THE CREATION OF NEW PLANTS.

Dr. Richardson's Fascinating Lecture.

Compact Between Insect and Plant.

Many ages ago, perhaps millions of years, said Dr. Richardson, a compact was made between a plant and an insect that was of the greatest importance to races yet unborn. The compact was that the plant should manufacture nectar and freely supply it as food, and the insect in return would carry the fructifying pollen grains from flower to flower. It was the most important compact made in the history of animate creation.

The second of the series of lectures on "Agriculture" was delivered by Professor A. E. V. Richardson (Director of the Waite Agricultural Research Institute) at the Prince of Wales Lecture Theatre, Adelaide University, last night. Taking as his subject, the "Creation of New Varieties of Plants," Dr. Richardson said a remarkable feature of modern agriculture during the past generation was the intense activity devoted to the improvement of farm crops. This had been largely due to the re-discovery of Mendel's work by DeVries, Tschermark and Correns, the epoch-making work of DeVries on the Mutation Theory, and the great stimulus given to plant-breeding by the establishment of schools of genetics in the older universities. Every agricultural crop of importance had been subjected to a critical study with a view to determining the best lines on which specific and desirable improvements might be brought about. Though systematic plant-breeding was quite a modern development, the amount of data already collected and the remarkable results already achieved were sufficient to indicate the enormous possibilities that lay ahead of this work.

Animal and Plant Breeding.

The great improvements wrought in flocks and herds by careful systematic breeding were apparent to the layman. The remarkable development of the Shorthorn cattle from the cattle of North-Eastern England by the Collings Bros., and later by Booth and Bates, was known to every cattle-breeder. The improvement effected in the Leicester breed of sheep by Robert Bakewell, of Dishley, was familiar to every sheep-breeder. Other illustrations nearer home were the remarkable improvement effected in the Merino sheep by Australian breeders during the last century. There was a great difference between the Merino of to-day and the animals which landed in Australia in 1797. The improvement by systematic breeding in the milk yields of dairy cows had been none the less remarkable. Similar improvements had been effected by single pen testing, and systematic breeding in the egg-laying strains of poultry. From a sitting of eggs obtained from the Victorian Department of Agriculture six white Leghorns were hatched which in the Burnley Egg-laying Competition produced 1,680 eggs, or an average of 286 eggs per bird. This was still the world's record for egg-laying.

The fundamental principles of breeding and inheritance were the same whether they were applied to animals or plants. The plant-breeder had at least one immense advantage over the animal breeder. He might work with hundreds of thousands of individuals, and could afford to make his selections with the utmost rigor, and take full advantage of the variations of type which were the basis of all improvement. The possibility of improving plants depended on variation and heredity. Unless variations occurred no improvement would be possible. Unless some variations were transmitted from parent to offspring no improvement would result. There was a close relationship between the development of theories of evolution and the development of scientific methods of breeding.

Darwin's Theory of Natural Selection.

The fact of evolution—that species arose by a modification of pre-existing species—was indisputable, and was supported by innumerable facts of classification, morphology, embryology, by the geographical distribution of plants and animals, and their succession in the geological strata. The explanation of evolution, however, was not yet quite satisfactory. Darwin based his theory on the following facts, (a) Variability; (b) struggle for existence; (c) natural selection; (d) heredity. No two plants and no two animals were absolutely alike. To the man in the street each member of a large flock of Merino sheep seemed precisely the same as each other member of the flock. To the enthusiastic stock breeder each sheep possessed certain peculiarities and attributes which distinguished it from every other sheep in the flock. Plants likewise were variable. Usually the variations from plant to plant were small. Occasionally quite large variations or departures from type were observed without any apparent reason. The large variations were usually stable, and were inherited. DeVries called them mutations. Darwin observed these "sports," but he considered them relatively unimportant in the origin of species, because they occurred infrequently. Darwin considered that the small fluctuating variations were all important in evolution and were the material on which natural selection operated. The individuals of a species differed from one another, and these increased or decreased their chances of survival in the struggle for existence.

If all the seeds produced in a year by a given species were to germinate, there would be far too many plants to reach maturity. A fierce struggle for existence resulted between the individuals of the species, and the fittest survived and the unfit perished. According to Darwin, the variations which survived in this struggle for existence were perpetuated by heredity. Thus variation produced the material on which natural selection operated, and heredity tended to perpetuate the variations. Darwin did not explain the cause of these variations, or the mechanism by which they were perpetuated by heredity.

The Theory of Mutation.

DeVries attacked the question of the kind of variation which furnished the material for evolution. He affirmed that the small continuous variations were of slight value in evolution, and advanced the hypothesis that large, discontinuous variations or "sports," furnished the basis for evolution. According to this view, species were not slowly and gradually changed into new forms, but new and distinct types arose suddenly from the parent form. The variety as a whole continued unchanged, but produced aberrant individuals or mutations which bred true to type, and were the real source of all progress. They now know that sports, mutations, and discontinuous variations were frequent, and that they were remarkably stable and bred true to type. The mutation theory did not deny the importance of selection as a means of improving agricultural plants, for even if a mutation did appear, it might still be improved in its lesser features by careful selection.

Mendel's Law of Heredity.

The law which Gregor Mendel formulated in 1865 was regarded as the greatest of biological discoveries. It furnished the starting-point from which the modern study of genetics had developed, and provided a scientific basis for plant breeding. Mendel sought to discover the law of inheritance in hybrid varieties of peas, and concentrated his attention on the mode of transmission of pairs of unit characters, e.g., tallness and dwarfness through several generations. Mendel communicated the results of his now world-famous experiments to the local scientific society at Brunn, but strangely enough they were unnoticed till 1900, when they were rediscovered and independently confirmed by DeVries, Tschermark, and Correns. After much experimentation, he decided to use the common garden pea for his investigations. A close examination of the different varieties in cultivation enabled him to separate 22 distinct types. He arranged these pure races into pairs of opposite or contrasting characters, and crossed representative plants of each pair separately. Thus he crossed tall peas with dwarf peas, peas with colored flowers with those possessing white flowers. He carefully preserved all the progeny of every crossbred plant and planted them separately each year. The results of his investigations might be concisely summarised as follows:—When two plants exhibiting two pairs of contrasting characters were crossed the progeny in the first generation consisted of plants bearing the two dominant characters, but in the second generation the characters segregated in the following proportion:—Nine plants possessing the two dominant characters, three plants exhibiting one dominant and one recessive, and one plant exhibiting the other dominant and the other recessive. This principle might be extended to three or more characters.

Value of Mendel's Work.

Mendel's results had been confirmed by many different workers in widely different fields of investigation. His law was a great contribution to evolution and to the science and practice of breeding. One great advance had been made possible by his discovery. The individual might be regarded as built up of so many definite unit characters, each of which was independently inherited in accordance with a definite scheme of inheritance. The final character of an organism depended on the number of factors existing in the two germ cells responsible for its formation.

The Darwinian account of the origin of species assumed that variations were continuous, and that any variation could be transmitted to the offspring. Neither of these assumptions was justified. Bateson and DeVries had shown how prevalent discontinuous variations, or "sports," or mutations, were in Nature, and Mendal and his followers had shown that heritable variation had its basis in the germ cells. Natural selection did not create a new variation, because this was decided by the presence of certain definite factors in the germ cell. Natural selection merely decided whether the new type was to survive or be eliminated in the struggle for existence. Now, it was worthy of note that the presence of a small number of factors carried with it the possibility of an enormous range of variation. They had seen that with the presence of two pairs of factors, awns or absence of awns, and black and white color in barley, there would be four pure-breeding forms produced by hybridisation. With 10 pairs of characters there would be 1,024 distinct pure-breeding forms produced in crossing, all of which could be isolated and raised in pure cultures. Thus the almost infinite variety in nature could therefore be accounted for by assuming the presence of a comparatively small number of factors in the parent germ cells. The Mendelian conception of unit characters, based on specific factors transmitted in accordance with a definite scheme of inheritance, was of the greatest service to the plant-breeder, whose final objective was the production of a type which would combine the greatest number of desirable characters. The desirable characters might be distributed among several plants. His task was to unite all these desirable characters into one variety. Before he could do this he must determine the inheritance of the factors upon which the characters depended. Once these factors had been determined, they could be brought under control and associated or separated at the breeder's will. He might combine in one plant the unit characters of two or more plants, and thus produce a new combination or variety.

Producing New Varieties.

There were two general methods by which new and improved varieties might be obtained.—1, by selection and 2, by hybridisation. Selection was based on the isolation and propagation of a heritable variation. Among a million plants in a field of wheat, there are bound to be some individuals possessing a useful character in excess of the average. It was the object of the plant breeder to secure crops of such individuals by selecting and isolating the improved form from its neighbours and cultivating it. These variations were not inherited because the germ cells were not in any way affected. Other variations might arise which were the result of a change in the reproduction cells. The variations were found to breed true to type. They formed the basis for improvements by selection. The selection of spontaneously occurring individuals exhibiting improved characters had provided them with the best of their cultivated plants. Selection was not creative in its action, it was preservative. Nature produced a desirable heritable variation, man isolated and propagated it. Selection played no part in the origin of desirable variations, it merely preserved and propagated them. Among plants which had been improved by selections were the cabbage and its cousins, the evening primrose, the five leaved clover, the shirley poppy and cereals.

Improved Cereals.

In 1886 there was founded at Svaloi in Sweden a plant breeding institute that was now world-famous. It owed its inception to a group of agriculturists who formed an association for the improvement of seeds in Sweden. The station had developed a method of selection which rested on the discovery and isolation among hundreds and thousands of individual plants comprising a field crop, of a few outstanding individuals showing heritable variation. The method used was single plant selection. Each selection was sown separately in rows. Most meticulous care was taken to test out thoroughly the merits of each individual selection over a period of years. When the tests were completed, the best strains were propagated and distributed as new varieties. The institute had been remarkably successful and the new varieties produced had been highly valued and extensively used through Northern Europe.

The classic experiments carried on by Hopkins and Smith with maize at the University of Illinois for more than 25 years had given most remarkable results. In 1896, Hopkins selected 163 ears from a crop of Burr's white maize, and after making an analysis of a few grains from each ear, divided them into four classes—high and low oil content, and high and low protein content. At the commencement of the experiments the average oil content was 4.7. After 10 years' selection for high oil, the strain gave an average of 6.65, the average of the low oil strain having fallen to 2.98 per cent., a difference of 3.6 per cent. At the end of 20 years' selection, the average of the high oil strain had risen to 8.02, the oil content of the low strain being 2.03—a difference of 6 per cent. In 1921, i.e., after 25 years' selection, the high oil plots averaged 9.94 per cent., and the low oil plots 1.70 per cent., a difference of 8.24 per cent.

Sugar-Beet.

The development of the sugar content of the beet was a remarkable example of how selection might be used to increase the quality of a farm-crop with great advantage to an industry. Since the introduction of beet culture in Europe by Napoleon, the sugar contents of beets had been gradually improved from 7 per cent. to over 18 per cent. Most of the progress had been done during the past generation, and progress was rapid when breeders isolated and bred those strains of beet which not only possessed high sugar-content, but which transmitted the high sugar content of their progeny. Owing to the improvement in the sugar content of the beet, which implied greater production of sugar per acre, the beet sugar industry had made remarkable progress, and now more than 50 per cent. of the world's sugar was produced by white labor from beets grown in the temperate regions of Europe and the United States.

Hybridisation.

Hybridisation, the second method, offered almost unlimited scope for improvement in garden plants, cereal crops, and fruit crops, by the production of new varieties. With hybridisation, the plant-breeder could create new forms and new combinations which never existed before. To understand how hybridisation was effected, it was necessary to have a knowledge of the structure of the flower. What might be regarded as a typical or perfect flower contained pollen-bearing and pollen-receiving parts, surrounded by the conspicuous insect signal which was termed the corolla, and a less conspicuous outer shield called the calyx. The calyx was the original protective shield about the flower bud, and its function was over when the flower opened. The most attractive part of the flower was the corolla, made up usually of bright showy petals. Within the petals was a circle of stamens bearing at their ends the anthers, or pollen sacs, containing immense numbers of minute pollen grains. In the central portion of the flower was the pistil, comprising the ovary with its egg-cell and above the ovary the tube-like style, ending in the stigma that received the fertilising pollen. The normal process of fertilisation was for a pollen grain to fall on the stigma, where it germinated. The contents of the pollen grain then fused with the egg-cell, and from the fertilised ovum a seed developed. By the most wonderful miracle in the organic world, the infinitesimal egg-cell hidden in the ovary was able to epitomise all the possibilities of a future plant of predetermined size, form, and habit. And each pollen grain contained, as did the ovule, all the hereditary potentialities of the entire plant. It would be almost unbelievable, did they not know it to be true, that a minute fleck of matter such as the pollen-grain should contain the potentialities of the future plant or tree, and that it should predetermine the details of structure even down to its remotest leaf and to the smallest detail of its flower and fruit.

An Important Compact.

Many years ago, perhaps millions of years ago, a strange compact was made between a plant and an insect that was of the greatest importance to races yet unborn. The compact was that the plant should manufacture nectar and freely supply it as food, and that the other in return should carry the fructifying pollen grains from flower to flower. Probably no more important compact had ever been entered into in the history of animate creation before or since. Out of this compact grew the rivalry that stimulated development and made possible the evolution of the whole race of plants that bore beautiful flowers and exhaled sweet perfumes. But for that alliance, there would never have developed in the world a conspicuously colored or scented flower of any kind. The alliance did not merely give things of beauty: it gave utility as well, for it made possible the bringing together of germplasms from plants growing far apart, thus insuring virile and variant strains. This in a large measure determined the amount and direction of evolution of the highest orders of plants. With rare exceptions the higher plants were precisely those that entered into this co-operative scheme whereby they trusted their fate to the insects. They risked much—possibly extermination—but they profited much, for the cross pollenation by the insects afforded the constant stimulus that underlay all evolution. There were some plants that did not join the union. Plants which remained outside the union were the mosses and lichens, and ferns. If these lowly plants had maintained their independence they had done it at a great sacrifice. They were not more independent than they were unprogressive, and indeed they were unprogressive because of their independence. There were other plants, however, that had left the plant-insect union. These apostates were the numerous gigantic trees that no longer depended on insects for the fertilisation of their flowers. Among these were the pine, fir, spruce, and the oak, and among field crops the useful maize plant. These trees and the maize plant long ago declared against further co-operation with insects, and adopted the method of producing large quantities of pollen and scattering it in the air, to be carried by the wind to female flowers, which in some cases grow on neighboring branches and in other cases on different trees. The method was, in one sense, wasteful, inasmuch as it involved the production of immense quantities of pollen.