THE DEBT OF SCIENCE TO DARWIN.

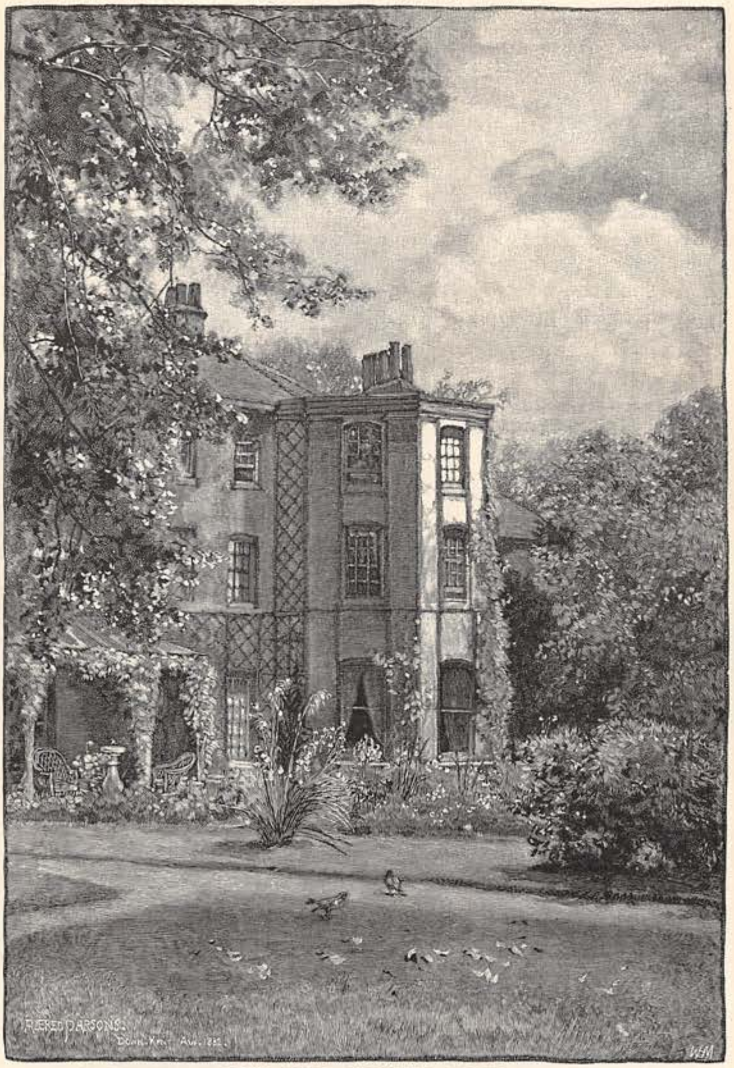
DARWIN'S STUDY.

THE great man so recently taken from us had achieved an amount of reputation and honor perhaps never before accorded to a contemporary writer on science. His name has given a new word to several languages, and his genius is acknowledged wherever civilization extends. Yet the very greatness of his fame, together with the number, variety, and scientific importance of his works, has caused him to be altogether misapprehended by the bulk of the reading public. Every book of Darwin's has been reviewed or noticed in almost every newspaper and periodical, while his theories have been the subject of so much criticism and so much dispute, that most educated persons have been able to obtain some general notion of his teachings, often without having read a single chapter of his works,—and very few, indeed, except professed students of science, have read the whole series of them. It has been so easy to learn something of the Darwinian theory at second-hand, that few have cared to study it as expounded by its author.

It thus happens that, while Darwin's name and fame are more widely known than in the case of any other modern man of science, the real character and importance of the work he did are as widely misunderstood. The best scientific authorities rank him far above the greatest names in natural science—above Linnæus and Cuvier, the great teachers of a past generation—above De Candolle and Agassiz, Owen and Huxley, in our own times. Many must feel inclined to ask,—What is the secret of this lofty preëminence so freely accorded to a contemporary by his fellow-workers? What has Darwin done, that even those who most strongly oppose his theories rarely suggest that he is overrated? Why is it universally felt that the only name with which his can be compared in the whole domain of science is that of the illustrious Newton?

It will be my endeavor in the present article to answer these questions, however imperfectly, by giving a connected sketch of the work which Darwin did, the discoveries which he made, the new fields of research which he opened up, the new conceptions of nature which he has given us. Such a sketch may help to clear away some of the obscurity which undoubtedly prevails as to the cause and foundation of Darwin's preëminence.

In order to understand the vast and fundamental change effected by the publication of Darwin's most important volume—"The



DOWN HOUSE, FROM THE GARDEN.

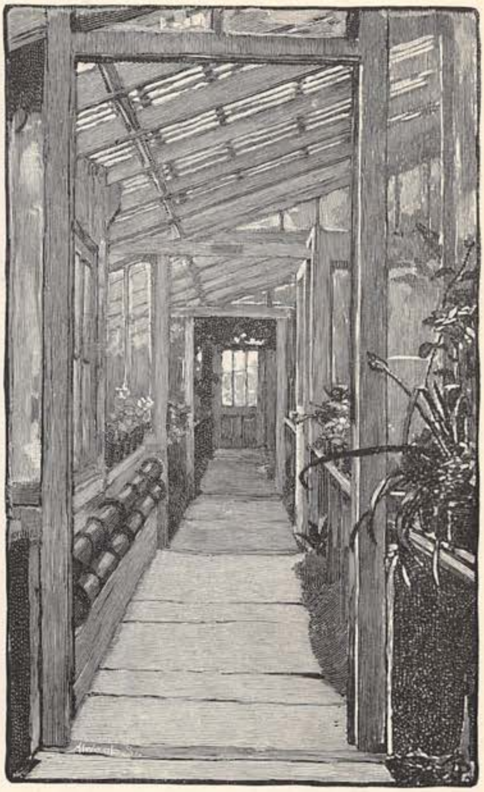
Origin of Species,"—we must take a hasty glance at the progress of the science of natural history during the preceding century.

Almost exactly a hundred years before Darwin, we find Linnæus and his numerous disciples hard at work describing and naming all animals and plants then discovered, and classifying them according to the artificial method of the great master, which is still known as the Linnæan System; and from that time to the present day a large proportion of naturalists are fully occupied with this labor of describing new species and new genera, and in classifying them according to the improved and more natural systems which have been gradually introduced. But another body of students have always been dissatisfied with this superficial mode of studying externals only, and have devoted themselves to a minute examination of the internal structure of animals and plants; and early in this century the great Cuvier showed how this knowledge of anatomy could be applied to the classification of animals according to their whole organization in a far more natural manner than by the easier method of Linnæus. Later on, when improved microscopes and refined optical and chemical tests became available, the study of anatomy was carried beyond the knowledge of the parts and organs of the body—such as bones, muscles, blood-vessels, and nerves—to the investigation of the tissues, fibers, and cells of which these are composed; while the physiologists devoted themselves to an inquiry into the mode of action of this complex machinery, so as to discover the use of every part, the nature of its functions in health and disease, and, as far as possible, the nature of the forces which keep them all in action.

Down to the middle of the present century the study of nature advanced with giant strides along these separate lines of research, while the vastness and complexity of the subject led to a constantly increasing specialization and division of labor among naturalists, the result being that each group of inquirers came to look upon its own department as more or less independent of all the others: each seemed to think that any addition to its body of facts was an end in itself, and that any bearing these facts might have on other branches of the study or on the various speculations as to the "system of nature" or the "true method of classification" that had at various times been put forth, was an altogether subordinate and unimportant matter. And, in fact, they could hardly think otherwise. For, while there was much talk of the "unity of nature," a dogma pervaded the whole scientific world which rendered hopeless any attempt to discover this supposed unity amid the endless diversity of organic forms and structures, while so much of it as might be detected would necessarily be speculative and unfruitful. This dogma was that of the original diversity and permanent stability of species, a dogma which the rising generation of naturalists must find it hard to believe was actually held, almost universally, by the great men they look up to as masters in their several departments, and held for the most part with an unreasoning tenacity and scornful arrogance more suited to politicians or theologians than to men of science. Although the doctrine of the special and independent creation of every species that now exists or ever has existed on the globe was known to involve difficulties and contradictions of the most serious nature; although it was seen that many of the facts revealed by comparative anatomy, by embryology, by geographical distribution, and by geological succession, were utterly unmeaning, and even misleading, in view of it; yet, down to the period we have named, it may be fairly stated that nine-tenths of the students of nature unhesitatingly accepted it as literally true, while the other tenth, though hesitating as to the actual independent creation, were none the less decided in rejecting utterly and scornfully the views elaborated by Lamarck, by Geoffroy St. Hilaire, and more recently by the anonymous author of the "Vestiges of Creation"—that every living thing had been produced by some modification of ordinary generation from parents more or less closely resembling it. Holding such views of the absolute independence of each species, it almost necessarily followed that the only aspect of nature of which we could hope to acquire complete and satisfactory knowledge was that which regarded the species itself. This we could describe in the minutest detail; we could determine its range in space and in time; we could investigate its embryology from the rudimental germ, or even from the primitive cell, up to the perfect animal or plant; we could learn every point in its internal structure, and we might hope, by patient research and experiment, to comprehend the use, function, and mode of action of every tissue and fiber, and ultimately of each cell and organic unit. All this was real knowledge, was solid fact. But, so soon as we attempted to find out the relations of *distinct species* to each other, we embarked on a sea of speculation. We could, indeed, state *how* one species differed from

DOWN HOUSE, FROM THE PATHWAY TO THE VILLAGE.

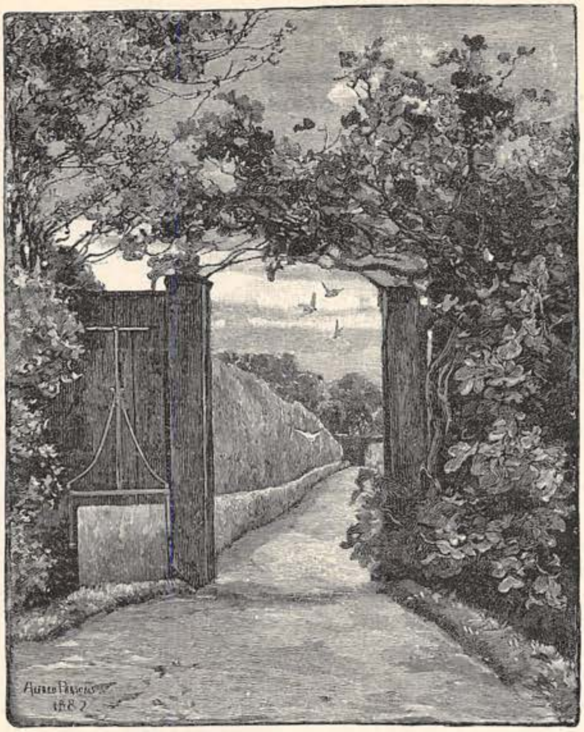
another species in every particular of which we had knowledge; but we could draw no sound inferences as to the reason or cause of such differences or resemblances, except by claiming to know the very object and meaning of the Creator in producing such diversity. And, in point of fact, the chief inference that was drawn is now proved to be erroneous. It was generally assumed, as almost self-evident, that the ultimate cause of the differences in the forms, structures, and habits of the organic productions of different countries, was that each species inhabiting a country was specially adapted to the physical conditions that prevailed there, to which it was exactly fitted. Even if this theory had been true, it was an unproductive ultimate fact, for it was never pretended that we could discover any reason for the limitation of humming-birds and cactuses to America, of hippopotami to Africa, or of kangaroos and gum-trees to Australia; and we were obliged to believe either that these countries possessed hidden peculiarities of climate or other conditions, or that this was only one out of many unknown and unknowable causes determining the special action of the creative power. All this was felt to be so unsatisfactory that the majority of naturalists openly declared that their sole business was to accumulate facts, and that any attempt to coördinate these facts and see what inferences could be drawn from them was altogether premature. In this frame of mind, year after year passed away, adding its quota to the vast mass of undigested facts which were accumulating in every branch of the science. The remotest parts of the globe were ransacked to add to the treasures of our museums, and the number of known species became so enormous that students began to confine themselves not merely to single classes, as birds or insects, but to single orders, as beetles or land-shells, or even to smaller groups, as weevils or butterflies. All, too, were so impressed with the belief in the reality and permanence of species, that endless labor was bestowed on the attempt to distinguish them,—a task whose hopelessness may be inferred from the fact that, even in the well-known British flora, one authority describes sixty-two species of brambles and roses, another of equal eminence only ten species of the same groups; and it is by no means uncommon for two, five, or even ten species of one author to be classed as a single species by another. All this time geologists had been so assiduously at work in the discovery of organic remains that the extinct species often equalled, and, in some groups—as the Mollusca—very far exceeded those now living on the earth, and these were all found to belong to the very same classes and orders,



THE GREENHOUSE IN WHICH MR. DARWIN'S EXPERIMENTS AND OBSERVATIONS WERE MADE.

and to form part of one great system. Much attention was now paid to the geological succession of the different groups of animals, which were found to exhibit a progressive advancement from ancient to recent times, while the great breaks in the series between distinct great geological formations were held to show that the older forms of life had been destroyed, and were replaced by a new creation of a more advanced organization suited to the altered conditions of the world.

And thus, perhaps, we might have gone on to this day, ever accumulating fresh masses of fact, while each set of workers became ever more and more occupied in their own departments of study, and, for want of any intelligible theory to connect and harmonize the whole, less and less able to appreciate the labors of their colleagues, had not Charles Darwin made his memorable voyage around the world, and thenceforth devoted himself, as so many had done before him, to a life of patient research in the domain of organic nature. But how different was the result! Others have added greatly to our knowledge of details, or have created a reputation by some important work; he has given us new conceptions of the world of life, and a theory which



DARWIN'S USUAL WALK.

is itself a powerful instrument of research; has shown us how to combine into one consistent whole the facts accumulated by all the separate classes of workers, and has thereby revolutionized the whole study of nature. Let us endeavor to see by what means he arrived at this vast result.

Passing by the ancestry and early life of Darwin, which have been made known to the whole reading public by countless biographical notices, we may begin with the first event to which we can distinctly trace his future greatness—his appointment as naturalist to the *Beagle*, on the recommendation of his friend and natural history teacher, Professor Henslow, of Cambridge University. It was in 1831, when Darwin, then twenty-two years of age, had just taken his B. A., that he left England on his five years' voyage in the Southern Hemisphere. It is probably to this circumstance that the world owes the great revolution in our conception of the organic world so well known as the Darwinian theory. The opportunity of studying nature in new and strange lands; of comparing the productions of one country with those of another; of investigating the physical and biological relations of islands and continents; of watching the struggle for existence in regions where civilization has not disturbed the free action and reaction of the various groups of animals and plants on each other; and, what is perhaps more important still, the ample leisure to ponder again and again on every phase of the phenomena which presented themselves, free from the attractions of society and the disturbing excitement of daily association with contemporary men of science,—these are the conditions most favorable to the formation of habits of original thought, and the months and years which at first sight appear intellectually wasted in the companionship of uncivilized man, or in the solitary contemplation of nature, are those in which the seed was sown which was destined to produce in after-years the mature fruit of great philosophical conceptions. Let us then first glance over the "Journal of Researches," in which are recorded the main facts and observations which struck the young traveler, and see how far we can detect here the germs of those ideas and problems to the working out of which he devoted a long and laborious life.

The question of the causes which have produced the distribution and the dispersal of organisms seems to have been with him a constant subject of observation and meditation. At an early period of the voyage he collected infusorial dust which fell on the ship when at sea, and he notes the suggestive fact that in similar dust collected on a vessel three hundred miles from land he found particles of stone above the thousandth of an inch square, and remarks: "After this fact, one need not be surprised at the diffusion of the far lighter and smaller sporules of cryptogamic plants." He records many instances of insects occurring far out at sea, on one occasion when the nearest land was three hundred and seventy miles distant. He paid special attention to the insects and plants inhabiting the Keeling or Cocos, and other recently formed coralline or volcanic islands; the contrast of these with the peculiar productions of the Galapagos evidently impressed him profoundly; while the remarkable facts presented by this latter group of islands brought out so clearly and strongly the insuperable difficulties of the then accepted theory of the independent origin of species, as to keep this great problem ever present to his mind, and, at a later period, to lead him to devote himself to the patient and laborious inquiries which were the foundation of his immortal work. He again and again remarks on the singular facts presented by these islands. Why, he asks, were the aboriginal inhabitants of the Galapagos created on American types of organization, though the two countries differ totally in geological character and physical conditions? Why are so many of the species peculiar to the separate islands? He "is astonished at the amount of creative force, if such an expression may be used, displayed in these small, barren and rocky islands; and still more so at its diverse, yet analogous action on points so near each other."

The variations which occur in species, as well as the modifications of the same organ in allied species,—subjects which had been much neglected by ordinary naturalists,—were constantly noted and commented on. He remarks on the occasional blindness of the burrowing tucutucu of the pampas as supporting the view of Lamarck on the gradually acquired blindness of the aspalax; on the hard point of the tail of the trigonocephalus, which constantly vibrates and produces a rattling noise by striking against grass and brushwood, as a character varying toward the complete rattle of the rattlesnake; on the small size of the wild horses in the Falkland Islands, as progressing toward a small breed like the Shetland ponies of the north; and on the strange fact of the cattle having increased in size, and having partly separated into two differently colored breeds. While collecting the remains of the great extinct mammals of the pampas, he was much impressed by the fact that, however huge in size or strange in form, they were all allied to living South American animals, as are those of the cave-deposits of Australia to the marsupials of that country; and he thereon remarks: "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."

He also saw, at this early period, the important fact that there is some great and constant check to the increase of wild animals, though most of them breed very rapidly, and, of course, would increase in a geometrical ratio were some such check not in constant action. He traces the comparative rarity of a species to less favorable conditions of existence, and extinction to the normal action of still more unfavorable conditions, and compares the destruction of a species by man and its extinction by its natural enemies as being phenomena of the same essential nature. The various classes of facts here referred to seemed to him "to throw some light on the origin of species—that mystery of mysteries, as it has been called by one of our greatest philosophers"; and he tells us that, soon after his return home in 1837, it occurred to him "that something might perhaps be made out on this question by patiently accumulating and reflecting on all sorts of facts which could possibly have any bearing upon it." We know from his own statement that he had already perceived that no explanation but some form of the derivation or development hypothesis, as it was then termed, would adequately explain the remarkable facts of distribution and geological succession which he had observed during his voyage; yet he tells us that he worked on for five years before he allowed himself to speculate on the subject; and then, having formulated his provisional hypothesis in a definite shape during the next two years, he devoted fifteen years more to continuous observation, experiment, and literary research, before he gave to the astounded scientific world an abstract of his theory in all its wide-embracing scope and vast array of evidence, in his epoch-making volume, "The Origin of Species."

If we add to the periods enumerated above the five years of observation and study during the voyage, we find that this work was the outcome of *twenty-nine* years of continuous thought and labor, by one of the most patient, most truth-loving, and most acute intellects of our age. During all this long period only a very few of his most intimate friends were aware that he had departed from the then beaten track of biological study, while the great body of naturalists only knew him as a good geologist, as the writer of an interesting book of travels, and the author of an admirable monograph of the arrhipedia or barnacles, as well as of a most ingenious explanation of the origin and structure of coral-reefs—a series of volumes which were the direct outcome of his voyage, and which gave him an established reputation. Even when the great work at last appeared, few could appreciate the enormous basis of fact and experiment on which it rested, until, during the succeeding twenty years, there appeared that remarkable succession of works which exhibited a sample (and only a sample) of the exhaustless store of materials and the profound maturity of thought on which his early volume was founded. From these various works, aided by some personal intercourse and a correspondence extending over twenty years, the present writer will endeavor to indicate the nature and extent of Darwin's researches.

ALTHOUGH, as we have said, Darwin had early arrived at the conclusion that allied species had descended from common ancestors by gradual modification, it long remained to him an inexplicable problem how the necessary degree of modification could have been effected, and he adds: "It would thus have remained forever, had I not studied domestic productions, and thus acquired a just idea of the power of selection." These researches, very briefly sketched in the first and parts of the fifth and ninth chapters of the "Origin of Species," were published at length (after a delay of nine years, owing to ill health) in two large volumes, with the title "Animals and Plants under Domestication;" and no one who has not read these can form an adequate idea of the wide range and thorough character of the investigation on which every statement or suggestion in the former work was founded. The copious references to authorities show us that Darwin must have searched through almost the entire literature of agriculture and horticulture, of horse and cattle breeding, of sporting, of dog, cat, pigeon and fowl fancying, including endless series of reviews, magazines, journals of societies, and newspapers, besides every scientific treatise bearing in any way on the subject, whether published in England, on the Continent, or in America. The facts thus laboriously gathered were supplemented by personal inquiries among zoölogists and botanists, farmers, gardeners, sporting-men, pigeon-fanciers, travellers, and any one who could possibly afford direct personal information on any of the matters he was investigating. Then came his own observation and experiment, to fill up gaps, to settle doubtful points, or to determine questions the importance of inquiring into which no one had ever suspected; and lastly, there was the power of arrangement and comparison, the originality and depth of thought, which drew out from this vast mass of heterogeneous materials conclusions of the highest value as bearing on the question of the possible change of species, and the means by which it had been brought about.

In order to determine the nature and amount of the variability of domestic productions, he prepared skeletons of all the more important breeds of rabbits, pigeons, fowls, and ducks, as well as of the wild races from which they are known to have been produced, and showed, both by measurements and by accurate drawings, that not only superficial characters, but almost every part of the bony structure varied to such an amount as usually characterizes very distinct species or even distinct genera of wild animals. Another set of experiments was made by crossing the differents breeds of pigeons and fowls which were most completely unlike the wild race, with the result that in many cases the offspring were more like the wild ancestor than either of the parents. These experiments, supported by a mass of facts observed by other persons, served to establish the principle of the tendency of crosses to revert to the ancestral form; and this principle enabled him to explain the interesting fact of the frequent appearance of stripes on mules, and occasionally on dun-colored horses, on the hypothesis, supported by a mass of collateral evidence, that the common ancestor of the horse, ass, and zebra tribe was a striped and dun-colored animal.

A number of very important conclusions were deduced from the facts presented by domesticated animals and plants, a few of which may be here referred to. For example, it was proved that the parts most selected or which had already most varied—as the tail in fan-tailed pigeons, which has more tail-feathers than any other of the eight thousand different kinds of living birds,—were most subject to further variation; and this showed that, when once any part had begun to change, variations became more abundant, thus furnishing materials to render still further change in the same direction comparatively easy. This is the secret of the rapid improvement of breeds or races, and is equally applicable to the formation of species by natural selection. Again, it was found that in many cases, when much variation occurred, there was a tendency to a difference in the sexes which had not before existed. This has been observed in sheep, in fowls, and in pigeons, and it is very interesting as indicating the origin of that wonderful diversity of sex which occurs in several groups of animals. Another curious fact is the correlation of parts which occurs in many animals, such as the tusks and bristles of swine, and the hair and teeth in some dogs, both increasing or becoming lost together; the beaks and feet of pigeons, both increasing or diminishing together; the color and size of the leaves and seeds changing simultaneously in some plants; and numerous other instances which serve to explain some of the peculiar characters of natural objects for which we can discover or imagine no direct use.

The effects of disuse in causing the diminution of an organ was exhibited by careful comparison and measurements of tame and wild birds. The sternum, scapulæ, and furcula to which the muscles used in flight are attached, are found to be diminished in domestic pigeons, as were the wing-bones in domestic fowls, the capacity of the skull in tame rabbits, and the size and strength of the wings in silkworm moths. The evidence afforded by the breeds of pigeons (which have been domesticated for so many centuries and in so many parts of the world) of the process of selection, whether unconscious or methodical, is very clearly set forth, and serves as a typical example with which to compare the various phenomena presented by allied species in a state of nature; and in considering that evidence he thus replies to some objections:

"I have heard it objected that the formation of the several domestic races of the pigeon throws no light on the origin of the wild species of the columbidæ, because their differences are not of the same nature. The domestic races, for instance, do not differ, or hardly at all, in the relative lengths and shapes of the primary wing-feathers, in the relative length of the hind toe, or in habits of life, as in roosting and building on trees. But the above objection shows how completely the principle of selection has been misunderstood. It is not likely that characters selected by the caprice of man should resemble differences preserved under natural conditions, either from being of direct service to each species, or from standing in correlation with other modified and serviceable structures. Until man selects birds differing in the relative length of the wing-feathers or toes, etc., no sensible change in these parts should be expected. * * * With respect to the domestic races not roosting or building in trees, it is obvious that fanciers would never attend to or select such changes in habits."

Still more remarkable, perhaps, is the collection of facts afforded by plants, which can be so much more easily cultivated and experimented upon than animals, while the general phenomena they present are strikingly accordant in the two kingdoms. As an example of the great mass of facts afforded by horticulture, he records that three hundred distinct varieties were produced, in the course of fifty years, from a single wild rose *(Rosa spinosissima)*. We find in these volumes enormous collections of facts on bud-variation, or the occurrence of changes in the flower or leaf-buds of full-grown plants, from which new varieties can be and often are produced; and, after a most full and interesting discussion of the cases, it is shown that some are probably due to reversion to an ancestral form, others to reversion to one parent when the plant has been derived from a cross, and others, again, to that spontaneous variability which seems to be the universal characteristic of all living organisms.

Three very interesting chapters are then devoted to the subject of inheritance, and a host of strange and heretofore inexplicable facts are brought together, compared, and classified, and shown to be in accordance with a few general principles. Then follow five chapters on crossing and hybridism, perhaps the most important in the whole work, since they afford the clue to so much of the varied structure and complex relations of animals and plants. Notwithstanding the enormous mass of facts and observations here given, the portion relating to plants is often but an abstract of the results of his own elaborate experiments, carried on for a long series of years, and given at length in three separate volumes on "The Fertilization of Orchids," on "Cross and Self-Fertilization of Plants," and on "The Forms of Flowers." These works may be said to have revolutionized the science of botany, since, for the first time, they gave a clear and intelligible reason for the existence of that wonderful diversity in the form, colors, and structure of flowers, on the details of which the systematic botanist had founded his generic and specific distinctions, but as to whose meaning or use he was, for the most part, profoundly ignorant. The investigation of the whole subject of crossing and hybridity had shown that, although hybrids between distinct species usually produced sterile offspring, yet crosses between slightly different varieties led to increased fertility; and, during some experiments on this subject, Darwin found that the produce of these crosses were also remarkable for vigor of growth. This led to a long series of experimental researches, the general result of which was to establish the important proposition that cross-fertilization is of the greatest importance to the health, vigor, and fertility of plants. The fact that the majority of flowers are hermaphrodite, and appear to be adapted for self-fertilization, seemed to be opposed to this view, till it was found that, in almost every case, there were special arrangements for insuring, either constantly or occasionally, the transference of pollen from the flowers of one plant to those of another of the same species. In the case of orchids, it was shown that those strange and beautiful flowers owed their singular and often fantastic forms and exceptional structure to special adaptations for cross-fertilization by insects, without the agency of which most of them would be absolutely sterile. Many of the species are adapted to particular species or groups of insects, and can be fertilized by no others; and careful experiment and much thought was often required to find out the exact way in which this was effected. In some instances the structure of the flowers seemed adapted to prevent fertilization altogether, till it was at length discovered that a particular insect entering the flower in one particular way caused the pollen to stick to some part of its body, which was always the exact part which the insect, on visiting another flower, would bring in contact with the stigma, and thus fertilize it. These investigations explained a host of curious facts which had hitherto been facts only without meaning, such as the twisting of the ovary in most of our wild orchids, which was found to be often necessary to bring the flower into a proper position for fertilization,—the existence of sacs, cups, or spurs, the latter often of enormous length, but shown to be each adapted to the structure of some particular insect, and often serving to prevent other insects from reaching the nectar which they might rob without fertilizing the flower,—the form, size, position, rugosities, or color of the lip, serving as a landing-place for insects and a guide to the nectar-secreting organs,—the varied odors, sometimes emitted by day, and sometimes by night only, according as the fertilizing insect was diurnal or nocturnal, and other characters too numerous to refer to here, so that it became evident that every peculiarity of these wonderful plants, in form or structure, in color or marking, in the smoothness, rugosity, or hairiness of parts of the flower, in their times of opening, their movements, or their odors, had its special purpose, and was, in some way or other, adapted to secure the fertilization of the flower and the preservation of the species.

The next set of observations, on some of our commonest English flowers of apparently simple structure, were not less original and instructive. The cowslip *(Primula veris)* has two kinds of flowers in nearly equal proportions: in the one the stamens are long and the style short, and in the other the reverse, so that in the one the stamens are visible at the mouth of the tube of the flower, in the other the stigma occupies the same place, while the stamens are half way down the tube. This fact had been known to botanists for seventy years, but had been classed as a case of mere variability, and therefore considered to be of no importance. In 1860 Darwin set to work to find out what it meant, since, according to his views, a definite variation like this *must* have a purpose. After a considerable amount of observation and experiment, he found that bees and moths visited the flowers, and that their probosces became covered with pollen while sucking up the nectar, and further, that the pollen of a long-*stamened* plant would be most surely deposited on the stigma of the long-*styled* plants, and *vice versâ*. Now followed a long series of experiments, in which cowslips were fertilized either with pollen from the same kind or from a different kind of flower, and the invariable result was that the crosses between the two different kinds of flowers produced more good capsules, and more seeds in each capsule; and as these crosses would be most frequently effected by insects, it was clear that this curious arrangement directly served to increase the fertility of this common plant. The same thing was found to occur in the primrose, and in many other species of Primulaceæ, as well as in flax *(Linum perenne)*, lungworts *(Pulmonaria)*, and a host of other plants, including the American partridge-berry *(Mitchella repens)*. These are called dimorphic heterostyled plants.

Still more extraordinary is the case of the common loosestrife *(Lythrum Salicaria)*, which has both stamens and styles of three distinct lengths, each flower having two sets of stamens and one style, all of different lengths, and arranged in three different ways: (1) a short style, with six medium and six long stamens; (2) a medium style, with six short and six long stamens; (3) a long style, with six medium and six short stamens. These flowers can be fertilized in eighteen distinct ways, necessitating a vast number of experiments, the result being, as in the case of the cowslip, that flowers fertilized by the pollen from stamens of the same length as the styles, gave on the average a larger number of capsules and a very much larger number of seeds than in any other case. The exact correspondence in the length of the style of each form with that of one set of stamens in the other forms insures that the pollen attached to any part of the body of an insect shall be applied to a style of the same length on another plant, and there is thus a triple chance of the maximum of fertility. Some other species of lythrum, of oxalis, and pontederia, were also found to have three-formed stamens and styles; and in the case of the oxalis, experiments were made showing that crosses between flowers with stamens and styles of unequal length were always nearly barren. During these experiments twenty thousand seeds of *Lythrum Salicaria* were counted under the microscope. For several years a further supplementary series of experiments was carried out, showing that the seeds produced by the illegitimate crosses (as he terms them) were not only very few, but, when sown, always produced comparatively weak, small, or unhealthy plants, not likely to exist in competition with the stronger offspring of legitimate crosses. There is thus the clearest proof that these complex arrangements have the important end of securing both a more abundant and more vigorous offspring.

Perhaps no researches in the whole course of the study of nature have been so fertile in results as these. No sooner were they made known than observers set to work in every part of the world to examine familiar plants under this new aspect. With very few exceptions it is now found that every flower presents arrangements for securing cross-fertilization, either constantly or occasionally, sometimes by the agency of the wind, but more frequently through the mediation of insects or birds. Almost all the irregularity and want of symmetry in the forms of flowers, which add so much to their variety and beauty, are found to be due to this cause; the production of nectar and the various nectar-secreting organs are directly due to it, as are the various odors and the various colors and markings of flowers. In many cases flowers which seem so simply constructed that the pollen *must* fall on the stigma and thus produce self-fertilization, are yet surely cross-fertilized, owing to the circumstance of the stigma and the anthers arriving at maturity at slightly different periods, so that, though the pollen may fall on the stigma of its own flower, fertilization does not result; but when insects carry the pollen to another plant the flowers of which are a little more advanced, cross-fertilization is effected. There is literally no end to the subjects of inquiry thus opened up, since every single species, and even many varieties of flowering plants, present slight peculiarities which modify to some extent their mode of fertilization. This is well shown by the remarkable observations of the German botanist Kerner, who points out that a vast number of details in the structure of plants, hitherto inexplicable, are due to the necessity of keeping away "unbidden guests," such as snails, slugs, ants, and many other kinds of animals, which would destroy the flowers or the pollen before the seeds were produced. When this evident principle is once grasped, it is seen that almost all the peculiarities in the form, size, and clothing of plants are to be thus explained—as the spines or hairs of the stem and branches, or the glutinous secretion which effectually prevents ants from ascending the stem, the drooping of the flowers to keep out rain or to prevent certain insects from entering them, and a thousand other details which are described in Kerner's most instructive volume. This branch of the inquiry was hardly touched upon by Darwin, but it is none the less a direct outcome of his method and his teaching.

But we must pass on from these seductive subjects to give some indication of the numerous branches of inquiry of which we have the results given us in the "Origin of Species," but which have not yet been published in detail. The observations and experiments on the relations of species in a state of nature, on checks to increase and on the struggle for existence,—were probably as numerous and exhaustive as those on domesticated animals and plants. As examples of this we find indications of careful experiments on seedling plants and weeds, to determine what proportion of them were destroyed by enemies before they came to maturity; while another set of observations determined the influence of the more robust in killing out the weaker plants with which they come into competition. This last fact, so simple in itself, yet so much overlooked, affords an explanation of many of the eccentricities of plant distribution, cultivation, and naturalization. Every one who has tried it knows the difficulty or impossibility of getting foreign plants, however hardy, to take care of themselves in a garden as in a state of nature. Wherever we go among the woods, mountains, and meadows of the temperate zone, we find a variety of charming flowers growing luxuriantly amid a dense vegetation of other plants, none of which seem to interfere with each other. By far the larger number of these plants will grow with equal luxuriance in our gardens, showing that peculiarities of soil and climate are not of vital importance; but not one in a thousand of these plants ever runs wild with us, or can be naturalized by the most assiduous trials; and if we attempt to grow them under natural conditions in our gardens, they very soon succumb under the competition of the plants by which they are surrounded. It is only by constant attention, not so much to them as to their neighbors,—by pruning and weeding close around them so as to allow them to get a due proportion of light, air, and moisture, that they can be got to live. Let any one bring home a square foot of turf from a common or hill-top, containing some choice plant growing and flowering luxuriantly, and place it in his garden, untouched, in the most favorable conditions of light and moisture, and in a year or two it will almost certainly disappear, killed out by the more vigorous growth of other plants. The constancy of this result, even with plants removed only a mile or two, is a most striking illustration of the preponderating influence of organism on organism, that is, of the struggle for existence. The rare and delicate flower which we find in one field or hedge-row, while for miles around there is no trace of it, maintains itself there, not on account of any specialty of soil or aspect, or other physical conditions being directly favorable to itself, but because in that spot only there exists the exact combination of other plants and animals which alone is not incompatible with its well-being, that combination perhaps being determined by local conditions or changes which many years ago allowed a different set of plants and animals to monopolize the soil and thus keep out intruders. Such considerations teach us that the varying combinations of plants characteristic of almost every separate field or bank, or hill-side, or wood throughout our land, is the result of a most complex and delicate balance of organic forces—the final outcome for the time-being of the constant struggle of plants and animals to maintain their existence.

ANOTHER valuable set of experiments and observations are those bearing on the geographical distribution of animals and plants—a branch of natural history which under the old idea of special creations had no scientific existence. It is to Darwin that we owe the establishment of the distinction of oceanic from continental islands, while he first showed us the various modes by which the former class of islands have been stocked with life. By a laborious research in all the accounts of old voyages, he ascertained that none of the islands of the great oceans very remote from land possessed either land mammalia or amphibia when first visited; and on examination it is found that all these islands are either of volcanic origin or consist of coral reefs, and are therefore presumably of comparatively recent independent origin, not portions of submerged continents, as they were formerly supposed to be. Yet these same islands are fairly stocked with plants, insects, land-shells, birds, and often with reptiles, more particularly lizards, usually of peculiar species, and it thus becomes important to ascertain how these organisms originally reached the islands, and the comparative powers different groups of plants and animals possess of traversing a wide extent of ocean.

With this view Darwin made numerous observations and some ingenious experiments. He endeavored to ascertain how long different kinds of seeds will resist the action of salt water without losing their vitality, and the result showed that a large number of seeds will float a month without injury, while some few survived an immersion of one hundred and thirty-seven days. Now, as ocean currents flow on the average thirty-three miles a day, seeds might easily be carried a thousand miles, and in very exceptional cases even three thousand miles, and still grow. Again, it is known that drift-timber is often carried enormous distances, and some of the inhabitants of the remote coral-islands of the Pacific obtain wood by this means, as well as stones fastened among the roots. Now, Darwin examined torn-up trees, and found that stones are often inclosed by the roots growing around them so as to leave closed cavities containing earth behind; and from a small portion of earth thus completely inclosed, he raised three dicotyledonous plants. Again, the seeds that have passed through the bodies of birds germinate freely, and thus birds may carry plants from island to island. Earth often adheres to the feet of aquatic and wading birds, and these migrate to enormous distances and visit the remotest islands, and from earth thus attached to birds' feet several plants were raised. As showing the importance of this mode of transport, an experiment was made with six and three-fourths ounces of mud taken from the edge of a little pond, and it was found to contain the enormous number of five hundred and thirty-seven seeds of several distinct species! This was proved by keeping the mud under glass and pulling up each plant as it appeared, and at the end of six months the result was as given above. It was also found that small portions of aquatic plants were often entangled in the feet of birds, and to these as well as to the feet themselves mollusks or their eggs were found to be attached, furnishing a mode of distribution for such organisms. Experiments were also made on the power of land-shells to resist the action of sea-water; and we have already referred to the observations on volcanic dust carried far out to sea illustrating the facilities for the wide extension by aërial currents of such plants as have very minute or very light seeds. This series of observations and experiments, supplemented by those of other observers, has been applied by the writer of this article to explain in some detail the remarkable phenomena presented by the distribution of animals and plants over the chief islands of the globe (" Island Life "). The facts are of a character so anomalous and apparently contradictory that, on the old hypothesis of the special independent creation of each species, no rational explanation of them could be found; and we may fairly claim that the clear and often detailed explanation which can be given by means of the theories and investigations of Darwin lend a powerful support to his views, and go far to complete the demonstration of their correctness.

Our space will not permit us to do more than advert to the numerous ingenious explanations and suggestions with which the " Origin of Species " abounds, such as, for example, the strange fact of so many of the beetles of Madeira being wingless, while the same species, or their near allies on the continent of Europe, have full powers of flight; and that this is not due to any direct action of climate or physical conditions is proved by the equally curious fact that such species of insects as have wings in Madeira have them rather larger than usual. Equally new and important is the Darwinian explanation of the form of the bee's cell, which is shown to be due to a few simple instincts which necessarily lead to the exact hexagonal cell with the base formed of three triangular plates inclined at definite angles, on which so much mathematical learning and misplaced admiration have been expended; and this explanation is no theory, but is the direct outcome of experiments on the bees at work, as original as they were ingenious and convincing.

We must, however, pass on to the great and important work, " The Descent of Man and Selection in Relation to Sex," which abounds in strange facts and suggestive explanations; and for the reader who wishes to understand the character and bearing of Darwin's teachings, this book is the fitting supplement to the " Origin of Species " and the " Domesticated Animals and Plants." To give any adequate account of this most remarkable book and the controversies to which it has given rise, would require an article to itself. We refer to it here in order to point out what is not generally known, that its publication was entirely out of its due course, and was not anticipated by its author three years before. In the introduction to " Domesticated Animals" (published in 1868), after explaining the scope of that work, he told us that, in a second work, he should treat of " Variation Under Nature," giving copious facts on variation, local and general, on races, sub-species, and species, on geometrical increase, on the struggle for existence, with the results of experiments showing that diversity of forms enables more life to be supported on a given area, while the extermination of less improved forms, the formation of genera and families, and the process of natural selection, would be fully discussed. This work would have given all the facts on which Chapters II. to V. of the " Origin of Species " were founded. In a third work he proposed to show, in detail, how many classes of facts natural selection explains, such as geological succession, geographical distribution, embryology, affinities, classification, rudimentary organs, etc., etc., thus giving the facts and reasonings in full on which the latter part of the " Origin of Species " was founded. Unfortunately, neither of these works has appeared, and thus the symmetry and completeness of the body of facts which Darwin had collected have never been made public. The cause is well known to have been the continued pressure of ill-health. The work on " Domesticated Animals " was thus delayed many years, after which came the labor of bringing out a much enlarged edition of the " Origin of Species." The " Descent of Man " was, apparently, at first intended to be a comparatively small book, but a difficulty connected with the origin of the distinctive peculiarities of the two sexes led to an investigation of this subject throughout the animal kingdom. This was found to be of such extreme interest, and to have such important applications, that its development with the completeness characteristic of all the writer's work led to the production of two bulky volumes, followed by another volume on the " Expression of the Emotions in Man and Animals," not less instructive. None of Darwin's works has excited greater interest or more bitter controversy than that on man; and the correction of the numerous reprints, and of a final enlarged edition in 1874, was found to be so laborious a task as to convince him that any such extensive literary works as those projected and announced six years previously must be finally abandoned. This, however, by no means implied cessation from work. Observation and experiment were the delight and relaxation of Darwin's life, and he now continued and supplemented those numerous researches on plants we have already referred to. A new edition of an earlier work on the " Movements of Climbing Plants " appeared in 1875; a thick volume on " Insectivorous Plants " in the same year; " Cross and Self-Fertilization " in 1876; the " Forms of Flowers " in 1877; the " Movements of Plants," embodying much original research, in 1880; and his remarkable little book on "Earthworms" in 1881. This last work is highly characteristic of the author. In 1837 he had contributed to the Geological Society a short paper on the formation of vegetable mold by the agency of worms. For more than forty years this subject of his early studies was kept in view; experiments were made, in one case involving the keeping a field untouched for thirty years,—and every opportunity was taken of collecting facts and making fresh observations, the final result being to elevate one of the humblest and most despised of the animal creation to the position of an important agent in the preparation of the earth for the use of the higher animals and of man.

The sketch now given of Darwin's work is in many respects imperfect, since it has given no account of those earlier important labors which would alone have made the reputation of a lesser man. None but the greatest geologists have produced more instructive works than the two volumes of "Geological Observations" and the profound and original essay "On the Structure and Distribution of Coral Reefs"; while the numerous researches on the fertilization and structure of flowers and the movements of plants would alone place him in the rank of a profound and original investigator in botanical science; the most distinguished zoölogists and anatomists might be proud of the elaborate "Monograph of the Cerripedia," of which a competent judge says:

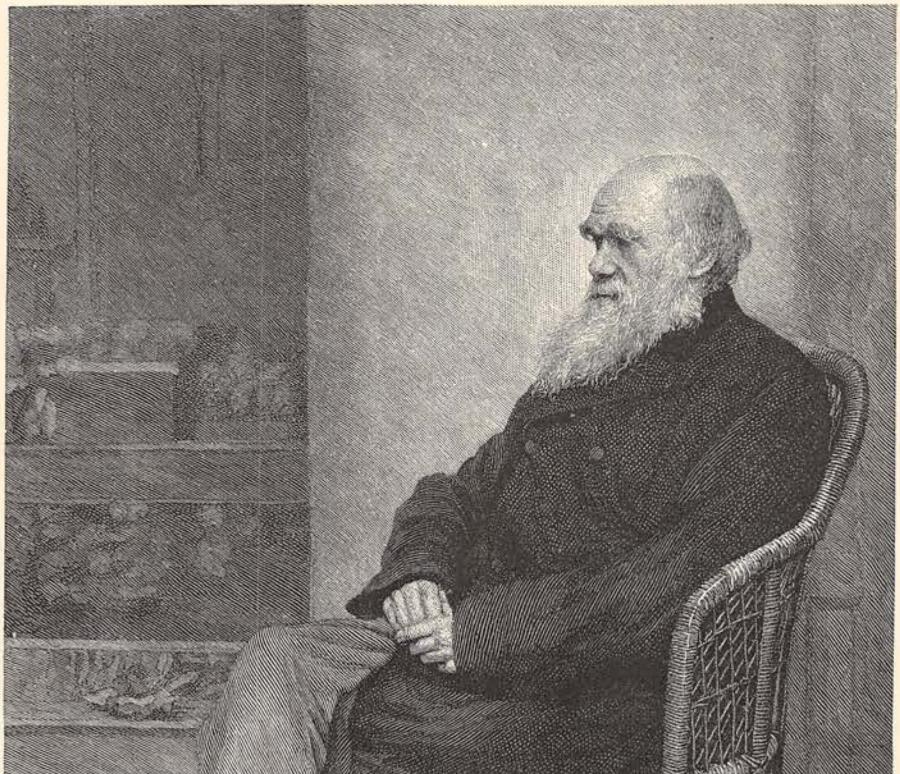
"The prodigious number and minute accuracy of his dissections, the exhaustive detail with which he worked out every branch of his subject—sparing no pains in procuring every species that it was possible to procure, in collecting all the known facts relating to the geographical and geological distribution of the group, in tracing all the complicated history of the metamorphoses presented by the individuals of the sundry species, in disentangling the problem of the homologies of these perplexing animals, etc.—all combine to show that, had Mr. Darwin chosen to devote himself to a life of morphological work, his name would probably have been second to none in that department of biology." ["Nature," Vol. 26, p. 99.]

Yet these works, great as is each of them separately, and, taken altogether, amazing as the production of one man, sink into insignificance as compared with the vast body of research and of thought of which the "Origin of Species" is the brief epitome, and with which alone the name of Darwin is associated by the mass of educated men. I have here endeavored, however imperfectly, to enable non-specialists to judge of the character and extent of this work, and of the vast revolution it has effected in our conception of nature,—a revolution altogether independent of the question whether the theory of "natural selection" is or is not as important a factor in bringing about changes of animal and vegetable forms, as its author maintained. Let us consider for a moment the state of mind induced by the new theory and that which preceded it. So long as men believed that every species was the immediate handiwork of the Creator, and was therefore absolutely perfect, they remained altogether blind to the meaning of the countless variations and adaptations of the parts and organs of plants and animals. They who were always repeating, parrot-like, that every organism was exactly adapted to its conditions and surroundings by an all-wise being, were apparently dulled or incapacitated by this belief from any inquiry into the inner meaning of what they saw around them, and were content to pass over whole classes of facts as inexplicable, and to ignore countless details of structure under vague notions of a "general plan," or of variety and beauty being "ends in themselves"; while he whose teachings were at first stigmatized as degrading or even atheistical, by devoting to the varied phenomena of living things the loving, patient, and reverent study of one who really had *faith* in the beauty and harmony and perfection of creation, was enabled to bring to light innumerable hidden adaptations, and to prove that the most insignificant parts of the meanest living things had a use and a purpose, were worthy of our earnest study, and fitted to excite our highest and most intelligent admiration.

That he has done this is the sufficient answer to his critics and to his few detractors. However much our knowledge of nature may advance in the future, it will certainly be by following in the pathways he has made clear for us, and for long years to come the name of Darwin will stand for the typical example of what the student of nature ought to be. And if we glance back over the whole domain of science, we shall find none to stand beside him as equals; for in him we find a patient observation and collection of facts, as in Tycho Brahe; the power of using those facts in the determination of laws, as in Kepler; combined with the inspirational genius of a Newton, through which he was enabled to grasp fundamental principles, and so apply them as to bring order out of chaos, and illuminate the world of life as Newton illuminated the material universe. Paraphrasing the eulogistic words of the poet, we may say, with perhaps a greater approximation to truth:

"Nature and Nature's laws lay hid in night;
God said, 'Let Darwin be,' and all was light."

Alfred R. Wallace.



Ch. Darwin