'of birds in the Carboniferous, the Devonian, and the Silurian rocks.' But not a trace of birds makes its appearance until the Oölitic, or perhaps the New Red Sandstone formation.

In the second lecture, the origin of birds from saurians (lizards of the crocodile type) is most learnedly maintained and illustrated. Conceive a long-necked *Plesiosaurus*, in its wallowings along a rocky shore, learning to erect itself on its hinder paddles, and then to take a spring; then the membranous wing of the huge bat-like pterodactyle, which was literally a flying lizard, to be developed, as in the flying fish and the flying squirrel; then scales to be replaced by some lighter covering, first, perhaps, a coarse hairy coat like that of the emu, then feathers adapted for flight. There is nothing impossible in all this. There are abundant analogies that might be cited in favour of such a hypothesis; nay, more, there are actual fossils of *Ornithoscelida*, which go far to prove that the above sketch has more of history in it than of hypothesis.

In Lecture iii. Professor Huxley illustrates his view of evolution by a most interesting exposition of the natural history of the horse. Fossil forms are known which have a triple hoof, and in our existing horse vestiges exist in the leg bones showing indications of such a formation. Quite recently a living horse was shown which had two side-hoofs on one leg,—a return to the primitive type, by a principle known as *atavism*, or reversion.

Professor Huxley thinks it probable that we must look to America, rather than to Europe, for the original seat of the equine series. Yet, at the Spanish conquest of Mexico the animal had so completely died out, that the Mexicans were amazed at the sight of a horse and his rider, and no traces of the existence of the horse were then found in any part of the Amerian continent. Nevertheless, the Greek and the Roman names for the animal, which were connected with the Sanscrit *açva*, 'the quick,' point to its existence in prehistoric times in the far East.

The volume concludes with an address, delivered at Baltimore, on University education, and a lecture on the study of Biology, or the science of living things. In the latter, which is a very able essay, he reiterates his conviction that man is but a member of one common plan and a modification of one great fundamental unity. Evolution, he considers—given time and the necessary conditions, external and internal, to affect it—will explain everything. 'In fact,' he says, 'the whole evidence is in 'favour of evolution, and there is none against it.'

This sentence is remarkable as coming from such an authority. And though it is contested and denied by so many, we cannot close our eyes to the fact that the doctrine is rapidly gaining acceptance with men of the highest scientific attainments.

The Effects of Cross and Self-Fertilization in the Vegetable Kingdom. By CHARLES DARWIN, M.A., F.R.S., &c. John Murray.

However prodigal Nature may be of her bounties, she keeps securely locked in her bosom the secrets of their production, and it requires all

the patience and skill of science rigorously applied to forge a key which will unlock the casket. In this quest there are few happy surprises in store for the worker, and he alone can hope for success who, like Mr. Darwin, devotes years of zealous and painstaking inquiry and experiment to find a way to the labyrinth where, in glorious simplicity, the goddess sits enthroned on law. How easily deceived we often are when we think we have arrived at the solution of our problem, and find that some smallest thread of the silken clue which was to lead us to success has been faulty and has given way, and our work must recommence; that some apparently most trivial aperture in the fortress of our experiments has escaped us, and the whole fabric of observation we have laboriously built up crumbles to pieces under our hands. Generalizations on the matters treated of by the author are easily made, but successive proofs of undue haste, leading to erroneous conclusions, have led inquirers to pause and prefer, at least for the present, the accumulation of facts to the enunciation of opinions. How easily mistakes may be made by the most experienced is shown in a matter upon which Mr. Darwin himself ventured at the commencement of this year to express a decided opinion, namely, that the almost universal absence of holly berries in the late season was the result of an unusual absence of bees in the preceding spring; but the testimony of many acute observers convinced the author that he was in error, and that the spring frosts having caused the dropping of the flower before the setting of the fruit was the *vera causa* of the deplored absence of our usual Christmas decoration. For eleven years, we are told in this charming volume, has Mr. Darwin pursued his investigations into the modes of fertilization of plants, but as yet little more than the alphabet of the subject has been learned, and there are few principles which can be considered as absolutely determined. There are many observers doing good work in this subject, one of the most vital interest to mankind—for to determine the circumstances which tend to plenty and what aids development, whether in animal or vegetable life, is at the very pinnacle of human achievement. In order to give a slight sketch of what is the work which is now being laboriously carried on in many parts of Europe, we may arrange all flowering plants under three classes. And first we have those plants called *Diœcious*, on which the flowers are all of one sex. A notable example is furnished by the common aucuba—the spotted laurel so generally cultivated. For many years these plants have been grown and become naturalized in our gardens, both in town and country, but only the female had been introduced, and it is only within the last few years that the enterprizing traveller Fortune has enriched us with the male shrub, and already we have not only numberless varieties of the once uniform evergreen, but in all our gardens the brilliant green and white of the leaves is embellished by the bunches of scarlet berries which add a thousand new graces to our old favourite. *Monœcious* plants are those which have male and female flowers; but these are distinct on the same plant, as we see on the charmingly variegated-leaved begonias, or in the tuberous-rooted varieties of the same plant, with their exquisitely coloured, drooping, and semi-closed bell-shaped flowers. These are easily

distinguished as to their sex even by the casual observer, without the necessity of examining stamens or pistils, by the three-lobed seed capsule at the base of the female flower. In the last division the flowers are *hermaphrodite*, that is, each flower contains all the organs necessary for the reproduction of the species. Who has not been tempted by the lovely golden-rayed lily of Japan, the *Lilium auratum* of late introduction, to stoop to conquer that the glorious perfume might be fully inhaled? But we should hardly say stoop: this might have been true when we commenced the growth, and were content, in the heated atmosphere of a stove or the closest corner of the greenhouse, with four to five of the silver and gold treasures suspended on delicate stems; while now, in the open ground, eighty to one hundred blooms, on stout rods ten to twelve feet high, reward our nearer approach to nature. From the midst of the partially recurved corolla hangs down a long stem or pistil, covered at the point or base with a syrupy fluid, and lower down five stamens with hinged anthers surround the central female organ. These anthers are covered with brown dust or pollen grains, ready to transfer itself to our cheeks as we intrude too closely, and unconsciously imitate the insect, which, in its quest for nectar at the base of the flower, gets its wings or body all powdered over with spores or dust, which is to act as the fertilizer in the next plant visited. Of this class there is a large proportion of plants which require no external influence in order to mature their seed—they are in fact self-fertilizers—whereas in the two other classes, the male and female flowers being either distinct on the same plant or on different plants, some agency of transport is necessary to convey the pollen from the anther of the stamens to the style of the pistil. It will be at once evident that a flower may be fertilized either by its own pollen or by pollen from some other flower—the first is distinguished by being called self-fertilization, and the latter by the term cross-fertilization. From very early times this mode of fertilizing flowers was practised, but without any knowledge on the part of the operators of the reasons for the proceeding; and the Egyptians, while they by this mode procured fruit on their date-trees, used the process in some cases most absurdly, showing that the true principle of action was entirely unknown, and that what they did was entirely empirical. The author says: 'It often occurred 'to me that it would be advisable to try whether seedlings from cross-'fertilized flowers were in any way superior to those from self-fertilized 'flowers. But as no instance was known with animals of any evil 'appearing in a single generation from the closest possible interbreeding, 'that is between brothers and sisters, I thought that the same rule would 'hold good with plants; and that it would be necessary, at the sacrifice 'of too much time, to self-fertilize and intercross plants during several 'successive generations, in order to arrive at any result. I ought to have 'reflected that such elaborate provisions favouring cross-fertilization, as 'we see in innumerable plants, would not have been acquired for the sake 'of gaining a distant and slight advantage, or of avoiding a distant and 'slight evil. Moreover, the fertilization of a flower by its own pollen 'corresponds to a closer form of interbreeding than is possible with

'ordinary bisexual animals, so that an earlier result might have been 'expected. I was at last led to make the experiments recorded in the 'present volume from the following circumstance: For the sake of 'determining certain points with respect to inheritance, and without any 'thought of the effects of close interbreeding, I raised close together two 'large beds of self-fertilized and crossed seedlings from the same plant of '*Linaria vulgaris*. To my surprise the crossed plants, when fully grown, 'were plainly taller and more vigorous than the self-fertilized ones. 'Bees incessantly visit the flowers of this linaria, and carry pollen from 'one to the other; and if insects are excluded, the flowers produce 'extremely few seeds, so that the wild plants from which my seedlings 'were raised must have been intercrossed during all previous generations. 'It seemed, therefore, quite incredible that the difference between the 'two beds of seedlings could have been due to a single act of self-fertiliza-'tion, and I attributed the result to the self-fertilized seeds not having 'been well ripened, improbable as it was that all should have been in this 'state, or to some other accidental and inexplicable cause. During the 'next year I raised for the same purpose as before two large beds close 'together of self-fertilized and crossed seedlings from the carnation, '*Dianthus caryophyllus*. This plant, like the linaria, is almost sterile 'if insects are excluded; and we may draw the same inference as before, 'namely, that the parent plants must have been intercrossed during every '—or almost every—previous generation. Nevertheless, the self-fertilized 'seedlings were plainly inferior in height and vigour to the crossed. My 'attention was now thoroughly aroused, for I could hardly doubt that the 'difference between the two beds was due to the one set being the off-'spring of crossed, and the other of self-fertilized flowers. Accordingly I 'selected, almost by hazard, two other plants which happened to be in 'flower in the greenhouse, namely, *Mimulus luteus* and *Ipomœa* '*purpurea*, both of which, unlike the linaria and dianthus, are highly 'self-fertile if insects are excluded. Some flowers on a single plant 'of both species were fertilized with their own pollen, and others were 'crossed with pollen from a distinct individual, both plants being protected 'by a net from insects. The crossed and self-fertilized seeds thus 'produced were sown on opposite sides of the same pots and treated in 'all respects alike, and the plants when fully grown were measured and 'compared. With both species, as in the cases of the linaria and 'dianthus, the crossed seedlings were conspicuously superior in height 'and in other ways to the self-fertilized. I therefore determined to begin 'a long series of experiments with various plants, and these were 'continued for the following eleven years; and we shall see that in a large 'majority of cases the crossed beat the self-fertilized plants. Several 'of the exceptional cases, moreover, in which the crossed plants were not 'victorious, can be explained. My experiments were tried in the 'following manner: A single plant, if it produced a sufficiency of flowers, 'or two or three plants, were placed under a net stretched on a frame, 'and large enough to cover the plant (together with the pot, when one 'was used) without touching it. This latter point is important, for if the

'flowers touch the net they may be cross-fertilized by bees, as I have 'known to happen; and when the net is wet, the pollen may be injured. 'I used at first "white cotton net," with very fine meshes, but afterwards 'a kind of net with meshes one-tenth of an inch in diameter; and this I 'found by experience effectually excluded all insects excepting thrips, 'which no net will exclude. On the plants thus protected several flowers 'were marked, and were fertilized with their own pollen, and an equal 'number at the same time crossed with pollen from a distinct plant.'

The author details a long series of experiments, which, in his opinion, go to prove that cross-fertilization induces finer and better plants, and he gives the result of those experiments on the *Convolvulus major*, the foxgloves, some of the thymes, the violet, and the common cabbage, as favouring his conclusions; while the common pea, the canna, or Indian shot, and some others gave results in favour of the self-fertilized plants. He goes on to say: 'Species were selected for experiment belonging to 'widely distinct families, inhabiting various countries. In some few cases 'several genera belonging to the same family were tried, and these are 'grouped together; but the families themselves have been arranged not in 'any natural order, but in that which was the most convenient for my 'purpose. The experiments have been fully given, as the results appear 'to me of sufficient value to justify the details. Plants bearing hermaphro-'dite flowers can be interbred more closely than is possible with bisexual 'animals, and are therefore well fitted to throw light on the nature and 'extent of the good effects of crossing, and on the evil effects of close 'interbreeding or self-fertilization. The most important conclusion at 'which I have arrived is that the mere act of crossing by itself does no 'good. The good depends on the individuals which are crossed differing 'slightly in constitution owing to their progenitors having been subjected 'during several generations to slightly different conditions, or to what we 'call in our ignorance spontaneous variation. This conclusion, as we shall 'hereafter see, is closely connected with various important physiological 'problems, such as the benefit derived from slight changes in the condi-'tions of life, and thus stands in the closest connection with life itself. It 'throws light on the origin of the two sexes, and on their separation or 'union in the same individual, and, lastly, on the whole subject of hy-'bridism, which is one of the greatest obstacles to the general acceptance 'and progress of the great principle of evolution.'

Mr. Darwin gives two lists of plants, the first of which he says are sterile, or nearly so, when insects are excluded, and the other of plants which, when protected from insects, proved to be fertile; but much careful watching is still needful before we can determine these points, and numerous inquirers are conducting most careful researches, and, what is much better, noting in their native habitats the growth of plants under various conditions, in order to settle points in plant history which we must as yet consider as unproved, and upon which it would be most unwise to arrive at any definite conclusions. The results obtained by the test of weighing the seeds obtained from cross and self-fertilized flowers were in favour of the latter in eight cases out of sixteen; two were equal, and six were below

the weight of the crossed flowers; but it was found that in general the plants raised from these self-fertilized seeds were very inferior in height and in other respects to those raised from the crossed seeds. With regard to the relative period of germination of crossed and self-fertilized seeds, Mr. Darwin says that many more observations are necessary before anything can be decided. After treating of the chief characters of flowers, especially with relation to the attractions they offer to insects in bright colours, and the exceptional cases of obscure colours, dark streaks or marks, as guides to the nectar and the storage of nectar, the different character of flowers as to being closed or open, and the hygrometric change of the petals, the author refers to the difficult subject of the apparently useless profusion of pollen grains. He says: 'In order to 'compensate for the loss of pollen in so many ways the anthers produce a 'far larger amount than is necessary for the fertilization of the same flower. 'I know this from my own experiments on spomœa, given in the Introduc- 'tion; and it is still more plainly shown by the astonishingly small quantity 'produced by cleistogene flowers, which lose none of their pollen, in compari- 'son with that produced by the open flowers borne by the same plants; and 'yet this small quantity suffices for the fertilization of all their numerous 'seeds.' Mr. Hassel took pains in estimating the number of pollen-grains produced by a flower of the dandelion (*Leontodon*), and found the number to be 243,600, and in a peony 3,654,000 grains. The editor of the 'Botanical Register' counted the ovules in the flowers of *Wistaria sinensis*, and carefully estimated the number of pollen-grains, and he found that for each ovule there were 7000 grains. With *Mirabilis*, three or four of the very large pollen-grains are sufficient to fertilize an ovule but I do not know how many grains a flower produces. With *Hibiscus*, Kölreuter found that sixty grains were necessary to fertilize all the ovules of a flower, and he calculated that 4863 grains were produced by a single flower, or 81 times too many. With *Geum urbanum*, however, according to Gärtner, the pollen is only ten times too much. As we thus see that the open state of all ordinary flowers, and the consequent loss of much pollen, necessitate the development of so prodigious an excess of this precious substance, why, it may be asked, are flowers always left open? As many plants exist throughout the vegetable kingdom which bear cleistogene flowers, there can hardly be a doubt that all open flowers might easily have been converted into closed ones. The graduated steps by which this process could have been effected may be seen at the present time in *Lathyrus Nissolia*, *Biophytum sensitivum*, and several other plants. The answer to the above question obviously is that with permanently closed flowers there could be no cross-fertilization. In spite of our limited space we must give a short extract of great interest. 'The extraordinary industry of bees and the number of flowers 'which they visit within a short time, so that each flower is visited re- 'peatedly, must greatly increase the chance of each receiving pollen 'from a distinct plant. When the nectar is in any way hidden, bees 'cannot tell without inserting their proboscides whether it has lately been 'exhausted by other bees, and this, as remarked in a former chapter,

'forces them to visit many more flowers than they otherwise would. But 'they endeavour to lose as little time as they can: thus in flowers 'having several nectaries, if they find one dry they do not try the others, 'but, as I have often observed, pass on to another flower. They work so 'industriously and effectually that, even in the case of social plants, of 'which hundreds of thousands grow together, as with the several kinds 'of heath, every single flower is visited, of which evidence will presently 'be given. They lose no time, and fly very quickly from plant to plant, 'but I do not know the rate at which hive-bees fly. Humble-bees fly at 'the rate of ten miles an hour, as I was able to ascertain in the case of 'two males, from their curious habit of calling at certain fixed points, 'which made it easy to measure the time taken in passing from one 'place to another. With respect to the number of flowers which bees 'visit in a given time, I observed that in exactly one minute a humble-'bee visited twenty-four of the closed flowers of the *Linaria cymbalaria;* 'another bee visited in the same time twenty-two flowers of the *Sym-'phoria racemosa;* and another seventeen flowers on two plants of a 'delphinium. In the course of fifteen minutes a single flower on the 'summit of a plant of œnothera was visited eight times by several 'humble-bees, and I followed the last of these bees whilst it visited in 'the course of a few additional minutes every plant of the same species 'in a large flower-garden. In nineteen minutes every flower on a small 'plant of *Nemophila insignis* was visited twice. In one minute six flowers 'of a campanula were entered by a pollen-collecting hive-bee; and bees 'when thus employed work slower than when sucking nectar. Lastly, seven 'flower-stalks on a *Dictamnus Fraxinella* were observed on the 15th of 'June, 1841, during ten minutes; they were visited by thirteen humble-'bees, each of which entered many flowers. On the 22nd the 'same flower stalks were visited within the same time by eleven humble-'bees. This plant bore altogether 280 flowers, and from the above date, 'taking into consideration how late in the evening humble-bees work, each 'flower must have been visited at least thirty times daily, and the same 'flower keeps open during several days. The frequency of the visits of 'bees is also sometimes shown by the manner in which the petals are 'scratched by their hooked carsi. I have seen large beds of mimulus, 'stachys, and lathyrus, with the beauty of their flowers thus sadly de-'faced.'

The general results of Mr. Darwin's experiments are set forth in p. 436: 'The first and most important of the conclusions which may be 'drawn from the observations given in this volume, is that cross-fertiliza-'tion is generally beneficial, and self-fertilization injurious. This is shown 'by the difference in height, weight, constitutional vigour, and fertility of 'the offspring from closed and from self-fertilized flowers, and in the num-'ber of seeds produced by the parent-plants. With respect to the second of 'these two propositions, namely, that self-fertilization is generally in-'jurious, we have abundant evidence. The structure of the flowers in 'such plants as *Lobelia ramosa*, *Digitalis purpurea*, &c., renders the aid 'of insects almost indispensable for their fertilization; and bearing in

'mind the prepotency of pollen from a distinct individual, over that from 'the same individual, such plants will almost certainly have been crossed 'during many, or all, previous generations. So it must be, owing merely 'to the prepotency of foreign pollen, with cabbages and various other 'plants, the varieties of which almost invariably intercross when grown 'together.'

'That wonderfully accurate observer, Sprengel, who first showed how 'important a part insects play in the fertilization of flowers, called his book '"The Secret of Nature Displayed:" yet he only occasionally saw that 'the object for which so many curious and beautiful adaptations have 'been acquired was the cross-fertilization of distinct plants; and he 'knew nothing of the benefits which the offspring thus receive in growth, 'vigour, and fertility. But the veil of secrecy is as yet far from being 'lifted; nor will it be until we can say why it is beneficial that the usual 'elements should be differentiated to a certain extent, and why, if the 'differentiation be carried still further, injury follows. It is an extraor- 'dinary fact, that with many species, flowers fertilized with their own 'pollen are either absolutely, or in some degree, sterile; if fertilized with 'pollen from another flower on the same plant, they are sometimes, 'though rarely, a little more fertile; if fertilized with pollen from another 'individual or variety of the same species, they are fully fertile; but if 'with pollen from a distinct species, they are sterile in all possible degrees, 'until utter sterility is reached. We thus have a long series with absolute 'sterility at the two ends,—at one end to the sexual elements not having 'been sufficiently differentiated, and at the other end to their having been 'differentiated in too great a degree, or in some peculiar manner' (p. 461).

That these inquiries are of great importance is shown by practical results already obtained from the knowledge we have gained that the reason why many imported plants in various districts utterly fail to be propagated arises from the absence of insects as fertilizers suited to the form of the flower, but in the great majority of cases, as yet, from unascertained causes. Inquiries like those of the author, tending to more exact knowledge of means by which the best species of useful plants may be obtained, become of more than national importance, and we commend to all interested in plant culture the interesting researches which Mr. Darwin in this volume has admirably detailed.

Winds of Doctrine: being an Examination of the Modern Theories of Automatism and Evolution. By CHARLES ELAM, M.D., Author of 'A Physician's Problems,' &c. Smith, Elder, and Co.

It often strikes those who bring only mother wit to the examination of the modern theories of evolution and automatism that great is the credulity of our men of science in rearing hypotheses of wide scope and bearing upon the most paltry foundations. The amount of evidence which as yet has been brought forward in their support is of the minutest character. The scientific imagination has framed hypotheses