In a number of cases it has been represented that it was difficult to control the gathering or collection of certain commodities because of the character of the labor and nature of the materials, but this contention is apparently not well founded because numerous importations of such goods are being offered which are found satisfactory.

There is no doubt but that a certain small per cent. oppose the proper enforcement of the law in reference to imported goods and apparently do much to defeat its purpose, but it is gratifying to know that the vast majority of importers, manufacturers, and various dealers have co-operated faithfully in its enforcement. Upon various occasions generous support and aid have been given by supplying specific information upon particular points involved, and it is largely due to this spirit of co-operation and assistance that it may be said the law is becoming more effective daily. The evidence furthermore shows that foreign dealers recognize the fact that the United States is no longer the dumping ground of their refuse products, which have little or no sale in their own country.

CHARLES DARWIN, AS A BOTANIST.*

By John W. Harshberger, Ph.D.

Charles Darwin lies buried in Westminster Abbey in the north aisle of the nave close to the angle of the choir-screen beside the body of Sir John Herschel, the celebrated astronomer, and not far off in the central part of the nave lie David Livingstone, the African explorer, and Sir Isaac Newton, the philosopher and mathematician. Truly in this cathedral-mausoleum and in the most prominent places lie the mortal remains of a galaxy of great men of whom the English-speaking race may be justly proud. No honor too great can be bestowed upon men of such sterling intellectual worth. Darwin formulated the principles of organic evolution; Sir Isaac Newton was the formulator of the law of gravitation; Sir John Herschel explored the starry realm and made many discoveries of importance, while David Livingstone with unequalled determination opened up the dark continent to the knowledge of civilized men.

* A paper read before the Association of Doctors of Philosophy, University of Pennsylvania, on the occasion of the Darwin Centenary Memorial meeting held Friday, February 12, 1909, at the University.

Each of them made explorations into the unknown and each contributed something to dispel the ignorance and superstition which enshrouded the true conception of the universe. Darwin began his scientific career with the voyage of the H. M. S. *Beagle*. He is usually considered to be a biologist in the narrow sense in which that term is generally used in its application to zoölogists, and yet some of his most important discoveries were made by him as a botanic investigator. We find all through the journal of his voyage around the world reference to his observations of the plant life of the countries which he visited. I cannot do better by way of an introduction to what follows than to make a few quotations from the pages of his diary where he mentions particularly his study of the plants in the field, while collecting them for the subsequent study of specialists, such as Sir Joseph Hooker, Professor Henslow, and Reverend M. J. Berkley. His delight and enthusiasm as a naturalist on seeing the Brazilian vegetation near Rio Janeiro for the first time are expressed thus: "Following a pathway I entered a noble forest, and from a height of five or six hundred feet, one of those splendid views was presented, which are so common on every side of Rio. At this elevation the landscape attains its most brilliant tint, and every form, every shade, so completely surpasses in magnificence all that the European has ever beheld in his own country, that he knows not how to express his feelings. The general effect frequently recalled to mind the gayest scenery of the Opera-house, or the great theatres. I never returned from these excursions empty handed." That comprehensiveness of view which characterize the writings of Darwin as a finished naturalist is exemplified in the journal, while he was an apprentice on board the *Beagle*. In one paragraph he gives us in a nutshell a complete description of the vegetation of South America which I, as a plant geographer, cannot refrain from quoting in full. Darwin writes: "Confining our view to South America, we should certainly be tempted to believe that trees flourish only under a very humid climate; for the limit of the forest-land follows, in a most remarkable manner, that of the damp winds. In the southern part of the continent, where the western gales, charged with moisture from the Pacific, prevail, every island on the broken west coast, from lat. 38° to the extreme part of Tierra del Fuego, is densely covered by impenetrable forests. On the eastern side of the Cordillera over the same extent of latitude, where a blue sky and a fine climate prove

that the atmosphere has been deprived of its moisture by passing over the mountains, the arid plains of Patagonia support a most scanty vegetation. In the more northern parts of the continent, within the limits of the constant southeastern trade-wind, the eastern side is ornamented by magnificent forests; whilst the western coast, from lat. 4° S. to lat. 32° S. may be described as a desert; on this western coast northward of lat. 40° S., where the trade-wind loses its regularity, and heavy torrents of rain fall periodically, the shores of the Pacific, so utterly desert in Peru, assume near Cape Blanco the character of luxuriance so celebrated at Guayaquil and Panama. Hence in the southern and northern parts of the continent the forest and desert lands occupy reversed positions with respect to the Cordillera, and these positions are apparently determined by the direction of the prevalent winds. In the middle of the continent there is a broad intermediate band, including Central Chile and the provinces of La Plata, where the rain-bringing winds have not to pass over lofty mountains and where the land is neither a desert nor covered by forests. But even the rule, if confined to South America, of trees flourishing only in a climate rendered humid by rain-bearing winds, has a strongly marked exception in the case of the Falkland Islands. These islands, situated in the same latitude with Tierra del Fuego and only between two and three hundred miles distant from it, having a nearly similar climate, with a geological formation almost identical, with favorable situations, and the same kind of peaty soil, yet can boast of few plants deserving even the title of bushes; whilst in Tierra del Fuego it is impossible to find an acre of land not covered by the densest forest." With the same scrupulous care of details and in his characteristic straightforward style, Darwin goes on in his journal to describe the history of the voyage with Captain FitzRoy, together with a sketch of those observations in natural history and geology which the young naturalist hoped might possess some interest for the general reader. Darwin's hope that his observations might prove of some interest as well as remain of general value has had a recent exemplification. At the meeting of the American Association for the Advancement of Science held in Baltimore during the last Christmas holidays, Prof. Roland Thaxter, of Harvard University, described in a very entertaining manner the result of a trip to the southern end of South America in the Straits of Magellan and by way of introduction spoke of the botanic observations of Charles Darwin on the beech forests of

that little known country, which showed the keenness with which every natural object was scrutinized by him. A peculiar family of sac fungi (Ascomycetes) contains only one genus Cyttaria having the appearance of the morel (Morchella), but without a stem. All known species are parasitic on the evergreen beech, Nothofagus. The fruit bodies of this fungous parasite often grow in dense clusters, springing from swollen portions of the host which it partially deforms. The different species which are found in Chile, Patagonia, Tasmania, and New Zealand are edible and at one time formed a staple food of the natives. Specimens were collected by Prof. Thaxter on his recent visit and in connection with this recent reminder of Darwin's observations on this fungus the following may be mentioned appropriately. The forest commences at the line of high-water mark, and was so thick that it was necessary to have recourse to the compass to find one's way. "In the deep ravines, the death-like scene of desolation exceeded all description; outside it was blowing a gale, but in these hollows not even a breath of wind stirred the leaves of the tallest trees and it was gloomy, cold, and wet. In the valleys it was scarcely possible to crawl along, they were so completely barricaded by great mouldering trunks, in the case of the Winter's Bark (Drimys Winteri) four to six feet in girth and the beech seven feet in diameter, which had fallen down in every direction. In this forest grows one vegetable production deserving of notice as an article of food to the Fuegians. It is a globular, bright yellow fungus, which grows in vast numbers on the beech trees. When young it is elastic and turgid, with a smooth surface; but when mature it shrinks, becomes tougher, and has its entire surface deeply pitted or honey-combed. In Tierra del Fuego the fungus in its tough and mature state is collected in large quantities by the women and children, and it is eaten uncooked. It has a mucilaginous, slightly sweet taste, with a faint smell like that of a mushroom." So much for the botanic observations of Darwin as recorded in the "Journal of Researches into the Natural History and Geology of the Countries Visited during the Voyage of the H. M. S. *Beagle* round the World."

Darwin's work as a botanist was many-sided. In the published list of 116 separate titles of books and papers contributed directly to science, 37 books and papers are strictly botanic, the rest are zoölogic, geologic, and devoted to the subject of general evolution. One-third then of all the scientific contributions of Darwin

are botanic and before commenting on the character of his botanic studies let me briefly enumerate his most important botanic writings.

The following important books should be mentioned: "On the Contrivances by which Orchids are Fertilized by Insects," 1862; "The Variation of Animals and Plants Under Domestication," 1868 (two volumes); "Insectivorous Plants," 1875; "The Movements and Habits of Climbing Plants," 1875; "The Effects of Cross and Self-Fertilization in the Vegetable Kingdom," 1876; "The Different Forms of Flowers on Plants of the Same Species," 1877; "The Power of Movement in Plants," assisted by Francis Darwin, 1880.

His minor botanic contributions I will divide for sake of treatment into the following categories: (1) papers dealing with the pollination of flowers; (2) papers dealing with plant distribution; (3) papers dealing with the movements of plants; (4) papers dealing with questions of physiologic botany. Darwin in the papers of the first group dealt with the agency of bees in the fertilization of papilionaceous flowers, on the fertilization of winter flowering plants, on the fertilization of the Fumariaceæ, but the most important contributions included in this group were those on the two forms or dimorphic condition of the species of Primula and their remarkable sexual relations, on the three remarkable sexual forms of Catasetum tridentatum and on the sexual relations of the three forms of Lythrum salicaria. Darwin retained his interest in questions of geographic distribution even after he had settled to the quiet life at Down. Two short papers are of interest in this connection. While on the *Beagle,* he had studied the problems connected with the origin of the vegetation of oceanic islands. To account for the distribution of many plants of the Pacific Islands the botanist must have recourse to sea currents to explain the phenomena. Darwin's paper on this subject in the *Gardener's Chronicle* deals with the vitality of seeds, his second paper treats of the action of sea-water on the germination of seeds and appeared in the *Journal of the Linnaean Society.*

The papers dealing with the movements of plants may be dismissed here without further comment, because most of the observations recorded in them were published in his more pretentious works on the same subject. I can find only two papers of a purely physiologic character, namely, one on the action of carbonate of ammonia on the roots of certain plants, and another on the action

of this same chemical on the chlorophyll bodies. Having briefly summarized the books and papers which bear strictly upon botany, it is important briefly to describe the botanic work which appeals to the speaker as being of the greatest import to the science. Darwin's activity as a botanist extended over a period of about fifty years, from 1831, when he left England on the voyage of the *Beagle,* until late in 1881, when on a call upon Mr. Romanes in London, in December, he was seized when on the door-step with an attack apparently of the same kind as those which afterwards became so frequent. During the fifty years of active life, he accomplished a tremendous amount of scientific work, notwithstanding the fact that he was a great sufferer and frequently was incapacitated altogether.

It would be incorrect to state that all of Darwin's botanic work will be lasting. The experience of breeders was inadequate to the purposes of Darwin's theories. It was neither critic nor scientific. Laws of variation were barely conjectured; the different types of variability were distinguished imperfectly. Quetelet's law of variation had not yet been published. Mendel's law of hybrids was unknown. Innumerable minor points which go to elucidate the breeder's experience were unknown in Darwin's time. No wonder that he made mistakes, and laid stress on modes of descent which have been proved to be of minor importance or even of doubtful validity. Yet with all these apparently insurmountable difficulties Darwin discovered the great principle which rules the evolution of organism, viz., natural selection. His scientific observations and experimental work were of the most painstaking and detailed character. He had developed a power of sticking to a subject until he had mastered it to his satisfaction. He used almost to apologize for his patience, saying that he couldn't bear to be beaten, as if this were rather a sign of weakness on his part. He often quoted the saying, "It's dogged as does it." He laid the foundations of modern scientific methods of thought and as the formulator of the principles of organic evolution his name will go down to posterity. In the twenty-seven years since his death, the problems in botany and zoölogy have been attacked from many standpoints until with the advances that have been made in paleontology, histology, cytology, physiology, taxonomy, and the breeder's art, the theories of organic evolution have been revolutionized almost entirely, and we have sects of Neo-Darwinists and Ultra-Darwinists and what not.

The advances that have been made by the assistance of many workers have necessitated a restatement of all of the most important doctrines which Darwin enunciated. Take, for example, the emphasis which he laid upon the principle that Nature abhors continuous self-fertilization. He has given us by his experiments narrated in "Cross and Self-Fertilization in the Vegetable Kingdom" some accurate data tending to show the actual effect of inbreeding for a great variety of species. His experiments were with some 57 species, belonging to 52 genera. One of his most extensive series of experiments was carried on with the common morning glory (Ipomœa purpurea). This species was bred, both crossed and self-fertilized, for ten generations. In every generation, the crossed forms were larger than the self-fertilized, the average being as 100 is to 77. Not only that, but they were more productive. In the sixth generation, however, there appeared a specially vigorous plant that overtopped its own competitor by half an inch, and exceeded in height all but three of the series. Darwin named this plant "Hero" and remarks, "I was so much surprised at this fact that I resolved to ascertain whether this plant would transmit its powers of growth to its seedlings." Accordingly, he fertilized a number of flowers of Hero with their own pollen and planted seedlings in competition with inbred plants and with the cross-bred as well. The results obtained showed that Hero and its descendants varied from the common type not only in acquiring great power of growth and increased fertility, when subjected to self-fertilization, but in not profiting from a cross with distinct stock. Although Darwin was surprised at Hero and its descendants, yet he mentioned the case as obviously contrary to the usual procedure among plants. We now know, however, that there are many hundreds of plants which possess cleistogamous flowers, which are habitually self-pollinated without any apparent diminution in vigor or hardiness, as, for example, our common blue violet which produces seed more abundantly underground from cleistogamous flowers than from the bright blue flowers which are one of the glories of our hillsides in the early springtime. The same general exception has been proved in animal breeding, where line breeding has been found one of the most powerful methods of improving the race of our common domestic animals, and that inbreeding of the most pronounced kind is not always detrimental provided the breeder selects the animals to be bred with reference to their vigor and fertility.

Darwin established the department of biology known to-day as ecology. With Darwin as a botanist we are especially concerned, so that we may refer in particular to work which he did in plant ecology. The first botanic book to appear was a little treatise on the pollination of orchids by insects, published separately, as it was too large to be incorporated with any other subject, and its object was to show that the contrivances by which orchids are fertilized are as varied and almost as perfect as any of the most beautiful adaptations in the animal kingdom, and secondly to show that these contrivances have for their main object the fertilization of the flowers with pollen brought by insects from a distant plant. One of the most curious of the orchids studied by Darwin was Coryanthes speciosa, the flowers of which are very large and hang down. The distal part of the lip petal forms a large bucket over which arise two appendages which drop fluid into it. When the labellum bucket is full the fluid overflows by a spout, which is over-arched by the column which bears the stigma and pollen-masses in such a position that an insect, which has had an involuntary bath in the liquid by falling into it, is compelled to force its way out through a narrow passage so placed that the insect first brushes its back against the stigma and afterwards against the viscid disks of the pollen-masses and thus removes them, to be carried in flight to another flower.

Darwin's ecologic observations on insectivorous plants began after his curiosity was aroused by the common sundew. He writes: "During the summer of 1860 I was surprised by finding how large a number of insects were caught by the leaves of the common sundew Drosera rotundifolia on a heath in Sussex. I had heard that insects were thus caught, but knew nothing further on the subject. I gathered by chance a dozen plants bearing fifty-six fully expanded leaves, and on thirty-one of these dead insects or remnants of them adhered." After the most painstaking experimental study of the plant Darwin concludes, "The results have proved highly remarkable, the more important ones being, first, the extraordinary sensitiveness of the glands to slight pressure and to minute doses of certain nitrogenous fluids as shown by the movements of the so-called hairs or tentacles; second, the power possessed by the leaves of rendering soluble or digesting nitrogenous substances, and of afterwards absorbing them; third, the changes which take place within the cells of the tentacles when the glands are excited in various ways."

During many years Professor Asa Gray of Harvard University maintained an active correspondence with Darwin, who was enabled to secure and observe a number of American plants of striking ecologic type. Stimulated to inquiry by a paper of Prof. Gray's on the movements of the tendrils of some cucurbitaceous plants, Darwin undertook the study of over 100 widely distinct species of climbing plants which presented sufficient novelty to justify him in publishing his book of 208 pages entitled "The Movements and Habits of Climbing Plants," which appeared in 1876. His study led him to divide them into four classes: first, those which twine spirally round a support, and are not aided by any other movement; second, those endowed with irritable organs, which when they touch any object clasp it; such organs consisting of modified leaves, branches, or flower peduncles. Plants of the third class ascend by the aid of hooks, and those of the fourth by rootlets. As to the evolution of the climbing habit Darwin concludes that leaf climbers were primordially twiners and tendril bearers (when formed of modified leaves) were primordially leaf climbers.

A typic flower has a pistil surrounded by a row of stamens so that it would seem at first sight easy for the pollen to fall on the stigma. Such self-pollination does happen, but in the majority of flowers there are three principal modes by which self-fertilization is presented. First, in many species the stamens and pistils are situated in different flowers; such species are called diclinous, which is either monœcious with the distinct flowers on the same plant or dicœcious on different plants. Second, Sprengel discovered dichogamy where the pistil and stamens mature at different times so that, as in Arum, when the pistil matures before the anthers these plants are proterogynous, when the anther matures before the pistil proterandrous. Darwin discovered the third method in the presence of two or more kinds of flowers (heteromorphism) on the same species differing in the relative position of the stamens and the pistil which are so placed as to favor the transference by insects of the pollen from the anther of the one form to the pistil of the other. Plants with two kinds of flowers are called dimorphic, those with three kinds trimorphic. The results of these studies were incorporated in a volume entitled "Different Forms of Flowers on Plants of the Same Species," 1877, dedicated to Professor Asa Gray as a small tribute of respect and affection.

The last volume by Darwin of a botanic character was one

entitled "Power of Movement in Plants," where, with this title as a text, Darwin shows that apparently every growing part of every plant is continually circumnutating though often on a small scale, and in this universally present movement we have the basis for the acquirement of the most diversified movements. Thus, the great sweeps made by the stems of twining plants and by the tendrils of other climbers result from a mere increase in the amplitude of the ordinary movement of circumnutation. The leaves of various plants, as the clover, sleep at night, in other cases various organs show movements to the light or from the light, as again are equally prevalent movements of stems, etc., towards the zenith, and of roots towards the centre of the earth. Darwin laid the foundation for the ecologic study of these various tropisms which the use of modern experimental methods of research have extended and made more exact by the automatic recording of the movements by suitably designed apparatus connected with the growing plant.

Other botanists may have exceeded Darwin in the extent and variety of their discoveries, but Darwin represents an era of philosophic thought, and as the centre of the intellectual maelstrom which his theories created, he naturally stands, as Saul did of old, head and shoulders above his scientific contemporaries. One of the greatest of these was Karl Naegeli. He was one of the first among German botanists to introduce a strict method of thought, but Naegeli's method was applied to facts which as facts were inaccurately observed. Darwin collected data from the literature in support of an idea, Naegeli applied his logic to observations which were in part untrustworthy, but this much must be said that Darwin's "Origin of Species," published in the year 1859, delivered us from the unlucky dogma of constancy. He removed the mediævally placed shackles from the theories of the organic world and introduced a new philosophy more in harmony with the facts—the end of which is not yet.