater length in the present writer's "Biological Discoveries and Problems."

(2.) *Results of the experiments.*—The chapters from the second to the seventh are devoted to the description of experiments on various plants, and the tabulation of the results as far as the number of fruits, the number of seeds, and the heights of the offspring are concerned. The experiments range over thirty natural orders of plants, over fifty-two different genera belonging to those orders, over fifty-eight species. The total number of plants that were bred, watched during their development, and measured, was 2,004. The mere numbers give us some idea of the indefatigable, pains-taking nature of our teacher, whilst the fact that the observations not only extend over so many individual plants, but also have to do with no less than thirty natural orders, encourage us to believe that any generalisation based upon these experimental results must be well founded.

(*a*) Height. In Chapter II. Charles Darwin narrates fully the history and results of his experiments upon one plant, a member of the order Convolvulaceæ. It is the *Ipomœa purpurea*, commonly known as the *Convolvulus major*. In this particular plant, on comparing the heights of the plants resulting from cross-fertilisation with the heights of those resulting from self-fertilisation the following numbers appear:—

Heights of plants from	C.F.	flowers	as	100
,, ,,	S.F.	,,		76

To illustrate in a yet more understandable way to most of us the difference between the average heights of the plants developed from cross and self-fertilised seeds respectively it is stated "that if all the men in a country were on an average six feet high, and there were some families which had been long and closely interbred, these would be almost dwarfs, their average height during ten generations being only 4 feet $8\frac{1}{4}$ inches."

Chapters III.—VI. are occupied with experimental details more briefly recorded as to the many other plants investigated, and Chapter VII. with a summary of the whole of the preceding pages. Of that summary I have made a summary, and I find that taking the average height of all the plants resulting from cross-fertilisation as 100, that of all the plants resulting from self-fertilisation is 87.

Two other points remain for discussion in connexion with these experiments. Thus far we have only compared self-fertilised plants with those cross-fertilised by pollen taken from plants of the same variety growing in the vicinity of the netted plants. Two other kinds of experiments were made. (i.) Flowers on the same plant were crossed, not flowers on distinct individuals. Suppose two individual plants A and B fixed by separate roots in the common earth. If A bear flowers a, a_1, a_2, and B bear flowers b, b_1, b_2, the former case was as when pollen from *b* went to the ovules of *a*. But this new case is as when pollen *e.g.* from *a* went to the ovule of a_1 or of a_2. Vigor of offspring springs not from mere crossing, but from the parents having been in slightly different conditions, for when the offspring due to this narrowed cross-fertilisation are compared with the offspring due to self-fertilisation (pollen of *a* to ovule of *a*) the *former* are the inferior. If 100 represented as before the average height of the cross-fertilised, 124 represented that of the rigidly self-fertilised! (ii.) Flowers were fertilised by pollen brought from plants of the same variety that grew at a distance from the one that was impregnated and had therefore been subject to external conditions even more distinct from those of the fertilised plant than the external conditions of any other growing in the same locality as the latter. Using our latter illustration again; whilst in the first experiments *a* flower, of plant A, was crossed by pollen from *b* flower, of B, and in the experiment just narrated *a* flower, of plant A, was crossed with pollen from a_1 flower, of the same plant A, and whilst in both these experiments the results were compared with the results of crossing ovule of *a* with pollen of the same flower *a*, in this last instance a new plant C of the same variety but hailing from a different locality comes into use. Pollen from flower *c* or c_1 or c_2, of plant C, growing perhaps in a different country is brought to the ovule of flower *a*, of plant A, and the result of this yet wider-reaching cross-fertilisation as compared with that of the cross-fertilisation between flowers of A and B that have long grown side by side and long been subject to like external conditions, is very striking. Plants springing from the ovules of plants growing at Beckenham that were crossed with pollen from some that grew at Colchester (pollen from *c* to *a*) had average height 100. Plants springing from an ordinary local cross (pollen from *b* to *a*) had average height 78. These Colchester plants had grown up with different surroundings from those of their Beckenham congeners and the nature of the former differed slightly from that of the latter. With the blending of two structures somewhat more different in their antecedents and therefore in their tendencies comes the yet greater possibility of further development and renewed strength.

(*b*) Fertility. The study of the relative fertility of different flowers as influenced by cross and by self-fertilisation includes two questions. (i.) As to the productiveness of flowers fertilised by their own pollen or by that from another plant. (ii.) As to the productiveness of the seedlings raised from the former set. The two classes of cases do not always run parallel. (i.) The comparative fertilities under this head were measured by counting the number of fruits produced and the number of seeds contained by those fruits of the cross and self-fertilised flowers. A series of experiments upon the same plants as those whence the height-data were obtained, resulted in the following numbers :—

Number of fruits	formed by	C.F.	flowers,	100
,,	,,	S.F.	,,	69
,, seeds	,,	C.F.	,,	100
,,	,,	S.F.	,,	93

A yet more elaborate series of experiments wherein the fertility of plants was estimated by various methods are expressed in a numerical table that may be summarised thus. Take the fertility of the cross-fertilised flowers as 100, the average fertility of all the self-fertilised is almost exactly 60.

This investigation of the relative productiveness of flowers leads to the account of plants that are absolutely self-sterile. Kölreuter had shown long ago that the flowers of *Verbascum phœniceum* (one of the Mulleins) were sterile with their own pollen, and Fritz Müller, most earnest of helpers in that propagandist work of evolution that consists in fact-finding, had discovered that on the stigmas of certain Orchids pollen from the stamen in the same flower acted as a poison. Other observers have shown that the number of plants whose ovules cannot be ripened by the pollen of the same flower is large, and the same observations that have established these facts have demonstrated in addition that this self-sterility is determined by external conditions, these same external conditions rendering the male and female sexual organs and elements too uniform for interaction one upon the other. Self-sterility would seem to have been gradually acquired through natural selection as it would be a preventive to self-fertilisation with its attendant evils, negative or positive.

But the discoverer of the fact of natural selection with his customary honesty urges certain objections to this view. (α) The absence of connexion between the sterility of self-fertilised parent-plants and the loss of vigor in the offspring of such plants. (β) Individuals of the same parentage differ in the degree of their self-sterility. (γ) The effect of mere alteration in external conditions in causing self-sterility. (ii.) The productive power of seedlings resulting from cross-fertilisation is also far greater than that of seedlings resulting from self-fertilisation.

(*c*) Differences other than those of height or fertility. The eighth chapter of the book deals with other advantages possessed by the plants that are the result of cross-fertilisation in greater degree than by those that are the result of self-fertilisation. These are three in number: (i.) greater strength (ii.) earlier flowers, (iii.) greater diversity of color.

(i.) Greater strength. Dealing with certain specimens of *Viola tricolor*, the common heartsease, in 1870, Darwin observed that from the great severity of the winter of that year all the offspring of self-fertilised ovules were slain, with the pathetic "exception of a single branch on one plant, which bore on its summit a minute rosette of leaves about as large as a pea." All of them were killed by the frost. But the cross-fertilised to a plant arose strong and living in the spring-tide of 1871. And as a general conclusion it is stated that whenever the experiments required the removal of the plants from the fostering comfort of their early home, the greenhouse, to the harsher world outside, the cross-fertilised children bore up better than the self-fertilised ones. These last also were more liable to premature death, weaklier infants that they were, than their stronger fellows. Of the many cases when two plants were doomed to be thrown away in their earliest hours, the majority were due to the failing of a self-fertilised little one, its weakness with a strange irony bringing about the destruction not alone of itself, but of one more worthy.

(ii.) Earlier flowering. The results of cross-fertilisation were generally earlier in their upspringing towards the sun than the self-fertilised. Thus 58 cases are on record of the periods of flowering on the part of a number of plants of both kinds. In 44 of the 58 the crossed plant flowered first; in 9 of the 58 the self-fertilised plant flowered first; in 5 there was a dead heat.

(iii.) Greater diversity of color. Given original parent plants of varied hue, and from these careful breeding both by method of self and of cross-fertilisation, it is observable after a certain number of fertilisations that the offspring of self-fertilisation become uniform in color, losing all diversity of marking and of tint, while the offspring of cross-fertilisation retain or even add to the primal variegation of color. Crossing of the uniformly-painted, self-fertilised plants with a fresh stock results in seedlings reverting to the diversified arrangement at first prevailing.

Summing up these consequences of cross-fertilisation and self-fertilisation we have (α) The greater physical strength of the seedlings that are the result of cross-fertilisation, giving them far more chance of survival during the earlier and dangerous hours of life, and fitting them in succeeding hours and days to encounter alterations of external conditions of considerable magnitude without succumbing. (β) Their superior height lifting them into air regions whither their weaker brethren cannot follow them, and yielding to breathing and feeding leaves ever greater opportunities of air and food. (γ) Earlier flowering, a distinct advantage when fertilisation depends upon active insects who are most active in the younger summer months. (δ) More diversity of coloring, therefore greater attraction of insects, and greater chance of fertilisation through insect agency. (ϵ) More numerous fruits each containing (ζ) more numerous seeds than are produced by the self-fertilised plants. In all directions, then, advantage and better hope in the battle of living things. Cross-fertilisation is clearly of greater value to its possessor than self-fertilisation. And it must never be forgotten that this same help-giving cross-fertilisation carries with it as inevitable and irresistible corollary, variation, and is therefore by its frequency and its effect strongest of arguments in favor of evolution.

CHAPTER XXIII.

(3) *Means of Fertilisation*, (4) *Sexes in Flowers*, (5) *Summary*, *and* (6) *The Writer.*

(3) *MEANS OF FERTILISATION.*—(*a*) In Cryptogamia. In the Algæ, the Characoæ, the Ferns and their allies the male element is generally very mobile. The antherozoids of these lowest plants are usually provided with cilia, and whether thus furnished or not are almost invariably capable of considerable movement. Hence transportation of these male elements from place to place, and the probability of fertilisation of a female element belonging to a plant other than that whence the antherozoid came. And this would be a case of cross-fertilisation. (*b*) Phænogamia. In the higher sub-kingdom of flowering plants or Phænogamia, whose members have pollen and ovules, two types of plants occur. (i.) Anemophilous plants (ανεμος = wind, φιλεω = I love). These are plants such as the plantain, the oak, the grasses, whose multitudinous, incoherent pollen grains are borne by the wind from flower to flower. By such an arrangement as this cross-fertilisation is again rendered well-nigh certain, and the fact that amongst anemophilous plants the male and female organs are generally in separate flowers, and very often on separate plants, points to the same method of impregnation. (ii.) Entomophilous flowers, or those whose pollen is borne from flower to flower by insects. As arguments in favor of cross-fertilisation of such plants as these Charles Darwin urges: (α) That insects do thus transfer the fertilising element from flower to flower. (β) That some birds perform the same function. The humming birds and the lories seem to be the busiest at this work. (γ) That many plants are dioicous (δις = twice, οικος = house) *i.e.*, the male flowers are on one plant, the females on another. (δ) That others that are not dioicous are monoicous and diclinous, *i.e.*, both male and female flowers are on the same

plant ($\mu o \nu o \varsigma$ = one, $o\iota\kappa o\varsigma$), but yet the flowers are either male or female, and never with both sexes combined on the same individual blossom ($\delta\iota\varsigma$, $\kappa\lambda\iota\nu\eta$ = bed). (ϵ) That even when plants are bisexual and each flower carries both male and female organs, yet the flowers are dichogamous ($\delta\iota\chi o\varsigma$ = double, $\gamma\alpha\mu o\varsigma$ = marriage). The male and female organs of any particular flower are not ripe and ready for interaction at the same time. Generally the stamens are ready for work before the carpels. Most plants are proterandrous ($\pi\rho o\tau\epsilon\rho o\varsigma$ = former, $\dot{\alpha}\nu\eta\rho$ = man). When, therefore, pollen of flower A is ready, the ovules of flower A are not ready. But those of B, an older flower of the same variety, may be ready, and by insects pollen from A may be carried to the flower of B whose ovules are ready to be impregnated thereby. (ζ) That the pollen of another plant of the same variety is prepotent over the pollen of the plant itself. If pollen from A and from B be placed simultaneously on the stigma of A when it is ripe, only the pollen of B will do work, and making its way down the canal of the style impregnate the ovule. Pollen of another kindred plant is more potent than that of the plant itself even if the latter be placed upon the stigma some hours the earlier of the two. (η) That in certain cases special arrangements of parts of the flower or special movements of parts prevent self-fertilisation. The structure of the stigma of Violet with its projecting lower lip, that closes the opening of the stigma as the proboscis of the insect, covered with pollen from the same flower, is withdrawn and allows the mouth of the stigma to open as the proboscis of the insect covered with pollen from another flower enters is an instance of the former. The special movements of parts of the Orchid flowers, notably *Spiranthes*, described on page 123, is an instance of the latter.

(4) *Sexes in flowers.* Discussion as to the order of evolution of unisexual and bisexual flowers follows. Charles Darwin is of opinion that plants were originally unisexual. The male and female organs were in distinct individuals, and on separate plants (dioicous). Later certain plants were evolved, bearing male and female flowers on the same plant (monoicous). Yet later, certain plants were evolved that were bisexual, having in each flower male and female organs (hermaphrodite, from Ἑρμης = Mercury,

Αφροδιτη = Venus). To this series of evolutions it may be urged, with all deep respect for its illustrious suggester, that considerable objections exist. (*a*) It is opposed to the general principle of evolution from the general to the special. In the higher forms of living things there is more specialisation of function, more division of labor, than in the lower. Special organs are found performing special functions. From this point of view it would seem more likely that in the earlier forms both sexes were in the same individual, and later on that further specialisation took place, and each individual became either male or female. (*b*) The study of the animal kingdom affords collateral evidence against the view enunciated in this work. The lowest animals are very clearly bisexual. The highest are very clearly unisexual, though, in the similarity of the early stages of the male and female, and in occasional abnormal reversions to the hermaphrodite condition, we have evidence as to their evolution from forms originally bisexual.

Perhaps part of the difficulty in this particular case of evolution is traceable to our habit of regarding all the brightly-colored and highly-scented flowering plants as higher in the scale than their less gay and less attractive fellows. The majority of people probably would unhesitatingly vote the rose to be higher than the oak. But it is not altogether certain they would be accurate in doing thus. If color and odor and beauty only are to be the measures of excellence, the judgment may be correct. But if bulk and strength and the beauty of strength, if effect upon the air and the soil, even if complexity of structure are to be taken into account, perhaps the decision may be impugned. The writer is strongly inclined to believe that the forest trees will be regarded as higher in the scale of vegetables than the flowering herbs. And the latter are bisexual, whilst the former are unisexual.

(5) *Summary.*—The volume closes with a general summary of the work recorded and the conclusions reached. Thence I select the three main generalisations. (*a*) Cross-fertilisation is generally beneficial to the plant, self-fertilisation injurious. (*b*) The advantages of the former follow from the individual plants concerned having been subjected to somewhat different conditions ; hence their sexual elements are, therefore, somewhat differentiated. (*c*) The

disadvantages of the latter follow from the sexual elements in the same plant not having been thus differentiated.

"There is the clearest evidence, as we shall presently see, that the advantage of a cross depends wholly on the plants differing somewhat in constitution, and that the disadvantages of self-fertilisation depend on the two parents, which are combined in the same hermaphrodite flower, having a closely similar construction. A certain amount of differentiation in the sexual elements seems indispensable for the full fertility of the parents and the full vigor of the offspring."

(6) *On the writer of the book.*—From this volume, as from all the rest, we can gather some faint hints as to the nature of its writer. (*a*) It is curious to note how the old phraseology of teleological explanation is still at times used. (i.) The phrase "in order that" occurs more than once. Thus, on page 372, we have:—"Almost every fruit which is devoured by birds presents a strong contrast in color with the green foliage, *in order that* it may be seen, and its seeds freely disseminated."

Ten pages further on we read:—"It may be admitted as almost certain that some structures, such as a narrow elongated nectary, or a long tubular corolla, have been developed *in order that* certain kinds of insects alone should obtain the nectar." And on page 385:—"We are thus led to infer that some plants either have not had their flowers increased in size, or have actually had them reduced and purposely rendered inconspicuous, so that they are now but little visited by insects."

(ii.) The word "instinct" occurs on page 415: "Their instincts, however, are not of a specialised nature, for they visit many *exotic* flowers as readily as the *endemic* kinds, and they often search for nectar in flowers which do not secrete any; and they may be seen attempting to suck it out of nectaries of such length that it cannot be reached by them."

The researches of so many naturalists, as recorded in Büchner's "Mind in Animals," translated by Mrs. Besant, have done so much to show that the word "instinct" is in many cases, if not in all, to be replaced by "education"—that the former word should be very cautiously used if it be employed at all, and may not improbably ere long pass out of our vocabulary.

L 2

(iii.) "The economy of Nature." I venture to think this phrase is very misleading, especially when used by one whose words carry so much power as those of Charles Darwin. It is seriously open to question whether that economy exists to any large extent. In many instances the most extensive waste is evident in Nature. A case may be mentioned from this very work. Two pages after the one (374) wherein we read: "So great is the economy of Nature," the following sentence occurs: "The Editor of the *Botanical Register* counted the ovules in the flowers of *Wistaria sinensis* and carefuly estimated the number of pollen-grains, and he found that for each ovule there were 7,000 grains." As at most three or four pollen-grains are enough to fertilise an ovule and as in many cases one will do the work, Nature cannot be accused of economy here. The whole history of anemophilous flowers with their crowds of pollen grains wafted in every direction by the wind and only a few here and there ever reaching a stigma and functioning as impregnators, and the huge waste of the eggs, say of fishes, millions of which never develop, are but two cases of the many that might be educed to show that in Nature waste is very prevalent.

(*b*) The marvellous labor of perseverance again shines out. The mere seed-counting alone involved immense toil. *Ex uno disce omnes.* "Fifteen capsules from self-fertilised cleistogene flowers contained on an average sixty-four seeds, with a maximum in one of eighty-seven." Not only were the heights of innumerable plants carefully measured and recorded, but to leave no stone unturned in the investigation as to their relative vigor in the latter experiments, the fully-grown plants were cut down and weighed.

Again on page 179: "On one of these plants several flowers were fertilised with their own pollen; and as the pollen is mature and shed long before the stigma of the same flower is ready for fertilisation, it was necessary to number each flower and keep its pollen in paper with a corresponding number."

After meeting passages such as these wherewith the work abounds one reads with a half-smile "It was too troublesome to collect and count the capsules on all the plants."

(*c*) The intense honesty of one who only labors to find out what *is*, comes out frequently, and evidently with a total unconsciousness, in these pages. Thus on page 128 he writes: "The results of my experiments on this plant are hardly worth giving, as I remark in my notes made at the time, 'seedlings, from some unknown cause, all miserably unhealthy.' Nor did they ever become healthy; yet I feel bound to give the present case, as it is opposed to the general results at which I have arrived."

And again on page 185: "But many of the plants were unhealthy, and their heights were so unequal—some on both sides being five times as tall as the others—that the averages deduced from the measurements in the preceding table are not in the least trustworthy. Nevertheless I have felt bound to give them, as they are opposed to my general conclusions."

(*d*) Ever and anon also a glimpse comes into the personal nature of the author. References to his sons' work, that of Francis and of George, meet us pleasantly.

Sometimes there is an anxiety that is almost childlike. When one reads: "In my anxiety to see what the result would be, I unfortunately planted the three lots of seeds (after they had germinated on sand) in the hothouse in the middle of winter, and in consequence of this the seedlings (twenty in number of each kind) became very unhealthy," one is half-reminded of the boy who planting cherry seeds, daily dug them up to see how they were getting on. When an extraordinary plant that though the result of self-fertilisation yet outgrew the ones that were the result of cross-fertilising is encountered, in the exuberance of his surprise he names it "Hero." Good, gentle, kindly, patient man, working serenely on. It is well for us that we have even such fragmentary glances as this at the great life that has made and shall make so many lives the happier and the nobler.

And throughout the work is visible the patient joy of the experimenter and at intervals the triumph, than which none is more sacred, of him that out of many facts draws the one large truth and offers it to the eyes of his fellows and of after-time.

F.—Forms of Flowers.

CHAPTER XXIV.

(1.) *The forms of flowers in regard to sex.*

THE next book from the pen of Darwin which calls for investigation has for its full title "The different forms of flowers on plants of the same species." It has been previously shown that cross-fertilisation is more advantageous to plants than self-fertilisation. This volume is devoted to the account of still further experiments that lead to the same conclusion. Following its author we shall consider: (1.) The different forms of flowers as far as the arrangement of their sexual organs is concerned. (2.) The different cases of plants that have both sexes in the same individual blossom, each flower, therefore, possessing a gynœcium, that is female reproductive organ, and andrœcium, that is male reproductive organ. (3.) Plants in which the sexes are to a greater or less extent separated. (4.) What are known as Cleistogamic flowers, that is flowers completely closed, and therefore not admitting the possibility of insect entrance. The derivation of the word Cleistogamic is from κλεις, key, and γαμος, marriage. There will follow a few words on (5.) Personal characteristics of the writer.

(1.) *The different forms of flowers as far as the arrangement of their sexual organs is concerned.*

(*a*) Bisexual Plants. The majority of plants belonging to the great flowering sub-kingdom have their sexes united in the same individual flower. Such plants are known as bisexual or hermaphrodite. Five prominent types of these hermaphrodite plants present themselves.

(i.) Bisexual plants, in which the gynœcia and andrœcia are of different lengths so that the stigma of the former and the pollen-bearing stamens of the latter occupy different levels in any given flower. These plants are known by the general name of heterostyled (from ἑτερος, different). A full account of these has already been given in the history of cross and self-fertilisation. Example: the Cowslip.

(ii.) Plants having in each individual plant two kinds of flowers, one of which (α) is quite perfect, contains male and female organs, and yet expands in the usual fashion, whilst the other (β) is very minute, completely closed, and with the reproductive organs partially aborted. Yet these cleistogamic flowers are perfectly self-fertile, and evidently effect their fertilisation with the smallest possible quantity of pollen. Example: Violet.

(iii.) Plants bearing (α) conspicuous and entomophilous flowers at the same time as they also bear (β) less conspicuous blossoms. The latter are not closed as in the case of the cleistogamic flowers, but are evidently a step in the direction of these. Self-fertilisation occurs with them as in the cleistogamic. Another slight difference is that in this particular case the conspicuous cross-fertilised flowers and the humbler self-fertilised occur on different plants of the same kind. I have named these heterochromous (ἑτερος = other, χρωμος = color). Example: Pansy.

(iv.) Plants that present at certain parts of their inflorescence or collection of flowers (α) blossoms much larger and more notable than (β) the ordinary flowers. Generally speaking the attractive blossoms are upon the outside of the inflorescences. The radiating florets white in hue of the flower of the daisy are instances of the specialisation now mentioned. These I name hetero-megathic (μεγαθος = size).

(v.) Plants carrying (α) perfect flowers and also (β) buds entirely closed and never expanding. These colored buds remind us of the cleistogamic flowers, but differ from them in two ways. They are not self-fertile and they are much larger and more noticeable. Example: Feather hyacinth These I name hetero-gemmous (γεμω = I bud).

(*b*) Plants presenting a greater or less separation of the sexes one from another.

(i.) Polygamous (πολυς = many, γαμος = marriage). This term, not one of the best, is applied to plants bearing flowers some of which are perfect and some imperfect. Some flowers will have both sexes present in them, others only one sex. This term should be rigidly applied only where bisexual, male and female flowers all occur. This polygamous division falls into yet further groups.

(α) Monoicous ($\mu o \nu o s =$ one, $o \iota \kappa o s =$ a house). If all forms are on the same plant these polygamous plants will be monoicous. The Maple is an example of a plant having bisexual, male and female, flowers all on the same plant.

(β) Dioicous ($\delta \iota s =$ two). Where the three forms are found on two plants only. A satisfactory example of this at present it is difficult to name.

(γ) Trioicous ($\tau \rho \iota s =$ three). If the bisexual flowers, male flowers and female flowers, are all found on different plants the name trioicous is given. The Ash is an instance of this.

(ii.) The next great division of plants when their sexual relations are under consideration is that including all those that present only two forms, that is bisexual and male or bisexual and female. These are generally called polygamous, but Charles Darwin very wisely points out that it is important to distinguish between plants bearing three kinds of flowers, as in the former case, and plants bearing only two kinds of flowers, as in the present case. Whilst he thus distinguishes the groups he does not give a name to that set of plants presenting only two distinct arrangements of the sexual organs. I venture to suggest for these the name of Diplogamic ($\delta \iota \pi \lambda o s =$ double). Two types of this two-fold sexual arrangement occur.

(α) Monoicous. Where the bisexual flowers and the unisexual flowers are on the same plant. Of these two divisions will exist according as the unisexual flowers are female or male.

1. Where the unisexual flowers are female; the gynomonoicous ($\gamma \upsilon \nu \eta =$ woman). Example: Atriplex.

2. Where the unisexual flowers are male; the andromonoicous ($\alpha \nu \eta \rho =$ man). Example: Bedstraw.

(β) Dioicous. Where the bisexual flowers and the unisexual flowers are on different plants. Of these two divisions will exist according as the unisexual flowers are female or male.

1. Where the unisexual flowers are female; the gynodioicous. The Thyme is an example.

2. Where the unisexual flowers are male; the androdioicous. No cases of this have been satisfactorily determined.

(iii.) Unisexual. In this division the sexes are completely separated in all the flowers, that is each individual flower is either wholly male or wholly female, and no bisexual flowers exist.

(*a*) Monoicous. The andrœcia and gynœcia are in these cases on separate flowers, but the two kinds of flowers are borne on the same plant. Example: the Birch.

(*β*) Dioicous. The andrœcia and gynœcia are in these cases on separate flowers. Example: the Oak. Thus any given Oak tree is wholly given up to the bearing of flowers that are either male or female. There will be observed upon it in spring-time only the long yellow tails, which children call "cat's tails" and the botanist male inflorescences, or the simpler green-colored gynœcia with their red-tipped stigmas.

This somewhat complex division of plants according to their sexual relationships will now be illustrated in a tabular form.

a. Bisexual.	i. Hetero-styled — styles of different lengths	*α.* Dimorphic—of two lengths ...		Cowslip.
		β. Trimorphic—of three lengths ...		Loosestrife
	ii. Cleistogamic—perfect and cleistogamic			Violet.
	iii. Hetero-chromous—conspicuous and inconspicuous			Pansy.
	iv. Hetero-megathic—ordinary and larger flowers			Daisy.
	v. Hetero-gemmous—ordinary and closed buds			Feather Hyacinth.
b. Sexes more or less separated.	i. Polygamous — Bisexual, male and female ...	*α.* Monoicous—all on one plant		Maple.
		β. Dioicous—on two different plants ...		......
		γ. Trioicous—on three plants		Ash.
	ii. Diplogamic — Bisexual and male or female	*α.* Monoicous — both on one plant	1. Gynomonoicous—Bisexual and female on same plant ...	Atriplex.
			2. Andromonoicous—Bisexual and male on same plant ...	Bedstraw.
		β. Dioicous—on different plants	1. Gynodioicous—Bisexual and female in different plants...	Thyme.
			2. Androdioicous—Bisexual and male in different plants ...	......
	iii. Unisexual—all flowers unisexual	*α.* Monoicous—male and female on same plant		Birch.
		β. Dioicous—male and female on different plants		Oak.

CHAPTER XXV.

(2.) *Bisexual Plants.* (*a*) *Ordinary flowers.*

IN Chapters I. to VI., and also in the eighth chapter of this volume, that contains as a whole only eight chapters, bisexual plants are discussed. No little confusion seems to occur in the minds of young students in connexion with the words "unisexual" and "bisexual." Thus the young scientist is apt to think that unisexual signifies that both sexes are in one individual. The exact converse of that is really what is connoted by the word. A unisexual plant is a plant that has only one sex in each individual flower. The plants to which the largest part of this book is devoted are bisexual—that is, have two sexes in the same flower, and, indeed, this is the most customary arrangement in plants. The study of the forms of flowers met with among those bisexual members of the Vegetable Kingdom comprises the investigation of (*a*) Normal flowers, that are easy of observation and dissection (*b*) Cleistogamic flowers, difficult of observation and still more difficult of dissection.

(*a*) Ordinary conspicuous bisexual flowers. A very large number of the flowers that by their beauty, their odor, their secretion of nectar, and yet other marks indicate that insect agency is necessary for their fertilisation are found on careful examination to have the andrœcia or male organs and the gynœcia or female organs of varying lengths in different flowers. Thus if the common Cowslip be opened flower by flower, now selecting the flowers from one plant and now from another of the species, the stamens will be found in some low down in the corolla tube whilst the stigma of the gynœcium dwells high up within the same tube. In other specimens the conditions will be exactly reversed and the stamens will be found inserted at the top of the corolla tube whilst the short style of the gynœcium has only raised the rounded stigma a little distance upwards from the bottom of the tube. The first flower has long style and short stamens; the second flower has short style and long stamens. To the Cowslip, and to all other plants whose individual flowers vary in the length of their styles (and of their stamens) the name heterostyled has been given. In the Cowslip there are only two lengths of styles, and two lengths of gynœcia, but in some few plants no less than three different lengths of the sexual organs are encountered. Hence a subdivision of the heterostyled into (*a*) Dimorphic (δις, twice, μορφη = form) where two different lengths are met with, and (*b*) Trimorphic, wherein three different lengths are encountered. The account of these will be followed by discussion as to the fertility of flowers, the nature of hybrids, the distribution of heterostyled plants, the evolution of these.

(i.) Dimorphic Plants. (α) Their structure. The Cowslip shall be fully described as an example and easily obtainable type of this group of flowers. The root, the stem, the leaves, the inflorescence and calyx present no difference in the two forms of Cowslip. The flowers of the short-styled form open a little earlier than those of the long-styled. The corolla in the short-styled—and therefore the long-stamened—form has a shorter throat or expanded portion near the insertions of the stamens than has the long-styled. The pollen-grains in the short-styled have a greater diameter than those in the long-styled, in the ratio of 100 to 67. They are spherical in shape in this variety; oblong in shape in the long-styled. Of course they are placed high up in the corolla. Still pursuing the study of the short-styled form, equally of course its stigma is low down in the corolla. The stigma is somewhat flattened and not globular, and the little papillæ which render the stigma rough are shorter in the short-styled form than in the long-styled. Lastly the short-styled produces more seed than its fellows. Some of these differences seem to have a significance; to others we are at present unable to attach any meaning. Thus the greater length of throat in the corolla of the long-styled may be connected with the fact that the large and globular stigma with its length of supporting style wants especial room. Again the greater size of the pollen-grains in the short-styled flowers is intelligible, inasmuch as the pollen-grains from the anthers of the short-styled flowers have to fertilise the ovules of the long-styled flowers. Hence when these grains are placed on the stigma they have a long journey down the long style before them; and it is well therefore that the grains whose pollen tubes have to be of greater length should be of greater size than the grains of the long-styled plant whose pollen tubes have but to traverse the short style of one of the other kinds of flower. Lastly, there would seem to be some significance in the papillæ of the long-styled stigma being of greater size. The pollen-grains coming to that stigma will need some time for the extension of their tubes down the long-style, and during that time are liable to be blown away by the wind. Entangled, however, in the long and large papillæ there is more probability of their remaining in the desired position during all the required time. I sum up the differences between the two forms in a table.

	Short-styled.	Long-styled.
Flowering	Earlier.	A little later.
Corolla ...	Throat small.	Throat expanded.
Stamens ...	Long.	Short.
Pollen ...	Grains larger, spherical.	Grains smaller, oblong.
Style	Short.	Long.
Stigma ...	Flattened: short papillæ.	Globular: long papillæ.
Seeds ...	More numerous.	Less numerous.

(β) Their fertilisation. Insects are essential for the fertilisation of the Cowslip, and it is manifest that four possible methods of cross-fertilisation may occur. Thus pollen from the stamens of a short-styled plant may be carried to the stigma of a short-styled plant. There would then be a cross between two similar forms of flower. This union, which has been clearly shown to be disadvantageous as compared with the alternative union, is called by Darwin illegitimate. On the other hand, pollen from the stamen of a short-styled plant may be, and is much more likely to be, carried to the stigma of a long-styled plant. I say "is much more likely," because the positions of the stamens in the first flower and the stigma in the second are identical, and hence an insect visiting the former and carrying away pollen on a particular part of its body, is likely in visiting the latter to brush off that pollen on the stigma. Such a fertilisation is called by Darwin a legitimate union. Yet, again, two similar cases may occur with the long-styled plant. Thus the pollen from the stamens of a long-styled individual may be carried to the stigma of another long-styled plant. There would then, as in the former case, be a cross between two similar forms of flower. This union is again as disadvantageous as in the former case when compared with the alternative union, and is likewise called by Darwin an illegitimate union. On the other hand, pollen from the stamens of a long-styled plant may be, and is much more likely to be, carried to the stigma of a short-styled plant. I say "is much more likely" because, as in the former case, the positions of the stamens in the first flower and of the stigma in the second are identical; and hence, as before, an insect visiting the former and carrying away pollen on a particular part of its body is likely, in visiting the latter, to brush off that pollen on the stigma. Such a fertilisation is called by Darwin a legitimate union.

Hence, to sum up, four kinds of fertilisation are possible —two illegitimate, where the pollen from a short-styled plant goes to the stigma of short-styled, or where pollen of long-styled plant goes to stigma of long-styled; two legitimate, where pollen of short-styled goes to stigma of long-styled, or pollen of long-styled goes to stigma of short-styled.

(γ) Experiments. Then commence the experiments, innumerable and repeated. The reader feels a sense almost of awe at the patience, perseverance, indefatigable energy of the great experimenter. Hundreds, nay, thousands, of flowers are crossed, first in one fashion and then in another. Many thousands of seeds are counted, many hundreds are allowed to germinate. Measurements of the plants, numbering of the fruits, weighing of the seeds without end. But out of the chaos of facts systematic arrangements spring and generalisations appear. Careful calculations, careful weighing of evidence, carefully arrived at conclusions. From the multitudes of experiments on multitudes of plants, after much toil, certain large general results flow. Thus dealing for a moment only with the cowslip, experiments upon some 240 flowers reveal the momentous fact that if 100 be taken to represent the fertility of the legitimate unions, 69 only will represent the fertility of the illegitimate. These relative fertilities are measured as they were in the experiments described in a former work by counting the number of fruits and estimating the weight of the seeds in them. Thus one hundred flowers fertilised in legitimate fashion produced 77 capsules, whose seeds weighed 39 grains. One hundred flowers fertilised in illegitimate fashion produced 45 capsules, whose seeds weighed 11 grains. And, moreover, the flowers that are legitimately fertilised have a better physique than those which are fertilised in any other fashion. "Thus, in the spring of 1862, forty flowers were fertilised at the same time in both ways. The plants were accidentally exposed in the greenhouse to too hot a sun, and a large number of umbels perished. Some, however, remained in moderately good health, and on these there were twelve flowers which had been fertilised legitimately, and eleven which had been fertilised illegitimately. The twelve legitimate unions yielded seven fine capsules, containing on an average each 57·3 good seeds; whilst the eleven illegitimate unions yielded only two capsules, of which one contained 39 seeds, but so poor that I do not suppose one would have germinated, and the other contained 17 fairly good seeds."

The advantage derived by dimorphic plants from the existence of two forms of flowers is obvious. By such an arrangement cross-fertilisation is in most cases secured; and we have elsewhere seen, and it cannot be too frequently repeated, that such cross-fertilisation is of advantage in this way. When collision occurs of a male and of a female cell, formed not only in different flowers of the same species, but in flowers differing from one another in certain minute points, such as the lengths of the sexual organs, there is greater likelihood of the resulting offspring possessing more force than would be present in an offspring resulting from the collision of two similarly circumstanced cells. And, further, with such collision of dissimilarly circumstanced reproductive structures there is greater likelihood of the variation which is so essential for all evolution.

Other species of Primula, as *P. elatior*, *vulgaris*, the common primrose, *Sinensis*, *auricula*, *Sikkinensis*, *cortusoides*, *involucrata*, *farinosa*, are then considered; in all nine species. And the whole genus Primula, as thus investigated, yields the following result, that if the fertility of the two legitimate unions, where pollen from the short or long stamen has passed to stigma of short or long style, be taken as 100, the fertility of the two illegitimate unions, if judged by the production of fruit, is 88·4, and if judged by the average number of seeds per capsule, is 61·8. The first chapter closes with an account of a series of experiments with *Hottonia palustris*, an aquatic member of the order Primulaceæ, and of *Androsace vitalliana.* Both these plants are heterostyled, both are dimorphic, and in both cases the illegitimate unions are far more fruitful in their results than the legitimate.

(δ) Hybrids. The second chapter is devoted to a discussion as to the relationships between the Cowslip, Primrose and Oxlip, and the decision is arrived at that the Cowslip and Primrose are good and true species, that is they present sufficient differences of structure and function to be placed in separate divisions under the same genus. Here, as everywhere throughout his writings no teleological meaning is attached to the word "species," and assuredly there is no conception of the impossibility of species passing one into the other. The term is simply a convenient label for a set of organic beings possessing certain points in common. But the most interesting part of the chapter is the statement as to the marks of hybrids. It is important to understand clearly in this connexion, as in the study of the origin of species, the meaning of the term "hybrid." The great groups of organic beings called Orders in our essentially artificial methods of classification consist of similar and more numerous groups called genera. Each genus comprises still smaller and still more numerous groups called species, and species are frequently divided into varieties. Thus the order Primulaceæ contains many genera, one among which is named Primula. The Primula genus again contains many species, one of which is called *P. vulgaris* (the Primrose), and another *P. veris* (the Cowslip), and a third *P. elatior* (the Oxlip); and lastly, each of these is apt to present varieties. For instance, the Polyanthus is a garden variety of the Primrose (*P. vulgaris*). If a plant is produced as the result of impregnation of an ovule by pollen from a plant belonging to another genus it is called a Bigener. If a plant is produced as the result of impregnation of an ovule by pollen from a plant belonging to another species it is called a Hybrid. If a plant is produced as the result of impregnation of an ovule by pollen from a plant belonging to another variety it is called a Cross-breed. If the pollen from one of the genus Primula fertilises an ovule belonging to a flower of *e.g.*, the genus Hottonia, a Bigener would result. If the pollen from one of the species *P. veris* fertilises an ovule from one of the species *P. vulgaris*, a Hybrid would result. If the pollen from one of the variety Primrose fertilised an ovule from one of the variety Polyanthus a Cross-breed would result.

Later on it will be seen that one of the supposed difficulties in connexion with evolution is due to the nature of hybrids. Hybrid plants are very frequently more or less sterile. This also obtains with hybrid animals. The mule, as is well known, is sterile either in the first generation or the second. In the book now under consideration much of this difficulty is placed on one side by a demonstration of the fact that plants produced within the limits of one species are frequently quite as sterile as hybrids—that is, that cross-breeds are frequently as sterile as hybrids. This important point will be dealt with later; for the present let us state the four marks that show the hybrid origin of any plant.

1. Its occurrence in localities where both parent forms exist.

2. Its character being intermediate between the characters of the two parents.

3. Its greater sterility when crossed with a similar hybrid.

4. Its greater fertility when crossed with one of the parents.

(ε) Other dimorphic Plants. Quitting the order Primulaceæ, the order Linaceæ is next studied. This order includes our own flax with its expressive if cumbersome name *Linum usitatissimmum.* Charles Darwin dealt with the exquisite *Linum grandiflorum*, and also with the less beautiful *Linum perenne.* These plants, like the Primrose, are heterostyled and are dimorphic. Pursuing the same method as before, the relative fertilities of the legitimate and illegitimate unions are 100 to 7.

Then follows the narration of experiment after experiment, upon plant after plant. It will only be necessary for us to mention the names of the plants considered, and the numbers that express the results of the experiments. In each case 100 will be taken as measure of fertility of the legitimate where calculable, and whatever other numbers are given will be the measure of the fertility of the illegitimate unions. The numbers are obtained by the two methods of comparing the number of fruits produced, and also the weights of the seeds produced. It is to be kept in mind that these relative numbers tell us whether the fertilisation of two very similar forms or the fertilisation of two slightly dissimilar forms, the one by the other, is the more advantageous for the plant.

Pulmonaria officinalis, 100 to 0.
Pulmonaria angustifolia, 100 to 35.
Polygynum fagopyrum, 100 to 46.
Leucosmia Burnettiana
Menyanthes trifoliata
Limnanthemum Indicum
Villarsia
Forsythia suspensa
Cordia
Gilia pulchella
Gilia micrantha
Phlox subulata
Erythroxylon
Sethia acuminata
Cratoxylon formosum
Ægiphila elata
Ægiphila obdurata
Mitchella repens, 100 to 20.
Borreria, 100 to 0.
Faramea
Suteria
Houstonia Coerulea
Oldenlandia
Hedyotis
Coccocypselum
Lipostoma
Cinchona Micrantha

The last nine of this list are all members of one botanical order, the order Rubiaceæ, best known to us through the medium of the little yellow or white bedstraw of the country hedges. It is remarkable that this order contains more heterostyled plants than any other. No less than seventeen of the genera into which it is divided are heterostyled. In connexion with this order and with its genus, Faramea, a particularly interesting instance of the transition from one form to another, which the ignorant are so persistently stating is never encountered, presents itself. In Faramea the anthers of the stamens in the short-styled flowers rotate on their axes, and in this way the pollen is easily brushed off on to the visiting insect. But the anthers of the stamens of the long-styled form do not rotate on their axes. They open along the inner side. This latter method of dehiscence, or opening, is ordinary in the Rubiaceæ. The rotation on the axes of the anthers is extraordinary. The latter movement has been almost certainly acquired much later in time than the ordinary method of dehiscence. As the plant became heterostyled, and the stamens of the short-styled form increased in length, they have gradually become possessed of this beneficial property of rotating on their own axes. But careful examination of many of the short-styled flowers shows that the power of rotation is not completely acquired. Many of the stamens do not rotate fully. Some do not rotate at all. Hence a certain proportion of the pollen is rendered absolutely useless, and it would appear that the evolution of this plant in this direction has not yet reached its maximum. And this is but one haphazard illustration out of multitudes that the careful observation of to-day is constantly revealing of cases where the transition stages that were to be expected on the theory of evolution present themselves and confirm that view.

(ii.) Trimorphic. (α) Their structure. The best illustration of the plants that are not only heterostyled, *i.e.*, with different lengths of gynœcium, but also trimorphic, is the Purple Loosestrife *(Lythrum Salicaria)*. If you pluck and dissect flowers of the Purple Loosestrife, you will find the following particulars common to all. A long tubular calyx; distinct, rather crumpled purple petals inserted upon the calyx near its summit; a number of stamens of varying lengths also inserted in the calyx but very much lower down than the petals; a gynœcium with free ovary, a style, and a stigma. But whilst these phænomena are common to all Loosestrifes, there are differences between the individuals. Thus, you may pluck and dissect one flower that has stamens in two groups, a short set and a long set. When that is the case the gynœcium will be found to be of such length that the stigma is mid-way between the anthers of the short stamens and the anthers of the long. You may pluck another flower and find the stamens in it in two sets, the one set of the same length as the short ones in the first, the other of the same length as the style in the first. And in this second flower the style will be longer than any of the stamens, and the stigma carried far beyond the reach of the anthers. Yet, again, a third will be encountered in which the stamens are in two sets, the one a long set and the other of middle length, and in this flower the style will be short and the stigma far below either set of anthers. Three forms then present themselves. The short-styled, which has stamens of mid-length and of great length, the mid-styled, which has stamens of short length and of great length, and the long-styled, which has stamens of short length and of mid-length. It will be seen that the length of the style is always different from that of either of the sets of stamens, and this will mean difficulty, if not impossibility, of self-fertilisation. For the future we shall name each by the length of its style. The reader must keep in mind that giving the length of the style implies also the length of the stamens. The two sets of stamens in each case are different in length from the length of the style.

The three forms of Lythrum differ in yet other ways than in the lengths of their styles or of their stamens. They vary in the size of their pollen-grains, in the size of their seeds, and in the number of their seeds. Thus—representing size by numbers—

Pollen-grains	from longest stamens of	short-styled form,	$9\frac{1}{2}$	to	$10\frac{1}{2}$.
,,	,, ,, ,,	mid-styled	,,	9	,,	10.
,,	,, mid-length stamens of	long-styled	,,	7	,,	$7\frac{1}{2}$.
,,	,, ,, ,,	short-styled	,,	7	,,	$7\frac{1}{2}$.
,,	,, shortest stamens of	long-styled	,,	6	,,	$6\frac{1}{2}$.
,,	,, ,, ,,	mid-styled	,,	6	,,	6.

On looking at this table, it will be observed that the largest pollen-grains are found in the anthers of the longest stamens, and the smallest pollen-grains are found in the anthers of the shortest stamens. If 100 be taken as the diameter of the largest grains, 60 is that of the smallest. Again, in the size of the seeds a similar parallelism obtains.

The largest seeds are met with in the ovaries of the longest styled, and the smallest seeds in the ovaries of the shortest styled. But when we consider the number of seeds produced by individual plants, the parallelism does not continue. The numeration of the seeds in eight carefully-selected, thoroughly-developed fruits, taken from plants growing wild, gave as result the proportional numbers 93 for the long-styled, 130 for the mid-styled, 83 for the short-styled. The mid-styled are, therefore, most fertile. A fine instance of special adaptation that must have required very many years at least for evolution up to the present condition, is shown in the arrangement of the Lythrum. The shortest stamens, deep down within the flower, could only be touched by the proboscis and narrow chin of a bee. We find their ends upturned and their lengths varying, so that they stand, as it were, in a narrow file, sure to be touched by the narrow entering proboscis. But the anthers of the longer stamens are nearly on the same level, and at greater distances from each other. As they have to brush, not against the thin proboscis, but against the broad body of the insect, this is the most advantageous arrangement for them.

(β) Their fertilisation. The fertility resulting from legitimate and illegitimate unions between the three forms of Loosestrife was first made the subject of multitudinous experiments. A legitimate union will occur when the ovule in a gynœcium, whose style has a particular length, is fertilised by pollen from stamens of the same length as the style.

(γ) Experiments. Some idea of the complexity of the reproductive system of this plant, and of the laborious nature of the experiments will be formed when it is considered that no less than 18 distinct unions must be made before results can be trusted. On each stigma 6 kinds of pollen must be tried, and as there are 3 lengths of stigma that will make 18 unions. 1. The result of the experiments is that if 100 be taken as expressing the fertility of the legitimate unions 33 expresses the fertility of the illegitimate, when the decision is based upon the number of flowers which fruited. If the decision be based upon the average number of seeds in each fruit the proportions are 100 to 46. 2. A further remarkable conclusion is that the greater the difference in length between the gynœcium whose ovule is being fertilised and the stamen whose pollen is fertilising, the greater is the sterility of the union. Thus if the ovules of the long-styled plant are fertilised first by pollen from mid-length stamens, and secondly by pollen from short-length stamens much better results follow in the former case, than in the latter. 3. And lastly the mid-style form has a much higher capacity for fertilisation than either of the others. Along with that is to be noted the fact that the stamens of the mid-style though not rudimentary are tending in that direction. This is shown by the fact that the pollen grains in the mid-styled form are less in diameter than the corresponding grains produced by the two other forms. We may regard this intermediate form of Lythrum as more female in nature than either of the others, and as possibly evolving in the direction of a unisexual female plant.

(δ) Other trimorphic plants. The next genus investigated is the Oxalis of the order Geraniaceæ, best known to English botanists by the graceful little Woodsorrel with its delicate leaves, split into three heart-shaped divisions. This is also heterostyled and trimorphic. Further, the difference in size of the pollen grains observed in the Lythrum is also seen here.

	Divisions of the Micrometer.
From the longest stamens of short-styled	15 to 16
,, mid-length ,, ,,	12 ,, 13
,, longest stamens of mid-styled	16
,, shortest ,, ,,	11 to 12
,, mid-length stamens of long-styled	14
,, shortest ,, ,,	12

The extreme differences in diameter in this case are as 100 to 69. With this genus the most striking differences between the results of the legitimate and illegitimate unions present themselves. If 100 be taken to represent the fertility of the legitimate, that of the illegitimate is represented by 0, as absolutely no flowers, the result of illegitimate union, formed any fruits at all.

One other trimorphic plant is dealt with, interesting as the only member of the great class Monocotyledones that is heterostyled. It is the Pontederia, an aquatic plant closely allied to the Lily order, growing on the banks of rivers in Southern Brazil. The size of its pollen grains:

	Divisions of the Micrometer.
Long-styled form, from the mid-length stamens (Average of 20 measurements.)	13·2
Long-styled form, from the shortest stamens ... (Average of 10 measurements.)	9·0
Mid-styled form, from the longest stamens ... (Average of 15 measurements.)	16·4
Mid-styled form, from the shortest stamens ... (Average of 20 measurements.)	9·1
Short-styled form, from the longest stamens ... (Average of 20 measurements.)	14·6
Short-styled form, from the mid-length stamens (Average of 20 measurements.)	12·3

The extreme differences in diameter are as 100 to 55. As only dried specimens could be obtained by Darwin of course no experiments could be made on this plant.

(iii.) The comparative inferiority of illegitimate offspring. This comparative inferiority shows itself in three principal ways, (α) stature, (β) general constitution, (γ) nature of the anthers.

(α) When legitimate plants growing under similar circumstances to their illegitimate companions were compared with them in height the results were that the numbers 28, 29, and 47 expressed the heights of the illegitimate whilst numbers nearly double these expressed the heights of the legitimate, one of which was 77 inches high.

(β) The illegitimate are weak in their constitution. They flower late in the season and sometimes do not produce flowers each year.

(γ) The anthers are often shrivelled, containing brown or pulpy matter without true pollen grains, and in many cases not opening at all. They are called contabascent (contabescere =to waste away). Adding these disadvantages to the lessened fertility that has already been demonstrated over and over again it must be clear that the impregnation of ovules in the illegitimate fashion is of much greater disadvantage to the plant than the impregnation in the legitimate method. And these conclusions are true of all the heterostyled plants upon which the experiments were made.

(iv.) Illegitimate unions and hybrids. In conclusion a striking comparison is made between the illegitimate unions in these heterostyled plants and the hybrid unions between distinct species. It has been shown above that hybrid is the name given to the result of the crossing of two so-called species. All the world knows by this time that there are two opposed views in respect to species. Those who hold, in antagonism to the facts and to the thinkers of modern scientific order, that species are all distinct creations were until recently in the habit of pointing triumphantly to the fact that hybrids were more or less sterile as proof positive of their view. It is to be observed that of late the triumphant tone has been somewhat modified. It is needless to state that the experiments and reasoning of Charles Darwin have mainly produced that modification. To understand thoroughly his reasoning in this connexion it must be remembered that the advocates of the Special Creation view hold that species alone have been thus separately manufactured. They do not maintain that varieties—that is the sub-divisions of species, are special creations. And yet all his experiments go to prove that the same sterility that is encountered when union between two species is effected is met with when mere varieties are crossed. If, therefore, such sterility is an argument in favor of the creation of species, it is an argument in favor of the creation of varieties, and at this last nobody has yet been rash enough even to hint. Reducing the matter to its extreme conclusion we should perhaps be justified in saying that when there was sterility between two individuals of the same variety, as very frequently does occur, we ought to argue from this that those individuals have been specially created. Comparing the hybrid unions between distinct species with the illegitimate unions between forms of the same heterostyled species we find—(α) In both cases every degree of sterility, from slight, through less fertility, to absolute barrenness. (β) In both cases the ease or difficulty of effecting the first union is dependent upon the external conditions to which the plants have been exposed. (γ) In both cases the degree of sterility in plants coming from the same parent is highly variable. (δ) In both cases the male organs are more affected than the female. (ϵ) In both cases the offspring are apt to be dwarfed and weak. (ζ) In both cases the offspring are profuse flowerers. Small wonder therefore that Darwin ends this part of his subject with phrases such as these.

"It is hardly an exaggeration to assert that seedlings from an illegitimate fertilised heterostyled plant are hybrids formed within the limits of one and the same species. This conclusion is important, for we thus learn that the difficulty in sexually uniting two organic forms and the sterility of their offspring afford no sure criterion of so-called specific distinctness. The sterility of their illegitimate unions and that of their illegitimate offspring must depend exclusively on the nature of the sexual elements and on their incompatibility for uniting in a particular manner. And as we have just seen that distinct species when crossed resemble in a whole series of relations the forms of the same species when illegitimately united, we are led to conclude that the sterility of the former must likewise depend exclusively on the incompatible nature of their sexual elements, and not on any general difference in constitution of structure."

(v.) The distribution of heterostyled plants. It is very general. Thirty-eight genera include heterostyled individuals. These genera are widely distributed throughout the world. Thus the three closely allied genera, Menyanthes, Limnanthemum, and Villarsia, inhabit respectively Europe, India, and South America. Heterostyled species of Hedyotis are found in the temperate regions of North and the tropical regions of South America. Trimorphic species of Oxalis live on both sides of the Cordilleras in South America and at the Cape of Good Hope. Again, the three great divisions of plants founded on the nature of their stem present heterostyled individuals. There are heterostyled trees, heterostyled shrubs, heterostyled herbs. Again, the nature of the habitat appears to be no impediment to the formation of such flowers. Plants dwelling upon alpine summits and in lowland glades, plants dwelling upon the land, plants floating or immersed in the water, or plunged in the stagnant marshes—all these may be heterostyled.

From the general nature of the distribution of these plants it will be anticipated that some advantage accrues to the owners of andrœcia and gynœcia of different lengths. The great advantage clearly is that as all the flowers on the same plant belong to the same form, when legitimate fertilisation takes place two distinct individuals must cross; and further all the individuals of the heterostyled plant can yield seeds, whilst in the other plants that will come next under consideration where the sexes are separated, only a certain number can yield seed. Of course the heterostyled plants, like the dichogamous and unisexual plants have this advantage over those plants that are liable to self-fertilisation, that the junction of two individuals is essential for fertilisation. Further, the trimorphic plants have a slight advantage over the dimorphic in the struggle for life. For suppose only two individuals of a dimorphic plant, like the primrose, to be side by side in an out of the way part of the world. It is even betting that both will belong to the same form, and in that case the full number of strong seedlings cannot be produced. But if the two plants growing side by side in an out of the way part of the world are trimorphic the betting is two to one that they will not belong to the same form. The odds, therefore, are two to one that legitimate fertilisation will take place and the full tale of strong seedlings result.

(vi.) The means by which plants may become heterostyled. The believer in evolution seeing certain results in the structure and functions of plants and animals is by the nature of his belief compelled to ask himself how these have been brought about. He has not the refuge of the unthinking. He does not avoid all difficulty and confess his own idleness by uttering the formula "It is the will of god." It is impossible, nay it is impious for him to explain the complex structures and relationships which he observes as being in any sense the result of plan or design on the part of hypothetical deity. Recognising the principles that living beings vary, and that only variations that are of use to the living beings are likely to be persistent, it is his honorable duty and difficulty to attempt to reason out the lines along which the variations have passed until they have become permanent. The question of the heterostylism of plants presents a difficult problem for the solution of the evolutionist. Let us see how the greatest of evolutionists deals with it.

(*a*) The first step towards a plant becoming heterostyled is probably variability in the length of the gynœcium and of the stamens. Without this initial variability in the length of the sexual organs the ultimate result is inconceivable. The plant variable as to the length of its reproductive apparatus would, like all plants, benefit by cross-fertilisation, and probably was at least in some degree self-sterile. So far then we have varying lengths in stamens and gynœcium, self-sterility to a greater or less degree, and the universal fact of benefit resulting from cross-fertilisation. Now natural selection would come into play. The variations in length being infinite at first, are by natural selection reduced to two sets of different lengths in different individuals, and that the long stamens should be associated with the short styles in the same flower would follow from the law of compensation or *balancement*. According to this principle excessive development of one part is apt to be accompanied by lessened development of another, and hence the long stamens would be associated with the diminished style in the same flowers, whilst the converse obtained in others.

(β) Herr Müller suggests that the ordinary plants may have been rendered heterostyled through habit, from continual application of the pollen of one set of anthers to a gynœcium of particular length. He conceives that in time any other method of fertilisation would be nearly or absolutely impossible.

(γ) A third view is that heterostyled plants have specially acquired an incapacity for fertilisation in particular ways. More probable than this, however, is the supposition that the male and female organs in two sets of individuals have become specially adapted for interaction one with another, whilst the sterility resulting from the crossing of individuals of the same form is an incidental and not a directly connected result. By "incidental result" is meant an accompanying result, but not one that is directly traceable to that action to which it is incidental. Probably, therefore, the species which became heterostyled at first varied, so that sets of plants resulted having different lengths of andrœcia and gynœcia, and that simultaneously their reproductive powers were so modified that the sex elements in one set were adapted to act on the sex elements of the other, and hence that the sex elements in the same set became ill-adapted for acting the one upon the other.

CHAPTER XXVI.

(3.) *Plants in which the sexes are separated.*

(*a*) THEIR Evolution. Our author commences here with a dissertation as to the way in which plants possessing both sexes may have passed into plants in which the sexes are separated. This conversion can only have been effected upon entomophilous or anemophilous plants. Self-fertile plants would never lend themselves to the development in the direction of separation of the sexes. Next, it is possible that the production of male and female elements by the same individual may have been too great a strain upon its powers. Again, the variations that are so persistently occurring may in some instances have taken the form of the production of large-seeded plants. That is to say, some few individuals may have resulted from variation, individuals that had seeds larger than the average, better supplied with nutriment, and therefore likely to be able to hold their own in the universal battle. This variety with the large seeds would tend to increase and by the law of compensation its stamens would be reduced in size. It would, in short, be moving in the direction of a unisexual female plant. As this particular set of plants would produce less pollen, certain other individuals would have to produce more pollen, and by the law of compensation their female organs would be reduced in size. And thus our first set producing the larger seeds and with their stamens aborted are likely to become unisexual female plants, and our second set producing more pollen with their gynœcia aborted are likely to become unisexual male plants.

Dimorphic heterostyled plants are still more likely to produce unisexual flowers by evolution, for the male and female organ here differ not only in structure, but in function, and one may say that there is twice as much chance in their case of the special development of the one set of organs and the gradual abortion of the other set.

(*b*) Size of the corolla. In the plants that have their sexes separated, the corollas of different flowers frequently vary in size. It is noticeable that the smaller corolla is always present in the female. Possibly the explanation of this is that the abortion of the stamens which has taken place in the female flower has spread from them to the petals, and this view is strengthened by the fact that in *Rhamnus Catharticus* not only the petals of the female flower have been reduced in size, but the reduction in size has extended even to the sepals. An objection to this explanation is afforded by Darwin himself, after his usual fashion. By the law of compensation the abortion of the stamens ought to have led to increased size of the corolla of the female flower, but perhaps we may argue that the energy saved by the abortion of the stamens has been totally directed to the female reproductive organs, and there has been none to spare for the corolla.

CHAPTER XXVII.

(4)—*Cleistogamic Flowers.*

EVEN before the days of Carl von Linné, more generally known by his Latinised name, Linnæus, it had been discovered that certain plants produced two kinds of flowers —the ordinary open ones and minute closed ones. Not until 1867 were these latter thoroughly understood, and named by Kühn.

(*a*) Structure. They are very small, and never open. The petals are rudimentary or absent, the stamens few, anthers small, pollen-grains few, emitting their tubes while still within the anther, gynœcium very small, stigma almost wanting. Flowers that are reduced in circumstances indeed. Everything is upon the smallest possible scale. Fifty-five genera, widely distributed throughout the vegetable kingdom, are known to produce such flowers, and the larger proportion of them, thirty-two out of the fifty-five, are genera whose ordinary blossoms are irregular in shape. The seeds produced by cleistogamic flowers differ neither in their appearance nor in their number from those produced from the perfect blossoms, but the fruits from the cleistogamic develop much more rapidly than those from the perfect. Darwin describes cleistogamic flowers of the following genera out of the fifty-five that show them—Viola, Oxalis, Vandellia, Linaria, Ononis, Impatiens, Drosera, Juncus, Leersia. The cleistogamic flowers owe their structure almost certainly to the arrested development of perfect ones.

(*b*) Advantages. They would seem to furnish these most desirable results to the plant. (i.) They insure the production of seed in seasons when perfect flowers, owing to climatic conditions, might be able to produce none. (ii.) They produce seeds with very little consumption of matter and very little transformation of motion. A wonderfully small expenditure of pollen is all that is needed for the production of seeds as numerous and as perfect as those of the complete flowers. Thus by calculation the whole of the pollen-grains of a cleistogamic Oxalis are but 400, of an Impatiens 250, of a Leersia 210, of a Viola 100. Let the reader compare these with the 243,600 grains of a Dandelion, the 3,654,000 of a Pæony. (iii.) It must not be forgotten that most of the cleistogamic genera are irregular-flowered; therefore their perfect flowers depend for fertilisation upon insects. Now insects, especially in our strange English climate, are very variable quantities. Hence seasons might occur, and do occur, when, not sufficient insects being present, or an absolute dearth of necessary insects occurring, no seeds would be formed were it not for the cleistogamic flowers. It is not difficult, therefore, to conceive of the gradual evolution of these closed, aborted, self-fertilising, and, on occasion, most useful flowers.

CHAPTER XXVIII.

(5) *Personal Characteristics.* (6) *Gradations.*

(5.) IT is now late in the day to call attention to Charles Darwin's enormous capacity for work, but the experiments recorded in the volume whose consideration now is drawing to a close furnish still further evidence of that capacity. Take two special illustrations. In studying *Thymus serpophyllum*, one of the gynodioicous plants, he is anxious to ascertain the relative numbers of the bisexual and of the female flowers. Hence he sets to work to examine every plant growing on the edge of an over-hanging cliff some 200 yards in length. As the plants were several hundreds in number, one has here a suggestion as to the amount of patient toil of which our naturalist is capable. Again on page 189 we find the statement that he counted under the microscope over 20,000 seeds of one particular plant before he arrived at certain of his important conclusions. An instance of the notable modesty to which we have had occasion heretofore to refer occurs in the first few lines of the present volume, wherein he states that the subject whereof he is about to speak ought to have been treated by a professed botanist, to which distinction he can lay no claim.

For the benefit and warning of those that talk lightly about the amount of faith which is required in scientific work it is well to quote one little phrase. In speaking of the *Linum* he does once use the expression "I had faith." Doubtless these three words will be quoted by the people who read the works of Darwin and other evolutionists for the purpose of collecting isolated sentences, and hurling them without their context at the heads of the preachers of evolution. But in this case, as in most of their quotations, the context destroys the arguments that have been based upon the particular utterance. "Nevertheless *from my experi-*

ments on Primula I had faith." That is the true faith, the faith founded upon experiments.

(6) Gradations. In the study of the different forms of flowers many interesting cases of gradations between forms that would a few years ago have been regarded as created specifically distinct occur. Upon page 291, in speaking of the *Euonymus Europœa* or Spindle-tree our writer states :

"We have a perfect gradation from the female bush (B), which in 1865 was covered with 'innumerable fruits,'—through the female A, which produced during the same year 97—through the polleniferous bush C, which produced this year 92 fruits, these, however, containing a very low average number of seeds of small size—through the bush D that produced only 20 poor fruits—to the three bushes, E, F, G, which did not this year, or during the previous years, produce a single fruit."

Again on page 320, dealing with the various forms of flowers in the genus *Viola*, which is one of the genera presenting cleistogamic flowers, we read :

"It is interesting to observe the gradation in the abortion of the parts in the cleistogamic flowers of the several foregoing species. It appears from the statements by D. Müller and Von Mohl that in *V. mirabilis* the calyx does not remain quite closed; all five stamens are provided with anthers, and some pollen grains probably fall out of the lobes on the stigma, instead of protruding their tubes whilst still enclosed, as in the other species. In *V. hirta* all five stamens are likewise antheriferous; the petals are not so much reduced and the pistil not so much modified as in the following species. In *V. nana* and *elatior* only two of the stamens properly bear anthers, but sometimes one or even two of the others are thus provided. Lastly, in *V. canina* never more than two of the stamens, as far as I have seen, bear anthers; the petals are much more reduced than *V. hirta*, and, according to D. Müller are sometimes quite absent."

Professor Oliver adds that he has seen flowers on *Campanula colorata* in an intermediate condition between cleistogamic and perfect ones.

G.—On the Movements of Plants.

CHAPTER XXIX.

A.—*Introduction.*

THIS is the latest and perhaps the most interesting of the contributions to Botanical science of Charles Darwin. The book is more interesting than any other from a personal point of view. On its title-page is inscribed "By Charles Darwin assisted by Francis Darwin," so that in this his last work, for the present, upon biological subjects we find the great naturalist aided by one of those sons who have given promise that the name of Darwin will lose nothing of its scientific fame as far as they are concerned.

Further, the subject matter of the book is of deepest interest. It will be remembered that one of the old distinctions between plants and animals was the presence of movement in the latter, and its absence in the former. That this distinction does not hold has been already demonstrated, but this book is devoted to the complete destruction of all arguments that attempt to dissever plants from animals on the ground of movement. It shows that movement is universal in plants—nay more, that in connexion with that movement there is at least nervous action if not nervous structure. It demonstrates the line along which the evolution of the more complex movements of plants has passed in the development of these last from the rudimentary and exceedingly simple form of movement presented by all parts of all plants. In the study of the Movements of plants we shall consider (A) the introduction, (B) circumnutation or the universal movement at which hint has been made, (C) its modifications, (D) nervous action, and (E) conclusion.

A. Introduction. In the opening pages of the book there is dealing with the following topics. The object of the book; certain technical terms necessary to be understood by its reader; the general nature of plant movement; its causes; its universality; and the methods of observation.

(1) The *object of the book* is to describe and connect together several large classes of movement common to almost all plants. It is needless to say that in this description there is constant evidence adduced in favor of the great principle of evolution as opposed to special creation.

(2) *Technical terms.* All the world knows that a plant consists of root, stem, and leaves, these last either the ordinary green leaves, or those modified and colored leaves which constitute the flower. The plant in its rudimentary condition within the seed, when it is known as Embryo, has the same three parts—root, stem and leaf. The rudimentary embryonic root, of small size and of very simple structure, is called the radicle (from *radix*, a root). The rudimentary stem, represented by a small simple structured bud, is called the plumule; whilst the first leaves that are formed, also small and simple, though rapidly becoming larger and more complex when once they are raised into the air, are the cotyledons. If anyone will study a seedling plant that has just emerged from the seed and is growing up into its new life they will find a radicle or young root growing down into the ground, a young stem growing up into the air and bearing in most English plants two young leaves, the cotyledons. The radicle, therefore, will mean to us the root of the young seedling plant. The part of the stem that bears, and is below the cotyledons or firstborn leaves is called the hypocotyl (ὑπο = under). The part of the stem that rises above and beyond and more into the air than the cotyledons is the epicotyl (επι = upon). It is very important that the unscientific reader become thoroughly acquainted with the meaning of these terms, and the relative positions of the parts they denote. From below upwards, once again, we have radicle or root, hypocotyl or stem beneath the first leaves, cotyledons or the first leaves, epicotyl or the stem above the first leaves.

Before Charles Darwin took in hand the subject of the movements of plants, certain movements were known and named —those dependent upon the action of light, and those dependent upon the action of gravitation. Many plants had been observed to have the habit of growing towards the light. Such growth towards the light is heliotropism (ἥλιος = sun,

$\tau\rho o\pi o\varsigma$ = direction). Certain others had been observed to bend from the light, and this movement was called aphelio-tropism ($\dot{\alpha}\pi o$ = from). A third form of movement as affected by the action of light is where the plant does not grow directly towards the light nor directly away from it, but assumes a position more or less transverse to the line of light. This form of movement is called diaheliotropism ($\delta\iota\alpha$ = across). In like manner there are three kinds of movements dependent on gravitation, or the attraction towards the earth. When a part of a plant grows straight down towards the earth, we have geotropism ($\gamma\eta$ = the earth). When a part of a plant tends away from the earth, we have apogeotropism ($\alpha\pi o$ = from). And when it tends to place itself transversely to the radius of the earth, dia-geotropism ($\delta\iota\alpha$ = across). Without pausing at present to inquire into the causes of these various movements, two other terms must even thus early be explained. They are Epinasty and Hyponasty. Epinasty (from $\epsilon\pi\iota$ and *nasco* = I grow) occurs when the upper face of a leaf or allied organ grows more quickly than the lower, and hence the part curves downwards. Hyponasty ($\dot{\upsilon}\pi o$ = under) is the reverse of this, where the lower face of a leaf or allied organ grows more quickly, and the organ curves upwards.

(3) *Nature of the movement.* It is, again, of vital import-ance that the manner of that movement, which is common to perhaps all plants, should be thoroughly grasped. It is essen-tially of the same nature as that of the stem of a climbing plant (see page 77). The particular part of a particular plant that is subject to this widely-diffused movement points successively to the north, the east, the south, the west, and back again to the north. Had the movement been quite regular, the apex of the organ that is moving would have described a circle. What actually occurs is that a series of ellipses are described. If the apex be observed at any given moment, and found to be pointing, we will say, due north, it will be seen next to return towards the south, and then again to move forwards to the north. These backwards and forwards movements are not along the same line. They are lines close together, and tracing out long ellipses. Succes-sions of such backwards and forwards movements and suc-cessive formations of such ellipses follow. But the axis of each ellipse points to a different point of the compass from

that pointed to by its successor or its predecessor. That is to say, there are a series of backwards and forwards movements along different lines, with description of a series of long ellipses, and also a general slow swing round from north to east, south, west. A double movement, therefore, of the part takes place. This movement is to be named circumnutation (from *circum*, around; *nuto*, I nod).

(4) *Cause of the movement.* The parts that cause movement are made of cells. Cells upon one particular side of the stem or leaf or branch that is to move become turgescent, that is swollen. Such turgescence occurring in many cells all placed upon one side of an organ will cause the organ to bend away from that side. With the increased turgescence of the cells the greater extensibility of their walls also occurs, and in many cases, as a sequel, there is increased growth of the part. If circumnutation has to take place it is clear that this increased turgescence and its accompanying phænomena must take place first upon one side, and then upon the opposite side, or perhaps still more accurately that the line of increased turgescence must slowly pass around and around the stalk of the leaf or the stem of the flower. So that it is concluded that increased growth first on one side and then on another in many cases, and increased turgescence of cells along lines first on one side and then on another, accompanied by an extensibility of the cell walls are the primary causes of this movement.

(5) *Circumnutation generally.* Apparently every growing part of every plant is continually circumnutating, though of course in many cases on an exceedingly small scale. The root down in the ground, the stem that has climbed up into the air, the leaves that spread forth from that stem, the tiny flower-buds on their minute stalks, and later, when these open, the sepals, petals, stamens, and even the carpels, are all constantly progressing slowly round and round in small circles. And not only is there this general and universal movement, but many parts possess special modification thereof. As these will have to be dealt with in succession let us name and define them.

(*a*) Revolving nutation. The convolvulus as it clambers spirally round and round the wheat stem or the branches of huge shrubs presents this modified form of circumnutation. The great sweeps made by the stems of all climbing plants, and by the tendrils of the vine or the passion flower are due to a mere increase in the extent of the ordinary movement.

(*b*) Leaf movements. This general name is given to those movements by which young leaves assume their normal and most advantageous position. The movements are due to a properly balanced combination of epinasty and hyponasty.

(*c*) Sleep movements. These are the movements by which leaves and flower-leaves also in many cases assume a vertical position at night. The technical name for such movements is Nyctotropic (from *νυξ* = night, *τροπος* = direction.)

(*d*) Light movements. The heliotropism and the apheliotropism to which reference has been made above.

(*e*) Gravitation movements. The geotropism and the apogeotropism to which reference has been made above.

(6) *The methods of observation.* It is necessary briefly to describe the plan adopted by the two observers, Charles Darwin and Francis Darwin, in innumerable experiments upon the movements of plants. Stated briefly it was as follows. The plants were grown in pots, either shielded entirely from the light or with arrangement for admitting the light in some particular direction only. A horizontal sheet of glass and a vertical sheet of the same material on one side permitted observation of the plant at the necessary times. A minute glass filament not thicker than a horse-hair and about half-an-inch in length was fixed to the part whose movement was to be observed by shellac dissolved in alcohol. To the thin end of the filament a very small dot of black sealing-wax was fixed, and a card with a black dot was attached to a stick driven into the ground hard by the filament. The observer by shifting his position and careful observation could always at a given moment find a position in which the black dot on the sealing wax and the black dot on the card as viewed through either the horizontal or vertical glass exactly covered each other. Then a spot in indian ink coinciding with their line of position was made on the glass plate. This observation was repeated at short intervals of time and the series of dots of indian ink were joined by straight lines. In this way a tolerably accurate tracing of the movement of the moving part was obtained upon the glass. This tracing was then transferred to paper.

In some cases the sealing-wax tip was discarded and two minute triangles of paper, $^1/_{20}$ of an inch in height, were fixed to the two ends of the glass filament. The indian ink dot was then made on the glass plate at a point corresponding with a line joining the two tips of the paper triangles.

(7) *Nervous action.* The most fascinating part of the book to the ordinary reader and possibly even to the scientific student will be the striking evidence that is adduced as to nervous action in plants. It is difficult as yet to discover any structures that can fairly be called nervous, as far as their histology is concerned, but certain parts of certain organs, however, assuredly have functions not possessed by other parts of the plant, and that it is difficult to call by any other name than nervous functions. For example, it will be shown that with some seedling plants only the upper part is sensitive to light, and that this upper part transmits an influence to the lower causing that to bend. So also the tips of radicles and the tips only are sensitive to stimuli and transmit an influence to the upper part, causing it to bend from or towards the stimulus in different cases. As it is in the possession of a nervous system that animals are popularly supposed to be entirely distinct from plants, all th evidence in favor of this remarkable nervous action of certain parts of plants will be very welcome to the evolutionist.

CHAPTER XXX.

B.—*Circumnutation.*

B. CIRCUMNUTATION. Turning to the investigation of the general movement known as circumnutation, without at present making any reference to its specialised forms, we have :—

(1) The study of the circumnutation of seedlings or young plants.

(2) The study of the circumnutation of mature plants.

(1) *Circumnutation in seedlings.* This part of the subject will be divided into—(*a*) The plants investigated; (*b*) movements of radicles; (*c*) of hypocotyls; (*d*) of cotyledons; (*e*) of epicotyls; (*f*) the rate at which the movement takes place.

(*a*) The plants investigated. The botanical student of the list given will see that the plants that were selected for observation fairly represent the whole of the vegetable series, with the exception of some of the very lowest Cryptograms. And hence the legitimate inference is that this kind of movement is common to every seedling species.

(*b*) Movement of radicles. Numberless experiments with the primary radicles, or small first roots of plants, demonstrated the fact that all young radicles circumnutate. Consider the value of this constant swing round and round, even on a small scale, of the end of the young root. As soon as ever the tip steals out from the seed it commences to circumnutate, and probably continues to do so, as far as its growing extremity is concerned, as long as growth lasts. This sweeping movement, bringing it into relation to different parts of the soil in which it is, gives it every chance of finding cracks and crevices through which it can make its way. It will be best for it to move in the direction of least resistance, and such direction of least resistance is more likely to be found by a little root persistently changing its position than by one that grows steadily, doggedly downwards. Accompanying the circumnutating movement of the radicle is its own longitudinal and transverse growth. It is not only sweeping round and round. It is elongating and it is expanding. And the force with which young roots elongate and expand is surprising. Thus the longitudinal growth is sufficiently vigorous to cause a downward pressure equal to lifting, in the course of twenty-four hours, a weight of a quarter of a pound, while the force exerted transversely by a growing radicle was experimentally shown to be able, in the course of six days, to make a fissure in a piece of wood, through a hole in which the radicle passed, that required a weight of 8lb. 8oz. for its formation when the radicle was absent. The secondary radicles, that is, those given off from the primary root, were shown by experiment to possess the movement of circumnutation.

(*c*) The hypocotyl. The hypocotyl, it will be remembered, is the part of the young stem lying between the radicle, or rudimentary root below, and the cotyledons, or first seed leaves above. The first notable peculiarity of this part of the plant is that it always breaks through the ground in the form of an arch. As many organs of different kinds besides the hypocotyls are also arched when they break through the ground, it is evident that this form must be of much value to the plant. It is of value because the young and more tender parts of the hypocotyl are thus saved from pressure and injury whilst breaking through the ground, and as both legs of the arch, which is shaped like an inverted V, are growing simultaneously, its crown is pushed up through the earth with twice as much force as if they were unarched. Indeed, the force with which a hypocotyl grows upwards is astonishing. Under the study of the epicotyl we shall mention an experiment that determined the force of archgrowth, as seen in the common bean. All the time that the arched part of the stem known as the hypocotyl is growing out of the ground it is circumnutating, and this last movement cannot fail to aid the part in breaking through and struggling out of the ground, especially if the soil be damp and soft.

(*d*) Cotyledons, or first leaves. The movements of these parts of the plants are more easily observable than those of either the radicle or the stem. We will take but one case. One of the Convolvulus order had a cotyledon that in the course of 16 hours 20 minutes moved up and down no less than 13 times. And this movement, it should be observed, was entirely independent of the supporting hypocotyl. The chief seat of the movement is in the lower or basal part of the cotyledon, that is, the part nearest to the stem whence it springs. The movement is constant, and is chiefly in a vertical plane. It was observed in 153 genera. Whilst the movement is constant throughout the day and night, about 4 or 5 in the afternoon there is in all cases a special rise of the cotyledons towards the stem that supports them. This our observers called the "great nocturnal rise." The movement is not governed so much by the actual amount of light that falls upon them as by change in the intensity and degree thereof.

In the movements of the cotyledons of many plants a structure known as the pulvinus (from *pulvinus* = cushion) is concerned. The leaf stalks or petioles of the leaves of *Oxalis sensitiva* and that of the Sensitive plant, *Mimosa pudica*, present this structure. It is an enlargement at the summit of the petiole, just ere that organ expands into the blade or lamina, with convex outline and a structure wholly of colorless, not green cells. It results from the "growth of the cells over a small defined space of the petiole being almost arrested at an early age." The movements of cotyledons gifted with pulvini depends upon the cells on one side of the pulvinus expanding more quickly than those upon the other side of the organ. When cotyledons destitute of pulvini move, the fact of growth being alternately more rapid on one side of the petiole than on the other, is the cause of motion.

(*e*) Epicotyl. The part of the stem above the point of insertion of the cotyledons circumnutates like its companions. After the manner of the hypocotyl or lower portion of the stem, the epicotyl is at first arched and possesses, therefore, from its shape and its power of circumnutation, the advantages in regard to escape from the ground that belong to the hypocotyl. The force wherewith young stems thus struggle from the soil up into the free light and air, may be gathered from an experiment on the epicotyl of the Bean. This in one plant grew upwards with sufficient force to be able to lift a weight of twelve ounces.

(*f*) Rate of movement. The speed with which parts that are circumnutating travel, was in certain cases estimated by observing them under the microscope, as their delicate apices traversed the divisions of a micrometer graduated to five-hundredths of an inch. A radicle thus watched was making way at the rate of 1-50th of an inch in 45 minutes. A cotyledon of a grass accomplished 1-100th of an inch in 22 minutes 5 seconds, and that of a cabbage, whose total oscillation backwards and forwards whilst journeying in any given direction was between 1-500th and 1-250th of an inch, passed over 1-50th of an inch in 6 minutes 40 seconds.

(2) *Circumnutation in mature plants.* The universal movement does not cease as the young plants grow older. It is to be seen in mature plants also. In these also the movement is not confined to one organ or part. It affects all. Circumnutation occurs (*a*) In stems. Here it will be best to mention the plants whose stems are known to swing steadily round, to discuss the amount of stem-circumnutation, to refer to special stem organs which, retaining the morphological character of the stem, retain also the momentous physiological character wherewith we deal.

(i.) Plants observed:—Iberis umbellata, Brassica oleracea, Linum usitatissimum, Pelargonium zonale, Tropæolum majus, Trifolium resupinatum, Rubus idæus, Deutzia gracilis, Fuchsia, Cereus speciocissimus, Hedera helix, Gasania ringens, Azalea Indica, Plumbago Capensis, Aloysia citriodora, Verbena melindres, Ceratophyllum demersum, some Coniferæ, Lilium auratum, Cyperus alternifolius. The number and widely different natures of the orders that have plants whose stems move, and the fact that no plant that has been observed does not move, yield a fair inference that the stem-movement is very general.

(ii.) Amount of movement. Taking but one case, that of Ceratophyllum, the stem was found to move through an angle of more than 200° in six hours and in one instance through 220° in three hours.

(iii.) Modified stems. It is very interesting to observe that when the stem of a plant is modified in position, in structure and to some extent in function, the great function of circumnutation is not lost. (*a*) Stolons. These are long offshoots from the ordinary upright stem that run horizontally along the ground and rooting at some distance from the parent plant send up aerial stems in their turn. The strawberry furnishes an illustration of this kind of stem. Stolons circumnutate. One belonging to a Saxifrage moved as to its apex in twenty-five hours through a distance of $\frac{3}{4}$ of an inch.

β. Flower-stalks. These modifications of stems whilst they are in a growing state perform movements and the movement is not confined to the main flower-stalks. It is seen also in the secondary ones.

(*b*) In leaves. (i.) Plants observed:—Sarracenia purpurea, Glaucium luteum, Crambe maritima, Brassica oleracea, Dianthus caryophyllus, Camellia Japonica, Pelargonium zonale, Cissus discolor, Vicia faba, Acacia retipoides, Lupinus speciosus, Echeveria stolonifera, Bryophyllum calycinum, Drosera rotundifolia, Dionæa muscipula, Eucalyptus resinifera, Dahlia, Mutisia clematis, Cyclamen Persicum, Allamanda Schottii, Wigandia, Petunia violacea, Acanthus mollis, Cannabis sativa, Pinus pinaster, Pinus austriaca, Cycas pectinata. Thirty-three genera belonging to twenty-five widely different orders present to us circumnutating leaves. Once more, as the leaves observed circumnutate, as none of them did not possess this property, the inference is fair that all leaves of all plants move.

(ii.) Rate of movement. A cabbage-leaf was observed. Its apex moved through an angle of 10° in twenty-four hours, the actual distance traversed in the time being, up and down, $^4/_5$ of an inch.

(*c*) Other parts. (i.) Stamens. In Cereus, one of the Cactus order, Morren has noticed a movement apparently circumnutatory. (ii.) The column formed by the one stamen and the gynœcium of a certain Orchid, the Stylidium, circumnutates. (iii.) Even the Cryptogamia, that cannot be truly said to have actual leaves, show the movement. The fresh-water Alga, Oscillatoria describes a circle in every forty seconds. Spirogyra moves in two and a-half hours four times in one direction, thrice in the opposite. The fungi called Moulds apparently circumnutate. In the highest therefore and in the lowest of plants this strange movement, so full of potentialities of development in many useful ways, is exhibited.

CHAPTER XXXI.

C.—*Modifications of Circumnutation.*

C. MODIFICATIONS OF CIRCUMNUTATION. Whilst all parts of all growing plants are circumnutating, certain parts of certain plants have certain special movements known by special names. Each and all of these diverse movements would appear, however, to be derived from the primordial, simple, universal form already dealt with.

(1) *Revolving nutation.* This is the form of specialised circumnutation encountered in climbing plants. The main difference between it and the more general form of motion is the greater extent of the sweep of stem or branch in the climbing plant. No need is there of micrometers and microscopes to watch it, nor even of glass plates and glass filaments, and sealing wax, and indian ink dots. So greatly is the amplitude of the movement increased, that the most casual observer notices the great alteration in position of the Clematis or the Passion-flower. In my analysis of the Climbing-plants I have presented the results of Charles Darwin's observations on revolving nutation, and therefore no more need here be said than that to our two experimentalists all the movements of climbing plants are modified circumnutation.

(2) *Epinasty and hyponasty.* These processes especially affect leaves. The upper or the under surface of these organs at times grows more rapidly than the under or the upper surface. Hence curving downwards or curving upwards of the leaf. An opening leaf-bud is an instance or is a multitude of instances of epinasty. At first all the tiny, green things are closely crowded together and nearly erect. Then one by one, as their upper surfaces grow more rapidly than their under, they curve slowly outwards and away from each other, seeking the sunshine. Instances of these

growth methods in leaves and in other organs are innumerable, but in all cases the movements resulting are from their nature and their effects evidently but modifications of circumnutation.

(3) *Nyctotropism.* The sleep of leaves. Our authors do not employ the term "sleep" or the more technical word "nyctotropism" unless the movement of the leaves is sufficiently marked to be distinguishable from the constant day movement already described. Unless the leaves at eventide move upwards towards the vertical position or downwards from the horizontal through an angle of at least 60°, they are not called nyctotropic. We shall deal with the position assumed, and the advantages accruing therefrom, the experiments that were made, the plants investigated.

(*a*) Position and its advantages. The blade of sleeping leaves is nearly or quite vertical at night and in many cases the upper faces of contiguous leaves are opposed. As the constant fact is only that the blade stands approximately vertical, the apex or the base or either edge of the leaf may look zenithwards. This position is assumed as the result either of alternation of turgescence on opposite sides of pulvini or of growth alternately preponderating on one side and then on the other of the petiole or midrib. The great advantage to the plant of this assumption of an erect position by the leaves at night is the protection of the upper surface from evaporation and radiation at a time when the sun being below the horizon, no compensation in the way of heat-return is possible. That this protection from radiation is of great moment, the experiments demonstrate.

(*b*) Experiments. Certain leaves of certain plants were compelled by the aid of pins and the like human contrivances to remain in a horizontal or day position during the night-time. Whilst other leaves were allowed to assume their normal nocturnal position, the former were exposed to a temperature of 4° on a March night. And in the morning all the leaves which were pinned opened were killed, whilst only one-third of those that had not been interfered with were injured.

(*c*) Examples. (i.) Of cotyledons that sleep. The cotyledons of the following plants have been observed to rise or sink at night to an angle of at least 60° above or beneath the horizon:—Brassica oleracea, Brassica napus, Raphanus sativus, Githago segetum, Stellaria media, Anoda Wrightii, Gossypium, Oxalis rosea, Oxalis floribunda, Oxalis articulata, Oxalis Valdiviana, Oxalis sensitiva, Geranium rotundifolium, Trifolium subterraneum, Trifolium strictum, Trifolium leucanthemum, Lotus ornithopodioides, Lotus peregrinus, Lotus Jacobæus, Clianthus Dampieri, Smithia sensitiva, Hæmatoxylon Campechianum, Cassia mimosoides, Cassia glauca, Cassia florida, Cassia corymbosa, Cassia pubescens, Cassia tora, Cassia neglecta, Cassia (three other Brazilian unnamed species), Bauhinia, Neptunia oleracea, Mimosa pudica, Mimosa albida, Cucurbita ovifera, Cucurbita aurantia, Lagenaria vulgaris, Cucumis dudaim, Apium petroselinum, Apium graveolens, Lactuca scariola, Helianthus annuus, Ipomœa cærulea, Ipomœa purpurea, Ipomœa bona-nox, Ipomœa coccinea, Solanum lycopersicum, Mimulus, Mirabilis jalapa, Mirabilis longiflora, Beta vulgaris, Amaranthus caudatus, Cannabis sativa. Altogether we have 153 genera observed, and of these 30 genera belonging to 16 families undergo a movement that is of sufficient extent to be called nyctotropic. Out of the 30, 24 presented the rising movement. We must hence opine that the sleep of cotyledons, whilst not universal, is fairly general. ii. Of leaves. In this connexion we may mention (α) the plants whose leaves sleep, (β) the method of their sleep, and (γ) the rate of movement. (α) The plants whose leaves are known to undergo the sleep movement are :—Githago, Stellaria, Portulaca, Sida, Abutilon, Malva, Hibiscus, Anoda, Gossypium, Ayenia, Triumfetta, Linum, Oxalis, Averrhoa, Porlieria, Guaiacum, Impatiens, Tropæolum, Crotolaria, Lupinus, Cytisus, Trigonella, Medicago, Melilotus, Trifolium, Securigera, Lotus, Psoralea, Amorpha, Dælea, Indigofera, Tephrosia, Wistaria, Robinia, Sphærophysa, Colutea, Astragalus, Glycyrrhiza, Coronilla, Hedysarum, Onobrychis, Smithia, Arachis, Desmodium, Urania, Vicia, Centrosema, Amphicarpæa, Glycine, Erythrina, Apios, Phaseolus, Sophora, Cæsalpinia, Hæmatoxylon, Gleditschia, Poinciana, Cassia, Bauhinia, Tamarindus, Adenanthera, Prosopis, Neptunia, Mimosa, Schrankia, Acacia, Albizzia, Melaleuca, Ænothera, Passiflora, Siegesbeckia, Ipomœa, Nicotiana, Mirabilis, Polygonum, Amaranthus, Chenopodium, Pimelia, Euphorbia, Phyllanthus, Abies, Thalia, Maranta, Colocasia, Strephium, Marsilea. (β) Concerning the method of this movement, of course the blades are placed in a position quite or nearly vertical. And this is usually affected by the rotation of the plane of the blade of the leaf. That rotation is effected either through the agency of a pulvinus or aggregate of small colorless cells, the pulvinus becoming alternately more turgescent on nearly opposite sides, or it is effected by the increased turgescence and increased growth on the opposite sides of the petioles destitute of a pulvinus. This nyctotropic movement is strikingly affected by external conditions. Thus the movement is delayed or fails if the ground is too dry. A definite temperature is necessary for it. Thus French plants, according to Rouer, do not sleep if the temperature falls below 5°. The violent agitation that follows from a strong wind prevents sleep, and, above all, unless the leaves are well illuminated during the day, they are not likely to sleep at night. This last fact shows us again that the important consideration is the change of intensity in the light. It is not so much the amount of light as the relative amount at different times that determines the movement. (γ) Rate of movement of *Oxalis acetosella.* The ordinary wood sorrel completed two ellipses at the rate of 1·25 per hour; *Marsilea quadrifoliata*, at the rate of one in 2 h.; *Trifolium subterraneum*, in 3 h. 30 m.; and *Arachis hypogæa*, in 4 h. 50 m. (δ) The study and history of these nyctotropic or sleep movements compel us to believe that they are but especial modifications of circumnutation that are of distinct advantage to the plant, inasmuch as they prevent radiation from the upper surface of the leaves during the night-time, a time at which no compensating heat supply is derivable from the sun.

(4) *Movements due to light.* (a) Kinds of movement. These are heliotropism, movement towards the light; apheliotropism, movement from the light; diaheliotropism, in which parts of plants place themselves transversely to the direction of the light (the transversal heliotropismus of Frank); paraheliotropism, a movement by which leaves exposed to more light than is good place themselves so as to be less intensely illuminated. This is the day sleep of plants. All these four kinds of movement differ essentially from the nyctotropic movements previously studied in that they depend upon the direction of the light, whilst the periodic movements noticed in sleeping plants depend upon the intensity of the light, and have no relation to its direction.

(*b*) Heliotropism. Studying the cases in which a plant bends, and then continues to move towards the light, it is necessary to mention—(i.) The plants that were investigated.— Beta vulgaris, Solanum lycopersicum, Apios graveolens, Brassica oleracea, Phalaris Canariensis, Tropæolum majus, Cassia tora. These only represent a few of the plants on which experiments were made. Heliotropism really obtains most extensively amongst the higher plants. There are extremely few whereof some part, be it stem, or leaf-stalk, or flower-stalk, does not bend towards a stream of light. Two interesting exceptions to the nearly universal heliotropism are worthy of recordal. They are insectivorous plants and tendril-bearing plants. But the insectivorous plants do not live upon carbon dioxide. Now it is known that the agency of light is essential for plants that feed upon carbon dioxide and decompose that gas whilst retaining its carbon. As the insect-eating plant does not feed upon the gas, little good would have resulted were it heliotropic. Again, had tendril-bearing plants been heliotropic, movement towards the light would have frequently resulted in their being drawn away from their supports.

(ii.) Modified circumnutation. Heliotropism and circumnutation graduate the one into the other, and the ordinary view that they are two distinct kinds of movement, will probably have to be abandoned by those that study the book of the two Darwins. For against this ordinary view that heliotropism and circumnutation are essentially distinct we have (α) The fact that a bright lateral light should stop circumnutation. Such a bright lateral light induces the plant to grow straight towards it, and, therefore, if the two movements are distinct from the other, puts a stop to circumnutation. (β) Only a lateral light would have this remarkable power, for plants lighted from above do continue to circumnutate. (γ) In the life of every plant, circumnutation precedes heliotropism, for stems and leaf-stalks are circumnutative in the darkness of the earth before any light falls upon them.

(*c*) Apheliotropism. A rare movement. Only two cases were observed, those of *Bignonia Capriolatus* and *Cyclamen persicum.*

(*d*) Diaheliotropism. The best illustrations of this assumption of position are afforded by young seedlings, whose first plant leaves are generally extended horizontally, and thus place their upper surfaces at right angles to the light. The student who will take the trouble to look at the leaves of all trees will be struck with the pertinacity with which the leaves under very unfavorable circumstances yet attempt to arrange themselves in the like horizontal position.

(*e*) Paraheliotropism. This occurs in certain plants when the sun shines too brightly upon them. The leaves change their position and present their edges to the light. Apparently, this is dependent upon the fact that the green color matter or chlorophyll of leaves is apt to be injured by too intense a light. The experiments of Weissner on the young leaflets of Robinia, our ordinary Acacia, show the importance of paraheliotropism. He fixed certain leaflets in such a position that they were intensely illuminated and unable to get away from the sun. In the course of two days they suffered exceedingly, whilst other leaflets that had not been interfered with, were in very good health.

(5) *Movements due to gravitation.* (*a*) Divisions. These are geotropism, when the plant bends towards the earth; apogeotropism, when it bends from the earth; diageotropism, when it assumes a position horizontal in respect to the earth.

(*b*) Geotropism. This movement is almost confined to roots. The ordinary root of an ordinary plant is largely affected by geotropism, and is thus directed steadily down into the ground. Aerial roots, that is, roots given off from the stems outside the ground, are in many cases under the like influence, but not in all, the Ivy to wit. With the exception of the roots, however, but few organs can be found showing movement due to geotropism. The seed capsules of one or two members of the order Leguminosæ are buried in the ground as the result of geotropism of their flower stalks. The *Trifolium subterraneum*, a species of clover, and the *Arachishypogæa* or ground nut, both present this remarkable phænomenon. In the latter case the pod has been observed to be buried in the ground to the depth of an inch, and this is effected by the curving over and growth downwards towards the earth of the stalk supporting the gynœcium. This is a movement of geotropism.

(*c*) Apogeotropism. A far more frequent movement than the former, and far more extensive. The hypocotyl of the Beet in 3 hours 8 minutes passed through an angle of 109° in a direction away from the earth.

(*d*) Diageotropism. No experiments were made upon this by our observers, and the statement that this movement actually exists, is based upon the researches of Frank.

Finally, we may conclude that the three kinds of movement dependent upon the action of gravitation, consist once again of modified circumnutation.

CHAPTER XXXII.

D.—*Nervous Action.*

D. NERVOUS ACTION IN PLANTS. Despite the fact that multitudes of the lower animals showed no trace of a nervous structure, and many of them no trace of nervous function, one of the distinctions between vegetables and animals most insisted upon aforetime was the absence of nervous energy in the former, and its presence in the latter. The experiments of Charles and Francis Darwin establish the fact that plants have nerve-energy.

Reducing nervous function to its simplest form, leaving out of consideration all complex and specialised structures, such as spinal cords and brains, and considering only nerve-fibres and nerve-cells in their simplicity, we find nervous structures are responsive to stimuli: we find they are sensitive: we find they have to do with movement: we find they have the power of transmitting energy. The nerve ends in the skin of an animal, are responsive to stimuli, *e.g.* of the prick of the pin. Certain of the nerve-fibres transmit to nerve-centres more internally placed, and consciousness of the external stimulus results. Energy may then flow down other nerve-fibres ending in certain muscles and thus these last be stimulated to contraction. Now, in plants all these phænomena are encountered. It will be shown that parts of plants are sensitive to stimuli, that from them transmission of influence to a distance takes place, that sensitiveness and movement occur.

In the treatment of this subject the following divisions of it will be studied: Facts; Effect of Pressure on the tips of radicles; of Caustic; of Cutting; of Moisture; of Geotropism; Secondary Radicles; Pressure above the apex of the radicle; Effect of Heliotropism; Coordination.

(1) Facts. Radicles growing in the ground encounter stones, roots, a score of obstacles. Radicles are sure to meet

with opposition, and this opposition they have to surmount. Experiments were made on the growing roots of plants. As result it was found that the delicate cap of the root when first it touched any opposition surface underwent a slight transverse flattening. This transverse flattening soon became oblique, and in a few hours was seen no more. By that time the apex was pointing at right angles to its original direction, and the radicle gliding along over the opposing surface in a new direction. Further, it was not the touched apex of the radicle that curved. A length of 8 to 10 millimetres ($^8/_{25}$ to $^2/_5$ of an inch) became curved. These facts (verified times and again) have to be explained. Three explanations offer.

(*a*) That the curvature is due to mechanical resistance to the growth of the radicle in its original direction. The objections to this are: (i.) The radicles have not the aspect of organs that have been subjected to pressure enough to account for the curvature. (ii.) The growing part just within the apex of the radicle is more rigid than the non-growing part above. Hence the latter ought to have yielded and curved, not the former. (iii.) An object yielding with the greatest ease serves to deflect the radicle.

(*b*.) That pressure checks the growth of the apex, and growth only continuing on one side, the radicle becomes rectangularly bent. But this does not explain the curvature affecting parts so far from the apex as 10 millimetres.

(*c*.) That the apex is sensitive to contact, and thence is transmitted influence to the upper part of the radicle. This upper part is thus stimulated to bend *away from* the touching object.

The plants upon the radicles of which experiments were made were *Vicia faba* (Common bean), *Pisum sativum* (Pea), *Phaseolus multiflorus* (Scarlet Runner), *Tropæolum majus* (Indian Cress), *Gossypium herbaceum* (Cotton). *Cucurbita ovifera* (Cucumber), *Raphanus sativus* (Radish), *Æsculus hippocastanum* (Horse-chestnut), *Quercus robur* (Oak), *Zea mays* (Maize).

(2) Effect of pressure on the radicles. When one side of the apex of a young radicle is pressed by any object, the growing part bends away from that object. This would seem to be an excellent adaptation for avoiding obstacles in the soil, and moving along a line of least resistance. We

must carefully notice that the apex only is touched, for if the pressure be applied a little above the apex, the bending is like that of a tendril towards the touching object. Studying this bending away from pressure when that pressure is applied to the apex we shall speak of the experiments, the effect of temperature, the discriminative power of the radicle, and the struggle with geotropism.

(*a*) Experiments. 55 radicles were treated in the following way. Little squares or oblongs of card were fixed to their conical tips by shellac. The seeds whence the radicles protruded were pinned inside the cork lids of glass vessels half-filled with water. All light was excluded. Careful observation was then made for the purpose of seeing if the radicles had worked straight down, or had bent in one direction or another. Out of 55 dealt with, 52 were bent often considerably from the perpendicular, and invariably away from the side to which the piece of card was attached. Exceedingly small pressure will determine their movement. A weight of matter less than ·32 milligrammes—about $\frac{1}{2000}$ of a grain, in two cases sufficed to excite movement.

(*b*) Temperature. The sensitiveness of the radicle, like all other functions of living beings, is only possible within certain ranges of temperature. A temperature rather above 21° C. destroys the sensitiveness of the radicles. Pieces of card placed on radicles when the temperature was higher than this, produced no effect whatever. Clearly the natural temperature of the earth in the early spring when radicles are busy, would not be so high as 21° C. The experiments reveal the fact that the most favorable temperature for the sensitiveness of the radicle is between 13° and 15°.

(*c*) Discrimination. Not only does the part above the apex of a radicle undergo movement when the apex is stimulated, but the latter remarkable organ has an extraordinary power of discriminating between two pressures. When a square of sanded paper and a square of paper so thin that it was not adapted for writing purposes, of the same size —about 1-20th of an inch—were fixed on opposite sides of the bases of 12 radicles, in almost all cases the radicle bent from the side with the sanded paper. The relative thicknesses of the two pieces of paper were between ·15 and ·2 millimetres in the case of the one, and ·045 millimetres in the other. Here then is evidence that the apex of the radicle has the capacity to discriminate between thin card and very thin paper, and so transmit influence to one side only of the upper part of the radicle.

(*d*) The struggle with geotropism. Experiments were made in the following manner. Eight beans were so placed that their radicles extended horizontally. Hence geotropism or the growth towards the earth would come into play. Eight other radicles placed in a like position were also treated as the radicles spoken of above; little pieces of card were fixed to the lower sides of their tips. The stimulus due to the cards would cause the radicles to curve upwards, that is, in the opposite direction to the geotropic movement; but in these cases before the expiration of twenty hours, seven out of the eight were bending downwards towards the centre of the earth. The cards seemed to have produced no effect. Geotropism had easily won the battle. In a second experiment three radicles with squares fixed to one side of the apex were suspended vertically. The stimulus of the squares tended to make them move from the vertical line, geotropism tended to keep them in the vertical line. But in this case within nine hours the radicles had bent considerably out of the vertical. Here then geotropism was defeated in the struggle, and the stimulus due to the pressure of the squares had triumphed. But in these two sets of cases it will be observed that whilst the action of the pressing card is constant that of geotropism varies. For in the first case with horizontal radicles geotropism acts on the radicle at right angles, whilst in the second case geotropism acts at a very oblique angle, and therefore at a disadvantage. It is concluded in consequence that the power of an irritant on the apex of a radicle is inferior to that of geotropism when the latter acts at right angles to the radicle, but is superior to that of geotropism when the latter acts obliquely on the radicle.

(3) Effect of caustic. Dry caustic or nitrate of silver was used to irritate one side of the apex upon fifteen radicles. There was evident proof that the radicles bent away from that side of the apex which had been irritated by the caustic.

(4) Effect of cutting. Exceedingly delicate slices were removed from the radicle, the cutting being made parallel to the sloping sides of the apex by aid of a razor.

Out of eighteen radicles thus treated 14 bent away from the cut surface.

(5) Effect of moisture. A few years ago the great German botanist Sachs showed that the radicles of young plants bend towards the side where moisture is. The Darwins arranged certain sieves containing seeds germinating in damp sawdust in such a position that the base of each sieve was at an angle of 45° with the horizon. It is plain that had geotropism alone acted the radicles would have grown perpendicularly down. But it was found that they grew persistently towards the damp sawdust in the sieve. They were deflected as much as 50° in many cases from the perpendicular. The tips of a number of radicles of the bean were covered with grease so that it was impossible for moisture to act upon them. These greased radicles in scarcely any cases curved towards the damp sawdust, and this was to be expected as the effect of the moisture could not possibly be transmitted through the grease covering.

(6) Of geotropism. The effect of geotropism is in nature as a nervous effect. The sensitiveness to gravitation appears localised in the apex of the radicle, and there is undoubted transmission to the upper regions of that organ. Radicles that had been left extended horizontally for some time were placed before they had begun to bend downwards in a vertical position and their bases cut off, and yet very shortly they bent as if still acted upon by geotropism. This would seem to demonstrate that some influence had been already transmitted to the bending region from the apex before the latter was amputated. That the action of geotropism is upon the apex was further shown by the removal of the tips of twenty-nine radicles and the after placing of them in a horizontal position. They did not become geotropic. Unmutilated radicles bent under the action of geotropism in eight or nine hours, but these whose apices had been removed were distinctly not affected by the attraction of the earth.

(7) Secondary radicles. The tips of secondary radicles are also sensitive to contact. Further they are sensitive to geotropism, but geotropism does not make these secondary radicles bend vertically down. The line of direction assumed by secondary radicles is a sub-horizontal one, somewhere

intermediate between a completely horizontal and a completely vertical line. This is the normal position of the secondary radicle, but if the primary be removed accidentally or designedly one of the nearest secondary radicles proceeds to grow perpendicularly down and to take the place of the primary. This is akin to what is frequently observed with the shoots of trees. If the main shoot be destroyed a lateral one will generally take its place, growing in a vertically upright direction instead of a sub-horizontal one.

(8) Pressure above the apex. All the experiments narrated and reasoning worked out thus far have had to do with stimulus applied to the actual apex. Whether the stimulus be that of contact, or of caustic, or of cutting, the influence transmitted to the upper part of the radicle has always been of such a nature as to make the apex bend *from* the source of irritation. But if any pressure be applied at the distance of a few millimetres *above* the apex the action is as that of a tendril and the radicle bends *towards* the touching object.

(9) Heliotropism. We have seen that the apex is sensitive to pressure, that the apex is sensitive to the action of the earth. When we turn to the consideration of the cotyledons, which are affected by light rather than by gravitation, we shall find kindred phænomena. There also the sensitiveness is localised—localised in the upper part of the cotyledons; its effect is transmitted to the lower part, nearer the main axis of the plant, and that part bends. It is beautiful to see the striking evenness in the action of stimuli upon radicles, upon cotyledons, upon leaves. The apex of the cotyledon and the tip of the leaf are the sensitive parts. From these is transmitted influence to parts at a distance from the apex, and these last, under that influence, undergo movement that affects the apex in its turn. It is almost impossible to fail in these instances to see the similarity to reflex action in animals. Reflex action is action resulting from an external stimulus and unattended with sensation, and in these cases there is an external stimulus of light or of contact acting upon a part of an organ. Its effect is transmitted up to another part of that organ. That effect is then—if I may use the phrase—reflected back to certain parts that move.

Here once again it is not the amount of light which determines the degree of movement of any part of a plant. It is the amount of change that affects this, and so is it in many instances in animals. The retina of the eye cannot perceive a dim light after it has been exposed to a bright one, and plants which have been kept in the daylight do not move so rapidly towards a faint lateral light as do others which have been kept in complete darkness.

Yet one final parallelism. The retina of the eye, after being stimulated by a bright light, feels the effect thereof even when the light has ceased, and so plant-leaves which have been moving under the action of light continue to move for some time after the light has ceased.

(10) Co-ordination of movements. Surveying all the different causes that will result in movement of the radicle of a young plant, growing in the ground, it is not difficult to picture to ourselves how they all work together for good. When the primary radicle first comes from the seed, geotropism guides it vertically downwards, and the capacity to be thus acted upon resides in its apex. But the secondary radicles that branch off from that primary one are acted on by geotropism so that they only bend obliquely downwards or in a slanting direction. Had the action of geotropism been identical on the main root and on its branches, we should have a bunch of roots all huddled up together. The tertiary radicles, or those given off by the secondary, are not influenced by geotropism at all. They spread themselves abroad in the structure of the earth in every direction. Meanwhile with all this downward growth there is circumnutation. The ends of the primary and secondary radicles are slowly revolving round and round. It is just possible that such movement may aid them in penetrating the ground, but this help could be but of the slightest. The real value of it is that as the tip is always endeavoring to bend to all sides, it will press on all sides, and as its discriminative power for different pressures is exceedingly marked, it will move constantly in the direction of less resistance by bending from the harder soil towards the more friable. So also where there is difference in amount of moisture, the sensitiveness of the apex of a radicle will come into play. It will bend towards the more moist region of the soil. And finally, as the direction taken by the apex of the root determines the whole course of the root, it is of the utmost

importance that that apex should pursue from the first the direction of most advantage to the plant. This desirable result follows from the fact that the sensitiveness to geotropism, the sensitiveness to contact, and the sensitiveness to moisture all reside in the tip.

CHAPTER XXXIII.

E.—*Conclusion.*

TAKING a retrospective survey of this, the last of Darwin's botanical works, and, indeed, at the present the absolutely last from his pen, we see (1) That all growing parts in all plants are continually circumnutating; (2) That the various movements known as heliotropism, geotropism, nyctotropism, movements of twining plants are but modifications of the universal circumnutation; (3) That the influence which modifies circumnutation may be transmitted after the fashion of nervous influence from one part to another. (1) We may extend the survey of the life-history of the root that was made a page or so further back to the life-history of the plant as a whole. Whilst the radicle is stealing out of the seed, anon circumnutating in the ground, and by its sensitiveness to various stimuli is penetrating the ground, now in one direction and now in another, but always along the line of least resistance, the stem is also breaking through the seedcoats. Generally the hypocotyl struggles out, but if the cotyledons or first seed leaves are to remain under ground, it is the epicotyl which breaks forth. Always are these organs arched at first, and thus twice as great pressure in the upward struggling is possible. These arched stem organs are circumnutating before they break through the ground and after. Upon the arch apogeotropism and heliotropism are both acting, the former directing the seedling blindly upwards, heliotropism guiding the stem through any crack in the soil, or through the interstices of entangled vegetation towards the light. As the stem arch grows upwards the cotyledons are drawn out of the ground. The swelling of these organs casts off the seedcoats, and now the cotyledons, bathed in the air and the sunshine, assume the function of leaves, and feed upon carbon dioxide. The hypocotyl is strengthened and the cotyledons are fully expanded. Both hypocotyl and cotyledons are swinging slowly round above ground, and now the stem grows up and leaves appear upon its sides. The branches outspread from the axils of these leaves, and the stem, leaves, and branches are all circumnutating. So indeed is every shoot, every leaflet, every flower-stalk, and hence from the stem, high climbing towards the sunshine, to the minute rootlets deep down in the darkness, all parts are moving through small ellipses or circles continually.

(2) The modifications of circumnutation are epinasty or hyponasty, wherein the upper or the lower surface of organs has excessive growth, the movements of climbing plants in which the extent of the circumnutation is largely amplified, the nyctotropic movements of leaves, of cotyledons whose result, attained by various means, is that the blade at night time is so placed that but little radiation from its upper surface occurs, the heliotropic movements due to the action of a lateral light, with their division into heliotropism, growth towards the light, apheliotropism, growth from the light, diaheliotropism, where the leaves place themselves transversely to the light, paraheliotropism, where the edges are directed towards the light, and lastly geotropic movements with divisions of similar nature to those just given under the light movements.

(3) Nervous action. Finally the most striking revelation of all those made in the series of experiments on the movements of plants is that of the resemblance between those movements and the reflex actions of animals. In the plant movement and in the animal movement a very small stimulus is sufficient. The habit of movement is transmitted from plant to plant and from animal to animal. The sensitiveness is localised. There is transmission of influence from the excited part to another part at a distance, and there is movement of this last part. It is hardly going too far perhaps to say that the tip of the radicle with its extreme sensitiveness, and its power of directing movements of distant parts acts in a fashion similar to the brain of a low animal. Assuredly it is not too much to say that it acts in a fashion similar to that of the spinal cord of some of the higher animals.

(4) Personal characteristics. Once again the loving patience of the experimenter shines out strongly in this work,

and it is evident that the care and perseverance which have made notable the elder naturalist have descended to the younger. The precautions taken against prejudiced observation are in some instances almost amusing. The directions of curvatures of radicles were noted before the record as to the method in which they had been treated was consulted, so that no wish as to the result of an experiment might be father to the thought

(5) Gradations. In this book as in the others occur many examples of the gradations that are the consequences of the working of evolution. One would think that roots and leafstalks were sufficiently distinct from each other, and yet when the radicle of an Ipomœa was cut off and the cotyledons planted they emitted roots from their bases and the petioles were enlarged into little tubers in exactly the same fashion as an ordinary radicle would have been. The nyctotropic movements of leaves are in some cases exceedingly complex, in others exceedingly simple; but there is every gradation between the most simple and the most complex in the kingdom of plants. So also with the heliotropic movements. On page 436 we read:—

"We have therefore many kinds of gradations from a movement towards the light, which must be considered as one of circumnutation very slightly modified and still consisting of ellipses or circles,—through a movement more or less strongly zigzag, with loops or ellipses occasionally formed,—to a nearly straight, or even quite straight, heliotropic course."

And lastly the gradual evolution of this same heliotropic movement out of the ordinary circumnutation is not difficult of observation:—

"First, we have a succession of ellipses with their longer axes directed towards the light, each of which is described nearer and nearer to its source; then the loops are drawn out into a strongly pronounced zigzag line, with here and there a small loop still formed. At the same time that the movement towards the light is increased in extent and accelerated, that in the opposite direction is lessened and retarded and at last stopped. The zigzag movement to either side is likewise gradually lessened, so that finally the course becomes rectilinear."

IV.—ZOOLOGICAL WORK.

Monograph of the Cirripedia.

CHAPTER XXXIV.

A.—*The Ray Society.* B.—*Older Accounts.* C.—*The Monograph.*

INVESTIGATING the great work contributed by Charles Darwin to the study of animals, it will be well to speak of the Ray Society, of the former history of the animals described, of the book itself.

A. In the year 1628, at Braintree, in that flattest of counties, Essex, was born John Ray. To this Cambridge man belongs the credit of being the first Botanist of real note in England. A fellow of Trinity, in succession lecturer on Greek and on Mathematics, and then humanity reader, holder thereafter of various offices in connexion with the government of the College, notable as a preacher in both his own college and the University, John Ray found time to spend many hours in the open air and to lay the foundations of the science of Botany in this country. Four years after the founding of the Royal Society in 1663, Ray was invited to join the body doomed in after time to be so illustrious, and in his day numbering among its members the handful of men that represented scientific thought in the reign of Charles II.

In 1844, a resolve was formed to erect a fitting monument to the memory of John Ray. The memorial, very happily for all, did not take the shape of a statue nor even of a dinner. The Ray Society was formed. The worthy object of that Society was to print and publish important scientific works, the nature whereof precluded the possibility of a sufficiently large purchase on the part of the general public to repay author or publisher. This would seem to be the noblest way of at once perpetuating the memory of a great scientific man, and continuing after his own heart the work that was dear to him. Hence the publications of the Ray Society are special treatises rather than general ones, and appeal not only more to the student than to the general public, but rather to the specialist than to the ordinary investigator. Tribute to the good work it has done is paid by Charles Darwin himself in his preface. "Had it not been for the Ray Society I know not how the present volume could have been published."

It was fitting work for this Society to produce Charles Darwin's great contribution to Zoological Science. The subject dealt with therein is intricate. The animals that are the objects of study are not, to most people, deeply interesting. For the full comprehension of the book much technical knowledge is required besides the inevitable patience. A large body of readers could not be expected, however greatly it might be desired. Yet the matter of the volume is so important, the collection of facts so large and significant, the lessons, in special Zoology and in general Biology, so many and so momentous that all students must be lastingly grateful to the Ray Society for publishing Darwin's Monograph on the Cirripedia.

B.—*The older accounts of the Cirripedia.*

In the childhood age of any science men are apt to romance where they cannot observe. A long time elapses ere they learn to note all that is perceptible, to wait patiently until the unseen of to-day become visible, and not to bridge over the interval between one observed fact and another by imaginary accounts of what has occurred. Perhaps no living beings have been the subject of so much of this unwise imagination as the animals studied in this work. These are the members of the class that comprises the familiar Barnacle (*Lepas*) found clinging to the keels of ships, especially if these are unprotected by copper; and the equally familiar Acorn-shell (*Balanus*) that is to be seen firmly fixed on the rocks of the sea-shore. As to the history of the Barnacles, the queerest fancies had been rife. It was the forerunner of a goose. Out of it the bird despised of many was evolved. They grew upon trees and upon occasion originated the Barnacle Goose. The Barnacle Goose is an actual Bird, though it is not necessary to say to-day that it has no connexion with the Barnacle. Yet in the old times such a relationship was believed, and gravely described in detailed fashion. In Gerrard's "Herbal" of

1597, it is recorded that "in the north parts of Scotland and the islands adjacent, called Orchades, are found certaine trees wherein doe growe certaine shell-fishes, of a white color tending to russet; wherein are conteined little lively creatures; which shels in time of maturitie doe open, and out of them grow those little living foules whom we call Barnacles, in the north of England Brant Geese, and in Lancashire tree Geese; but the other that do fall upon the land perish and come to nothing." According to the quaint old man, on the wreckage of ships appears a "spume or froth." This "breedeth unto certaine shels." These same shells are clearly the actual Barnacles. Then anon the shell gapeth and after issue of "a lace or string," exeunt "the legs of a bird hanging out; and as it groweth greater, it openeth the shell by degrees till at length it is all come forth and hangeth only by the bill; in short space after it cometh to full maturitie and falleth into the sea where it gathereth feathers and groweth to a foule bigger than a challard and lesser than a goose, having blacke legs and bill or beake and feathers blacke and white."

It is therefore small matter for wonder that there have been grave doubts as to the precise placing of the Barnacles and their allies in the scale of organised beings. Whether they were to be animals or plants or both, or neither, seemed at first difficult of decision. And when it was granted that take them for all in all, they were animals, yet their precise locale in the kingdom Animalia was doubtful. They were pushed hither and thither and relegated first to one sub-kingdom, then to another, much after the fashion of the unfortunate Sponges. This is always the fate of organisms high or low, barnacle or man, when they are not understood. For long, there was indecision as to whether the Cirripedia were ringed animals or soft-bodied animals, as to whether they were Annulosa or Mollusca. Their strange shape, their shells arranged in two sets, their sedimentary condition, all seemed to point them out as allies of oysters and their fellows and as members of the soft-bodied sub-kingdom. But even before the Monograph observation had been sufficiently active in its work to make it reasonably sure that these beings were of the Annulose type, and of that highest Annulose type known as Crustacean. Strauss in 1819 suggested they were connected with the Crustacea. As far ago as 1834 Martin St.

Ange, in his "Mémoire sur l'organisation des Cirripèdes," had shown that when Barnacles or Acorn-shells were well-cleaned as to their exterior, the ringed structure was perfectly evident. The discovery of the stages through which these animals pass in their development by T. Vaughan Thompson, threw a flood of light upon their history and zoological relationships. Not, however, until the publication of the work now under discussion was the assurance previously given rendered doubly sure and the exact position of this strange group of animals accurately determined.

C.—*The Monograph.*

The work itself consists of two volumes. The first, issued in 1851, deals with the Cirripedia generally, and with the division to which the Barnacle belongs especially. The second, published in 1854, resumes the account of the class as a whole and further deals in detail with the division of it that includes the Acorn-shell. In our investigation the two volumes will be considered together. We shall consider briefly the divisions our author makes of the class Cirripedia, the description of the chief members of the class, not forgetting the history of their metamorphoses and their distribution.

(1) Divisions of the Cirripedia. Sub-order (*a*) Thoracica. With the limbs attached to the thorax and the abdomen rudimentary. This includes the two best-known members of the order, the Barnacle (*Lepas*), the Acorn-shell (*Balanus*).

Sub-order (*b*) Abdominalia. With the limbs attached to the abdomen. This only comprises one animal, the Cryptophialus minutus, parasitic within the shell of Choncolepas Peruviana, one of the Gasteropoda or whelk class.

Sub-order (*c*) Apoda. The members of this order have no cirri at all. In this group is but one genus of one species, Proteolepas bivincta, met with off the coast of St. Vincent. It lives as a parasite inside the sac or softer external covering which is itself within the shell of Alepas cornuta, one of the class Cirripedia.

(2) Description of the adult Cirripede. In the first volume the Lepas or Barnacle is described. In the second the Balanus or Acorn-shell forms the chief subject of study. We will consider (*a*) The Barnacle. (*b*) The Acorn-shell. (*c*) The Abdominalia. (*d*) The Apoda. To the former

pair much attention will be given. To the latter pair only a few lines will be devoted.

(*a*) The Barnacle. The very many and very complex facts now to be stated as to this animal shall be arranged under the following heads. Its general Structure, Digestion, Absorption, Circulation, Respiration, Secretion, Nervous System, Sense Organs, Motor Organs, Reproduction, Development.

(i.) Structure. Everyone knows the general appearance of the Barnacle. A long stalk, flexible and soft, is fixed by one end to an old piece of drift-wood, and bears at the other a shelly creature protruding many delicate, fringed cirri that sweep ceaselessly through the sea-water. Not everyone knows the full significance of each part of the animal. Really the Barnacle is affixed by its head region. That long, brown, flexible peduncle or stalk is formed of its antennæ. By these it has attached itself to its support. Where the stalk joins the rest of the animal, there will be the head region of the creature. All the shell-covered, cirri-bearing part is called the capitulum (*caput* = a head, *ulum* is a diminutive termination), so that our Barnacle is a body or capitulum from whose head-region the antennæ have outgrown in a long stalk or peduncle whose other end has become affixed to some basis of support.

The capitulum of the Barnacle has a shell-envelope. This consists of two pairs of valves or pieces of shell, named the scuta (*scutum* = a shield) and the terga (*tergum* = back). Of these the scutum is the lower or the one nearer to the peduncle. The tergum is the higher. The carina (a keel) is intermediate between these pairs, occupying the convex edge of the animal. These valves are of chitin (the hard material met with in many insects, the black-beetle to wit), strengthened by calcareous salts. They are formed not by direct secretion or separation of salts from their solution in the sea-water wherein the Barnacle lives, but by metamorphosis of the outer body-wall of the animal. The valves are connected by membrane that is also of chitin without any hard mineral matter.

Within the shell part of the capitulum lies the softer internal lining of the shell. This is the "sac." And within the sac lies the true body of the Barnacle. The main part of this body, when the scutum and tergum of one side are removed, is the anterior part of the thorax. It must be understood that the higher ringed animals, Spiders, Scorpions, Insects, Crustacea, have three body regions. A head, bearing jaws and sense organs; a thorax, bearing motor organs or legs and wings; an abdomen, or tail, containing sexual apparatus and much of the digestive and circulatory. Now in the Barnacle the head region is greatly reduced, save as concerns its huge extension into the peduncle. The abdomen region is reduced almost to nothing. Two small segmented spine-bearing caudal appendages to the long intromittent male organ are attached to the exceedingly rudimentary abdomen. As to the thorax, or middle part of the body, its anterior part in the Barnacle is large, unsegmented, and carries no limbs. And this part is the Prosoma (προ = before, σωμα = body). The rest of the thorax is segmented, and bears the cirri, or limbs. Therefore we find in this animal a long peduncle formed of antennæ, running into the head region of the creature. Behind this small head region, jaw-bearing, is the first part of the thorax or prosoma not carrying appendages. Then follows the segmented part of the thorax, bearing the limbs. Lastly the exceedingly reduced abdomen, with its two small caudal appendages.

(ii.) Digestion. The food of the Barnacle is of animal nature. The mouth is surrounded by organs known as the labrum, or upper lip, very enlarged and prominent, two toothed mandibles, with palpi, two pairs of more delicate, spiny maxillæ. A long œsophagus entering the curved stomach in a curious manner leads from the mouth. From the other extremity of the stomach passes off the intestine to the external aperture hard by the caudal appendages.

(iii.) Absorption. Digested food transudes through the walls of the alimentary canal into the general body cavity.

(iv.) Circulation. The Barnacle is heartless. It has no blood-vessels at all. Blood it has, in the shape of a fluid that is provided with corpuscles, and is probably nutritive. This fluid is present in the general cavity of the body, but is not contained in any definite system of tubes. It rather soaks its way through the tissues and amongst the organs of the body. The main lacuna, or space in the midst of the body organs through which the blood unconfined in definite vessels flows, is on the ventral side of the creature, *i.e.*, on the side nearer the sky, as the Barnacle is always on its back, kicking its legs into the air. This median, ventral lacuna, or space, lies at the base of the cirri, or limbs, and extends into them. Two other longitudinal spaces exist. These lie dorso-laterally, *i.e.*, not on the dorsal, or back line of the body, nor on the lateral, or side line, but mid-way between these two lines.

(v.) Respiration. By aid of the general surface of the body. Especially also by aid of filaments attached to the bases of the cirri, where they join the body. The testes, or male organs, intrude into the interior of these filaments, so that the latter are at best only partially subservient to respiration.

(vi.) Secretion. The function of organs whose especial work is to separate certain special materials from the blood. Of these two chief sets are:—

(*a*) Hepatic. The liver is only represented by certain yellow glands in the walls of the stomach.

(*β*) Cement-glands. We have seen that the Barnacle is in some sense standing on its head. The long peduncle at the end whereof it is swaying in the drifts and currents of the sea-water and whose opposite end is affixed to rock or ship-keel is but the modified antennæ of the animal. The little hair-like, jointed organs seen on the head of an insect or the long, majestic, many segmented organs of the lobster have here become a solid organ affixing to its support the being out of whose anterior end they grow. The commencement and maintenance of the attachment is by secretion. In the interior of the animal are the cement-glands or organs that form the cementing substance. They are of the shape familiar to chemical workers in the retort. They are placed near the summit of the stalk or peduncle of the Barnacle, *i.e.*, near the end of it that is attached to the body of the creature. As to their origin and structure, they are very incontestably modified ovarian tubes. They are the ducts of the female organs metamorphosed in some measure. The cement is in nature allied to chitin and escapes through openings in the antennæ or peduncle.

(vii.) Nervous system. The general type of arrangement in the nervous system of the ringed animals is to be seen in all Crustacea and therefore in the Cirripedia. The nervous centres are adjacent to the ventral surface. They are a chain of ganglia connected by nerve cords and giving off nerves. But whilst all but one of the pairs of ganglia are on the ventral side of the body, that one is on the dorsal. The first of all the nerve-swellings is in the anterior and dorsal region of the body and is the brain of the annulose being. How is this cerebral, dorsal, supra-œsophageal pair of ganglia connected with the ventral and infra-œsophageal? Through the medium of a double cord that runs from the former to the first of the latter and passes on both sides of the œsophagus or gullet. This cord embracing the œsophagus is called the circum-œsophageal commissure (*circum* = around, *commissure* = a nerve junction). So that we have cerebral ganglia above the gullet (supra-œsophageal), two cords embracing the gullet (circum-œsophageal) and connecting the former with the first pair of ganglia on the ventral side of the body (infra-œsophageal). These last are, of course, lodged in the thorax and succeeded by other kindred pairs.

(α) Supra-œsophageal. Less concentrated than in other high Crustacea. In them are certainly combined a dozen ganglia. The six pairs belonging to the segments that carry respectively the eyes, two pairs of antennæ, mandibles, and two pairs of maxillæ of the best-known Crustacea are here conjoined, as in all the best known Crustacea, into one.

The branches are: 1. Antennary. These, as they pass to the peduncle, or metamorphosed antennæ are the homologues of the antennary nerves of the lobster. 2. Muscular. From the region where the ganglia conjoin these run forwards to the adductor scutorum and backwards to the œsophageal muscles. 3. Ophthalmic. Forwards to the two ophthalmic ganglia, whence nerves pass onwards to the single eye.

(β) Circum-œsophageal collar. This gives off: 1. Middle branches. 2. Ovarian from the anterior end.

(γ) First infra-œsophageal or first thoracic. This gives off the following branches. 1. Visceral. From its under side to the viscera in the prosoma. 2. Anterior. To mouth organs and olfactory sacs. 3. Postero-lateral. To first cirrus and subjacent muscles.

(δ) Second, third, fourth thoracic. Supply the second, third, fourth pairs of cirri.

(ε) Fifth thoracic. Supplies fifth and sixth cirri and also gives off a nerve to the male intromittent organ.

(viii.) Sense-organs. (α) Of touch. The antennæ are modified into the peduncle. The extremities of those of the last larva or of the pupa stage are to be seen at the fixed end of the peduncle. (β) Of smell. Beneath the second pair of maxillæ are two simple openings or two projections. Behind the openings or within the projections are sacs with a pulpy lining, possibly olfactory. (γ) Of hearing. There is an opening just below the base of the cirrus. A passage leads thence, enlarges as it passes inwards and acquires a pulpy lining. In the enlarged region is suspended a delicate bag of elastic tissue fibrous without, hyaline within. A nerve enters this suspended sac. (δ) Of sight. The eye is placed deeply on the stomach, and light to reach it must traverse the exterior membrane and the corium that join the two scuta. The organ is in reality double. It has two lenses, two pigment-capsules.

(ix.) Motor organs. The six pairs of cirri are motor organs. They are attached to the first six thoracic segments and represent respectively the last of the three pairs of maxillipedes, the chelate or clawed limbs, the two forcipate limbs, and the two pointed limbs of the lobster. Each cirrus has a pedicel of two joints, that divides into two rami or branches of many segments. The cirri are provided with spines. If we turn to the muscles met with in the body of the Lepas they may be thus classified. (α) Of the scuta. An adductor muscle that approximates the two valves; also muscles folding the membrane between the two scuta. (β) Of the prosoma. The front non-appendage-bearing region of the thorax has certain intrinsic muscles whose contraction alters its shape. (γ) Of the mouth. Retractors of the protuberent mouth, folders thereof. (δ) Of the peduncle. Here are three layers, longitudinal, transverse, oblique. (ϵ) Of the cirri. Muscles to the pedicels of those organs and intrinsic muscles of the rami.

(x.) Reproduction. The class Cirripedia is on the whole bisexual. But in three genera of the Barnacle division (*Ibla*, *Scalpellum*, *Alcippe*), and in the order Abdominalia the sexes are separate, Lepas the Barnacle is bisexual and it will be best to briefly describe the arrangement of its reproductive organs ere reference be made to the more abnormal forms. (α) Lepas. 1. Male organs. The testes are tubular, small, lying on the stomach, entering into the hollow interior of the cirri or branchial filaments. They end in large vesiculæ seminales lying in the ventral region of the thorax. From the vesiculæ run two canals to join at the base of the large penis.

2. Female organs. The ovaries are two glandular internal masses on the stomach near the base of the first pair of cirri. From them two oviducts sweep round within the flanks of the prosoma and run as two tubes into the peduncle. There they give off many branches. The ova or eggs escape from the ovarian tubes into the peduncle and *viâ* the circulatory, lacunar spaces pass to aggregate together beneath the chitin-tunic of the sac. Ultimately the eggs are free in the sac of the cirripede and are found held together in two leaves called the ovigerous lamellæ (ovum = egg, gero = I carry, lamella = a plate). These lamellæ are attached to two folds of the skin, the ovigerous frena (frenum = a bridle). Probably impregnation takes place whilst the ova are in the sac, and it will be seen that cross-impregnation is at least possible.

β. Other genera. In these curious Cirripedes, the males are minute, mouthless, stomachless beings, little more than bags of spermatozoa. They are found attached in numbers to the large female. In some Lepadidæ there are ordinary bisexual animals and *also* males of the rudimentary and parasitic kind. These are known as "complemental males."

(xi.) Development. Barnacles are oviparous. Their eggs after impregnation remain in the sac until hatched. They lie two to four deep, held together by a membrane which, whilst it holds them as a whole, also separately invests each individual egg. From the egg emerges not the adult, but the first larval form.

(*a*) First stage. The animal is ·008 inch in length, has a globular carapace, altogether different in shape from the shell-covering of the adult. The abdomen is much better marked and ends in an upturned, horny point. Mouth on a prominence between the limbs. Certain lateral horn-like bodies on the carapace are really cases containing antennæ. Two others on the inferior aspect contain the antennules. A single, simple eye completes the sense-organs. Three pairs of legs. The first has but one ramus or branch instead of two as in the adult. Many exuviations or moultings occur during this early stage ere the second condition is reached.

(β) Second stage. Compressed in shape. Mouth in front of limbs, without jaws as yet. Antennules have disappeared. Two simple eyes. Three pairs of legs, shorter relatively than are those of the first stage. Those of the first pair have only one ramus still.

(γ) Third stage. ·065 inch long. Compressed in shape. The carapace is now nearly bivalve. Mouth is now within carapace. Rudimentary jaws appear. Antennæ are by this time very complex with three segments. The first next the head is the largest and bears a spine. The second has one or more spines and an adhesive sucker. The third, smallest and most distant from the head is spiny. Within these remarkable and important organs are the cement-ducts. The eyes are compound now and are fixed to certain internal folds of the skin of the larval body, that project into the cavity thereof and are called apodemes (αποδημεω = I go abroad). Legs, six pairs, each having a pedicel of two segments and two rami on that pedicel. Two rudimentary ovaries.

Metamorphosis. Within this third larval condition lies huddled up the adult Barnacle. The larva fixes itself by the aid of the cement gland's secretion pouring out from the middle of the three segments of the antennæ. The shell, sac, thoracic skin, eyes, legs of the larva are cast off and the young adult is set free from its larval investment, but is attached by the peduncle to its support.

(*b*) We will consider the Acorn-shell under the same heads as we did the Barnacle. (i.) Structure. The whole of that which is visible externally is the shell or testa, or lower solid part, and the operculum attached by membrane to the shell and more or less enclosed within it at its upper region.

(α) The Testa. The shell or the lower more solid portion presents the basis, that is the part that is attached directly to the rock, and the compartments or divisions of the shell supported by that basis. The basis corresponds with the part attached to the peduncle in the Barnacle, which is really the anterior end of the creature. It is either membranous or calcareous. In the latter case it consists of two horizontal plates, the one directly against the support and the other parallel to it, connected by radiating partitions. The growth of the basis is only circumferential. Compartments or divisions of the shell. The particular compartment whence the cirri are exserted through the opening in the operculum is the carina. The one exactly opposite to it at the other end of the body is the rostrum (from *rostrum*, a beak). Three compartments lie on either side between these two end ones. The one nearest the carina is the carino-lateral. The one nearest the rostrum is the rostro-lateral. The third intermediate one is the lateral. As far as the construction of the wall of each compartment of the shell is concerned we find three types. 1. A middle wall, or paries, bounded by two radii. The radius is marked with lines more or less vertical. 2. A wall or paries, bearing on each side an ala (*ala* a wing). The alæ are marked with more or less horizontal lines. 3. A paries, or wall, carrying on one side a radius, on the other an ala. The carinal compartment comes under the second type, and so does generally the rostrum. The rostro-lateral comes under the first type; the rest under the third. It will be seen that these compartments, which often project beyond the operculum, are typically eight in number. Rostrum, carina, two carino-lateral, two lateral, two rostro-lateral. But by the abortion of some and fusion of others the number may be reduced. Thus our particular study at the present moment, Balanus, the Acorn-shell, only has six. This diminution in number is due to the fusion of the rostrum with the two rostro-lateral. As to the structure of the walls of individual compartments, we have a similar arrangement to that in the basis. Each wall consists of an outer and an inner plate, or lamina, joined by partitions. These partitions are again connected by transverse smaller ones. The compartments grow at their bases. (β) The operculum is to a large extent the homologue of the shell covering of the Barnacle. It consists of two scuta and two terga that are connected with the summits of the compartments by a membrane known as the opercular. The four opercular valves are the only movable ones, and two of them, the scuta, have the body attached to them. These valves grow only by their basal margins, so that the body becomes attached at continually lower points, and the opercular membrane is moulted at certain intervals, each successive opercular membrane being a little larger than its predecessor.

Finally the sac within which the body is enclosed is entered by an orifice between these movable valves of the operculum, and surrounds the body. The thorax of that body has, as in the Acorn-shell, a prosoma and segments, and on the rudimentary abdomen are the two jointed bristle-bearing caudal appendages.

(ii.) Digestion. The food is animal, swept into the mouth by the constantly moving cirri. It passes between the notched but not swollen labrum, or upper lip, the mandibles, each with three to five double teeth, and the maxillæ, down the œsophagus to the stomach. The stomach has six to eight cæca, or blind extensions, and presents an intro-gastric tube of chitin. This does not extend either forwards into the œsophagus or backwards into the intestine, but is a complete internal model of the stomach; it is expelled at intervals, filled with excrementitious matter.

(iii.) and (iv.) As in the Barnacle.

(v.) The respiratory organs are represented by folded membranes within the sac. There are two in the angle between the side of the shell and the base of the compartments of the basis. They are specialised parts of the body-wall that would seem to serve as organs for bringing into close contact the blood-fluid of the general cavity and the water with air dissolved in it of the sea. Water is pumped in and out by the motion of the opercular valves. These folded membranes are homologues of the ovigerous frena of the Barnacle, but are functionally respiratory.

(vi.) Secretion. Of secreting organs we have only to say the same as in connexion with Lepas, save that the cement apparatus is more complex. The cement secretion is all given out by the basis, and serves for the attachment of the animal to the rock. In the middle of that basis will be found the two small antennæ. Thence several cement trunks pass from the centre of the basis about half-way to the circumference. These cement trunks are studded along their course with cement glands, that grow smaller as we pass out from the centre to the circumference. From each cement gland pass off two principal ducts. One of these runs directly into the circular canal that, sweeping right round within the circumference of the basis, pours out large quantities of cement. The other duct divides into two. One of these two passes directly into the circumferential canal, and the other, joining with a branch from the most adjacent cement gland on the next cement trunk, the two pass together into the circumferential canal.

(vii.) Nervous system. The nervous system, as in the Acorn-shell, is very complex and difficult to understand without the aid of a diagram. Above the œsophagus, as in most ringed animals, is a pair of very distinct supra-œsophageal or cephalic or cerebral ganglia, possibly representing a brain. From the supra-œsophageal ganglia and their locality pass off the following nerves. (α) Ophthalmic in the middle line of the body, running forwards to a ganglion or nerve swelling, the ophthalmic ganglion, whence proceed nerves right and left to a plexus with the next that are mentioned; there runs also anteriorly the ophthalmic nerve to the eye. (β) Antennular from the ganglia themselves. These enter into a plexus with the nerves (α) and then sweep onwards down into the peduncle. (γ) A nerve on each side to the muscle that draws together the two scuta. This is the nerve of the adductor scutorum. (δ) The supra-splanchnic (supra = above, σπλαγχνα = viscera), a nerve that runs into a plexus formed by it and the splanchnic nerve to be presently described, and with this latter supplies the internal organs. (ϵ) The two nerves that run from the brain above, round the œsophagus, one on each side to the large ganglion on the ventral side. Thus the supra-œsophageal ganglia or brain are connected with the infra-œsophageal (infra = below) by the two circum-œsophageal (circum = around) cords.

From the one large infra-œsophageal nerve swelling pass off the following nerves. (α) In the middle line in front a nerve to the olfactory organs. (β) On each side of this three nerves to the jaws. (γ) Splanchnics from the sides of the ganglion. (δ) Thoracic, also springing from the sides and passing to the wall of the thorax. (ϵ) Nerves to the cirri. These are six in number on each side. The first takes origin from the upper and anterior region of the ganglion, the rest from the posterior region. The fifth and sixth arise together, and, after they have separated, the sixth gives off a nerve to the male intromittent organ. This last nerve is the sole representative of the abdominal nerve cord.

(viii.) Sense-organs. (α) Touch. Certain threads pass from the opercular membrane—*i.e.*, the membrane connecting the movable opercular valves with the immovable shell, into the substance of the shell. They may be subservient to the sense of touch. (β) Taste. Possibly the mouth appendages are in some sense gustatory. (γ) Smell. As in the Barnacle. (δ) Ear. As in Barnacle. (ϵ) Eye. The single ophthalmic nerve ends in a circular disc with pigment-cells, to which the external integument acts as cornea.

(ix.) Motor organs. The study of these falls into four divisions. Muscles of operculum. Muscles of thorax. Of mouth. Of cirri.

(α) Muscles of operculum. These are: 1. the adductors of the scuta, drawing those two valves towards each other. 2. Longitudinal muscles from basis to operculum. These run from the basis or fixed aspect of the Acorn-shell to the upper or free ends of the movable valves of the operculum. There are, in all, three pairs. They are of striped or voluntary fibre and act as depressors of the operculum whilst they also widen the orifice of the sac. The converse action to the action of these muscles, whereby the operculum is raised away from the basis is effected by the general pressure of the animal's body against the fixed basis.

(β) Of thorax. From the prosoma or unsegmented anterior part of the thorax run eight pairs of muscles to the investing shell. Three pairs are superficial. Five pairs lie more deeply within the body of the animal. From the prosoma also run muscles to the jaws, to the first pair of cirri and to the hinder segments of the thorax. Again the segments of the posterior part of the thorax, as distinct from the individual prosoma, have their own muscles. Inside each are intrinsic muscles, a dorsal, a lateral and a dorso-lateral between the two former on each side.

(γ) Of mouth. The labrum has two muscles that draw it inwards. The mandibles possess depressors and elevators. The outer maxillæ have flexors and extensors.

(δ) Of Cirri. The movement of the thoracic segment to the which they are attached determines largely the motion of the cirri. But each cirrus has also its own intrinsic muscles. The first cirrus represents homologically the third leg of insects, the third foot-jaw of the lobster. The succeeding represent the five ambulatory lines of the lobster, viz., the huge claws, the two forceps-bearing limbs and the two pointed limbs.

(x.) Reproduction. The Acorn-shell is bisexual and its male and female organs are on the same general plan as are those of Barnacles. But in some Cirripedia, notably *Ibla*, *Scalpellum*, the animals are unisexual. When this is the case, the males are very curiously aborted beings. They are exceedingly minute and are fixed to the female. As many as fourteen have been found within the sac of a female cirripede of the same species. These strange rudimentary males are without mouth or stomach, have very few muscles, one eye, one testis, vesiculæ seminales, an intromittent organ eight or nine times the length of the bag-like body. They are in fact little more than bags of spermatozoa whose existence is necessarily brief.

As a rule the animal within whose sac these aborted males are found is female. But in some Ibla and Scalpella the animal thus supporting the rudimentary males is bisexual. Then the males are named "complemental." For in the bisexual nature of the ordinary animal sufficient provision for impregnation seems to exist and yet here are these additional males to be seen.

(xi.) Development. In the main as that of the Barnacle. The larva passes through three stages. To the account of the third stage, as given under Lepas, our observer adds one or two points. Discussing the homologies of the body segments of the larva, he finds the six head segments, only six of the normal eight thoracic (the first two having disappeared), and three of the usual half-dozen abdominal. The parts that are identical in the larva of this stage and the contained adult cirripede are the last three segments of the antennæ, the mouth, the rami of the cirri. The great length of these last causes them to occupy a greater space than is afforded by the internal cavity of the thorax of the pupa. Hence the thorax of the contained adult is found in the head region of the pupa, or third larval stage. When the carapace of the containing larva splits and is cast off, along with it go also the ear sacs, the basal segment of the four antennal segments, and the eyes.

The after changes of the adult cirripede are that the valves, at first membranous, become calcareous, the muscles of the antennæ become threadlike, the cæca of the stomach increase in number, the internal reproductive organs are formed, and the male intromittent organ elongates.

(*c*) Abdominalia. The *Cryptophialus minutus*, solitary in its order, has its first thoracic segment distinctly marked off from the rest, and bearing rudimentary organs that represent the first pair of feet-jaws or maxillipedes of Crustacea, and the first of the three pairs of legs of the insects. The ensuing seven thoracic segments have no appendages. The three segments of the abdomen that are, in our Barnacles and Acorn-shells, reduced to almost nothing are here developed and carry three pairs of cirri. The labrum of the mouth becomes a large lancet-formed organ. The lower end of the œsophagus has discs of teeth and brushes of hairs. Its metamorphoses are not as those of other cirripedes. All the earlier changes are but indicated by shadowy alterations of form in an egg-like larva, and no distinct development of organs occurs. The last pupal stage is also specially distinguished from the like stage in other members of the order by the absence of swimming limbs.

(*d*) Apoda. The *Proteolepas bivincta*, solitary in its order, is an articulated animal, minus any shell, attached by two threads, that represent the carapace of other Cirripedia to the interior of the sack of *Alepas cornuta*. It has no appendages of the body save those around the mouth. That mouth is suctorial. There is no stomach nor distal opening to the alimentary canal. A strangely reduced creature, and yet a cirripede undoubtedly.

3.—*Distribution of Cirripedia.*

(*a*) In time. Geologically considered, Cirripedia are not encountered ere the Eocene period. The oldest genus is Balanus. There is a table in the second volume of the "Monograph," page 174, that will give all requisite information on this point.

(*b*) In space. Very general. Cirripedia extend from Lat. 74° 18′ N. to Cape Horn. Shores that are of sand, or mud, or shingle, are unfavorable to them. They are not seen in the coral-reef lands. Taking the division of Dana into zones of temperature, we find that of 147 species in the order Cirripedia, 37 are met with both in his torrid and temperate zone, 46 in the torrid alone, 57 in the temperate alone. On the whole, therefore, a leaning towards the temperate.

On following Charles Darwin in his study of certain earth regions, we find that in the North Atlantic region, including Europe and the United States, and extending from the Arctic Ocean to 30° N., there are 31 species, 22 of which are peculiar to that region. In the African, south of 30° N., there are 11 species, 5 of which are peculiar. In the region that reaches from Tierra del Fuego to Behring's Straits, there are 22 species, of which 15 are special. In the Indian Archipelago 37 species, 24 special; and in Australia and New Zealand 30, of which 21 are peculiar to the region.

And thus I have attempted to give some analysis of a book that is a monument of research and of acute reasoning. I have of purpose dealt only with the Cirripedia generally, and the two best known members of the order specially. Even in doing this I am aware that I have gone beyond the range of the non-scientific reader. But this the nature of the subject compelled. It must be remembered that this volume is intended not alone for the non-scientific reader. There is the hope that it may be a help and guide to the scientific student. And hence I have tried, in dealing with this abstruse book on an abstruse subject, to systematize and simplify. It is my desire that herein students may find an intelligible epitome of the history of the great order Cirripedia, such as will be of service to them in examination in both the passive and active sense—in the passive sense, when university authorities are inquisitive; in the active and more important sense when the student is investigating these animals for himself.

I have abstained from dealing in detail with a large part of the Monograph of the Cirripedia, inasmuch as it is exceptionally technical. It is devoted to an exceedingly careful account of the different genera and species of the order. It exhausts the subject. To these pages all students will turn, until Evolution in the future has resulted in the production of species and genera of cirripedes other than those now known. From these pages the student will turn with renewed reverence for the great generalizer, who is also so patient and so completely master of detail.

V.—WORKS ON EVOLUTION.

I now approach the *magnum opus*. It may be said that the quartett of books dealing with Evolution constitute as a whole the great work. First in point of time and therefore foremost for our consideration, comes the Origin of Species. This states the theory of Natural Selection clearly, and gives the reasoning upon which the acceptance thereof is based. The second volume, Animals and Plants under Domestication, gives the mass of facts upon which the reasoning is based. Then comes the Descent of Man wherein the part of Evolution of greatest interest to man is discussed, and finally the Expression of the Emotions. In this the points wherein man is supposed to differ most essentially from his fellows are studied without any shaking of the general conclusion.

A.—Origin of Species.

CHAPTER XXXV.

(1.) *The Meaning of Species.* (2.) *Historical Review.*

(1) THE WORD "SPECIES." My first endeavor will be to make plain the meaning of the word "species." It is a term, at one time much more convenient than at present, employed in the classification of plants and of animals. The most casual observer of either of the two great kingdoms of living beings, notices in the mechanical way that is the observation of many, that there are varying degrees of resemblance between organised beings. He sees that certain plants or animals closely resemble though they are not identical with each other, whilst certain other plants or animals are widely different from the former groups. He speedily thinks out and uses a rough kind of classification. The biologist recognises in living things two great kingdoms—the Animal and the Vegetable. He recognises in each kingdom strongly marked groups, which he names sub-kingdoms. Thus, among animals he sees a large number possessing back-bones, and he constitutes them the sub-kingdom Vertebrata. Studying this sub-kingdom he notices that there are groups therein strongly marked off one from the other, but not so strongly as were the sub-kingdoms. These he calls classes. Thus, finding a number of creatures who suckle their young, he constitutes them the class Mammalia. Investigating this class, he observes yet smaller groups, and to these he gives the name of orders. To one of these groups he applies the title Carnivora. The orders are divisible into genera. The order named, for example, contains such genera as Canis, Felis, Leo, Ursus—the dog, the cat, the lion, the bear. But of genera there are divisions. Thus, of the dog kind are many sorts. There are the dog (*Canis familiaris*), the wolf

(*Canis lupus*), the jackal (*Canis aureus*). These are species of the genus Canis. Species frequently present varieties. Of the species *Canis familiaris*, there are several forms. Greyhounds, bloodhounds, spaniels, terriers, collies, are all varieties of the species. It is no definition of a species, however, to say a species is a division of a genus and contains varieties, and yet that is all I have done so far. Is a definition of a species more accurate than this possible? Some years ago the answer would have been ready enough. In the books of a few years back, unfortunately perhaps in not a few of the present day, there are elaborate definitions of the word. Perhaps the most typical one as representing the old habit of thought on the subject is that which settles a species to be a group of living beings that have descended from one pair of progenitors. It is hardly necessary to point out that this definition springs from the evil habit of expecting scientific accuracy in books written by unscientific persons. As long as our ideas of natural science were derived from or even colored by the mythologies of past ages, so long nothing accurate could be hoped for; as long as geologists clung to the "six days" theory, little progress could be expected; as long as biologists took the account of the origin of animals given in the works of old world thinkers as satisfactory, little progress was possible in their branch of study. But of late the light of common sense, of reason, has been brought to bear on these works; so remarkable, considering the time wherein they were written, that many have fallen into the error, as it seems to me, of regarding them as applying *verbatim et literatim* to all times. As, however, the application of the writings of the Jewish nation to the life of the present day has been seen to be unwise, as the code of morality for the most part taught therein has been found quite insufficient for later times—as even the beautiful religion taught in the New Testament, and displacing the barbaric religion of the Old, has in its turn to yield to a yet more beautiful philosophy, so has the application of the writings of the Jewish nation to natural science been seen to be unwise, so has the knowledge of natural phænomena taught therein been found, naturally enough, quite insufficient in later times, so have the scientific theories propounded in the Bible to yield to a more beautiful, because more true, philosophy.

The old idea of species was founded upon the statements of the Christian mythology. Everyone believed that each species of animal, each species of plant, was the result of a distinct creation; that the unknowable so far became knowable as to say, "Let there be canis; let there be vulpes; let there be rosa; let there be rubus." There are still many people who cleave to this along with other kindred antique notions, and of these people some few are men of recognised standing in the scientific world. Hence have arisen two schools of thought as to the origin of species—the one holding the theory of special creation, the other that the multitudinous species of living beings have been evolved from a few primordial forms, perhaps from one primordial form. This latter view is that of the evolutionists. A well marked variety may therefore be called an incipient species. From these remarks it will be seen that I look at the term "species" as one arbitrarily given, for the sake of convenience, to a set of individuals closely resembling each other, and that it does not essentially differ from the term "variety," which is given to less distinct and more fluctuating forms. The term "variety," again, in comparison with mere individual differences, is also applied arbitrarily, for convenience sake.

(2.) Historical review. In this work are first clearly enunciated reasons for the notion that species of animals and of plants are not the result of special creation, but that the multitudes now inhabiting the earth have been evolved under certain natural laws from a small number of primordial forms. It should be distinctly understood that Charles Darwin is not the first to suggest that the Old Testament account is unsatisfactory. Other writers ere his time had done that, but he was the first who grappled with the difficulties attending this view of the evolution of the many from the few. He was the first who attempted to explain—the first to lay down the definite principles that seemed to him to have governed this same evolution. Mankind is not content with the bare statement that "new species have been produced by descent with modification from those separately created." Mankind wants to know the how and the why.

Turning to Darwin's own work on the "Origin of Species," we find, even in the writings of Aristotle, most modern of ancients, the theory of Natural Selection suggested.

Between 1801 and 1815 Lamarck upheld the doctrine that all species, even to man, were the descendants of other species, but he believed that the simpler forms of living beings in existence at the present day were spontaneously generated. There are epidemics of thought. The Elizabethan age, rich in its dramatists; the eighteenth century, with its essayists and historians; the present day, with its scientific writers, are cases in point. Noticeable in this connexion is the fact that in the years 1794 and 1795 three of the greatest thinkers of Europe, denizens of different countries, were all broaching the same idea. Geoffroy St. Hilaire, Goethe, Erasmus Darwin (grandfather of our Darwin) were simultaneously, in France, in Germany, in England, hinting at the probability of the origin of higher forms of living being from the lower.

Eighteen years later Dr. Wells, the first who saw the truth and therefore the simplicity of the formation of dew, was also the first of the moderns to actually recognise the principle of Natural Selection; but he applied that principle to man alone. In 1822, and again in 1837, the Dean of Manchester dares to state that species are only higher and more lasting forms of varieties, whilst Professor Grant, who lived far enough into this century to give the present writer his first lesson in Comparative Anatomy, utters his belief that species are descended from other species, and improve in their descent. Von Buch and Rafinesque in 1836, and Haldeman, of America, seven years later, show that the new theory, as yet shaped into little definite form, was spreading to countries outside England. Finally, the authors of the remarkable "Vestiges of Creation," Owen, the younger St. Hilaire, Herbert Spencer, Naudin, Baden Powell, Von Baer, Huxley, Hooker, are some of the most distinguished among those who have stated their belief in or the probability of the truth of the descent of species from species without Special Creation. But not one of these great thinkers ever did much more than state his belief that this explanation of the origin of species was more probable than the mythological one. It was reserved for Charles Darwin, not only once more and in more clear and less mistakeable language to give voice to the new idea, but to support it with arguments of such a nature that the main body of the scientific world has yielded to them as unanswerable. It was his fortunate lot to reply to the longing question of all men—How has this come to pass?

And in this place, ere the discussion of his great work is undertaken, it were well to remind my readers that there was with this man no hurry, no rushing at conclusions. In 1837, returning from his historic voyage round the world in the "Beagle," he has an idea that something may be thought out on this momentous subject, the origin of species. Therefore, after his patient, methodical fashion, he accumulates facts for five years. During two more years after that he notes and thinks. In 1844 he sketches only the conclusions that seem probable. Fifteen years later he publishes an abstract of his views, because there is dread that the Destroyer may interpose and smite him dead ere he has spoken his great message to the world, ere the voice that is to reverberate through the centuries to come is to have utterance. In 1859, with ill-health heavy upon him, he sees it needful to publish the conclusions he has reached without all the facts that have guided him to those conclusions. The "Origin of Species" startles the world, and that world is for ever thankful that the life of its distinguished author has lasted even long beyond the time when he was able to publish, in the "Animals and Plants under Domestication," the series of observations that had conducted him to, and had firmly and incontrovertibly established the conclusions enunciated in the former work.

CHAPTER XXXVI.

(3.) Variation under Domestication.—Artificial Selection.

(3.) VARIATION UNDER DOMESTICATION.—It has been often stated that the variation of living beings under domestication is a truism. Ordinary people need to be reminded of truisms, especially when argument is to be based thereon. The first part of the "Origin of Species" is, therefore, devoted to this subject. (*a*) In plants. Familiar to everyone, and especially to floricultural folk, is the way wherein florists, by careful observation and selection, produce new varieties of fashionable flowers. The numbers of varieties of pelargonium or of fuchsia produced within the memory of those now living illustrate that to which I refer. The florist does not originate the changes ultimating in these new varieties. He watches. Nature, in her infinite variety, offers to him upon some particular plant a new form of leaf, a new blending of colors in the flower. He observes, he selects, he breeds carefully from the oddity. Within a short space of time, by his careful selection, he has aided in the production of a form of flower with the original faintly-marked peculiarity so intensified that the plant is hailed with delight as a new variety, and named Mrs. This, or General That. Let it be noted carefully, man has done this. Man, with his small powers, following the bent of his inclination, not following out what is of benefit to the plant, has helped to produce a new variety.

In 1793 some wild Scotch roses were planted in a garden. One of them bore flowers tinged with red. From this one, by selection, were produced twenty-six varieties within twenty years. In 1841 three hundred varieties were recognisable, all originating from the one variable plant of 1793. Between 1813 and 1835 four hundred varieties of pansy were derived from the wild and the garden violet. All the varieties of dahlia have sprung from one original species since the year 1802 in France, since the year 1804 in this country. The varieties of apricot are all derivable from one wild species now to be found in the region of the Caucasus. All the various forms of plums have been formed by man's selection and evolved from the bullace, or *Prunus insititia*.

(*b*) In animals. So far reference has only been made to examples of the production of varieties of plants under the treatment of human beings. But in the investigation of animals similar facts are encountered. Horses, dogs, cattle, at once are suggested to our minds. Let us take, however, the more striking instance chosen by Charles Darwin. It is the case of the domestic pigeon. Under this general head rank carriers, tumblers, runts, barbs, pouters, turbits, jacobins, trumpeters, laughers, fantails. These differ in appearance, in the nature of their skeletons, in the period whereat the full plumage is acquired, in their eggs, in the manner of flight, in voice, in numberless points of internal structure. Yet all these varieties are believed by naturalists to have taken origin from the rock pigeon (*Columba livia*). For at least 5,000 years pigeons have been the pets of man, and during that time the selection of birds showing at first only slightly marked peculiarities has been pursued so carefully, so steadily, that there are now at least twenty sorts of pigeons, presenting differences more marked than are those obtaining between some genera of birds and of mammals. Few people could be found who would for a moment question the origin of all these widely varying forms from the one common parent within the period of man's sojourn upon the earth. The carrier, more especially the male bird, is remarkable for the wonderful development of the carunculated skin about the head; and this is accompanied by greatly elongated eyelids, very large external orifices to the nostrils, and a wide gape of mouth. The short-faced tumbler has a beak in outline almost like that of a finch; and the common tumblers have the singular inherited habit of flying at a great height in a compact flock, and tumbling in the air head over heels. The runt is a bird of great size, with long massive beak and large feet; some of the sub-breeds of runts have very long necks, others very long wings and tails, others singularly short tails. The barb is allied to the carrier, but, instead of a long beak, has a very short and broad one. The pouter has a much elongated body, wings, and legs; and its enormously-developed crop, which it glories in inflating, may well excite astonishment, and even laughter. The turbit has a short and conical beak, with a line of reversed feathers down the breast; and it has the habit of continually expanding slightly the upper part of the œsophagus. The jacobin has the feathers so much reversed along the back of the neck that they form a hood; and it has, proportionally to its size, elongated wing and tail feathers. The trumpeter and laugher, as their names express, utter a very different coo from the other breeds. The fantail has thirty or even forty tail feathers, instead of twelve or fourteen—the normal number in all the members of the great pigeon family; these feathers are kept expanded, and are carried so erect that in good birds the head and tail touch; the oil-gland is quite aborted.

"Yet they are all pigeons," cries the thoughtless one, "you can never make them anything but pigeons." This cry is but another instance of the habit of mistaking names for things. They are all pigeons because their history is known. Were it not known, each would be placed in a separate spécies, perhaps a separate genus, from all the rest. The name simply expresses their community of origin.

(*c*) Circumstances favorable to man's selection. These are a high degree of variability in the individual animals and plants, many individuals, upon whom to work and from whom to select, favorable conditions for the propagation of the variation and careful attention by man to the living beings under consideration. These all explain themselves, but two other circumstances call for comment.

The changed conditions to which our domestic plants and animals are subjected appear to act directly on the organism as a whole, or indirectly on the organism by causing changes in the reproductive organs.

In connexion with the use and disuse of parts, it should be noted that not one of our domesticated animals is known that has not, in some country or another, drooping ears. As they are, when in a domesticated condition, no longer subject to being hunted by their quondam foes, they are no longer on the alert, no longer constantly listening and starting at the slightest sound that can be construed as sign of danger. Hence, ears are no longer erected at frequent intervals and have not been these many years. Hence, the old habit has been lost and the ears, once habitually erect, droop. The statement that our domestic animals, when allowed to run wild, revert to the aboriginal condition, rests upon no decisive facts.

Above have been given one or two of the instances of human ability, with limited knowledge, with limited power, with limited time, to produce by artificial selection, on the basis of pleasure to mankind, not of profit to the plant or animal, varieties that, but for ancient prejudice, would be regarded as distinct species, or even as distinct genera.

CHAPTER XXXVII.

(4.) *Variation under Nature.*

(4.) I TURN from the consideration of variation under domestication to variation under nature. This exists. Of that no doubt can be. Those differences that mark off individuals of the same species, nay, actual descendants of the same two parents one from another, those individual differences are due to the infinite variation of nature. Man has times and again taken advantage of her variability in connexion with plants or animals under his own observation.

Does anyone exist whose youthful being was not brightened by a ray of hope when some far-seeing friend tendered the problematical half-crown as payment for the discovery of two blades of grass exactly alike? I, for one, can remember not a few fruitless hours, spent in the search for the identical grass blades, at a period when time was of less value and half-crowns of as great moment as now. Not altogether fruitless were the hours. I came face to face with the great mother even in those childish seekings, and no child, no man can do that without being the happier and the holier. Nay more, even then the great truth sank into the mind of one unconscious, to dawn upon me again in the after time as almost a new revelation, that she was not uniform, but infinitely variable. One has to give up the idea that the two identical grass blades are to be found, as one has to abandon the hope of finding the pot of money at the foot of the rainbow, and many another dream of childhood; but one is not the worse for parting with the fanciful beliefs, nor the worse, let us hope, for having held them once upon a time.

Nature is infinitely variable. You will never see two human beings exactly alike. Even the two Dromios and the brothers Antipholus have points of difference that the master, after his wont, does not fail to bring out in the immortal farce. Two wild roses built on precisely the same model never bloomed. The very leaves upon the same bough are never quite identical.

CHAPTER XXXVIII.

(5.) *Natural Selection.*

(5.) NATURAL SELECTION.—Given this variation under nature, the question arises—how is it connected with the formation of species? What is the relation between this universal variation and the Evolution of the many from the one? To understand this it is needful to consider the struggle for life that is unceasingly visible.

(*a*) The struggle for life. The world is one great battle-field. Over all its surface, within the depths of its waters, in the very air that belts it round is eternal strife. All living beings, from loftiest to lowest, are fighting unceasingly. The life of our huge cities, with its struggle of class against class, and of individual against individual, with, on the part of him that would triumph, an unremitting toil and an intense devotion to himself and his that are needful as they are awful in their desperation, with its doing unto death of the many that is the inevitable accompaniment of the success of the one—that life, I say, that is so full of the terrible that the very stars shiver as they look down upon it and hear the sound of the city's inarticulate moaning pass by them into the infinite, like a wandering ghost—that life is the type of all life. In the darkness of the soil of the earth the roots of the plants are struggling with each other for food. In the microscopic drop of water the Infusoria sweep ceaselessly round and round, striving for the food that is not sufficient for them all. Never ending contest. Interminable strife. Every living being is an Ishmael. Its hand is against all others. The hands of all others are against it. And as among men, so also among the more lowly organized creatures, the bitterest struggle is ever between those who are akin one to another. Wherefore is the contest? For wealth or glory, or a lasting name? Nay, for bare life. The struggle everlasting is for the very means of existence. It is as the struggle of a famine-stricken multitude for the bread that is not sufficient for their wants. *Væ victis*, woe to the conquered is the cry of the world. If plant or animal succeed not, away with it! Let it perish, trodden to death beneath the feet of its stronger brethren hurrying onwards for food.

How does Nature, in her silent fashion, take advantage of the eternal variations occurring in the flowers that turn her bosom into a firmament of many colors, of the variations occurring in the animals that traverse her wide plains or pass through her solemn woods?

(*b*) The theory. By Natural Selection or the Survival of the Fittest. The former phrase is Charles Darwin's; the latter is that of Herbert Spencer. Let us try to understand them, for phrases such as these are as the utterances of the prophets of old times, and are to stir the thoughts of men long years after they are first spoken.

Who, then, are to be the survivors in this battle? Who are doomed to be numbered among the slain? Those best fitted for the struggle will survive. Those least adapted to the circumstances of the unending fight are doomed. The fittest will hold out the longest. That which possesses in strength or in any other way an advantage over its fellows will conquer them in the struggle for existence. Now, mark! If any variation in any individual plant or animal is of such a nature that its possessor will be better fitted for life-work, that possessor will have an advantage over its fellows—will stand a better chance than they of surviving, will transmit its variation to its offspring, possibly in intensified form. The offspring, even better fitted than their parent for life, triumph yet more completely over their fellows. Thus is the original slight variation strengthened until, after a long time, forms result so differing from the first individual that presented the variation, that the biologist is constrained to regard them as belonging to a species other than that comprising the original plant or animal.

This is the great principle of Natural Selection, or the Survival of the Fittest. The variations that are of benefit to the beings possessing them are naturally selected. The enunciation of this principle, and the elucidation thereof, have been in especial the work of Charles Darwin.

(*c*) Multiplication and checks. Following his plan let us dwell for a moment on this life-struggle wherein all living things take part. All plants and animals tend to increase at a rate that to those who have not considered the question appears marvellous. Man, one of the slowest of breeders, will double in numbers if population is unchecked, in between twenty and twenty-five years. It has been calculated that one pair of elephants, the animals ranking lowest in this respect, would produce in 750 years no less than 19,000,000 descendants all living at the same time. What checks exist then to prevent this world-embracing increase of organised beings? The old answer is only too ready—Disease and Death. No living beings can exist without food. The quantity of food for any given plant or animal within the reach of that plant or animal and obtainable by it, determines whether it will live or die. The average number of any particular species is dependent, therefore, on the amount of its food. Very often the average number is dependent on whether the species under consideration is a prey to other beings or not. Climate again plays an important part in this determination as to which are to survive, which are to succumb. It is hardly necessary to point out that climate reacts upon animals and plants in their life-struggle by acting upon their food supplies. Epidemics are another limiting check. With the lower plants or animals, as with the highest, these agencies for the limitation of numbers work, and with the lower beings these and such as these alone. But in each of these is, as it were, an element of brutality. Nature does not prevent the production of living things. She remorselessly kills them by the thousand after they have been produced. It is well, therefore, when advancing knowledge gives to the highest of animals other means of limiting the number of its offspring than are offered by the blindly acting forces named above. Animals of a predatory nature are also a cause of destruction to others and to plants. These all play their part in the universal struggle. Certain other points of great moment remain in connexion with this struggle for life.

(d) That the relations of organised beings in this contest are infinitely complex. Red clover depends for its existence as a species on humble bees. The number of humble bees depends on the number of field-mice, for the field-mice destroy the combs and the nests of the bees.

The number of mice is not altogether unconnected with that of the cats in the locality. "Hence," says Charles Darwin, "it is quite credible that the presence of a feline animal in large numbers in a district might determine the frequency of certain flowers in that district."

(e) Closely allied species will wage the most internecine warfare. They have similar structure, similar habits, require similar food. They therefore come into contact with each other—nay, they are face to face contesting for the food whereon their very existence depends.

(f) The structure of every living being will be related even though the relation is not always perceptible by us to that of all others wherewith it comes into competition, wherefrom it has to escape or whereon it has to prey.

(g) Again, Natural Selection works upon living beings at all ages, not necessarily upon adults alone. Any variation in the larval condition of an insect that better fits its possessor for its struggle with its fellows and its surroundings will be likely to become established, and in not a few cases to react upon the organs of the adult.

(h) Further, the theory of Natural Selection is not opposed to those remarkable instances among animals where a number of individuals live together in colonies with division of labor, the result of the different capacities and different structures of members of the same species. Of this the hive bees furnish the most familiar example. Here are drones or males, queen bees or females, neuters or ordinary working bees. Division of labor is a distinct advantage. Bees, therefore, tending to produce eggs, which, under certain conditions, become males, under others become females, and under yet others become workers for the community at large, will have such advantages over bees only producing eggs that will develop into males or females as to determine their survival, as the fitter.

(i) Natural Selection is aided by that intercrossing of individuals that seems universal. Of course, where the two sexes are in separate individuals, as in the higher animals and in some plants, such intercrossing must occur, and the different natures of the male and female parents will give opportunity of variation in their offspring. In most plants, and in some animals, the sexes are united in the same individual. An ordinary flower contains both pollen or ferti-

lising dust and ovules or unripe seeds. Nevertheless, self-fertilisation in plants is the exception, not the rule. Of late years it has been shown, notably by Charles Darwin and Sir John Lubbock in England, that in the flowers that the botanists of the past believed to be always self-fertilising exist the most elaborate arrangements for the prevention of self-fertilisation. Precautions in structure, precautions in function, are taken, as it were, to prevent the unripe seeds of flower A from being fertilised by the pollen of flower A, whilst structural and functional facilities are afforded for the fertilisation of the ovules of A by the pollen of B—*i.e.*, some other member of the same species. Even in the few cases where self-fertilisation does seem to occur, an occasional intercross with some other individual of the same species is always attended with increased vigor on the part of the offspring. In fact, the intercrossing of individuals among both plants and animals, either constantly or occasionally, seems universal. It is almost needless to point out that this concourse of two separate beings in the reproduction of their kind gives much more opportunity for variation, and therefore a much wider field for the action of Natural Selection.

(k) The principle of Natural Selection involves the idea of divergence. If the principle be true, as variations occur useful ones will be selected, and in transmission to descendants they will be strengthened. More than one kind of variation—nay, many variations, may occur in the same species of animals or plants. Those that are of use will all be perpetuated and intensified, and as they are of different natures, affecting different organs, it follows that the individuals possessing these variations, and their descendants, will tend to differ more and ever more from one another and from their common ancestor. There are so many places to be filled up, there are so many different kinds of circumstances to be encountered, the surroundings of living things are so endless in their diversity, that the more diversified, the more strongly marked off one from another the descendants of primordial forms become, the more chance have they of taking places as yet unoccupied in nature, of adapting themselves to conditions as yet not satisfied.

(*l*) This principle helps to explain the advancement that is so recognisable in organised beings. Natural Selection must lead to the improvement of species. Variations occur. Only those variations that are of use are selected and last. Hence a steady advance in organisation, an ever-increasing adaptation of the structure and functions of the living thing to the conditions of its environment. The old talk as to the perfection of nature must be reconstructed. There is much that is very remarkable in the adaptation of certain structures to particular functions, but it is quite impossible to speak of nature, as a whole, as if absolute perfection reigned. There are thousands of gigantic blunders in the universe, blunders that we can see, and whose ill effects are too sadly evident, though we are powerless to remedy them. The world is only "in its go-cart." Terrible errors, the most wanton waste, the awfullest sacrifice of living things, meet us at every turn. The "perfection" of nature is not in her having attained. It is in her increasing advancement. She stands not still, rests not quiescent in a beatific seventh heaven of perfect, designed adaptation. She is ever advancing, ever improving, ever casting away the weaker and the worthless, rejecting the results of her false trials, and retaining the strong, the worthy, the true. Nothing is more comforting, nothing more peace-giving, when one is weary by reason of the way, than this consciousness that in the evolution of all things, of thought as well as of form, the best must survive. Its development is slow, is the work of so many, many years that some of us are apt to grow impatient. But it is certain. The fittest survives in thought as in form. But the evolution of the highest species occupies centuries; an advance of one step towards better things occupies years, and the lifting of a world of thinking men and women to a loftier standpoint than they held aforetime is a labor that lasts long, and involves toil and patience without end. Natural Selection involves the extinction of intermediate forms. Some alteration in the structure or the habits of a living being is for its good. The more marked that alteration becomes, up to a certain limit, the better for its possessor. When that stage in development is attained wherein the change is so noticeable that the adaptation of the organ or the function to the circumstances of life is as complete as possible, the representatives of that stage will have a better chance than all their predecessors in the struggle for existence. They will therefore slay those predecessors. The intermediate forms less adapted to the life conditions than those to which they have given rise, and even, perhaps, in some senses than those whence they took origin, must die out. They have done their work, and they pass. They have been the stepping-stones for all things to advance to something better than had been attainable before. They are like the Russian soldiers who fell slain into the ditch, and made a path for their successors to tread onward and take the citadel.

(*m*) Low forms. And yet certain lowly organised forms last. All the world does not consist of men and oak-trees. Low down among the animals and vegetables are beings possessed of life, but in its humblest, dullest forms. Without nerves or sense-organs, with little or no power of movement, they lead their strange, solemn life without a dream of the mightiness around them. The tree grows its hundred years, and spreads giant arms leaf-laden to all the winds of heaven. Its time comes and man fells it, and hews it into timbers for some stupendous vessel that shall bear men and women, and merchandise, and books and messages of love, and news of births and deaths, over fathomless seas to continents that are leagues asunder. And through it all, and through time dating back to the days when ships were unknown, perhaps when man himself was not, the one-celled Protococci, the specks of protoplasm called Amœbæ live out their little lives, and are born and die every hour. Does Natural Selection account for these? Assuredly yes. They are fitted to the conditions wherein they are, and they survive. From such as they, it may be, originated in the past, by variation, the beings that in the myriads of years have by variation under Natural Selection given origin to the loftier plants and animals. They, however, are the lineal descendants of the beings that underwent no variation. They are adapted to the same life-conditions as their ancestors. They fill the same place. They survive because they are exactly adapted to their surroundings.

(*n*) Circumstances favorable to Natural Selection. Charles Darwin names: great individual variability, large numbers of individuals, inheritance, little tendency to reversion, isolation, large areas. It will be seen that some of these are identical with those of value for Artificial Selection. The first needs but little discussion. But, to my thinking a word ought to be said on the second point. The more especially is this necessary when we bear in mind the use often made of Darwin's insistment on the value of numbers in Natural Selection by the teachers of improvidence and worse than improvidence to the people. The folk who are most opposed to that needful conjugal prudence that is at once the safeguard and the hope both of individual and nation, on the few occasions when they introduce aught of scientific talk into the discussion, persistently remind us that Darwin speaks of the value of numbers in Evolution. Therefore man is to endeavor to produce as many of his kind as he can, that thus Nature may have large store whereon to work, and that thus may be the chance of many variations. Placing for the moment entirely on one side the crime of bringing into the world beings whose lives can only be a burden to themselves and to others, I believe that even if we regard this momentous question from the Evolution point of view alone, it may be shown that large numbers are not necessarily of great value in Natural Selection. Truly, with large numbers there is more probability of variation. But the variation is not necessarily a good one. It is not necessarily a variation in the direction of advance. Nay, it is more likely to be a retrograde variation, in the direction of lower organisation and less perfect working. Repetition of similar parts or of similar offspring does not mean loftiness, but lowness of organisation with man. The production of numberless children of a sad sameness cannot give so much opportunity of variation in the direction of better physique and better performance of bodily functions from the lowest to the highest, that known as mental, as the production of a smaller number under more favorable conditions as to descent, as to birth, and as to after surroundings. I have discussed this question at greater length in my pamphlet on "Darwinism and Small Families."

Inheritance, or transmission of qualities structural and functional from parent to offspring, is an essential for the view maintained in the "Origin of Species," and the fact that it exists is familiar to all.

Reversion, or the throwing back to an ancestral form, as when a horse is born marked with stripes, is antagonistic to the last principle, and where reversion is weakest Natural Selection will work best.

Isolation, if only as lessening the chances of an intercross with other living beings whose character might be such as to obliterate the new variation, is of value.

Large area over which the modifying species may range, Darwin considers as of even more moment. For the life conditions are more complex, and each new form will come into collision with more numerous beings.

CHAPTER XXXIX.

(6.) *Laws of Variation.*

(6.) LAWS OF VARIATION. An interesting question, as difficult as it is interesting. Is it possible to lay down any generalisations that can be educed from the many observed facts? Our Master says, "Our ignorance of the laws of variation is profound." Nevertheless he has given us not a little help and instruction in this as in all other matters.

(*a*) Changed conditions have clearly much effect. Altered climate, altered food, altered modes of life, all work greatly. But they are not enough to explain all the variations that occur.

(*b*) Tendency to vary. For the present, as so many instances occur of variations that are not explainable on the ground of changed conditions, the evolutionist is obliged to speak of a "tendency to vary." He is fully conscious of the vagueness of the phrase. He only uses it for the time, as convenient, and in no sense as explaining these variations, that are due to causes at present not comprehended by him.

(*c*) Use and disuse. We find that parts falling into less and less use, and even ultimately into disuse, become aborted, whilst parts in full employ are apt to become especially developed. A few instances of abortion from lessened use may with advantage be given. In the island of Madeira are over 550 species of beetles; 200 of these have wings so reduced that they cannot fly, and of the 29 genera peculiar to Madeira all the species of 23 are in this state. The eyes of the burrowing mole are rudimentary. The various animals inhabiting the darkness of the caves of Kentucky are for the most part blind. The muscles for moving the ear are present in man, but are very small, and, as a rule, not functional.

(*d*) Acclimatisation. Our domestic animals live and breed in the most diverse climates. On page 113 we read:—" As we may infer that our domestic animals were originally chosen by uncivilised man because they were useful and because they bred readily under confinement, and not because they were subsequently found capable of far-extended transportation, the common and extraordinary capacity in our domestic animals of not only withstanding the most different climates, but of being perfectly fertile (a far severer test) under them, may be used as an argument that a large proportion of other animals now in a state of nature could easily be brought to bear widely different climates."

(*e*) Correlated variation. "Correlated growth" implies that in living creatures the modification of certain parts of the body structure is invariably accompanied by variation of other parts without apparently any known connexion between the two. The time will come when we shall see something of the "why" dogs without hair are provided with imperfect teeth. And, indeed, may it not in this very case be suggested that hair is a modification of epidermis, and that teeth are developed from the epithelium or mucous membrane of the mouth, while all the world knows that epidermis and epithelium are largely identical in nature? The time will come when we shall be able to explain why short beaks in pigeons are associated with small feet, long beaks with large feet—why a relation exists between the color of hair, eyes, and skin, and the liability to consumption —why mildewed vetches, when eaten by horses, affect only those that are marked with white, and affect them only on the white regions of their body.

(*f*) *Balancement* or compensation. Excess of development in one part of an organism entails lessened development in some other part. The varieties of the cabbage that yield many leaves do not yield many seeds. The male cirripede wholly given up to reproduction has all other functions and the organs that perform them reduced exceedingly. (See page 228.)

(*g*) Multiple, rudimentary, lowly-organised structures are variable. The many similar stamens of a rose flower or the many similar body segments of a Centipede are multiple organs. They are eminently liable to variation. That rudimentary organs vary may be due to the fact that, as they are useless any variations in them are not liable to be checked by Natural Selection.

(h) Highly developed parts variable. Thus the brain of man, an organ highly developed in him as compared with its development in his allies is highly variable in different individuals.

(i) Specific characters more variable than generic. The marks that distinguish one species of a given genus from another species are much more likely to exhibit variation than the marks that distinguish one genus from another genus of the same order.

CHAPTER XL.

(7.) *Difficulties.*

THAT there are great difficulties in the way of a full acceptance of the theory of Natural Selection—that there are many facts not easily to be reconciled with the theory—that much, very much, is to be done ere we can feel that more than a very partial explanation of natural phænomena is possible by this hypothesis, none is so conscious as the distinguished philosopher who first enunciated the principle. With the charming frankness and honesty that have ever marked his every utterance he states these difficulties in full. He states them with a clearness not always discoverable in the statements of those who are opposed to his views. Indeed, the strongest arguments they are able to adduce in controverting the views of Charles Darwin are those that he himself has brought forward in his "Origin of Species" as opposing his own conclusions on that most momentous question. He arms his antagonists. He places in their hands the strongest weapons that can be used against his theory. Thankfully enough have they accepted at his hands these same weapons, and it is matter for regret that they have not in all cases further learned from him something of that stately and peaceful courtesy that has been his throughout all the years of controversy, throughout all the time when such coarse and virulent abuse has been hurled at him as only falls to the lot of the founders of great creeds or of great philosophies. Charles Darwin is too honest not to state the objections to his own views. He is too confident in the truth of his doctrine not to meet those objections face to face and to strive his utmost to show that they are, in not a few cases at least, groundless. And, finally, ere we proceed under his guidance to the discussion of these objections, let it be noted that on the view that all species are separate creations, that none is evolved from any other, the difficulties that lie in the path of the student of biology increase a thousandfold. The objections that are not easily overcome by the evolutionist are insurmountable by the advocate of Special Creation save by the formula, "It is the will of god."

If Natural Selection be a true hypothesis; if the many species that now live on earth have been evolved in the course of ages from a few forms, perhaps from one form of living matter, the first difficulty encountered is *(a)* the absence of the intermediate forms, the dearth of connecting links. If B has been evolved from A by successive gradations, why do we not find forms representing every stage in the process? Where are the multitudinous beings with particular structures or habits more marked than they are in A, less marked than they are in B? These questions seem to the present writer to be the outcome of a failure to fully comprehend the great principle under discussion. At least, there should be no indulgence of the expectation of meeting these transitional forms alive on the earth at the same time as that whereunto they have given rise, or even in many cases at the same time as that whence they took origin. For the principle of Natural Selection involves the idea of extinction. This cannot be too often stated. If a variation is naturally selected because it is of use to its possessor in the battle of life, the more strongly marked that variation becomes, up to a certain point, the better for the possessor. When that limit is reached, when the point of maximum satisfaction of the conditions of life then present is attained, the animal or plant is better fitted for living than any representative of the preceding stages. It will, therefore, infallibly slay its precursors. Further, whilst B is more likely to survive than any of the transitional forms connecting it with A, the latter probably will have a better chance than the forms that lie between it and B; for it must be remembered that there are numberless individuals of A that have not varied. Only some few, possibly only one, varied and gradually evolved B. Those that did not present any variation still remain fitted to their conditions of life. Their structures and functions are well adjusted to the conditions of their particular environment. They will therefore play their part in the extermination of the intermediate forms.

In connexion with this subject it seems advisable to point out another very common source of misconception as to the origin of species. So many of us seem to look for actual transitions between species now existing, forgetting that in many cases two species now existing and allied to each other have probably descended from a third form. My meaning will be rendered more apparent if I take a particular case. The opponents of the theory of the survival of the fittest, and even not a few of its adherents, are constantly complaining that they cannot see any connecting links between man and the higher apes. With a passing suggestion that a certain lack of perceptive ability seems evident here, and a casual reference to Aztecs, Bushmen, Hottentots, and English roughs, one turns to this aspect of the question. It has never, to my knowledge, been stated by any evolutionist that man is a lineal descendant of the man-like or anthropoid apes. It is more probable that he and they are the common descendants of some one ancestral form; that from that one ancestral form by variation along different lines were evolved the huge bestial gorilla and the human being that culminates in a Christ or a Shakspere. But though he that understands the full meaning of the term "Natural Selection" will not expect to find connecting links between species that are allied living synchronously with those species upon the earth, he will expect to find them represented in the past. His expectation will at present be but imperfectly realised. Turning to our chief record of the living things of the centuries that are past—turning to the series of fossil remains that lie embosomed in the earth, the student anticipates that there at least he will encounter these intermediate forms. He is not wholly disappointed. Many are met with, and the number is increasing every hour. But to say that at present we have found a hundredth part of the beings we desired would be false. Place side by side all known fossils, all known living things and the series is, alas! only too incomplete. We are still far from the day when the whole wondrous series, from the lowest speck of protoplasm up along a thousand different lines, through myriads of slight, accumulating variations to the loftiest plants and animals may lie before the awe-stricken gaze of humanity.

Here then is a difficulty of no small magnitude. Why are not the connecting forms present in the strata of the earth? How does the advocate of the view held by Charles Darwin answer? In the first place, as has been shown, some such intermediate forms are found, and the presence of even one would be a distinct argument in favor of the idea of Natural Selection, Again the geological record is most imperfect. Of this no doubt can exist. Many living things in the past times had structures that did not admit of preservation. It is more than probable that there were long periods during which no provision was made by Nature for the preservation of living bodies when they had ceased to live. Only under certain favorable conditions can organic remains be preserved. Such favorable conditions have not always been forthcoming, and millions of organised beings must have died, and decaying, broken up into the carbonic acid, water and ammonia, that are the ultimate destination of all bodies of plants or animals, without any of them being preserved either in whole or in part, to teach a future age. Coming down to our time, with all our ghastly ceremony and retention of the dead matter after life has ceased, how much likelihood is there of the preservation of many of our endless varieties of domestic plants, domestic animals, or men? Many living beings have been so constructed as not to allow of their bodies becoming preserved. Long periods of time, many long periods of time, have elapsed during which no plant or animal remains could under the conditions then obtaining, be preserved. But of greater moment than these, in the reply to the difficulty to be combatted, is the fact that of the geological record, imperfect as it is, our knowledge is imperfect. What wide areas, what depths of earth, what seas and foundations of seas are yet to be explored! Man has been working for a fragment of time over an atom of space. In the future, working in the light of Evolution it is our hope, nay, our assured conviction, that link after link in the infinitely ramifying chain of living things will be found. The whole, in all probability, never will, never can be known, but each new discovery will not only in itself be of importance. It will, without doubt, suggest so much. For a discovery is like an uttered or written thought. Its value lies not alone in what it is, but in that which it suggests. No higher praise can be awarded to a thought either written or spoken than that it sets other people thinking, that it takes its place in many minds, and entering the great world of ideas, finds it has kinship with not a few of the inhabitants.

(*b*) Is it possible, cry the opponents of Natural Selection, to conceive that a highly organised structure—such for example, as the human eye—can have been evolved from a more simply constructed sight organ? Is it possible, say they, to conceive that, from the minute collection of pigment cells constituting the eye of an infusorian, the visual organ of a Mammal can have been evolved? The study of Comparative Anatomy reveals, however, every single step in the gradation from the one to the other, in the particular instance chosen at least, and there is less difficulty in believing that each term of this series have been evolved from its predecessor and will evolve its successor, than in believing that each, with all the co-ordinated structures that with it constitute a given organ, have been the result of an act of special creation. As bearing upon this question of the origin of complex structures, it is worthy of note that of late years the remarkable organs connected with the senses of sight, hearing, smell, and taste have all been shown to originate from involutions of the integument of the embryo. The tongue, with its three kinds of sensory papillæ; the nose with its convoluted bones covered by the delicate membrane with its internal world of microscopical structures; the ear with its canal, its membranes, bones and fluids; the eye, with its coats, the least whereof presents a succession of six or seven layers, with its lenses, muscles, and ligaments—all these are formed from the integument and the tissues immediately subjacent. Yet again we must never forget that we are far too ignorant of what is or is not of actual use to a living being to determine offhand that this or that particular modification, however slight, is of no value. We can only judge for the most part of large effects, and therefore in our usual complacent fashion, are ready to state that slight alterations, though tending towards some palpable result, are of no conceivable importance.

(*c*) One great argument, usually brought forward in opposition to the Darwinian hypothesis, is that the animals and plants of Egypt have, during the last three or four thousand years, presented scarcely any variation. The fact tells as strongly for Charles Darwin as against him; for during the last three or four thousand years the conditions of life in Egypt have remained absolutely uniform.

(*d*) Many structural characters appear to be valueless to their possessors. These therefore, say the antagonists, cannot have been influenced by Natural Selection. In reply it has been urged, (i.) That great caution must be exercised in determining what are useful and what are useless. Who would have anticipated that the multitude of curious structures encountered in the flower of the orchid, had one and all the most minute and special reference to the cross-fertilisation of that plant by means of insects? (ii.) The principle of correlated growth must be borne in mind. The modification of some one part may be of use to the creature. Alterations in its structure will be accompanied in other organs by alterations not necessarily of use to the being under study. (iii.) Once again the conditions of life play an important part.

(*e*) Instinct. It is especially when the student turns to the habits of living animals that he is inclined to join issue with the advocates of Natural Selection. Even though he be willing to grant its potency in the modifications of form, he may experience difficulty in applying its principles to those functions in living beings which are frequently looked upon as holding a different rank from the ordinary bodily functions. He may feel some doubt whether the principle of the survival of the fittest will explain the gradual evolution of instinct, or that untaught ability whose highest phases seem to blend with the lower forms of reason. But none will deny that in the higher animals at least there are infinite variations in mental qualities. Few will deny that similar variations in mental qualities occur even amongst beings lower in the scale than man and the domestic animals. Of such mental variations some are for the advantage, some to the disadvantage of their possessor. The good and the bad alike come under the great law of inheritance, and will be transmitted to descendants. As surely as a particular variation in structure, better fitting plant or animal for the life struggle, will be transmitted with intensification, so surely will a variation in mental qualities better fitting an animal for the battle of existence, be transmitted with intensification, until the bee is building its cell, the ants present their classes of soldiers, slaves, food suppliers, egg producers, or the cuckoo ceases to make its own nest, and by force wrests from its weaker fellows a home for its young. Herein, moreover, once again lies man's greatest hope. Of physical advance on the part of man the future holds out but little prospect. Of the mental advance of human kind the probability is as great as our longing for it. Of variations in thought, in taste, in creed, in philosophy, there will be, as far as we can judge, no end. And he that fears and doubts as to the future of his race when he sees the myriad forms of mental variation of this very day—he that raises his voice aloud in the cry that humanity is drifting towards the quicksand, or on to the rocks, or over boundless seas that beat on no created shore—he that can see looming in the future nothing but hopelessness and ruin—knows not of the calm assurance wherewith the student, in his better moments at least, looks into the dread face of the coming time. For him, firmly cleaving to his belief that the tendency of all things is to the better, there is no absolute freedom from anxiety, no entire absence of dread, for he is human. But he looks beyond his own narrow and ever narrowing life, looks beyond the scene and the time wherein he plays his infinitesimal part, and in the dim haze of the after years beholds, shaping themselves forth, still as shadows and as yet unformed, the creatures of a world which shall be as the fabled Eden of old and as the earth was in the golden age when the gods dwelt among men. He knows that the men and women of the ages he is never to look upon will be of a race higher than his; that envy and selfishness and pride will not always hold their accursed sway, but that all living shall move over the broad and bounteous earth, informed with gentleness and inspired with love. He believes that towards that far off divine event the whole creation moves, and in his every thought, word, and deed, that are not marred by his baser self, he strives, as he has strength, to hasten on the time when the peace and beauty of that hour shall descend upon a sorrow-stricken world.

(*f*) Hybridism. If the pollen of a flower of a given species is placed on the stigma of another flower of an allied but not identical species, very generally the resulting plant, whilst partaking of the nature of both parents, differs from both of them in being sterile. The mention of the name of the mule is enough to remind everyone that in the animal kingdom the same sterility of the offspring of closely allied species is a recognised phænomenon. By many the fact is regarded as overwhelming evidence against the views of Charles Darwin. If that distinguished naturalist had ever said that new species were formed by the crossing between older forms, the facts connected with hybridism would tell strongly against him. But it is hardly necessary to say that he has never made any such statement. Nay, more, he has endeavored to show that the sterility of crosses and their hybrid progeny has not even been acquired through Natural Selection. Those who hold that species are in every case the result of a separate act of creation, point to the sterility of crosses between species as a proof of an arrangement to prevent variation and consequent formation of new forms. It is as just to drag in the phrase of "special provision of sterility to prevent crossing," as it would be to speak of a special provision whence result difficulties in grafting trees that are closely allied. Sterility, be it observed, results from causes other than crossing. Thus, species exposed to new unusual life conditions are often for a time sterile. As Charles Darwin has pointed out, here is a remarkable case of parallelism. Slight changes in the conditions add to the fertility of living beings; considerable changes temporarily destroy it. Crossing between forms very closely allied, as in the constant cross fertilisation of plants, has distinct advantages; crossing between forms more widely differing destroys fertility.

In the words of the great author of that work, I would remind all that in the hypothesis of Natural Selection we have only a hypothesis. There is at present, on the main question, only one other hypothesis before us, that of the numberless species on the earth having each and all originated from distinct acts of creation. It is the bounden duty of all whose minds are not in bondage to choose of the two theories the one that is in accordance with, links together, and makes comprehensible the larger number of facts. The theory of Natural Selection is in accordance with our knowledge of the domestic animals and plants, and with our knowledge of animals and plants not yet under the sway of man. The theory of Natural Selection links together the species, genera, classes and sub-kingdoms of living things, and renders intelligible the wonderful series of organic life. We see, after studying this hypothesis, a meaning in the endless gradations whereby every form of plant and animal graduates into all others. The presence in so many beings of rudimentary organs apparently of no functional importance, the facts in connexion with development whose number and value are hourly increasing, the great principle of structural types in the two kingdoms of animated nature—a thousand things such as these are full of meaning to us now. The flood of light thrown by Charles Darwin on the labors of the biologist have given to him the power of working as one no longer blindly groping in the dark. He toils in the light of a dawn that is to grow into a day of knowledge, the brightness whereof is by us not to be conceived.

With the acceptance of this view there is no loss of the beautiful. Nay, in very truth a new loveliness is added to all nature as we study her with this for guide. A holier wonder than we knew aforetime falls upon us, a deeper awe dwells within us, and in our heart of hearts we feel our reverence deepening as our superstition fades away.

CHAPTER XLI.

(8.) *Arguments for Natural Selection.*

IN truth the whole of the "Origin of Species," and of this analysis of the book up to this point, have been reasoning and fact-producing in favor of the theory. But the latter part of the book and the latter part of this epitome are specially devoted to the statement of arguments on behalf of the survival of the fittest.

(*a*) Distribution of organic beings in time. The student of geology, despite the small amount of evidence as yet at his command, has ere this recognised the important fact that there has been much extinction of animals and of plants in the past, accompanied by the appearance of new and more highly organised forms. As he traces out the fossils of the strata that are the burying-grounds of past ages, he finds that forms that are prevalent in certain layers are not to be found in adjacent ones, while other forms have appeared that were not encountered before. This extinction and appearance are not comprehensible on any theory of Special Creation. But they are both understandable, and, indeed, are intimately connected, on the view of Natural Selection. Of course, the extinction is not in reality sudden. Rarity precedes it. And in the more recent tertiary formations, as in the cases where, through man's agency, animals have been exterminated, there is evidence enough of this precedent rarity and subsequent extinction.

The marine forms of life change almost simultaneously throughout the world. Thus our European chalk formation can be recognised in many distant regions under the most different climates, where not a fragment of the mineral chalk itself can be found—namely, in North America, in equatorial South America, in Tierra del Fuego, at the Cape of Good Hope, and in the peninsula of India. For at these distant points, the organic remains in certain beds present an unmistakeable resemblance to those of the chalk.

As to the land forms we have not at present sufficient evidence to decide whether a kindred truth obtains in relation to them. Now this parallel succession of living beings of kindred nature throughout the world fits in with the great theory. For the new species resulting from successful variation are dominant as having advantages over their parents who once were dominant. The new forms that win will be of allied nature, having the advantageous variation in common. The older forms that lose and are extinguished will be of allied nature having the disadvantageous characteristic or characteristics in common.

The close connexion structurally between extinct forms and also between them and living beings is only to be understood on the view of descent from a common form.

Again, on the theory of Natural Selection the later animals and plants in the geological strata ought to be more highly organised than the earlier ones. And this is the case.

(b) Distribution in space. Three large facts stand out prominently in the study of the geographical distribution of living things. (i.) Neither the similarity nor the dissimilarity of the inhabitants of various regions can be wholly accounted for by climatal and other physical conditions. The old and the new world present in physical conditions a striking parallelism. Yet their flora and fauna are very different. (ii.) Barriers such as mountains on land or an isthmus in the ocean are closely related to the differences between the productions of various land or sea regions. (iii.) There is a notable affinity between the living beings of the same continent or of the same sea. The species differ from each other, but they are related.

(iv.) A question of deepest import arises in this connexion. Have species appeared originally at one or at more than one place on the earth's surface? Was there for each new species one centre of evolution or more than one? Charles Darwin decides in favor of the former view. He considers it as probable that one particular area has been the scene of the appearance of each new species and that from that area certain of its individuals have migrated to "fresh woods and pastures new." This decision necessitates the discussion of means of dispersal. If one area of land or sea was the primal home of a given species it behoves us to inquire by what methods that species has spread thence into other regions. Change of level in the land or the floor of the sea is one means. Water-currents are other agents. The flow of brook or river seawards and the waves of ocean play their part in bearing seeds of plants far from their original home. It is surprising how many seeds are entirely uninjured by prolonged immersion in sea-water. Winds as well as waters aid in the diffusion. Living birds in their flight from place to place bear seeds adherent to their soil-stained claws or to their feathers, or even carry them uninjured, undigested within their bodies to be deposited on the earth of other lands. And the consideration of the fact that icebergs are no inconsiderable helpers in this prevalent dispersal leads to reference to the glacial period.

There is overwhelming evidence that within a very recent period, geologically speaking, Europe and North America were arctic regions. Further, there have been in the past alternations often repeated of cold or glacial epochs with times when the temperature was higher, and thus arctic forms of living things would slowly move southwards and northwards, southwards and northwards age after age. Every ten or fifteen thousand years, says Mr. Croll, these glacial conditions return, and it is not difficult to imagine what changes in the geographical distribution of plants and animals would be effected by these vast recurring transitions from lower to higher temperature and from higher to lower.

The denizens of fresh-waters are wonderfully allied throughout the world. At first when we consider the physical barriers between lakes and lakes, rivers and rivers, this seems rather inexplicable. But here again birds are agents in the transportal of seeds from one piece of water to others.

(v.) Oceanic Islands. Certain facts in regard to the distribution of plants and animals upon islands are very understandable on the theory of Evolution but not upon that of Special Creation. The total number of species on an island is usually small, but the number of endemic species or those not found elsewhere is relatively large. Galapagos islands have only twenty-six species of land-birds ; of these twenty-one are endemic. Again, members of the great Vertebrate class Amphibia (frogs, toads, newts, salamanders) are not known upon oceanic islands. And this is to be expected, as these animals and their ova are killed by sea-water. So also on islands over 300 miles from a mainland no terrestrial mammal is encountered for the like reason. But aerial mammals, such as bats, are to be met with on these islands.

Again, there is a connexion of deepest interest between the depth of the water that lies between two adjacent islands or an island and an adjacent continent and the relationship between the flora and fauna of the two places. When the depth is not great the difference is not great. When the depth is excessive the difference between the living beings of the two places is more marked.

Again, the fact that the species on any given island have affinity to those on the nearest mainland is intelligible enough upon the view taken and taught by Charles Darwin.

(c) Classification. It is well-known that all systems of classification are essentially artificial. Nature knows no classification. Time was when men believed that they could draw hard and fast lines between one group of living beings and another. On the theory of Special Creation this ought to have been eminently possible. But further study has shown this to be impossible. All living things graduate one into the other. It is not only impossible to separate man from his allies, the Quadrumana from the rest of the Mammalia, the Mammalia from the Birds, the Vertebrata from the Invertebrata. It is not possible to separate absolutely animals from the plants or even the living from the non-living. And all this is both instructive and encouraging. It is all strong evidence in favor of Evolution and against Special Creation. On the latter view no reason can be shown why this gliding of species into each other should be. On the former this is fully to be understood. And thus as man comprehends the connexion of all forms of matter, living and non-living, he is led to embrace Evolution as the only explanation of this as of so many other facts.

Whilst this is the broad and most general aspect wherein to regard the facts of classification one or two minor points are not important. We can by aid of Evolution understand why parts that are not concerned with any habits special to the being possessing them are important in classification. The reproductive organs are the most valuable in classification. It is also possible to understand why rudimentary organs are useful in grouping animals or plants, and why mere analogical resemblances as that of a bat to a bird or of a mouse to a shrew-mouse are very misleading and valueless to the classifier.

(*d*) Morphology. The study of organs. More especially is it Homology or the study of likenesses in structure that strengthens in every case the view of the Evolutionist. That man's arm and hand, and the bird's wing, and the crocodile's fore-leg, and the fish's fin are all built on the same general plan is very intelligible when we conceive that man, bird, crocodile, fish have all evolved from a common Vertebrate progenitor. Not, I think, very intelligible on any other hypothesis.

(*e*) Development. In their life-history the higher animals pass through stages that represent the adult conditions of animals lower in the scale. These stages are not identical with the adult conditions of the more lowly organised beings. They only resemble them. They suggest rather than actually imitate. What is the meaning of this on the theory of Special Creation? No explanation is offered by the advocates of this view. But this development of man from a form that is not distinguishable at first from the complete condition of one of the lowest living things, through stages that suggest invertebrate adults, fishes, reptiles, birds, to his final condition is all very understandable if we hold that man is the result of development of lower forms into higher and yet higher until that which is to-day the highest is reached.

(*f*) Rudimentary organs. Here again are structures that are, to the special creationist, insurmountable objections, that are to the evolutionist guides and supporters. Man has, on the back of his hands, rudimentary hairs. No one has seriously suggested that these are of any functional import. On the one theory they are meaningless, redundant. On the other they are meaningful and tell of descent from an ancestral form, covered from top to toe with hair. So also with the useless wisdom teeth of man. They are troublesome in their arrival, are not used during their stay, and are a cause of pain in their departure. They are of no use because the jaw of man is nearly rectangular in outline, and in the right angle these teeth cannot work on the food. Once on a time when the jaw of our progenitor was obtuse angled, these teeth could and did work on the food. To-day they are slowly vanishing, are rudimentary. Still they are present. Without any significance on the theory of Special Creation, other than that of blundering, they are quite to be understood on the theory of Evolution. And thus with hundreds of rudimentary organs in plants and animals

And now let us pause and look back. Species is an arbitrary name for a group of beings having certain points of resemblance one to another. Two views have obtained as to their origin. That each species is the result of a separate act of creative power on the part of a god. That the many species of to-day are the result of development from some few forms or one primordial form of living being. In favor of the former view are the first chapters of Genesis and no facts. In favor of the latter are the following. Variation under domestication occurs. Artificial selection, exercised by man according to his tastes and fancies, not necessarily in accordance with the well-being of the plant or animal, has produced new beings that but for their known history would be named species or even genera distinct from any yet known. There is also variation under nature. There is a natural selection or survival of the fittest. As all plants and animals vary, whenever any variation is of such nature that it gives its possessor a better chance in the eternal life battle, that variation is likely to be transmitted, to be intensified, to become permanent. Against the theory are the absence, either to-day or in the yesterday, as recorded in fossils, of transitional forms, organs of great complexity as the human eye, organs that seem of little importance, instinct, hybridism. Not one of these same difficulties is in any degree lessened by the doctrine of Special Creation. They are not surmounted by saying, "It is the will of god." Each one of them can be and has been encountered and explained by the evolutionist. On the other hand, the facts of the distribution of living things in time and in space, of classification, of homology, of development, of rudimentary organs, all strengthen and are explained by the theory of Evolution, all weaken and are inexplicable by that of Special Creation. Let it be added that every new discovery of every hour ranks itself on the side of Evolution, and is foe to Special Creation, that all scientific thinkers of every order of thought are to-day

Evolutionists, whilst the ignorant are, to a person, Special Creationists. Choose you, reader, this day, whom you will serve

CHAPTER XLII.

B.—*Animals and Plants under Domestication.*

THIS is the sequel to the "Origin of Species" promised in that volume. It contains the immense collection of facts upon which the conclusions arrived at and stated in its predecessor were based. Such a collection of facts has rarely, if ever, been made by one man. Necessarily, as the two large volumes are the record of accumulated facts, this is a work to be read rather than analysed. To comprehend it the student must master its innumerable details for himself. It is the duty of the analyser here to stand aloof. The detailed analysis that has been made of each of the other books would here be out of place. It is, again, superfluous to enumerate the beings as to which facts are recorded. Their name, like the number of the facts, is legion.

It is within the limits of this volume that Dr. Darwin broaches the idea of his theory of Pangenesis. The facts to be connected by this hypothesis are the various methods of reproduction in plants and animals, the action of the male element upon the female, the phænomena of development, the functional independence of the elements of which the body is composed, variability, inheritance, and reversion.

The attempt to connect all these various facts is made by the suggestion of the provisional hypothesis of Pangenesis. This assumes that (1) Every part of the body throws off gemmules, or exceedingly minute portions. (2) These gemmules circulate through the body, and, if supplied with proper nutriment, multiply by self-division and develop into the cellular structures or simpler structures whence they sprang. (3) They are transmitted from parent to offspring. (4) They may be developed in the immediately succeeding generation, or may lie dormant through many generations, at last to develop. (5) They are thrown off by cells or simpler structures at all stages of development.

(6) They have a mutual affinity, and tend to aggregate in buds, or in the sexual elements. (7) Their development depends upon their union with other gemmules that naturally precede them in the ordinary course of growth. Such union with their normal predecessors determines their development.

The conclusions arrived at are in the main identical with those broached in other volumes. This book is the supporter of those others by multitudes of facts. All, therefore, that is wisely to be done in regard to it is to briefly summarise those conclusions. They are as follows.

(1) Wild animals can be tamed. Complete subjugation by man depends on the tamed animal being social in habit, fertile under domestication, of service to man.

(2) Domesticated animals and plants vary greatly. They have been none the less exposed to greater condition changes than their wild fellows. Therefore

(3) Natural species probably vary.

(4) These variations are not only structural, but functional. Not only does the nervous system vary, but the mental attributes also change in the different individuals.

(5) New characters appear and disappear at any stage in the life-history, and are generally inherited by the descendants at corresponding periods of life. New characters are especially liable to appear in the male. Both these facts have much bearing on sexual selection.

(6) Not only do structural differences and mental differences obtain among our domestic animals. What are vaguely named "constitutional" differences also appear. The time of the second dentition, the period of gestation, adaptation to varying climates, tendencies to disease, liability to parasites and to the action of poisons differ much in different animals. Plants also differ under domestication in their adaptation to soils, power of resisting frost, times of flowering and fruiting, proportion of certain chemical substances in their seeds.

(7) There is a difference between domestic races and species and the wild. The latter are sterile when crossed. The former are not. The sterility of species when crossed seems to depend exclusively upon differences in the reproductive organs of the individuals that are crossed. Again, species long domesticated cease to be sterile when crossed. And finally in this connexion it is known that the life-con-

ditions of species in a state of nature have long been uniform. Now domesticated living beings have been subject to changed life-conditions within a very recent period. And changed life-conditions act specially on the reproductive organs.

(8) The points of resemblance between domestic varieties and natural species are many. (*a*) Both transmit their characters to their offspring. (*b*) In both prepotency of one form over another occurs. (*c*) In both there is liability to reversion to ancestral forms. (*d*) In both the laws of variability are the same. (*e*) The sub-division of both on the principle of descent with modification is possible.

(9) Domestic varieties differ from species in that when they do present points of difference one from another, those differences affect parts of the body of less moment than those that differ in species. If we remember that the differences in the former case are due to man's artificial selection, and in the latter to natural selection, this is understandable.

(10) Some domestic breeds, like almost all species, have varied by slow and insensible degrees. Some breeds and scarcely any species have originated from an original variation strongly marked.

(11) The tendency to reversion when domesticated living beings are exposed to the old wild conditions has been very greatly exaggerated.

(12) As causes of variation we have again—(*a*) Changed conditions. (*b*) Unequal combination of the characters of the two parents. (*c*) Reversion. (*d*) Use and disuse of parts. (*e*) The law of compensation or balancement. (*f*) That of correlation.

Finally, it may be interesting to quote the last few sentences of this remarkable book of facts and conclusions. They give no little insight into the views of Charles Darwin upon a topic of interest to all.

"An omniscient Creator must have foreseen every consequence which results from the laws imposed by Him. But can it be reasonably maintained that the Creator intentionally ordered, if we use the words in any ordinary sense, that certain fragments of rock should assume certain shapes, so that the builder might erect his edifice? If the various laws which have determined the shape of each fragment were not predetermined for the builder's sake, can it with any greater probability be maintained that He specially ordained for the sake of the breeder each of the innumerable variations in our domestic animals and plants—many of these variations being of no service to man, and not beneficial, far more often injurious, to the creatures themselves? Did he ordain that the crop and tail-feathers of the pigeon should vary in order that the fancier might make his grotesque pouter and fantail breeds? Did He cause the frame and mental qualities of the dog to vary in order that a breed might be formed of indomitable ferocity, with jaws fitted to pin down the bull for man's brutal sport? But if we give up the principle in one case—if we do not admit that the variations of the primeval dog were intentionally guided in order that the greyhound, for instance, that perfect image of symmetry and vigor, might be formed—no shadow of reason can be assigned for the belief that variations, alike in nature and the result of the same general laws, which have been the groundwork through Natural Selection of the formation of the most perfectly adapted animals in the world, man included, were intentionally and specially guided. However much we may wish it, we can hardly follow Professor Asa Gray in his belief 'that variation has been led along certain beneficial lines,' like a stream 'along definite and useful lines of irrigation.' If we assume that each particular variation was from the beginning of all time preordained, the plasticity of organisation, which leads to many injurious deviations of structure, as well as that redundant power of reproduction which inevitably leads to a struggle for existence, and, as a consequence to the Natural Selection or survival of the fittest, must appear to us superfluous laws of nature. On the other hand, an omnipotent and omniscient Creator ordains everything and foresees everything. Thus we are brought face to face with a difficulty as insoluble as is that of free will and predestination."

C.—The Descent of Man.

CHAPTER XLIII.

Introduction.

WHILST the general question of the formation of different species is of interest to the ordinary student as well as to the scientific man, to the former a very special interest centres in the question as to the origin of the human race. It is in "The Descent of Man" that this subject of deepest interest is discussed. But it is well to inform the intending reader that a very large part of the book is devoted to the study of a certain principle in Evolution, and to its working in the animal kingdom generally. The whole of the two volumes is not given up to the study of man. A very large part is devoted to the principle of Sexual Selection, a principle second only in importance to that other, enunciated by the same man, which the world knows to-day as Natural Selection. In the introduction, we are told that "The sole object of this work is to consider, firstly, whether man, like every other species, is descended from some pre-existing form; secondly, the manner of his development; and thirdly, the value of the differences between the so-called races of man."

Nevertheless, nearly one-half of the first volume and the whole of the second are devoted to the study of selection in relation to sex throughout the whole of the animal kingdom. Following the author, we shall divide our consideration of the book into two parts: (1) On the Descent of Man; (2) On Sexual Selection. Under the first, we shall study (*a*) The Evidence of Man's Descent from some Lower Form; (*b*) The Manner of the Descent; (*c*) The Races of Man. Under the second head, or the study of Sexual Selection, we shall consider (*a*) Its Principles; (*b*) The Secondary Sexual Characteristics of Animals lower than Man; (*c*) Those of Man Himself.

CHAPTER XLIV.

1.—*Descent of Man.* (*a*) *Evidence of Man's Descent from some Lower Form.*

LIKENESSES. It is notorious that man is constructed on the same general plan as other mammals. In the early chapters of "The Descent of Man," the fact of this resemblance in general plan is worked out into special details, and a large number of facts are given in evidence of the striking oneness between man and the animals most closely allied to him. It will be convenient to arrange this evidence of similarity under the two heads of Homology and Analogy. Homology (from ὁμοιος = like, λογος = discourse) is likeness in *structure*; Analogy (from αναλογια) is likeness in *function*. The structural resemblances between man and his fellows will be enumerated first, the functional resemblances second.

(i.) Homologies. (*a*) In embryo. Man is developed from an egg $\frac{1}{125}$th of an inch in diameter, differing in no respect from the eggs of other animals. For some little time during the early stages of development it is impossible to distinguish the human embryo from that of an invertebrate animal. For yet further period of time, though it is possible to say, "We have here a vertebrate," it is not possible to say what kind of vertebrate. By degrees, however, as we study the development of this being, it is borne in upon us that we have a vertebrate, and then that we have a mammal under consideration. Truly the distribution of blood vessels in the front part of the body in the early time, and certain structures known as visceral arches also in the anterior regions of the body, leave us for a little while in doubt as to whether it be a fish or some higher vertebrate that we are studying; but in good time that doubt is dispelled, and it is clear to us that an air-breathing vertebrate is before us. The feet and the hands of this human being are developed in a manner no different from the development of the feet of the reptile or the wings and the feet of birds. Development passes through many and many a stage before we can be assured what kind of mammal we are dealing with. For some time after it is clear that the animal is higher than fishes or reptiles or birds, it is not clear which member of the class *Mammalia* is presented to us, and it is only in the very latest stages of development that the young human being presents marked differences from the young ape. It would be wearisome to enumerate all the structures seen in the development of man that speak trumpet tongued of his origin from the lower animals. But a few for the comfort of the believers and for the refutation of the thoughtless may be noted. The heart that is to have four cavities hereafter is at first a simple pulsating vessel. The alimentary canal that is to have its own opening distinct from the genital and the renal apparatus, at first opens in common with these. The lower end of the vertebral column which is to be shortened and aborted, projects at first like a tail some distance beyond the rudimentary legs. The kidneys, with their highly complex structure, are represented at first by organs no other than the Corpora Wolffiana of fishes. The convolutions of the brain of the fœtus at the seventh month are identical with those of the adult condition of the lower monkeys.

(β) In adult. Passing from the embryonic homologies we find in the adult condition still further and overwhelming evidence of the oneness between man and his allies. Rudimentary organs—stupendous stumbling blocks in the narrow sunless path of the Special Creationist—are as so many aids in the journeying of the Evolutionist. A rudimentary organ is a part that has not attained full development structurally, and that does not perform any definite function. Rudimentary organs, on the theory of Special Creation, are not comprehensible. To the believer in deity, they say, "Your god is a blunderer." Here is an organ occupying room, absorbing blood material, and making no return in the way of work to the body corporate. Rudimentary organs in biology are as certain classes of society in sociology. These latter occupy room, they absorb so much of the results of production, and they make absolutely no return to the body politic.

I will arrange these rudimentary organs in the order that is familiar to those who have studied Comparative Anatomy and Physiology, or Human Anatomy and Physiology, under my guidance. The order wherein the facts as to any given animal or class of animals are arranged is as follows: Structure, Digestion, Absorption, Circulation, Respiration, Secretion, Nervous System, Sense Organs, Motor Organs, Reproduction, Development. We find rudimentary organs of deep significance in man connected with his structure, his digestion, his sense organs, his motor organs.

1. Structure. The hair-covering. One of the great distinctions often loudly insisted upon between man and the lower animals is the general hair-covering of the latter and the restriction of hair to certain regions of the body of the former. Therefore, of course, cry the unthinking, man is a Special Creation. But against this hypothetical distinction the following facts, very difficult of explanation on the Special Creation theory, very understandable upon that of Evolution, are to be urged. There are rudiments of hair over the greater part of the body-wall. Let the reader hold the hand up and see the light glinting athwart the back of the fingers. He sees light-tinged several very small hairs. They are rudimentary. Of what physiological value are they? Why are they there on the theory of Special Creation? On the theory of Evolution they are intelligible enough. They are relics of the past, remnants of the whilome universal hair-covering of ancestral bodies.

Again, the fœtus during that dim, strange life within the mother is, at the sixth month, thickly covered with fine, wool-like hair, named by the doctors lanugo. Bearing in mind the fact that early stages of the higher animals are largely identical with adult conditions in the lower, we comprehend this covering from top to toe with fur. On any theory other than that implying man's ascent from the lower animals, it is incomprehensible.

Again, at times are born of normal parents very terrible beings. They are, save in their origin, not human. With small skulls projecting horribly above the eyebrows, with brains smaller and smoother than those of their more happy brothers and sisters, with projecting jaws, of feeble, very feeble intelligence, unable to acquire the power of speech, inattentive but full of imitative quickness, strong, active, ever on the move as to body and as to face, climbing and crawling on all fours, and not walking erect—these strange beings are covered from head to foot with hair. What *is* the meaning of this? Is the blasphemer of man and nature ready, as he looks upon beings such as these, to repeat his shibboleth of man made in the image of god? Was god ever of this form and uncomeliness? That such talk as this should still be rife throughout the poor world! The Special Creationist, one of these microcephalous (μικρος = little, κεφαλον = brain) idiots born of man and woman, should for ever smite with silence. To the Evolutionist, sad as is the sight, there is a lesson and an inspiration. This is to you a reversion to the old order of things, a testimony as to whence you have arisen. This is to you also an inspiration towards that struggle after yet loftier conditions that is the heritage, the possession, and the bequest of each true heart.

Lastly, it is to be observed that the lower a race of man, and the lower the individual man, the more marked is the hair-covering. Your savage race, your savage individual, are much more bedecked with the ancestral covering than are the cultivated peoples. The huge, strong animal man, all muscle and bone, and largely devoid of thought, has shaggy limbs and deep chest hair-shielded.

The tail. The foolish folk who are hopeful of dismissing great scientific truths with a sneer or a smile are for ever asking what has become of man's tail. It is late in the day to point out that this is a question betraying the ignorance of ordinary Anatomy that is habitual with the foolish folk. In the first place, the higher apes have no more of a tail than has man. Again, man has a tail. It is rudimentary, but it is present. The os coccygis, or bone of the caudal vertebræ at the lower end of the vertebral column, consisting of four or five vertebræ reduced to the most simple and aborted form, is a rudimentary tail. Why should this functionless structure be present at all, if man is made in god's own image? Again, in the embryonic condition of man there is present a very respectable tail. Finally, in certain diseased conditions, the human being reverts to the old ancestral form, and a caudal appendage appears.

The humerus. The bone that extends from the shoulder to the elbow is called the humerus (*humerus* = shoulder). In the Carnivora, as dog, lion, there is a hole just above the lower end of the bone, where it is about to enter into the elbow-joint. This hole is just above the two prominences to be felt by one who will grasp the elbow sideways between finger and thumb. These prominences are the condyles of the humerus (κονδυλος = knuckle). Hence the hole (*foramen* = hole) immediately above (*supra* = above) these condyles is the supra-condyloid foramen. The Carnivora possess this aperture. It transmits in them the large nerve and generally the large artery of the arm. And such protection in transmission is of great value. For the Carnivora, for the most part, strike out the life of their prey with mighty down-sweep of the arm. Their huge arm-muscles contract with enormous power. It is well, therefore, that the delicate nerve and artery, on which too great pressure would work injury, should thus be protected. In some of the order Primates, the order of monkeys, apes, and man, these foramina are always present. And in the highest, man, there is generally a trace of this passage, and in many cases it is well developed.

Hard by the supra-condyloid foramen is another lower down and midway between the two condyles. This is the inter-condyloid foramen, common in lower mammals, in man-like apes and occasionally present in man. Of this our author writes: "It is remarkable that this foramen seems to have been much more frequently present during ancient than during recent times."

2. Digestion. Consider the wisdom-teeth of man. They are the four hindmost teeth, two in each jaw. These are cut, say the books, between the ages of 17 and 25. These are cut, say the dentists, never at all in many cases. Admittedly they appear comparatively late in life. The opinion is held strongly by many of those best able to judge, that in many cases they never appear. Many persons well over the limit age of twenty-five have not cut all their wisdom-teeth. The writer possesses only 1·5 out of 4. These teeth then, coming late, giving much pain at their advent, often giving much pain during their sojourn in the jaw, necessitating in many cases removal that is proverbially not unaccompanied with pain, too far back in the mouth to be of any value in masticating the food, present insurmountable difficulties on the theory of Special Creation. But to Evolution they are, as are all observed facts, a help and not a hindrance. They are structures that are dying out from

disuse. They are on the path to become rudimentary organs. Possibly many centuries hence only the merest rudiments of them will be even discoverable by the dissector. These rudiments will to the anatomist of the future present no difficulty, as in his time the fetishism of Special Creation belief will have passed wholly and Evolution will be the belief of all. In our jaws, the lower whereof is in outline well-nigh rectangular, teeth in such a position as the wisdom-teeth can do no work. In the jaws of our progenitors with an obtuse-angled lower jaw they would have been of some use. And so at this hour they are dying out.

Cæcum. The alimentary canal of man has many parts ranging one after the other. The gullet or œsophagus leads into the stomach. That organ opens into the small or narrow intestine and this again into the large or broad intestine. Of the large intestine there are three divisions. And the first of these is the cæcum. It is so named from *cæcus*, blind, as the small intestine does not join end on to this first region of the large but runs into it a little distance from one end. And this end is closed or blind. So that a body passing down the small intestine into the cæcum would have for a moment choice of routes. It might run a little way downwards to find its passage further barred to it by the wall of the blind end of the cæcum or it might at once turn upwards into the pervious continuation of the large intestine. To this cæcum is attached in man a rudimentary organ. From its narrowness and outward aspect it is named *appendix vermiformis* or worm-shaped appendage. In man it may be absent or it may be largely developed. It is only hollow throughout a portion of its length. The end one-third or one-half is always solid. $^4/_5$ of an inch in length, of diameter $^1/_3$ of an inch. It is to man useless. Nay, it is worse than useless. It is at times a special death-dealer. Small, hard bodies as the seeds of fruits entering the appendix cause inflammation and death. In the animals lower than man this organ is of great size and functional moment. That of the orang is long and convoluted. The vegetable-eating animals have a long appendix, as the student for the first time dissecting a rabbit knows. Once again, what significance has this organ on any other view than that man is descended from an animal in which the appendix was of size and use?

3. Sense-organs. Ear. If the reader will run his or her finger carefully along the outer margin of the ear from below upwards, the finger as it nears the summit of the organ will encounter a tiny blunt projection. It is so small that it is often not perceptible to sight. Touch will however always discern it. Going from below upwards the projection is perceived just as in the upward passage the front face of the top-joint of the finger ceases to feel the gentle pressure of the inner fold of the ear. This strange projection is a vestige of formerly pointed ears. The eye is supposed to have only two eyelids. But a cursory examination of the inner corner of the eyeball next to the nose reveals a small red fold known technically as the caruncula (a wattle on a cock's head) lachrymalis (lachryma = tears). The ugly name denotes the connexion of the red fold with the tear apparatus. Indeed, the tears formed by the lachrymal gland that is upon the outer and upper part of the eye flow athwart that organ constantly, for we are weeping imperceptibly all life long, and pass through two holes in the caruncula into the nasal cavities. This small red fold is a rudimentary third eyelid. Watch a bird's eye, an owl's if you can get one. You will see every now and again a fold flit horizontally across the eye. The bird winks transversely. It has a large thin eyelid that is constantly drawn from inner to outer side of the eye by its own special muscle. All birds, all reptiles, many lower mammals, possess the structure. In man it is rudimentary and as an eyelid is functionless.

4. Motor organs. The muscles of the human frame furnish other examples of instructive rudimentary organs. A horse much worried by summer-flies whisks off the reachable ones by his tail. But those who know the parts of his body out of reach of the whisking organ are many. And of these tormentors he gets rid by a skin-twitch, that is as an earthquake to small insects. This twitch of the skin is effected by a muscle rejoicing in the name *panniculus carnosus* (carnosus=fleshy) resident in the skin. Of this muscle we have remnants. A thin layer in the neck called the platysma myoides (πλατυς=flat, broad, μυων=muscle, ειδος) certain small bundles of tissues met with near the shoulder, the scalp muscle, control over which gifts its owner with

much power of amusing children by moving the skin of the head, all are fragments of the *panniculus*.

But the muscles of the external ear are the most interesting remainders. Every one has them. Very few can make them contract. An excellent example of function-change preceding structure-change. The function of contraction has disappeared ere the structures have been eliminated. In the lower animals these muscles are of use in directing the ear soundwards. To us they are useless. Even those who have the power of contracting these muscles at will, of whom fruitless but persistent endeavor makes one think with unreasonable bitterness, find their unique accomplishment of no further value than as a source of mirth to the little folk.

CHAPTER XLV.

(ii.) *Analogies.*

(ii.) ANALOGY. It is not too much to say that every single function of the body of a living man is performed by him in like fashion to the performance of the body-functions of his closest allies. His digestion, absorption, circulation, respiration, methods of secretion, the actions of his nervous system, of his sense organs, of his motor organs, and of his reproductive system differ in no essential from the functions of the animals most closely allied to him. It is impossible to mention any real physiological difference between human beings and the other higher members of the order Primates.

It would be wearisome to the non-technical reader to trace out the physiological unity of man and his fellows in all minute details. It will be better to select a few striking illustrations that will come home to everyone.

(α) Parasites. The human body is infested externally and internally by animal parasites that are, of course, far lower in the scale of organisation than their host. But these parasites are not peculiar to him. The same beings that render his life a burden to him make miserable the existence of animals other than man. He has no prerogative of parasitism. He shares his tormentors in common with the animals to which he proudly boasts himself superior. This unity of parasitism argues a close similarity if not actual identity between the nature of the skin of man and his allies, and between the nature of their internal organs. If the parasites are identical the habitats of the parasites cannot be very dissimilar.

(β) Lunar periods. There is a mysterious law connecting certain normal processes of animal bodies with the recurrence of particular phases of the moon. We name it law not entertaining any belief that such connexion is the result of the decision of some outside power. A law of nature is only the verbal expression of certain connected phænomena that follow one after the other in regular sequence. We call it mysterious because at present it is not possible to explain the connexion between the body phænomena and the lunar periods. The growth and duration of various diseases, the process of gestation and yet other processes connected with the reproductive function follow definite periods that are usually expressed in terms of one or more months. But this remarkable phænomenon is not peculiar to man. Other Primates, other Mammals, other Vertebrata, and even animals as low down as insects, are subject to the same law.

(γ) Diseases. As man does not stand alone in his parasitical relations so also he has no monopoly of disease. Every ailment that may affect him is liable to affect his inferiors. Even such a fashionable illness as a slight cold is not confined to drawing room tenors. Rengger found the Cebus Axaræ liable to suffer from catarrh with all its familiar symptoms. With this monkey also there was the same risk of the slight cold developing into something more serious. The Cebus in not a few cases suffered consumption and died of the disease. Nor let it be imagined that lung affections were the only ills to which the poor monkey flesh was heir. The list of its possible ailments is as extensive as that of a hypochondriac. Amongst them rank apoplexy, intestinal inflammation, and cataract in the eye. When the young ones were teething they were fractious, they cried, and in some cases had convulsions, and a few died of fever. As to the diseases that are known as contagious they are communicable from man to the lower animals and from the lower animals to man. Witness the terrible cases of hydrophobia passing from dog to man, of glanders from horse to man, of small-pox from cow to man. An ape has caught typhoid fever from its keeper and the keeper has caught typhoid fever from the ape. And all this proves that the blood and the tissues of the higher animals, including man, must be wonderfully similar. The microscope had revealed likeness in structure in the blood of all Mammals; chemical analysis had revealed likeness in composition; but this unity of disease speaks still more plainly as to the close similarity both in structure and composition of the body tissues and the blood of man and apes.

(δ) The effect of drugs identical upon us and our neighbors. Opium, or chloroform, or quinine, or any other of the innumerable constituents of the pharmacopæia affect monkeys as man. The former easily acquire the taste for tea or coffee or tobacco, and the drug that especially acts upon the nervous system—alcohol—is no exception to this general rule. Nowadays, that the proofs of Evolution are becoming recognized by the most unwilling as overwhelming, almost the last room of the collapsing fortress that they defend is labelled nervous system. As to skeleton and digestive apparatus and lungs and heart, they are willing to recognize, they are willing to admit, there is distinction not difference. But according to them the nervous system of man is immeasurably superior to that of any other animal. It is interesting, accordingly, to find it recorded that alcohol, a drug acting on the nervous system, produces similar effects upon the monkeys to those produced upon ourselves. As human beings are variable in their behavior under the influence of alcohol, so are the monkeys. One will become quarrelsome and eager for the fray; settled melancholy falls upon the existence of another, and he sheds endless tears; a third is moved to exceeding moroseness, and a fourth to joviality. Though the conduct whilst under the influence of the drug is thus variable the sameness of the "next morning," so noticeable in man, is to be observed in them. They are cross and dismal, and wear the look of shame; they hold their heads, presumably aching, with both hands. The parallelism fails, however, in one point; on the next morning, the monkeys will not take a hair of the dog that bit them. Thus, Brehm. The present writer, however, is distantly acquainted with a monkey that had, alas, developed this human failing. It was a music hall monkey, and nightly, after its performance, drank itself into a state of intoxication ere it went to sleep. This creature, on the morrow, would drink, in quite patrician fashion, soda and brandy.

(ϵ) The healing of wounds. Man's wounds are repaired by the same process as that obtaining in the lower animals. Even the power possessed by lowly organized creatures of restoring parts that had been removed is, to some extent, his. It is a familiar fact, that children born with double thumbs, after removal of the supernumerary digit, are subject to its re-growth.

(ζ) Reproduction. The whole process connected with the maintenance or extension of the number of the species "is strikingly the same, from the first act of courtship of the male to the birth and maturing of the young." Finally, monkeys are born in a condition that needs as much parental care as our own babyhood. And the supposed distinction in regard to the time taken ere the adult condition is reached hardly holds. It is well known, in tropical countries, maturity, at least as denoted by the possibility of reproduction, is much earlier than in our own climate. The observations upon the Orang seem to establish the fact of that same maturity being reached about the age of twelve or fifteen.

(η) Mental powers. We have seen that one of the last points of defence of the crumbling fortress of Special Creation is the structure and nature of the nervous organs. The evidence that has been already adduced might be accepted by many as accurate, whilst they would still complain that the higher functions of the nervous system were peculiar to man. They would admit the action of alcohol on the brain, but they would contend that the loftier mental functions are not common to man and the lower animals. It is necessary, therefore, to drive them also from this point of the stronghold.

In comparing the mental powers of man with other animals, it is essential to keep in mind that the comparison is not between the loftiest man and other Primates, but between man as a genus and the different apes as representative of other genera. If the highly civilised European be taken for comparison, of course the difference between his mental development and that of the Troglodytes or Gorilla is enormous. But such selection begs the whole question. It is necessary to compare the highest apes with the lowest man. The most ordinary person gives the name of man to a William Ewart Gladstone, to a microcephalous idiot, and to a Tasmanian savage. The Evolutionist has to show, what is indeed very easy of demonstration, that the difference between the brain powers of the higher apes and the lowest savage is very much less than the difference between the brain powers of the lowest savage and the cultivated Englishman.

The study of animals scatters to the winds the common boast of the common mind that the higher mental powers are peculiar to man himself. There is no single function of the mind in man that has not its representation in the lower animals. 1. General. The perception of pleasure and of pain, which is at the base of all mental development, is clearly theirs as well as ours. Terror and suspicion, the outgrowths of the perception of pain, courage, ill temper, revenge, love for the opposite sex, for the offspring, and for the superior, jealousy—the outcome of love—pride, shame, magnanimity, all these are to be observed in the lower animals. Dogs suffer from boredom, birds feel wonder and exhibit curiosity. The principle of imitation runs far down through the animal kingdom. The power of attention is also present, and present as it is in man in various degrees in different individuals. "A man who trains monkeys to act used to purchase common kinds from the Zoological Society at the price of five pounds for each; but he offered to give double the price, if he might keep three or four of them for a few days, in order to select one. When asked how he could possibly so soon learn whether a particular monkey would turn out a good actor, he answered that it all depended on their power of attention. If when he was talking and explaining anything to a monkey, its attention was easily distracted, as by a fly on the wall or other trifling object, the case was hopeless. If he tried by punishment to make an inattentive monkey act, it turned sulky. On the other hand, a monkey which carefully attended to him could always be trained."

Those that have read the story of the return of Ulysses, or those that have kept dogs themselves, will not need to be told that those animals have excellent memories. Imagination, long held to be the especial prerogative of man, cannot be claimed as his alone. Your dog after a long day's ramble is lying in front of the fire asleep. Presently a tremor passes through his limbs. He moves his ears. The different muscles of his body twitch. He half rises; subdued growls and even short barks escape him. He is fast asleep all the while, but he is dreaming of the adventures of the day. How is it possible to dream without imagination? Reason is said to stand at the summit of the faculties of the human mind. It is late in the day to give instances of reason in animals. He that may wish to read an accumulation of such instances will find them recorded for him in the first volume of this series. Professor Büchner's "Mind in Animals" (Geistesleben der Thiere) as translated by Annie Besant, is an answer to those who deny the possession of reason by the lower animals, and by the denial induce us almost to doubt its possession in certain cases by the highest.

Coming to more special cases. The use of tools, the idea of property, the construction of houses, language, abstract ideas, the sense of beauty, religious belief, have all been instanced as possessions of the human race alone. 2. Tools. The Tasmanians and the aborigines of Australia, confessedly men, had no tools at all, and the chimpanzee in a state of nature uses a stone to break open a nut. An American monkey in a state of domestication went further, and used a stone to break open boxes; and others of the race have been observed to use pieces of stick after the fashion of a lever. 3. Property. Very low savage races have little conception, if any, of the idea of property, and that the idea of property is not confined to man will be admitted by anybody who has ever seen a dog with a bone. 4. Houses. Some of the Tasmanians, to whom reference has been already made, had no houses whatever. The aboriginal Australians built a house each night, but abandoned it the next morning; and in this you have an interesting illustration of a transition stage towards a more complete and definite order of things. On the other hand the anthropomorphous apes in volcanic regions build for themselves temporary platforms, and thus escape the lava flow that occasionally devastates the forest ground. 5. Language. As to the Special Creation of language, if language mean the power of communicating between animals, language is very common indeed in the animal kingdom. Insects communicate with each other in countless instances; but it is usual to say that man has "articulate language." I would like a definition of "articulate." If it means language that can be understood by his fellows then the language of the lower animals is articulate. Again, let it not be forgotten that a child at first does not possess what we call articulate language at all; that in the course of its early months out of its interjectional cries is gradually fashioned the more definite speech. Let it be remembered that one of the Gibbons—*Hylobates*—has a distinct octave of notes in its voice. Let it be remembered that a parrot can be taught to use definite words and to put them in definite order; and that the clicking language of the Caffre, and the grunting language of the Bushman are very little, if at all, higher than the collection of sounds that can be uttered by animals other than man. 6. Abstract ideas. The possibility of conceiving these could not have been developed in man until an advanced stage of mental Evolution, and probably not until after language had made considerable progress. But we have no right to say that the lower animals have not a conception of abstract ideas. They cannot tell us that they have; they cannot give us the name that they *may* be cognizant of for their mental conception. But we have no right to say that they do not possess the general concep- of goodness, kindness, or beauty. On the other hand, what conception of the abstract has the brutal and drunken man of the lower orders, or the dim-minded primeval savage?

7. The sense of beauty and its possession by many animals will come under discussion in the second part of this work.

8. Finally comes the question of religion. There is no evidence that man was aboriginally endowed with what Charles Darwin calls "the ennobling belief in the existence of an omnipotent God." Certainly savage races have been found in whom the conception of deity did not exist. But the belief in spiritual agencies as the cause of natural events appears almost universal. In the savage times every natural phænomenon not understood at all by the savage mind is referred to some supernatural agency. With the Tasmanian or the Australian every event is caused in this supernatural way. As he struggles a little further upwards from the lower animals, certain events whose history he begins to understand are eliminated from the category of supernaturally-caused phænomena. But a large residue exists still that he does not yet understand, and that he therefore continues to ascribe to spiritual action. He has passed into the stage of Fetishism. Still moving forwards Fetishism becomes Polytheism. The number of phænomena attributed to the supernatural are still fewer as the

number of phænomena that are now understood is increasing. From Polytheism Evolution leads him to Monotheism. A Monotheist laughs to scorn the idea of deity interposing in distinct details. He comprehends the nature of the storm, the movement of the planets, the ebbs and flows of human thought. He traces all these to their natural causes, and only retains a vestige of the older superstition in the vague belief that somewhere at the back there is a first cause. It will be seen therefore that Evolution of mankind in respect to religious belief has passed through the stages of no inquiry at all into causes; of reference upon enquiry of all phænomena to spiritual agency; of the reference of certain phænomena to multitudinous spiritual agencies, as in Fetish worship; of the reference of still fewer phænomena to still more defined and less numerous deities; of the reference of the myriad observed and understood phænomena to a single first cause; and is passing to the time when this one remnant will vanish and nature will be found to be complete in herself. Myriads of gods at the back of each individual event; thousands of Fetishes at the back of each of the enormous number of non-understood events; hundreds of gods at the back of each of the diminishing number of unstudied things; a trio of gods; and then a single god as first causes of all phænomena; and so through the myriads, the thousands, the hundreds, the three, the one, down to the None.

(θ) Moral sense. The last rallying point for the forces antagonistic to Evolution is the Moral Sense. Even the men that will admit that bodily structure and a large part of the mental functions are not special to man are loth to believe that what is named the moral sense is not a special intuition from a higher source given to men alone. It behoves the Evolutionist, therefore, to investigate the Evolution of this function of brain matter.

1. First, let it be observed that there are many men destitute of moral sense. Certain whole races habitually, and occasionally members of the highest civilised races, appear to have no conception of the distinction between right and wrong. The hardened criminal of the London slums cannot by any amount of tuition or punishment be brought to understand the difference between righteousness and wrongfulness.

2. Considering the Evolution of the moral sense, certain

principles are recognisable. The first essential to the development of the moral sense is the gregarious nature of animals. It is impossible to conceive of a solitary animal having any idea of right and wrong. A man living the whole of his life absolutely alone on a desert island, for example, could never know what society would praise as good, or what society would stigmatise as bad. He has no standard of reference whatever, and would live to the end of his days performing actions that gave him pleasure, avoiding actions which gave him pain, but without any rule of moral conduct, inasmuch as there would be none of his fellows to check him or to praise him in certain courses. But with animals living in a flock or tribe comes the first possibility of the development of the moral sense. This leads to the succeeding principles. 2. The social instincts would lead an animal to take pleasure in the society of its fellows, to sympathise with them, to perform services for them. 3. Memory comes into play. If, on occasion, the social instincts just mentioned were made to yield to some temporary impulse, for the moment stronger, but far less enduring and less frequently recurrent, a feeling of dissatisfaction would grow upon the mind. Nay, more! the society in which the animal lived would punish when the temporary impulse overcame the desire to do that which was good for all. That punishment, repeated and intensified, would gradually teach the lesson that certain actions were not to be performed, because they were opposed to the general well-being, and these actions would be labelled "Wrong." Such other actions as the society did not punish, inasmuch as they were in no sense opposed to the general well-being, would be labelled "Right." This is the manner of growth of the knowledge of right and wrong in the human child. At first the mind is probably a perfect blank. Certain actions are performed that give the child pleasure. These it soon learns to will. Certain other actions are performed that give the child pain, and these it learns not to will. First, then, its standard of the things to be done and the things to be left undone is entirely a personal one. But very early, society, at first in the kindly form of nurse or of mother, and later on in much harsher guise, points out that many acts yielding happiness to the individual conflict with the happiness of the race. The child learns that some of the actions towards which it inclines, not clashing with the general well-being, are not punished, and these it labels "Right." It learns that other actions pleasurable to itself are productive of so much pain to others that they are punished, and these it labels "Wrong." And here the standard of what is to be done and what is not to be done is no longer a personal one. It is the standard of the society in which the individual lives. Hence, at first, the morality of the child has only reference to its own family circle, and the morality of the savage has at first only reference to his own tribe. The savage may be all things that do not become a man as far as outsiders are concerned, but for the tribe he must show bravery, endurance, and all virtues that help it in its struggle with other tribes. He may be as false and treacherous to his enemies as he pleases, and these are accounted virtues to him. And this savage state, in which morality extends no further than the limits of the tribe or nation, and does not enter into foreign politics at all, is reproduced amongst the inferior order of thinkers in so-called civilised nations in the political complications of to-day. But, in the higher stages of man's moral sense, the standard has no longer reference to the individual or to his own tribe. It covers a wider range. That action is good which tends to the welfare of the totality of human beings, and that action is bad which tends to lessen the sum of all the world's happiness. Then the narrow patriotism that stops at the borders of one's own land evolves into that higher form of patriotism, which, knowing no distinction of countries or of peoples, claims the whole world as fatherland. The stages in the Evolution of the moral sense thus far are reference to the happiness of the individual, reference to the happiness of the family or tribe, reference to the happiness of all men. 4. Given the power of language, whereby the wishes of the members of the same community can be expressed, that which we call public opinion would come into play in the making of the moral sense. 5. Habit, strengthening social instincts and impulses and obedience to public opinion, would play its part in the evolution of morality.

1. Gregarious nature of animals. That the lower animals in many cases live together in flocks is obvious enough. Any one that has been near a rookery would corroborate this. Other birds besides the much-cawing ones are gregarious. So are wolves, cattle, and monkeys. The commonest

service performed by members of a flock one for the other is warning of danger. Beasts of prey hunt in packs. The *Hamadryas* monkeys unite their forces to overturn a large stone too heavy for one, that they may seize upon the insects underneath. 2. Possibly the feeling of pleasure that certainly animals possess in their association one with another is an extension of the family affection. It would be strengthened by Natural Selection on account of the protection they would thus afford each to the other. 3. The more enduring social instincts triumph over the less persistent, and this is well, for though the occasional impulse may at times prompt man to a noble deed, far more generally it impels to mere personal gratification, and if this latter be the case retribution follows inevitably in pain of body or of mind. Dissatisfaction ensues, and there is resolve to follow the more universal impulse of aiming at the good of all in the future. He that is thus dissatisfied, that thus resolves, and that acts upon such resolution is the man that possesses a conscience. Even if the same momentary impulse yielded to affords the individual greater gratification than he would feel had he given way to the more enduring principle of action, yet is he conscious that the judgment of his fellows would be against him, and the dissatisfaction mentioned above ensues once more. It is only in the worst men that neither of these feelings comes into play and then the sole restraining motive is fear of punishment.

That morality is at first limited to the tribe is shown by the fact that the murder of individuals, suicide, the robbery of strangers, the strangling by the Indian Thug, slavery, the torture of enemies, faithlessness to strangers even with greatest fidelity towards fellow-tribemen, barbaric treatment of women—all these are not regarded in the savage races as immoral, and intemperance, inchastity, and even indecency in the earlier times, are regarded in no sense as evil. Out of this low, early form grows the higher morality that regards the good of all as the end of action.

And perhaps the highest stage of any moral culture is when a man has learned to be a law unto himself, not in the slavish and crude fashion of the young days, but in such manner that in his inmost heart of hearts it is actual pain if aught of his deeds or words, or thoughts even unknown

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to the world are of such nature as to do harm to that world were they known of men. "Blessed are the pure in heart" is lofty moral teaching. It is well that certain men and women are afraid to do wrong because of their belief that their deity knows their actions. It seems that a higher morality is the possession of those who are afraid of doing wrong because their fellow men would know of their actions. But the highest morality appears to be where a man is ashamed of doing that which is wrong because he himself would know thereof.

CHAPTER XLVI.

(*b*) *Manner of development of Man from some lower form.*

(i.) GENERAL. (*α*) Variability. Man is an eminently variable animal. It is as difficult to find two individuals alike as the proverbial two blades of grass. The anatomist tells us that the teeth, the arteries, the muscles, all the internal viscera, are as variable in individuals as are their faces. And this diversity extends to the mental powers.

(*β*) Causes of variation. Of the causes of this variability we are, however, largely ignorant. But they would seem to be connected with the external conditions to which men are exposed. Associated with this cause are the effects of the use and disuse of parts. The familiar instance of the blacksmith's muscular arm points the moral of this last. If the eye is destroyed the optic nerve diminishes in size and becomes of lower organisation. The Papayan Indians, passing nearly the whole of their lives in canoes, have thin legs and thick arms. The Quechua Indians on the heights of Peru, breathing a rarer atmosphere than ordinary mortals, have chests and lungs of huge size.

(*γ*) Atavism. Reversion to the form of structure present in ancestral conditions is met with in man and points to the line along which he has evolved. The two-horned condition of the uterus and its slight internal longitudinal fold are connected with the fact that in many Mammals that organ is double. The malar or cheekbone on each side of the face is also double in some of the Primates and in other Mammals. This is a regular condition in the fœtus at two months, and in some men the bone remains double throughout life.

(*δ*) Correlated variation has been explained in our dealing with the Origin of species, and in man, as in the lower animals, occurs frequently.

(*ε*) Rate of increase. But for some check to increase, man, like any other animal, would rapidly populate every square foot of the globe. The population of the United States would under favorable circumstances double its number in twenty-five years. If this rate of increase continued, in the course of 657 years there would be four men for every square yard of surface of the globe. Certain checks upon increase must therefore exist. The primary one is the difficulty of getting food. Severe epidemics and wars at times do their work. Periodical famines, accidents, infanticide, licentiousness—all are mentioned as checks to the unlimited increase of humanity. It is pleasant to reflect that the time is rapidly coming when less painful and more scientific means than these will be adopted by man himself, and thus prevent the necessity of the reduction of the surplus population by these cruel devices of a rigid and determined Nature.

(ζ) Natural Selection. Finally in considering the manner of development of man Natural Selection of course comes into play. To sum up, we have seen that man is variable, and, though the causes of the variations may not be clear, apparently they are the same and follow the same general laws as those which determine the variations of the lower animals. Man, like other animals, increases at present beyond his means of sustenance. Hence must follow struggle for existence, and then comes into play the principle of Natural Selection. The difference between the hands of the higher apes and of man is of such a nature that those of the human beings are better adapted for diversified uses. In the earlier times any animals presenting variation of the hands, thus adapting them more thoroughly for such different uses, stood a better chance in the struggle for life. Further, for many human actions it is necessary that the arms and the upper part of the body should be free, and this could only be if the body be erect. The gradual development of the erect posture then becomes possible, and it should be remembered that there is every gradation to-day between the Marmoset, habitually on all fours, and the erect man. With the erect posture would come advantage from a broader pelvis, a curved spine, and a head fixed well on the summit thereof. And all these changes have been attained. The erect posture would give the possibility of using weapons instead of teeth in warfare, and thus the great canines have fallen into disuse, and the jaws become reduced in size. That the brain and spinal cord should increase under the agency of Natural Selection is obvious enough, as every variation in that direction would give better mental faculties, and better chance in the great battle. And so with all parts of the body and their functions. Not one of the slight differences between man and his allies exists that is not of such a nature that its gradual development would have been aided by Natural Selection, as each stage in that development would represent a greater capacity of the individual for dealing with surrounding life conditions.

And if we turn to the more purely intellectual and moral faculties the manner of development of man from the lower forms presents no more difficulty. Such faculties being of high importance to primeval man and his bulky progenitors would have been advanced through the survival of the fittest. The tribes possessing the largest number of men endowed with these advanced faculties would be likely to supplant other tribes. As we get rid in more or less barbaric fashion of our morally and intellectually low people, as those but poorly endowed do not stand the same chance of becoming wedded and producing children that the more highly intellectual possess, despite our sympathies, our hospitals, and our jails, there is a tendency to increase in the number and the standard of the intellectually able.

(ii.) The genealogy of man. Assuming then that the evidence is sufficient, and in truth I have given but a part of it, to establish the probability of man's origin from the lower animals, there comes the enquiry as to what is the exact line of descent. At present, advanced as is our zoological knowledge, it is questionable whether it is sufficiently advanced to trace out the line with unerring accuracy. Some parts of it, however, are at least discoverable. Charles Darwin does not follow Haeckel into the interesting and intricate genealogy that he suggests, but carries us thus far. Clearly man is a Vertebrate and a Mammal. He is also to-day recognised as one of the order, Primates, including Man, Gorilla, Orang, Chimpanzee, Gibbon, Baboon, Spider monkey, Marmoset, and Lemur. The old distinction Bimana (two-handed), and Quadrumana (four-handed)—the outcome of man's conceit—is for ever done away with. Man is to be classed zoologically with the Monkeys and the

Apes. Now the order Primates has three sub-orders. Anthropidæ (ανθρωπος = man, ειδος = likeness), including Man alone; Simiadæ (*Simia* = ape), Apes and Monkeys; Lemuridæ, the Lemurs. Consider the sub-order Simiadæ. This is divided into the Catarrhini (κατα = narrow, ρις = nose) or monkeys of the old world, with narrow nostrils, and the Platyrrhini (πλατεος = broad) or monkeys of the new world, with broad nostrils. Man, by the character of his teeth and the structure of his nostrils assimilates to the former rather than the latter. Again the Catarrhini or old world monkeys are split up into two groups. The lower comprises the non-anthropomorphous monkeys such as Semnopithecus, and the higher anthropomorphous, including the Gorilla, Chimpanzee, Orang, and Gibbon. As none of these last possesses a tail, or the ugly bare places highly colored that are borne by the other monkeys on the posterior regions of the body, and are called callosities, it is probable that some ancient member of the anthropomorphous sub-group of the Catarrhine division of the sub-order Simiadæ gave origin to man. It is hardly necessary to-day to point out the folly of saying that man has sprung from apes. No evolutionist has ever made so reckless and ridiculous a statement. All that the evolutionist contends for is that there is evidence that man and the apes have sprung from some common ancestral form. I subjoin a table of the classification of man and his allies.

PRIMATES	Lemuridæ	Lemurini		Lemur.
		Cheiromyini		Chiromys.
	Simiadæ	Arctopithecini		Marmoset.
		Platyrrhini		Spider-monkey.
		Catarrhini	Cynomorpha	Baboon.
			Anthropomorpha	Gibbon, Orang, Gorilla
	Anthropidæ			Man.

As the apes that appear most nearly allied to the probable progenitor of man are of the old world stock, the earliest man probably lived on the African continent. And if we are asked to produce fossil remains, or even living forms of the intermediate stages between him and us, we remind the inquirer of the imperfection of the geological record in the very region of the earth where probably man first appeared. We remind him again that intermediate forms are always liable to be exterminated. The intermediate forms and man's brute progenitor have probably alike been slain in the battle for life. Almost certainly the anthropomorphous apes will in time be exterminated. Consider what will be the break then between man in a state of civilisation, far higher than ours, and some ape lower even than the Gibbon. Consider in those days how the sneering non-scientist will point still more triumphantly to the immense difference between man and any of the lower animals. Ah! man will be wiser then. Long ere the extinction of the anthropomorphous apes occurs, he will have learned the glorious lesson, so slowly being learned to-day, that man is ascended from a lower form of animal.

Following our teacher, we can trace the genealogy of man further back than the Primates. The Simiadæ are structurally closely connected with the Lemuridæ, the lowest division of the Primates. Without following Haeckel steadily down through the vertebrate sub-kingdom, Charles Darwin carries us at once to the lowest class of Pisces, or fishes. He holds that all the members of the vertebrate sub-kingdom are derived from some fish-like animal. Certainly each of the classes glides into the others. The Duckbilled Platypus or Ornithorhyncus of Australia connects the Mammalia with Birds and Reptiles. The fossil Pterodactyles connect the Reptiles and the Birds. The Icthyosaurians connect the Reptiles and the Fishes. The lowest of all in the vertebrate series is the strange Amphioxus or Lancelet, a vertebrate, but of the very lowest nature. The older naturalists placed it amongst the worms. Possibly this may be a persistent form of the progenitor of all the vertebrate sub-kingdom. Now the Lancelet or Amphioxus is strikingly similar to the Ascidian. The commonest form of Ascidian is a simple tough leathery sac with two openings, that the visitor to the Brighton Aquarium may see to-day by the dozen. This strange little being, far down in the animal kingdom, in its development, in the position of its nervous system, in its respiratory apparatus, and in a structure representing our vertebral column, more than suggests the Vertebrata, and therefore "we should thus be justified in believing that at an extremely remote period a group of animals existed, resembling in many respects the larvæ of our present Ascidians, which diverged into two great branches—the one retrograding in development and producing the present class of Ascidians, the other rising to the crown and summit of the animal kingdom by giving birth to the Vertebrata."

CHAPTER XLVII.

(c) *On the Races of Man.*

WHETHER mankind consists of one or several species has been long a question with the Anthropologists, who, on account of the diversity of opinion amongst them, are divided into two groups, named Monogenists ($\mu o \nu o \varsigma =$ one, $\gamma \epsilon \nu o \varsigma =$ race) and Polygenists ($\pi o \lambda \upsilon \varsigma =$ many). The former hold that man consists of but one single species. The latter hold that there are several species of human kind.

(i.) Polygenist arguments, It is clear that the evolutionist will come under the former category; that is, he will believe that all the races of man are descended from a single primitive stock. First, therefore, comes consideration of the arguments in favor of the Polygenists. They are as follows:—

(α) The difference of appearance and characteristics in the races. The Negro, the Hottentot, the Mongolian, and the Englishman are clearly in many respects widely different from each other.

(β) The different climates they inhabit.

(γ) The long duration of these different characteristics. Negroes apparently identical with existing Negroes lived 4,000 years ago.

(δ) The sterility that is supposed to exist between individuals of different races.

(ii.) Monogenist arguments. (α) The races of man do not remain distinct when mingled together in large numbers in the same country. They blend. In Brazil is a mongrel population of Negroes and of Portuguese.

(β) The distinctive characters of every race are highly variable.

(γ) The so-called distinct species, that is the races of man, graduate into each other without any intercrossing.

Fourteen eminent naturalists have been asked as to into how many species they would divide Man. Their answers are respectively, 1, 2, 3, 4, 5, 6, 7, 8, 11, 15, 16, 22, 60, and 63.

The extinction of certain races is a historical fact, and follows chiefly from the struggle for existence or the competition of tribe with tribe and race with race.

But after all, the more important question for us is as to the formation of the races. Accepting the view that man is a single species there are yet so many varieties in that species that the Anthropologist—and the Evolutionist must be something of an Anthropologist—is bound to attempt to explain the manner of development of the different races. All the explanations that have availed us in the study of the lower animals do not give us much help in the study of man. The effect of external conditions, even after exposure to them for a great length of time does not appear to be notable. Thus the naked inhabitants of Tierra del Fuego live on the Algæ or Seaweeds washed up by the summer sea on their rocky shore. The Botocudos of Brazil wander lazily through their tropical forests, leisurely devouring of the abundance of fruits. And yet these two races resemble each other almost exactly. So also the Esquimaux, feeding solely on animal matter, clothed with thick fur, living in the night of the world, at temperatures many degrees below the freezing point, differ but slightly from the Southern Chinese, whose food is vegetable, and who live naked lives under a hot glaring sky. Nor can the differences between the races of man be explained solely by the inherited effects of the use or disuse of parts. The principle of correlated growth also aids but little. Hence, the naturalist thirsting for and striving after better explanations than any of these leads us to the principle of Sexual Selection. Under the action of that great principle hereinafter to be studied, does he believe that the human races have been led along their development in diverging lines. By this not only the human race, but animals below it in the scale have been modified. Darwin enunciates the doctrine of Sexual Selection. Its enunciation and proof would have rendered his name immortal, even had not the yet greater generalisation of Natural Selection fallen from the same honored lips. With the statement that this principle is needed to explain the origin of the different races of man, we pass to the second part of the work.

CHAPTER XLVIII.

(2.) *Sexual Selection.—(a) Its principles.*

IN studying this great principle, that is to explain to us not only facts in connexion with the races of man, but many otherwise non-understandable facts in connexion with animals of less lofty organisation, we shall investigate—

(*a*) Its principles.

(*b*) Secondary sexual characters in animals lower than man.

(*c*) Secondary sexual characters in man himself.

(*a*) The principles of Sexual Selection. I will endeavor to state the broad general principle earlier in our investigation than its distinguished author states it. He, as usual, after his inductive fashion, gives the facts first and the generalisation after. I am inclined to think that when once a generalisation has been established irrevocably, it is best to give the student the result first, and then to enumerate the facts upon which it has been built.

(i.) The general principle of Sexual Selection is as follows. That individuals of one sex of certain species of animals, generally the male sex, have varied in external characters; that the females have, for some reason or another, selected these individuals that have thus varied, and have rejected their fellows who continued in the ordinary road; that this variation of the selected males, in consequence of their producing all the offspring, or more offspring than the non-selected ones, has been transmitted and intensified; that this process being repeated generation after generation has led from the first slight variation up to permanent characteristics of the male animal. So that Sexual Selection will imply the choice by the females of particular males possessing particular qualities, and the consequent increase of those particular qualities until they are marked and persistent.

That the males and females differ in their organs of reproduction is a self-evident proposition, and these differences are the primary sexual characters. But we are here concerned with differences not directly connected with the organs of reproduction, and these differences Hunter has called secondary sexual characters. With almost all animals there is a struggle between the males for the possession of the female. Hence the latter have the possibility of a choice, and would select one out of several males. Again, with migratory birds, the males arrive at the place of breeding ere the females come, and the advent of the first female means a contest on the part of several males for her possession. And yet, again, in several cases the males of a certain species greatly exceed in number those of the opposite sex.

(ii.) Numerical proportion between the sexes. The principle of Sexual Selection would be very easy of acceptation if it could be shown that there was a larger number of males than of females in a given species. Very wide inquiry has been made by Darwin into the matter, but the materials are, unfortunately, scanty. By one means and another, however, he has collected a considerable mass of data, but they do not in all cases tell in favor of his argument. In most of the domesticated animals the sexes are nearly equal at birth. Take race-horses for example. In 25,560 births, they presented 99·7 to 100 as the proportion between the male and the female. With man the male births in England are as 104·5, in Russia as 108·9, and with the Jews of Livonia as 120 to 100 females.

But in considering Sexual Selection, the question is not as to the proportion of the sexes at birth, but the proportion of the sexes at maturity. Here, again, however, an element of doubt comes in. With man, at all events, more males die than females during the early years. Nevertheless out of the immense number of observed cases the general conclusion is that the males of some few mammals, of many birds, of some fishes and insects, are more numerous than the females. Here are a few numbers to substantiate this proposition :—

Man in England, 1857 to 1866	104·5	males,	100	females
,, in Russia	108·9	,,	100	,,
Horses	99·7	,,	100	,,
Dogs	101·1	,,	100	,,
Sheep	96·7	,,	100	,,

Pigs	116·6 males,	100 females
Cochin Chickens	94·7 ,,	100 ,,
Lepidoptera	127·7 ,,	100 ,,

Polygamy, where one male unites himself with two or more females, would lead to the same result as inequality in number of the sexes. Now a large number of the higher animals are polygamous. The gorilla amongst Mammals, the Ruminant animals generally, the lion and the seal amongst the Carnivora, peacocks and pheasants amongst birds, and even the stickleback amongst fishes, are all polygamous animals.

(iii.) Again, it is to be noted that where there is difference in external appearance in the sexes it is the male which is in almost all cases modified, and careful investigation of the domesticated animal shows that the male is also more liable to vary. Where brilliant colors or the like external marks, which are to-day usually ascribed to the action of Sexual Selection, occur not only in the male but the female, the probability is that they have been acquired by the male first, and then, after a time, transmitted to the offspring of both sexes. This opens up exceedingly interesting questions in relation to variation, to transmission, and to sex. One simple principle induced by the naturalist from the immense body of facts is as follows. Variations that appear in either sex late in life are generally developed in that one sex alone, and conversely, variations which appear early in life in one sex are likely to be developed in both. Now the variations that Sexual Selection would take advantage of and aid in preserving, transmitting, and intensifying are those that appear principally not in the early years or months of the animal's existence. Hence they are liable to appear only in the one sex.

CHAPTER XLIX.

(b)—Secondary Sexual characteristics in the animals lower than man.

IT is necessary to remind the non-technical reader that the system of classification adapted by Darwin and still in the main used by scientific men to-day is as follows.

The kingdom Animalia is broken up into five kingdoms, Protozoa, Cœlenterata, Mollusca, Annulosa, and Vertebrata. Each of these sub-kingdoms is again divided into classes. The relationships of these classes to one another and to the sub-kingdom will be best understood if I subjoin a table giving the sub-kingdoms, classes, and examples of each.

ANIMALIA.

SUB-KINGDOM.		CLASS.	EXAMPLE.
Protozoa		Gregarinida	Gregarine.
		Rhizopoda	Amœba. Foraminifera.
		Infusoria	Vorticella.
Cœlenterata		Porifera	Sponge.
		Hydrozoa	Hydra.
		Actinozoa	Sea Anemone.
Mollusca	Atriophora	Polyzoa	Flustra.
		Ascidioida	Ascidia.
		Brachiopoda	Terebratula.
	Branchiophora	Lamellibranchiata	Oyster.
		Gasteropoda	Snail.
		Pteropoda	Haliotis.
		Cephalopoda	Cuttle-fish.
Annulosa	Pseudhæmata.	Scolecida	Tape-worm.
		Echinodermata	Echinus.
		Gephyrea	Sipunculus.
		Annelida	Earth-worm.
	Arthropoda	Arachnida	Spider.
		Myriapoda	Centipede.
		Insecta	Fly.
		Crustacea	Lobster.
Vertebrata		Pisces	Salmon.
		Amphibia	Frog.
		Reptilia	Snake.
		Aves	Pigeon.
		Mammalia	Horse.

(i.) Bisexual animals. In the lower classes of animals the sexes are united in the same individual. Thus all the Protozoa, Cœlenterata, and certain classes, as Polyzoa, Ascidioida Brachiopoda, Scolecida, Echinodermata, Gephyrea, Annelida are bisexual. It is not to be expected in animals having both sexes in the same individual that secondary sexual characteristics should exist. Upon these animals Sexual Selection would not work. Yet it is to be kept in mind that many of these bisexual animals are beautifully colored. The corals, sea anemones, jelly-fish and star-fishes are all gay of hue, whilst it is evident that their colors cannot serve as a sexual attraction. Nor do they in all probability serve as a protection, though here we are not on ground so certain. We must regard the presence of bright colors in these bisexual beings as due to the chemical nature or minute structure of their tissues independently of any benefit thence derived. The great sub-kingdom Mollusca presents no secondary sexual characteristics. But this is not surprising when we remember that the majority of its members are sedentary beings, and do not seek one another for the act of reproduction. In a large number of cases impregnation of eggs takes place either by the discharge of eggs and of spermatozoa into the surrounding water, or by the discharge of the spermatozoa into that water, and their passage perhaps over a considerable distance into the female. Even in the highest class of Mollusca, that of the cuttle-fish or Cephalopoda, actual contact of the male and female seems rare. Therefore, as we have here a sub-kingdom of sedentary creatures, not seeking one another in act of courtship, and performing the act of reproduction in some cases even without the male and female being in the presence one of the other it is not remarkable that no secondary sexual characters are encountered in this sub-kingdom. The class Annelida does not present any sexual differences, but again this is not surprising for it is a class whose members are bisexual. But passing on to the highest divisions of the great sub-kingdom of ringed animals there we shall find in the Arachnida, Crustacea, and Insecta marked sexual differences. We do not meet with them again in the Myriapoda, but these again are bisexual.

(ii.) Unisexual animals. (*a*) Amongst the spiders we find males very brightly colored, whilst the females of the same species are dull in hue, and in one genus, Theridon, the male has the power of making a stridulating sound by rubbing parts of its outer skeleton against other parts. The females have not that power.

(β) Considering the Crustacea, we find in the lower parasitic species males of small size with perfect swimming legs and good sense-organs, females larger and destitute of these organs. It would seem that here is arrangement in the male for discovering and seeking the female. The peculiar thread-like bodies, believed to be olfactory organs, are always much more numerous in the male than the female. The pincers or chelæ, whose most striking illustration is seen in the lobster, are larger in the male than the female, and probably serve in the combats for the possession of the female.

(γ) Secondary sexual characters in Insects. But it is in the insects especially amongst invertebrate animals, that the most striking differences between male and female are encountered and that Sexual Selection appears to have come most strongly into play.

In the huge class of Insecta the sexes differ at times in the structure of their motor organs, the wings and legs, in their sense organs, as in the colored or colorless antennæ of the male or female. But of course the chief interest is in structures that give one male an advantage over the other in the trial by force or the trial by song. The secondary sexual characteristics of importance to us will be those of organs enabling a particular male to conquer others in combat or in the more peaceful contest of song, or of beauty of color. Taking the various orders of Insecta in the succession in which they are considered by Darwin we shall find, in each, instances of secondary sexual characteristics.

Thysanura (*θυσανος* = fringe, *ουρα* = tail). Example: Springtail. This order includes minute and very ordinary insects. The sexes do not differ, but the males undoubtedly pay court to the females.

Diptera (*δισ* = twice, *πτερα* = wings). Example: Fly. But little difference between the sexes. The males, however, fight, and the gnats dancing up and down, backwards and forwards in the warm summer air are believed to be males courting the females.

Homoptera (*ὁμοιος* = similar). Example: Cicada. The females are mute, but the male cicada is one of the noisiest denizens of the tropical forest.

Orthoptera (ορθος = straight). Example: The Locust. The males of this order are remarkable for their musical power. The sounds to which they give rise can be heard at the distance of a mile.

Neuroptera (νευρον = a nerve.) Example: the Dragon-fly. Considerable diversity of color in both sexes, but the males, on the whole, are more highly colored.

Hymenoptera (ὑμην = god of marriage). Example: Bees and Wasps. Fights have been over and over again observed between males for the possession of some particular female. In the bees, where there is variation of color, the advantage is on the side of the male.

Coleoptera (κολεος = sheath.) Example: Beetles. The great horns rising from the head of the stag-beetle and other members of this order are peculiar to the male.

Lepidoptera (λεπις = scale). Example: Butterflies. Weak and fragile as are butterflies and moths the former at least are very pugnacious. The wonderful arrangement of colors on the wings of members of this order appears to have intimate relation to Sexual Selection. When the sexes do differ it is the male that is the more beautiful, in almost all cases. In a few instances the females are colored the more splendidly. With the moths or night-fliers, that are busy at a time when color would not be perceived, there is, as far as has been observed, no difference in the color of the two sexes. We must remember that where the female is, as in certain cases, bright and variegated of hue, two explanations are possible; the one that the colors have been acquired for protection, the other, that the male having first acquired them through the agency of Sexual Selection, they have, after a long time, been transmitted to both sexes. Of course, neither of these explanations covers the very rare cases where the female is brightly colored and the male of dull hue. Two other points remain for consideration. Mimicry, as Mr. Bates first pointed out, is frequent amongst this order of insects. Certain butterflies in South America resemble the Heliconidæ in every strip of shade and color. Now the Heliconidæ, though beautifully marked insects, are protected from the attacks of birds.

"Mr. Bates referring to the discussion which had taken place at the previous meeting respecting mimetic resemblances, introduced Mr. T. Belt, the gentleman who had favored him with many of the facts as to the aversion of insectivorous birds to the Heliconidæ. . . . Mr. Belt gave a detailed narration of his observations on this subject, and stated that not only were the perfect insects of Heliconidæ protected by their unpleasant odor, but that the larvæ also were rejected by fowls. . . . Mr. Bates said that one group of Heliconidæ was furnished at the apex of the abdomen with a process from which, when the abdomen was pressed, a very disagreeable odor was exhaled, but he had never seen any fluid ejected."—(Proc. Ent. Soc., Dec. 3, 1866, p. 45).

The butterflies that mimic these protected species have in this case acquired their color because their ancestors have been mistaken by the birds for Heliconidæ and not eaten. And, lastly, it must not be forgotten that insects in the larva condition or caterpillar stage, are often beautifully colored. The colors stand in no definite relationship to those of the mature insect, nor do they serve in any way as a protection. Mr. Wallace suggests that these conspicuously-colored caterpillars have a disagreeable taste, "but as their skin is extremely tender, and as their intestines readily protrude from a wound, a slight peck from the beak of a bird would be as fatal to them as if they had been devoured." Hence, as Mr. Wallace remarks, 'distastefulness alone would be insufficient to protect a caterpillar unless some outward sign indicated to its would-be destroyer that its prey was a disgusting morsel.'

(δ) Pisces or fishes. Turning now to the vertebrate classes, we shall find yet other cases of the males possessing characters with which the females are not endowed—characters that would seem to be the result of continued Sexual Selection. Observation has shown that fishes, in spite of the method of impregnation of the ova after they have left the body of the female, nevertheless court and fight. The stickleback is a polygamist. The males are bold and pugnacious; the females are placid creatures. The male salmon and the male trout are both fighting animals, and during the breeding season the former has developed upon its lower jaw the curious straight projection which serves to strengthen and protect the jaws when one male charges against another. Where color difference obtains the advantage is again on the side of the male. A strange fish inhabiting the fresh waters of South America has in the male sex its mouth fringed with a complete beard of soft hairs. The blennies during the breeding season become much more brightly colored, and have a crest developed upon the head. The change of color and the development of the crest are confined to the males. The salmon, the bull-trout, the char, the pike, and the stickle-back are a few of the many cases where special development of color occurs in the male during the breeding season. And, finally, certain fishes are known to make peculiar noises that in some cases are described as musical. The Umbrina can be heard giving out its peculiar drumming sound at a depth of twenty fathoms, and the fishermen of Rochelle say that the males alone make the noise during the spawning time.

(ϵ) Amphibia. Two principal orders of Amphibia are known: the Urodela ($ουρα$ = tail, $δηλος$ = evident), examples, the Salamander and the Newt, and the Anura ($α$ = without, $ουρα$ = tail), examples, the Frog and the Toad. In both orders there is difference of color between the male and the female, though in the latter order the difference is of intensity rather than of hue. But in the frog we have a striking male secondary sexual character in its vocal apparatus. The croaking that makes night hideous in the vicinity of a country pond in the summer time is mainly due to the male frogs whose vocal organs are much the more highly developed.

(ζ) Reptilia. Of the four orders into which the class Reptiles is divided the lowest is the Ophidia ($οφις$ = snake) or snakes. The difference between the male and the female in color is, as in the frogs, a difference of intensity and the more highly pronounced tints are on the male. During the breeding season the scent glands near the posterior end of the body are especially active. The second order Lacertilia (lacerta = a lizard), or lizards, includes many pugnacious species whose male members fight during the spring or early part of the summer whenever they meet. The contest usually continues until the tail of one of the combatants disappears from his own body and enters into that of his victor. Crests, pouches, appendages on the snouts and horns are met with in the males of lizards, that are absent in the corresponding females. The tortoise and turtles of the order Chelonia ($\chi\epsilon\lambda o\varsigma$ = tortoise) present but little sexual difference, though the huge tortoise of the Galapagos island referred to in the "Naturalist's Voyage round the World" has a voice, or rather a hoarse bellow. And this hoarse bellowing noise, audible at a distance of more than a hundred yards, is possessed by the male only and during the pairing season only. The Crocodilia are certainly combative at the breeding time and from the glands close to their jaws a notable odor is emitted at that period.

(η) Aves or birds. It is in this class that the most marked and most diversified secondary sexual characters appear. We may arrange the facts in regard to birds under four heads—their fighting, their music, their ornament, and their exertion of choice plumage of adults and young.

1. Their fighting. When Dr. Watts wrote "Birds in their little nests agree" he showed himself to have been no observer of nature. Birds in their little nests do not agree. Almost all male birds are exceedingly pugnacious, fighting with beaks, and wings, and legs. Individuals of this sex are in many cases larger and more powerful than the females, and, especially amongst the polygamous birds, are furnished with special weapons such as the spurs of the game-cock. Even the peacock will engage in fierce contest, though its more usual rivalry is that of display.

2. Their music. When in the spring evenings the rich flood of varied song in woods and country lanes is charming the day to sleep, not all of us that are witched with the exquisite harmonies and melodies remember that the birds are contending with each other. There is intense rivalry between the males in their singing. In these cases of singing birds the muscles of the larynx of the male are stronger than in the opposite sex. The singing birds are usually small and not brightly colored, and this might be expected, for the large birds fight for the possession of the female and again those that are brightly colored will contend for the female in display, but the birds that are neither powerful nor beautiful will enter into contest of song.

3. Their ornament. Combs, wattles, colors, plumes of feathers, horns, top-knots, are but a few of the different structures encountered in birds that are clearly for a decoration to them. Even the very iris of the eye is at times more

brightly colored in the male than in the female. It is impossible to look at the difference between the magnificent decoration of the peacock and the simplicity of the pea-hen, or at the winter ornamentation of the male bird of paradise and the obscure coloring and absence of ornament of the female, or, indeed, it is impossible even if we consider the innumerable cases less conspicuous than these where the male birds are provided with color and the female destitute thereof, without feeling assured that in the past the males possessing such color have been steadily selected by the females generation after generation, and that the present high coloring is the result of Sexual Selection. It would seem that the birds take a personal delight in displaying their beauty. Contrast the behavior of the peacock with that of the polyplectron. "When the peacock displays himself, he expands and erects his tail transversely to his body, for he stands in front of the female, and has to show off, at the same time, his rich blue throat and breast. But the breast of the polyplectron is obscurely colored, and the ocelli are not confined to the tail-feathers. Consequently the polyplectron does not stand in front of the female; but he erects and expands his tail-feathers a little obliquely, lowering the expanded wing on the same side, and raising that on the opposite side. In this attitude the ocelli over the whole body are exposed before the eyes of the admiring female in one grand bespangled expanse. To which ever side she may turn, the expanded wings and the obliquely-held tail are turned towards her."

Where the amount of ornamentation in birds is but little, they make the most of it. It is the prettiest sight to see a bullfinch pushing out his breast as he moves before the female, and exhibiting as many of his crimson feathers at once as possible. That the males show themselves off to the greatest advantage within their power is known to all observers of birds. One of the beautiful bronze-winged pigeons of Australia, according to Mr. Weir, acts as follows:— "The male, whilst standing before the female, lowers his head almost to the ground, spreads out and raises perpendicularly his tail, and half expands his wings. He then alternately and slowly raises and depresses his body, so that the irridescent metallic feathers are all seen at once, and glitter in the sun."

The strong influence of Sexual Selection comes out all the more prominently when it is remembered that many of the characters which render the male conspicuous and of excellent beauty in the eyes of the female are of disadvantage in other ways. Thus not a few of the ornaments acquired by birds have been acquired at the expense of lessened powers of flight or of running, and the bright colors and gorgeous feathers that are attractive to the female may serve as a guide to the animals preying upon the possessors of them.

4. The exertion of choice by the female birds. This is an important question. If the females do not exert choice and prefer certain males, the whole fabric of Sexual Selection falls to the ground. The evidence in favor of the exertion of such choice is as follows. 1st. The length of courtship. The long time during which both sexes of certain birds meet at particular places, day after day, will depend, at least partially, on the act of courtship being of some duration. In Germany and Scandinavia such meeting of the black cocks lasts from the middle of March, through April, to May. 2nd. Unpaired birds. There is evidence that some males and some females of the same species, living in the same places, do not please each other, and, as a consequence, do not pair. In many cases, where the female of a pair of birds dies suddenly, her place is instantly filled by another female. Thus with the magpies and partridges the birds are never seen in the spring-time alone. There are always many males and females ready to repair the loss of a mated bird. It is to be observed that there are both males and females thus ready. Why have not these, that we may call spare birds, paired. It is possible for us to believe, following Mr. Weir, that as the act of courtship is a prolonged affair, it may happen that these particular males and females have not succeeded in pleasing each other, and have not paired. 3rd. Mental qualities of birds. The exertion of a choice on the part of a female implies a certain amount of intelligence. It is necessary to remind the reader that the mental qualities of birds are by no means of a low order. Affection for one another, recognition of people, benevolence towards injured members of their tribe, sympathy with pleasure, acute powers of observation—all are possessed by these animals. We may argue that some sense of beauty,

at least, is also theirs, if it were only from the fact that certain humming-birds ornament the outside of their nests, and that the bower-birds of Australia build the most remarkable structures, decorated with feathers, shells, bones, and leaves. 4th. Distinct cases of preference of particular males by females are on record. Audubon, the naturalist of the forests of the United States, is sure that the female deliberately chooses her mate. Female pigeons have been known to show strong antipathy towards certain males without any assignable reason. The female widow bird of the Cape of Good Hope will have nothing to do with a male destitute of the long ornamental tail-feathers that are his great attraction to her.

5th. Variability in birds. Another essential, if Sexual Selection is to be of any avail in modifying the characteristics of animals, is the variability of animals, and especially the variability of their secondary sexual characteristics. Such variability exists in birds. Slight individual differences of color or of the shapes of parts in relation to the secondary sexual characteristics are the most important for the work of selection, and the evidence is strong that such individual variations are more apt to occur in the males than in the females. Besides the variability of secondary sexual characteristics, it is necessary to establish their gradations the one into the other, and of these there are countless instances. Take but the one case that is dealt with at length by Darwin, the formation of the ocelli, or eye-like spots on the plumage of birds. An ocellus is essentially a spot of color within a ring of another color. Let us go back to the butterflies for a moment. Our common meadow-brown butterfly has almost numberless gradations from a simple minute black spot to an elegantly-shaded ocellus. In a South African butterfly there are gradations from exceedingly small white dots encircled by a scarcely visible black line to perfectly symmetrical and large ocelli. In birds it is possible to observe the formation of these circular spots from the breaking up and contraction of stripes of color. Even the peacock, with its magnificence of feathering and of color, can be connected with ordinary birds by a series of intermediate forms. "Thus the several species of Polyplectron manifestly make a graduated approach in the length of their tail-coverts, in the zoning of the ocelli, and in some other characters, to the peacock."

5. Plumage in relation to age and sex. The last point to be considered in dealing with the class of birds is the transmission of characters as limited by age in reference to Sexual Selection. The reader will bear in mind two or three principles of inheritance. The tendency to inheritance of particular characters at corresponding ages in different individuals. The transmission of a character appearing late in life in one sex to that sex alone. The transmission of a character appearing early in life to both sexes. Comparing the plumage of males and females in the adult condition with that of the young there are six classes of cases encountered in Aves. These six will be enumerated, exemplified, and in the explanation as given by Charles Darwin will be repeated.

	MALE.	FEMALE.	YOUNG.	EXAMPLE.
1st.	—More conspicuous.	Less conspicuous..	Like the female ...	Duck.
2nd.	—Less conspicuous..	More conspicuous.	Like male	Cassowary.
3rd.	—Like female... ...	Like male	Special plumage...	Robin.
4th.	—Like female ...	Like male	Like adults	Kingfisher.
5th.	—Distinct winter and summer plumage	Same	Like adult winter plumage	Indian Eglet.
			Like adult summer plumage	Razor-bill.
			Like the females only	American Goldfinch.
			Intermediate between males and females	Many wood birds.
			Different from males and females	Heron.
6th.	—Unlike female ...	Unlike male... ...	Males like adult males ... ...; Females like adult females	Black-cap.

Class 1st. Explanation. The most probable view seems that variations in color or in other ornament have occurred in the males late in life, and have only been transmitted to the males.

Class 2nd. Explanation. Probably the females have been the more numerous, and have been the active animals in the courtship, whilst the males have been the courted ones.

Class 3rd. Explanation. The colors have been acquired through Sexual Selection by the male late in life, and through transmission have been limited to the same age (for the young do not possess the colors) but have not been limited to the same sex for the females do possess them.

Class 4th. Explanation. Three explanations are possible. That the male varied when mature, and transmitted his variations to both females and young. That he varied when young and transmitted his variation to both females and young. He may have varied when adult and transmitted his plumage to both adult sexes, and later by a failure of the first law of inheritance transmitted it also to his young.

Class 5th. Explanation. An exceedingly complex class. Three distinct elements are concerned; sex, age, and the season of the year. When the young resemble the female in her summer dress or the adults of both sexes in their winter dress the cases differ little from those under class 1st and class 3rd. The only difference is the limitation of transmission to the breeding season. But when the young differ in their plumage from either the summer or the winter plumage of the adult the case is more difficult. Perhaps the young have retained an ancient state of plumage, or perhaps the winter plumage of the adult is the most ancient condition.

Class 6th. Explanation. Probably the males in this class differing from those included in the first have transmitted their colors to their male offspring at an earlier age than that at which they themselves acquired them. In all cases where color is under consideration we must not forget that protection may come into play, especially in relation to the females. Ground birds are so colored as to imitate the ground; birds haunting reeds and sedges are obscure in hue; sea birds are often green.

(θ)—*Secondary Sexual characteristics in Mammals.*

Mammals generally. Turning to the highest class Mammalia of the highest sub-kingdom Vertebrata, we shall consider their weapons, their voice, odor, color, and the evidence of the choice exerted by the females.

1. Weapons. With Mammals battle decides who is to be the possessor of the female much more frequently than charm display. The teeth of such creatures as the Narwhal, the spur on the leg of the Ornithorhyncus, the horns of the

Deer tribe are illustrations of weapons much better developed in the male, and used by him in his contests for the female. Usually only one form of weapon is possessed, though the male Muntjac Deer has both horns and prominent canine teeth. The mane of the Lion is probably connected with its warfare as it forms a good defence against the attack of its rival.

2. Voice. Almost all male Mammals use their voices much more at the breeding season than at other periods. The nose of the male Sea Elephant during that time is exceedingly elongated, even to the length of a foot, and its voice, probably strengthened by this nasal extension, is wild, and hoarse, and gurgling. The female Sea Elephant never has the nose extension, and her voice is largely different. The male gorilla again has a voice of tremendous power, and he possesses a resonant, song-increasing sac in connexion with his larynx not possessed by the opposite sex.

3. Odor. The odors of many animals, disagreeable as they are to the human olfactory sense, are in several cases at least connected with the reproductive function. Of course no reference is here made to those odors which would appear to be means of defence, but odoriferous glands in many other cases are especially developed in the males and especially during the breeding time, and in some species the odoriferous glands are confined to the males. Probably the odor emitted serves to excite or allure the female.

4. Color. There are several cases of male quadrupeds that differ in color from the female. The great red male kangaroo strikingly contrasts with the female with its delicate blue tints. The African squirrels present much brighter coloration in the male animals. So it is with certain bats and with the *Mus minutus* of Russia. Very marked sexual difference of color obtains in the seals, and very common is the sexual difference amongst all ruminants. In the order Primates we find the male of the lemur coal black, the female reddish yellow. The male mandril has its face blue, with the ridge and tip of the nose red; white stripes shaded with black in many cases traverse the blue; on the forehead is a crest of hair, on the chin a yellow beard; and these are but a few cases taken from the order Primates of difference in color between the male and female, where striking coloration belongs to the former.

5. Choice. There seems to be little doubt that the Mammals, like the birds, exercise a choice in pairing, and that this choice is exerted by the females. Mr. Mayhew, who has studied dogs with exceeding care, is convinced that females are strongly attracted by males of large size. Mr. Blenkiron, the greatest breeder of racehorses in the world, shows that those animals are capricious in their choice. Similar statements are made with respect to bulls, to the reindeer, to pigs; and hence we may infer that individual antipathies and preferences do exist, and that they are usually shown by the female.

CHAPTER L.

(c) *Secondary Sexual Characteristics of Man.*

THROUGHOUT the human race man is generally taller, heavier, stronger than woman. The body, and especially the features are more hairy, and the voice more powerful. It will be noticed that these differences between man and woman are exactly the same as the differences between the male and female apes. Probably in the earlier times Sexual Selection came largely into play by women choosing the strongest and tallest men. With barbarous nations it is not to be expected that the choice should be at first of the intellectual or artistic man. When brute force is all in all, bodily strength would be the main attraction to the female, and therefore the law of battle would be with those barbarous races the decider as to what men would breed and transmit their qualities to their descendants. With barbarous nations, as for example, the Australian, women are a constant cause of war between individuals of the same tribe and between members of different tribes, and in the earlier races also, when artificial advantages or attractions are added to the natural ones, at first these are especially employed by the male. The ornaments that adorn the bodies of the savage races are at first confined to the male members thereof. We may admit then that Sexual Selection will have considerable action in the early time, though its action would be opposed by certain practices which are prevalent in that early time. These would be communal marriages or promiscuous intercourse, infanticide, early betrothals and the low esteem in which women are held by savages. All these would certainly interfere with the action of Sexual Selection to some extent. But it must not be supposed that with savages women are in quite so abject a state in relation to marriage as has often been stated. The evidence of Mr. Winwood Reade in respect to the negroes of Western Africa, that of Williams in respect to the Fiji Islanders, of Shooter as regards the Caffres, and of Birchell as to the Bushmen, all show that a very considerable amount of choice is exercised by women, even of the very lowest tribes. Hence we are entitled to believe that as the males of the human race differed in certain secondary sexual characteristics from the females, having greater strength, more powerful voice, larger development of hair covering, being in many cases more highly ornamented, and as the females, even of the most savage races, exercise choice in the selection of their mates, by degrees as the males possessing certain qualifications were persistently selected, and males not possessing those qualifications rejected, the race descending from such unions would show more and more of those qualifications. At first the qualities to be admired by the woman in the man would be of a low order. They would be in the main brute force. Hence, the physique of the race would steadily improve, the weaker males not producing offspring. But as time rolled on, other variations than those of mere bodily size and strength and color and hairiness, would appear. As the brain evolved towards more complex structure and more complex function, variations of mental characteristics would be noticeable, and by degrees the females would begin to exercise choice between the men differing in mental characteristics one from another. Bodily differences would not lose altogether their sway. Very righteously, even to-day, beauty of form and face attract. But bodily differences would no longer be the sole determining causes of selection. The advancing woman would consider not alone face and physique, but mental and moral character. The artistic nature of those from whom selection was to be made would be considered, and hence to-day the question becomes a far more complex one, and the results far more momentous than in the dim past. To-day, woman has to consider beauty of face, beauty of form, social position, strength of mind, strength of moral character. She has to make her choice between men differing in infinite degrees in all particulars, and she has to make that choice conscious that her selection will influence not alone her life and his, but the lives which will spring from them. When all men and all women are striving after the possession in themselves of the healthiest, purest body, and the healthiest, purest mind, and when each man and woman in the search for the partner that is to make existence life, seeks after one that possesses both body and mind of the highest possible order, then will spring "the crowning race of human kind."

D.—Expression of the Emotions.

CHAPTER LI.

(1) *Introduction.*

THE evolutionist has to explain not only bodily structure and the lines along which that structure has evolved towards greater and greater complexity. He has also to discuss the manner of evolution of function. And while it is his duty to endeavor to explain how such functions as digestion or as circulation have arrived at the condition that is theirs to-day, with their manifold relationships and subdivisions, especially does it behove him to deal with those most remarkable of functions—the mental ones. To explain how the excessively simple mind functions of lower animals have gradually passed on to higher and more complex conditions is his duty. And the outward expression of these emotions that are part of the mental behavior of the higher animals must, if it be possible, be accounted for by him on the principle of Evolution, and not of Special Creation of particular modes of communicating to the outside world our inward feelings. The Special Creationist can say that every mode of expression of every emotion has been designed and given to man by god. The Evolutionist has to show how given certain muscles and certain outward body-forms in man and the lower animals, all the infinite variety of gestures and glances whereby we speak our inmost feelings are explainable. To this task, the last work of Darwin to be considered by us is devoted.

The Expression of the Emotions consists of an introduction, an enumeration of certain general principles, the study of expression in animals other than man, the study of expression in man himself.

(1.) Introduction. Herein is enumeration of other works on the subject and an explanation of the method adopted in the investigation. (*a*) Other works. These are as follows :

DATE.	AUTHOR.	WORK.
1667	Le Brun	Conférences sur l'expression.
1774—82	Camper	Discours sur le moyen de representer les divers passions.
1806	Sir Charles Bell	Anatomy and Philosophy of Expression.
1807	Lavater	L'Art de connaître les hommes.
1839	Burgess	Physiology or Mechanism of Blushing.
1862	Duchenne ...	Mécanisme de la physionomie humaine.
1865	Gratiolet	De la physionomie et des movements d'expression.
1867	Piderit	Wissenschaftliches system der mimik, und physiognomist.

All the above authors have written from the point of view of believers in Special Creation. To none of them had the light come. Herbert Spencer, in "The Principles of Psychology," is the only man who has dealt with this subject as an evolutionist. But it has been reserved for the foremost of evolutionists to treat the subject in full detail in the book now under consideration.

(*b*) Methods of Observation. (i.) On infants. In these the original forms of expression are least likely to be masked by conventionalities. (ii.) On the insane. These are liable to strong emotions and give unrestrained expression to them. (iii.) On faces the muscles of which are stimulated by galvanism. (iv.) On the great works of art, paintings and sculptures. Little aid came hence. The artist depends so largely for his effects upon accessories that his productions are of little value to the evolutionist. (v.) On various races. A paper of sixteen questions sent to Europeans in different parts of the world, and enquiring as to method of expression in savage races received such answers as demonstrated that "the same state of mind is expressed throughout the world with remarkable uniformity." (vi.) On animals other than man.

CHAPTER LII.

(2) *General Principles.*

(2.) GENERAL PRINCIPLES. These are three. (*a*) The principle of serviceable associated habits. "Certain complex actions are of direct or indirect service under certain states of the mind, in order to relieve or gratify certain sensations, desires, etc.; and whenever the state of mind is induced, however feebly, there is a tendency through the force of habit and association for the same movements to be performed, though they may not be of the least use."

(*b*) The principle of antithesis. "Certain states of the mind lead to certain habitual actions, which are of service, as under our first principle. Now when a directly opposite state of mind is induced, there is a strong and involuntary tendency to the performance of movements of a directly opposite nature, though these are of no use; and such movements are in some cases highly expressive."

(*c*) The principle of the direct action of the nervous system. When we studied Sexual Selection, and the colors and forms whose evolution was referable to that principle, we found certain arrangements of hues that could not be satisfactorily explained upon the hypothesis of Sexual Selection. These, we were obliged to say, were due to the inherent chemical nature of the tissues of the animal. So, in the study of the expressions, we encounter certain movements and outward manifestations not explainable by either of the two former principles. These we ascribe to the direct action of the nervous system, to the inherent nature of the nervous structures.

(*a*) Serviceable associated habits. It is a fact well-known to physiologists "that the conducting power of the nervous fibres increases with the frequency of their excitement."

When our minds are greatly moved by any emotion the movements of our bodies are affected, and these movements readily become associated with the mind-conditions that precede or accompany them. In time the movements come to be performed as often as the same causes arise, even though the movements are not of the least use. Thus if we are falling back on a feather-bed we, none the less, stretch out our arms. The start at something novel or surprising is another illustration. In our earlier condition and in large measure even in the condition of man to-day the unexpected is the dangerous. The start at a novelty or a wonder is the remnant of the leap away from the dangerous. It is no longer of use, but on the principle now under discussion it remains with us as a form of expression.

(*b*) Antithesis. A given state of mind is accompanied by certain outward expressions that are serviceable. On the principle of antithesis when exactly the opposite state of mind supervenes, exactly the opposite outward expressions to the former are shown, though they are in no way serviceable. Compare the aspect of a dog advancing towards a strange dog on battle bent with that of the same animal fawning on his master. Or compare a cat softly purring against the silk-dress of an elderly maiden lady what time the aroma of tea is in the air with the same cat surveying an advancing terrier.

The deaf and dumb are largely taught by "opposites." The shrug of the shoulders that says "I can't" is another illustration. When a man, greatly daring, looks that he *can* and will do something, the shoulders are firmly set and squared and the head is erect, the ears at their furthest from the shoulders. Impotence is expressed by the raising of the shoulders, the half-droop of the head and the shoulders and ears are as close together as possible.

And generally as actions of a given kind have grown into association with certain emotions, opposite actions have grown into association with opposite emotions, although the actions are in no sense of use.

(*c*) Direct action of nervous system. Take, as examples, the change of color in the hair under strong emotion. This is not to be explained on either of the two former principles. Or again, trembling, which is palpably of no service, under strong emotion. This last may be understood if we remember that in the normal condition of the body there is a certain definite flow of nerve energy along the nerve-fibres to the muscles. Now, any strong excitement of the nervous system may interrupt that flow of nerve-energy, may render it intermittent instead of constant. This would mean intermittent action of the muscles instead of their regular, normal tonic contraction. Hence trembling. It is well-known that almost any function of the body is liable to alteration under strong emotion. The secretions of the alimentary canal, of the liver, of the kidneys, of the skin, are all liable to be affected in their nature by emotion, and it is not remarkable, therefore, that under strong emotion other functions than those of secretion should be interfered with and the unwonted action of the muscles known as trembling occur.

An overflow of nerve-force as under strong emotion will, unless the will be exercised, travel along the most usual routes, and if these are not sufficient, it will overflow into those that are less customary. Hence the muscles of the face and of respiration are the first to come into action, then those of the arms, then those of the legs, then those of the body.

As it is known that violent muscular actions often relieve or remove us out of the reach of pain, we can understand the contortions of one in agony. "We thus see that the undirected radiation of nerve-force from the nerve-cells which are first affected—the long-continued habit of attempting by struggling to escape from the cause of suffering—and the consciousness that voluntary muscular exertion relieves pain, have all probably concurred in giving a tendency to the most violent, almost convulsive, movements under extreme suffering; and such movements, including those of the vocal organs, are universally recognised as highly expressive of this condition." In the exhibition of rage we have less of the purposeless than in the last case. All the gestures suggest the act of fighting. And here principle (*c*) blends with principle (*a*).

CHAPTER LIII.

(3.) *Expression in animals other than man.* (4.) *In man.*

(3.) THIS falls into the study of general methods of expression and then expression in special animals.

(*a*) General methods of expression. (i.) Vocal. We have seen that when the nervous system is excited all body-muscles are likely to be convulsed. The muscles pertaining to the voice-organs will not be excepted. Hence outcries. Further, if it be granted that the habit of uttering music-sounds arose in connexion with courtship in the earlier ages, we can understand why love, rivalry, triumph are all expressed in song.

On the other hand, consider the universal "pooh!" A man is disgusted. There is a tendency to blow from the mouth because so often has the disagreeable object attacked him *viâ* the mouth. The Oh! of wonder is due to a tendency under astonishment, when one knows not what the next moment may bring forth, to prepare for emergencies. The mouth is opened widely for prolonged expiration. When the next expiration comes the mouth is slightly closed, the lips protruded. The voice issuing now must be in the form of the Oh! that wells up from the crowd at the Crystal Palace on a firework night.

If pain is felt as well as surprise all the muscles contract. Those of the face contract and the lips are retracted. Fear also sets all the muscles, including those of the voice-apparatus a-tremble. The mouth is dry, as the salivary-glands cease to act and the husky, tremulous, hard "Ah" breaks forth.

(ii.) Dermal. Under fear or anger hairs are erected, feathers ruffled, scales raised, the body inflated. In every case the apparent size, and therefore the awe-inspiring qualities, of the animal are increased. Accompanying this dermal erection are voluntary gestures, as opening the mouth, showing the teeth, utterance of harsh sounds, threatening movements.

(iii.) Ear-movements. These are either the retraction of the ears close to the head, or their erection. The former is intelligible as a safeguard against the seizure of the ear by the toothed foe, the latter as necessary to hunted animals, as enabling them to judge whence danger threatens.

(*b*) In special animals. (i.) Dog. When a dog is angry, the stiff gait and tension of the muscles are understandable on our first principle. Anger has led to struggles, in which every muscle has had to be at its fullest tension. That in anger, under this general tension, the tail should be raised rather than depressed, follows from the elevator muscles being probably more powerful than the depressors of the tail.

The licking of the hand, or even, on the part of great favorites, of the face of master or mistress, is connected with the parental habit of licking the young for the purpose of cleansing them.

The rubbing of the body against the owner has to do with the fact that the contact of the mother's body with the puppy's has associated the sense of contact with the emotion of love.

Finally, dogs laugh.

(ii.) Cats. The attitude of an angry cat is connected with its mode of fighting. Where dogs use teeth, cats use fore-legs for striking. A crouching position is, for her, the best. The lashing of the tail under the emotion of anger may be due to the fact that nerve-energy is liberated in large quantity. Hence an uncontrollable desire for some kind of movement, and that of the tail is the least disturbful to the general position of the body. The erection of the back, of the fur and of the base of the tail serves the old purpose of making the animal look more terrific and more dangerous.

(iii.) Horses. The nostril is in these animals the most expressive feature. In the throat of the horse is a valve. When the animal breathes rapidly, or pants, expiration and inspiration only occur through the nostrils, not the mouth. The nostrils have, therefore, become very expansible. The expansion of them, the heart-palpitations that you can feel through the saddle, the snorting, are only special forms of that general muscular action that takes place when a horse, terrified, leaps and flies away from danger.

(iv.) Ruminants. The pawing of a bull in anger is not quite understandable. These animals do not fight with their fore-feet. But this pawing throws up clouds of dust and drives away irritable flies. Hence the habit may, on our first principle, be indulged in under any irritation.

(v.) Monkeys. Every expression of man is to be seen in these, his allies. They chuckle or laugh when pleased. They weep when grieved. They are dejected when out of health. They turn red when angry. They protrude their lips in a pout when sulky. "When we try to perform some little action which is difficult and requires precision, for instance, to thread a needle, we generally close our lips firmly, for the sake, I presume, of not disturbing our movements by breathing, and I noticed the same action in a young Orang. The poor little creature was sick, and was amusing itself by trying to kill the flies on the window-panes with its knuckles; this was difficult, as the flies buzzed about, and at each attempt the lips were firmly compressed, and at the same time slightly protruded."

(4.) Expression in man. Various forms of expression exhibited by man under various mental conditions are now dealt with in detail, and, where it is possible, explanation of each is given.

(*a*) Suffering and weeping. In the expression of suffering an exceedingly general movement takes place. It is the firm closing of the eyelids and compression of the eyeball. This action serves to protect the eyes from becoming overcharged with blood. If the student will observe the series of muscular actions on the part of a person who is first asked to raise the eyebrows and then gradually to contract the muscles round the eyes with as much force as it is possible, he will see that the movements take place in the following order. The corrugators of the eyebrow contract first after the eyebrows have been raised. These draw the eyebrows downwards and inwards. Almost simultaneously the orbicular muscles contract, producing wrinkles round the eye. Then the pyramidal muscles of the nose draw the eyebrows and the skin of the forehead still lower down. Next, those running to the upper lip contract and raise the lip, and if the suffering take expression in screaming, as the upper lip is thus drawn up, the depressor muscle of the angle of the mouth is contracted so as to keep the mouth wide open and allow the issue of a full volume of sound.

As to the cause of the contraction of these muscles around the eyes during the utterance of screams, it should be noted that similar contraction takes place in loud laughter, and coughing, and sneezing, and in shouting. The greatest exertion of the body muscles, as in gymnastic exercises, does also lead to the contraction that is under consideration. The experiments of Professor Donders show that during any violent expiratory movements the arteries and the veins of the eye are distended. Now the firm closure of the eyelids will prevent this distension of the blood-vessels from causing pain and inconvenience to the eye.

(*b*) Secretion of tears. It is to be noted that young infants do not weep, and on the other hand that many animals lower in the scale, as, for example, the Indian elephant, do indulge in tears. To explain the reason why tears are secreted, not only during a screaming fit, but when any violent expiratory effort is being made, we have the following suggestions:—

(i.) The spasmodic contraction of the eyelids pressing strongly upon the eyeball would be liable to cause tears to be secreted in the same way as a slight blow on the eyelid does.

(ii.) It is known that the internal parts of the eye act in a reflex manner on the lachrymal gland. Further, it is known that during violent expiratory efforts the vessels of the eye are filled with blood, and there is pressure within the eye. This distension of the eye vessels may act in a reflex manner on the lachrymal glands.

(*c*) Grief. One of the most noticeable movements of the face in the expression of grief is the raising of the inner ends of the eyebrows, so that those parts become oblique. They assume this position because the contraction of the muscles named orbicular, the corrugator of the eyebrow and the pyramidal of the nose, whose conjoint action is to lower and contract the eyebrows, is partially checked by the more powerful action of the muscles of the forehead. Still the question comes why should grief cause the central part of the frontal muscle, and also those that surround the eyes, to contract? The answer would appear to be that as in infants these muscles have been repeatedly contracted for the protection of the eye in screaming, the same action was performed by our progenitors generations ago; and that as we grow out of childhood we prevent when grief settles down upon us the utterance of screams, but habit is so strong that we cannot prevent a slight contraction of the above-named muscles. The depression of the corner of the mouth, so characteristic of grief, is effected by one principal muscle on each side, and according to Duchenne this is one of the facial muscles that is least under the control of the will.

(*d*) Joy. Under this emotion the mouth is acted on by the great zygomatic muscles which draw the corners of the mouth backwards and upwards. At the same time some of the muscles to the upper lip contract to a certain extent and the orbicular muscles of the eye are also contracted. The brightness of the eye under the emotion of joy is partially due to the condition of tension of the organ, a consequence of the contraction of the orbicular muscles and a consequence of the eye-balls being well filled with blood at the time. Under pleasurable emotions sounds of some kind are usually emitted, and this is probably the result of the fact that throughout a large part of the animal kingdom vocal sounds are employed as a call or as a charm by one sex to the other. Perhaps the habit of uttering loud and repeated sounds from a sense of pleasure first led to the retraction of the mouth corners and to the contraction of the muscles around the eye, and when we smile to-day, the smile being an incipient laugh, the same muscles are brought into slight play.

(*e*) Love. With this emotion there is always a strong desire to touch the object of affection, and we notice the same principle of pleasure derived from contact in the lower animals.

(*f*) Reflexion. Men of all races frown when they are perplexed in thought. Now the earliest expression noticed during the first days of infancy is that displayed during screaming. In this expression the muscles round the eyes are contracted. Screaming is caused at first by any unpleasant sensation, and so the habit of contracting the brows or frowning, has been followed by children during many generations whenever unpleasant sensation has been their lot. This habit has become associated with the sense of that which is disastrous or disagreeable. Another cause of the frowning in meditation is that vision is the most important of the senses and in the primeval times the closest attention must often have been directed towards distant objects, and such close attention would involve the contraction of the muscles ultimating in a frown. When the reflexion becomes abstraction the lines of vision of the two eyes are usually slightly divergent. The eyes are not really fixed upon any object in deep abstraction, and this divergence of the lines of vision is due to the complete relaxation of certain muscles of the eye.

(*g*) Ill-temper. The methods of expressing ill-temper are very identical throughout the human race and the members of the groups most nearly allied to it. The tendency to protrude the lips when sulky is a universal characteristic, and is observed in all the man-like apes. It is more marked in savage races than in civilised.

(*h*) Decision. The firm closing of the mouth is the most remarkable method of expression in this connexion. Now the mouth is generally closed firmly before and during muscular exertion and by the principle of association the mouth would also be closed when a decision was made that involved exertion. As to the causes of the closing of the mouth during muscular exertion we have the following suggestions. Sir Charles Bell holds that the chest must be distended with air and kept distended to form a fixed support for the muscles that are to contract. Gratiolet holds that muscular exertion necessitates a retarded circulation, that arrested respiration retards the circulation, and hence that the closing of the mouth is necessary for the arrested respiration, for the retarded circulation, for the muscular exertion. Piderit holds that the closing of the mouth during strong muscular exertion is explained by the principle of the influence of the will spreading from one set of muscles to another.

(*i*) Rage. In this emotion the heart and circulation are always affected. The respiration is in like manner modified, and the excited brain gives greater strength to the muscles and larger energy to the will. The protrusion of the lips during rage and the tendency to bite in young children under this emotion are only explicable on the view of descent from a lower form.

(*j*) Sneering. The characteristic expression here is due to the retraction of the upper lip and the exposure of the canine teeth on one side of the face. A trace of this expression is seen in the smile of derision. Now it would seem that this uncovering of the canine teeth reveals the animal descent of man. Our semi-human progenitors in the act of defiance preparatory to battle uncovered their canine teeth as we still do when the feeling of ferocity is strong upon us, or even when merely sneering at or defying our fellows without the least intention of attacking them with the teeth.

(*k*) Disdain. The movement referred to in the last paragraph is also met with here. But in scorn and disdain, other expressions also are used. The partial closure of the eyes would seem to imply that the despised person is not worthy of regard. Movements about the mouth and nose are all of the kind that we employ when an offensive odor is perceived and there is desire to shut it out from our consciousness. The snapping of the fingers is intelligible if we remember that the sign of flipping away an object with thumb nail and fore finger is well-known amongst deaf and dumb gestures as denoting the insignificant and contemptible.

(*l*) Disgust. The vomiting that is apt to follow upon especially disgusting objects gives rise to the belief in the possibility that our progenitors had at one time the power, which is still possessed by the ruminants, of voluntarily ejecting food. The protrusion of the tongue in letting a disagreeable object fall out of the mouth may also be explained why the putting out of that organ is regarded as the sign of contempt and dislike.

(*m*) Signs of affirmation and negation. How are we to explain the fact that the nod almost universally implies "Yes," the shake of the head "No"? With infants, the first act of denial consists in refusing food, and the observer of children will see that they invariably refuse the food by moving their heads laterally away from the breast of the mother, or from anything offered to them with a spoon. On the other hand, in accepting food they bend their heads forward. There seems little reason to doubt that these two primary movements of rejection and acceptation are at the root of the negative shake of the head and the affirmative nod.

(*n*) Surprise. The wide opening of the eyes and elevation of the eyebrows would be connected with the desire to see as much as possible of the object that is strange and unusual. Why the mouth should be opened is a more complex question, but when we listen intently to any sound, we either stop breathing or breath as quietly as possible by opening the mouth widely. Surprise, therefore, and attention would involve the mouth being open; and, again, as there is only a certain amount of nerve energy in the body, and as in astonishment that would be largely concentrated on particular organs, the nerve supply to the muscles of the jaw would be lessened, and the jaw would drop from its own weight.

(*o*) Fear. The attitude and gestures of fear are easily explained, with the exception perhaps of the dilatation of the pupil. This dilatation may be connected with the fact that the fears of man have more frequently been excited in the presence of lessened light, or no light at all, when the pupil would be dilated, than in other conditions.

(*p*) Blushing. That the young blush more frequently than the old, and women more than men is self-evident; but it must be remembered that infants do not blush at all. Accompanying the blush of shame is the turning away of the body as though one would hide one's face from the gaze of others, and there is also a certain amount of confusion of mental power. This last is explainable on the ground of the intimate sympathy existing between the circulation in the surface of the head and more deeply placed organs, such as the brain. The essential element in all cases of blushing is self-attention, and the fundamental element in the acquirement of the habit has been self-attention to personal appearance, not to moral conduct. Hence, it is the face that is especially subject to this expression of emotion. It is only in a secondary fashion, through the force of association and habit, that we blush on account of the opinion of others on our conduct. Attention closely directed to any part of the body interferes with the ordinary condition of the blood vessels of the part. Consciousness strongly concentrated on any part of the body produces direct physical effect thereon, and it would seem that the consciousness directed primarily to the face of the person has determined an abnormal condition of the blood vessels in the face, the expansion of these blood vessels ultimating in blushing.

CHAPTER LIV.

Conclusion.

MY task is accomplished. It has been a pleasurable and an onerous one. Very pleasurable to have had some hand, however feeble, in the making the thoughts of a great thinker more readily known; very onerous, because there is a dread of having perhaps, in some wise, misinterpreted him. It has been my desire to present his work to others in its true light. Here and there, I am aware that I have pushed some of his conclusions further than perhaps he himself would be willing to believe they go, but I have done so under a strict and stern sense of duty. Whilst he himself writes habitually as the purely scientific man I have taken his facts and generalisations and looked at them in the light of Freethought. I believe that I have been justified in doing so. Science, if I understand it rightly, is to be regarded as face to face, as antagonistic with the belief in the supernatural, and I hold it legitimate to take the teachings of our greatest and push them to what seems to me their logical conclusion. Every great discovery in science of fact or of large general truth has been antagonistic to religious belief. I am not of those who consider that the business of the scientific man is simply to state scientific facts, and to be silent as to the inductions from them. Indeed, it is impossible to do so. The statement of the facts must lead to the making of such induction on the part of all that hear them, and it is best to state honestly along what lines and antagonistic to what views they work.

Looking back over the list of works of this remarkable man that have been our study we are struck with the vastness of the monument he has raised. "The Naturalist's Voyage round the World," with its wonderful accuracy of observation, and suggestions deeply interesting of the thoughts enlarged in future volumes; "Geological Observations on

South America and the Volcanic Islands," and the "Coral Reefs," with their contributions to geological science, and their broaching of new and daring hypotheses that are to-day facts; the "Climbing Plants," in which we have the first evidence of his pertinacity and patience in experimental research; the "Fertilisation of Orchids," wherein the structure and functions of all the genera of the most complex vegetable order are worked out to the minutest detail; the "Cross and Self-fertilisation of Plants," and the "Forms of Flowers," with all their accumulated evidence showing the advantage of cross-fertilisation, the disadvantage of self-fertilisation, the greater possibility of variation under the one than under the other; the "Movements of Plants," for ever slaying one of the old world distinctions between plants and animals; the solitary zoological work "Cirripedia," in itself a volume that might have been the product of a life time; the "Origin of Species," wherein the great theory of Natural Selection is clearly stated with all the arguments on its behalf and almost more than all the arguments against it; the "Animals and Plants under Domestication," an encylopædia of the facts upon which his conclusions in the preceding volume were based; the "Descent of Man," in which the most interesting instance of Evolution is specially dealt with and the great theory of Sexual Selection enunciated; the "Expression of the Emotions," with its close analysis of the muscular movements accompanying certain mental conditions, and its explanation of the meaning and development of them: all these are from the pen of one man.

Looking back over them again we cannot fail to be impressed with those two large attributes of genius that are especially his—unrivalled powers of observation, unrivalled powers of generalisation. And the homage that we pay him to-day is, I am assured, but the feeblest of utterances as compared with the heartfelt gratitude and wondering praise that will be the reward of this great thinker in those future times when the very lowliest in the land shall have full grasp of the meaning of his teaching, as to-day have only the most thoughtful, and when the most thoughtful of those after times shall have passed on to stages of thought as far in advance of his, as his is in advance of the past and present.

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