

"MENDELISM."

BY MR WM. CUTHBERTSON.

[Read 13th January, 1909.]

Mendelism gets its name from Gregor Johann Mendel, who was born on July 22nd, 1822, at Heizendorf bei Ordau, in Austria Silesia. He was the son of what Scotch people would call bein or well to do working folk. In 1843 he entered as a novice the Koniginkloster an Augustinian foundation in Alt-Brunn. In 1847 he was ordained Priest. From 1851 to 1853 we are told he studied Physics and Natural Science at Vienna. Then he returned to his cloister and became a Teacher. Subsequently he became Abbot and died in January, 1884. His experiments were carried out in the garden of his Convent, and we can picture the patient painstaking worker devoting all the time he could spare from his religious duties to his garden. It was in the year 1865 Mendel communicated in a Paper or Lecture to the Natural History Society of Brunn an account of his experiments in plant hybridisation. His Lecture was subsequently published in the transactions of the Society, and thereafter it was completely lost sight of until 1900 when its existence and importance were simultaneously discovered by three independent observers—De Vries, in Holland; Correns, in Germany; and Tschermak, in Austria.

In August, 1901, the Royal Horticultural Society of England published a translation of Mendel's remarkable paper in its Journal, and since then the subject has received a lot of attention in this country.

In an introductory note, written by Professor Bateson to the translation of Mendel's paper in the Journal of the R.H.S. he says :

"The conclusion which stands out as the chief result of Mendel's admirable experiments is of course the proof that in respect of certain pairs of differentiating characters the germ-cells of the hybrid, or cross-bred, are pure, being carriers and transmitters of either the one character or the other, not both. That he succeeded in demonstrating this law for the simple cases with which he worked it is scarcely possible to doubt.

"In so far as Mendel's law applies, therefore, the conclusion is forced upon us that a living organism is a complex of characters, of which some at least, are dissociable and are capable of being replaced by others. We thus reach the conception of unit-characters, which may be re-arranged in the formation of the reproductive cells. It is hardly too much to say that the experiments which led to this advance in knowledge are worthy to rank with those that laid the foundation of the Atomic laws of Chemistry."

I will now proceed to describe a few of Mendel's original experiments. The plant he adopted to work on was the garden pea (*Pisum sativum*). This plant is an ideal one in many respects for such work. It is *self*-fertilized, and has been known, as Darwin long ago pointed out, to breed true to variety for fifty years at least. Besides breeding true to character and not at all liable to interference by insects of any kind, it has a number of varieties carrying distinct characters, *e.g.*, there are round seeded and wrinkled seeded types, yellow and green seeded ones, tall and dwarf forms. Now each of these characters breeds true. A stock of round seeded peas never throws wrinkled ones, and the reverse is almost equally true. A pure stock of dwarf peas, like English or American Wonder, rarely if ever gives tall plants, and I might say that Alderman or *Ne Plus Ultra*, which grow five or six feet high, never give dwarf forms

12 inches high. The same applies to the colour of the seed. Let me here quote a few lines from an article by Rev. W. Wilks, secretary of the R.H.S., on one of those points—colour of the seeds :

“In other words, if you cross *pure yellow* and *pure green* peas either way—it matters not which is seed-bearer and which pollen-bearer—you will get all yellow seeds. If you sow these hybrid seeds, each will, if it germinates, produce a plant which will bear, say, forty seeds, thirty of which will on the average be yellow, and ten green. The green, if sown and sown and sown for countless generations will always bear green seeds, true to the original green parents (barring the always possible intervention of insects). Not so the thirty yellow. These when sown will, on the average, produce ten plants bearing all pure yellow seeds, which will be constant and true to the original yellow parent for countless generations. The remaining twenty plants will be impure yellows, each plant producing, on the average, one quarter of their seeds pure yellow, one quarter pure green, and one half impure yellow, which last will repeat the process and proportion practically for ever.”

Let me take the case of the tall and dwarf peas which is an experiment I have carried out with Gradus and English Wonder. Mendel crossed a tall pea 6 ft. with a dwarf one 1 foot. It mattered not which way he made the cross, *i.e.*, if the tall variety was pollinated with pollen from the dwarf variety or the dwarf variety was pollinated with pollen from the tall variety the result in the first generation was the same—all the plants were tall. But in the second generation, *i.e.*, the plants raised from the seed saved from the plants of the first generation gave a remarkable result. Three-fourths of them were tall—one-fourth were dwarf. Something more remarkable was to follow. The seeds of these plants were carefully harvested and the produce of each plant was kept separate and sown out the following year. It was then found that those which had been *dwarf* in the preceding generation re-

mained *dwarf*, but a proportion of those which were tall again broke up, if I may use that term, and gave again a proportion of dwarfs in the same ratio as before. This led Mendel to the conclusion that a cross between plants bearing differentiating characters results in producing one-fourth which breeds true to one of the characters, and one-fourth which breeds true to the other character and half the plants carry a two-fold character and do not breed true.

You will have gathered that the tall pea has the power to assert itself over the dwarf form in the first generation—the tall, therefore, was called by Mendel *dominant*, but what of the dwarf form which though not apparent in the first generation was *there* all the same. It was termed *recessive* by Mendel. It receded, or was hidden in the first generation, but appeared in the second. Five years ago I started crossing Sweet Peas, and, to my astonishment, I found as a result of crossing the very finest red with the very finest white I got a rather poorly-coloured red form. The reciprocal cross gave me the same result. I knew little or nothing of Mendelism then. I sowed some of the seeds saved from the poor red flowers and the following year had a brilliant illustration of Mendel's law revealed. I remember well those rows of sweet peas. They were sown in a long field and the produce consisted of crimsons and reds in great quantity, and a small proportion of pure whites! I proved *red* was dominant over *white*. Since then I have proved for myself many of these Mendelian Laws or principles. I have found that purple or blue (the colour of the wild sweet pea), dominates all others, even crimson. Crosses made last year between “The King” (crimson) and “Lord Nelson” (deep blue) gave in F_1 nothing but flowers of a dark maroon shade. Again, “The King” crossed with a light blue gave blue flowers only. Another interesting cross is white and primrose. White is dominant in F_1 , primrose appears in F_2 . Then in sweet peas there is another interesting and useful experiment. I have found that the new Giant Spencer or waved form is recessive to the old type of flower. This is rather remarkable. A fine waved flower

like "Mrs Hardcastle Sykes" crossed with a primrose flower gives in F_1 , slightly hooded flowers of pale blush colour. Some years ago when visiting the University experimental farm at Cambridge, I had pointed out to me the remarkable discovery which had been made by Mr Bateson and his collaborators. "Emily Henderson" sweet pea was found to produce two kinds of plants differing in the shape or structure of their pollen. Some plants produced only round pollen grains, others produced elongated pollen grains. Being self-fertilized like all other sweet peas, these plants bred true to these characteristics, but on being crossed, the round-pollen plants with the long-pollen plants, a wonderful, and, I am sure, quite unexpected result was found. In the first generation the plants had purple coloured flowers with long pollen which was supposed to be a reversion to a former ancestral type. These plants were self-pollinated and in F_2 Generation, Purple Invincible, Picotee edged, Painted Lady, tinged white and white flowers were found. Whence arose all these colours or varieties as seedsmen would call them? Latent determining factors must have been present, or absent, in one or both kinds of "Emily Henderson," and until they met in the way they did colour could not be developed. "Emily Henderson," therefore, as we all knew it was only pure for whiteness and only so long as the two kinds (differentiated only to appearance by the shape of their pollen grains) were continuously selfed.

To leave sweet peas and garden peas, let me name a few other plants and a few animals which give equally interesting results. Some remarkable experiments with wheats have been carried out over a series of years by Professor Biffen, at Cambridge, with a view to improve the quality of English grown wheat. I cannot here go fully into the aims of Professor Biffen. I can only refer to a few experiments he has made, some confirmatory of others—others for the first time on record. Many of these experiments I have had the pleasure of seeing in process. He found beardless wheat dominant over the bearded. The beards go under in the first generation but re-appear in the second. Again a wheat with

a white felted chaff, crossed with a red smooth one, gave in F_1 , one of a rough and red character, so that smoothness and whiteness are recessive.

But I must tell you of what I think is the most interesting of all Professor Biffen's experiments. You know that certain wheats are most liable to attacks of rust, which does enormous damage to the crops. Professor Biffen crossed a variety which was immune from rust with one which was distinctly and always liable to it. The result in F_1 generation was—all the produce was badly rusted and indistinguishable from the plants of the rusty variety growing alongside. In fact, the first hybrids were so affected with rust that Professor Biffen said it was difficult to find an area of one eighth inch unattacked with fungus. Even the awns and grains were affected. With difficulty a little seed was saved from the plants, and next year 250 plants were raised, and the result was at mid-summer 64 of the plants were free from the rust and 195 were badly infected. At harvest the seed was saved from those individual plants and sown next year, each in small plots. The plants which were immune from the disease in the former year gave produce which remained rust proof, though alongside plots affected with rust. Professor Biffen says that the green plots stood out sharply among the orange plots of badly rusted individuals. He therefore came to the conclusion that immunity was recessive and susceptibility dominant. But it opened up a wider question which is of the deepest interest to Dr Hall and the gentlemen of his profession present. How the ability to resist disease is carried through the first generation in the midst of such unfavourable conditions to appear in the next, and to continue to produce a race of plants which remain immune may very well become a question for pathologists. In what does this immunity consist? Is it an ability to resist disease or is it to be accounted for in the presence and absence theory that disease will not develop until, or unless, it meets its counterpart in the other parent—introduced into the new individual by the gamete of one of the parents? To proceed, I must only mention, as I have already said, a few other examples which have

been worked out—*e.g.* Red Flesh in Tomatoes is dominant over Yellow Flesh. In Rabbits coloured coats are dominant over white ones. In Fowls the Rose comb is dominant over the single comb. In horses the bay, or brown, colour is dominant over the chestnut.

A very remarkable example is found in mice. There is a race of mice called Japanese Waltzers which spend most of their time twirling round and round in a very small circle. When crossed with another breed the progeny in the first generation do not waltz, but in the second generation when the cross breeds are bred amongst themselves the waltzing recurs. This is like the dwarf character in the peas—in the first generation waltzing is recessive—it must be there, but it keeps out of sight—it is for the time being dominated by the normal condition if I may so term it, *but* it recurs in F_2 or the second generation in Medelian ratio we are told.

Now at this stage it may be legitimately asked: What is the advantage of being able to revive in the second generation a form which has disappeared in the previous one? I can best answer the question by a reference again to the wheat experiments. Let us deal with two varieties.

The first is an ideal wheat—it yields a good crop, it has strength, likewise all the other qualities which satisfy the miller and the baker, *but* it is most liable to disease.

The second form, which is to be the other parent in the cross, is a wheat of coarser type altogether which is of less value to the miller and the baker, but it is disease proof.

I have already explained that in the second generation a proportion of the plants from the cross will be disease proof but if I tell you that a small percentage, possibly one in sixteen, will not only be disease proof, but will carry some or all of the good qualities of No. 1 you will see we are getting on. This is what happens, and the Cambridge workers are hopeful that they will before long produce new varieties of

wheat in quantity which will help the British farmer to produce at home what is presently so largely imported from abroad.

I have worked out the following experiment with sweet peas thus—Starting with the object of obtaining a cream or primrose coloured Spencer or waved flower I crossed “Countess Spencer,” which is pink and of the large waved type, with “Mrs Collier,” which is primrose coloured but of the old fashioned shape—the result was I obtained in the second generation the following percentages, about one in sixteen true “Countess Spencer”; one in sixteen “Primrose Spencer” (what I was working for). This cross I made a year too late to be commercially profitable. It was made in America a year or two earlier, but I will tell you of one which I have made simultaneously with the Americans. In 1904 I set out to obtain a large waved or Spencer crimson flower. I crossed in that year “Countess Spencer” with “King Edward,” which is a red of the old type. In 1905 the flowers produced were all pinks of the old type. In 1906 I was rewarded by obtaining what I expected—plants producing real large waved crimson flowers. These were, of course, saved as individuals, and in 1907 one or two very specially looked after because they bred absolute true. In 1908 they continued true, and this year they are being sold.

I want to carry your mind back to the beginnings of the life of a plant. It arises from the union of a pair of cells or of cell contents. In the parent plant are the young ovules which cannot become fertile seeds until they are fertilized or impregnated by the pollen cells. I want you to observe that it is at this union the different characters are brought into the embryo plant from the different parents. It may be characters, tallness, dwarfness, or for colour or something else. No matter they must come in at the beginning. Recent studies in Cytology (that is the microscopic study of the minute constituent parts of organisms) have been devoted to endeavour to discover how these distinct maternal and paternal hereditary features are carried. (Just at this point it is

interesting to remember that while they enter into partnerships in the embryonic cell they must separate prior to the foundation of their own reproductive cells, or we could not obtain the results I have been describing to you this evening.) Observations of this kind can only be carried on by the most skilled microscopists. Only under very high power is it possible to follow the structure of the nucleus of plant or animal. I shall not enter into a description of chromosomes and chromomeres found in the nucleus, the latter being granular particles supposed to be the carriers of the different characters or allelomorphs. These things are only observed working with high power lenses, say one-twelfth or 1000 diameters.

When we read that—

“Mendel’s discovery is of an importance little inferior to those of a Newton or a Dalton,” or

“Mendel’s discovery is one of the greatest contributions ever made to the Science of Biology,” or

“Had Mendel’s work come into the hands of Darwin, it is not too much to say that the history of the development of evolutionary philosophy would have been very different from that which we have witnessed,” and Lock says, “the first great debt that Science owes to Mendel is the demonstration that there exist *definite* and *separate* unit characters in plants and animals.”

Now, if I could clearly show you how this is proved—more clearly than I have already done, I shall be satisfied with my evening’s work.

Let me take as an example, maize or Indian corn—there are two popular kinds, yellow seeded and white seeded. It is not generally known, Lock says, that the endosperm (the albumen or reserve food surrounding the embryo or germ) of a grain of Indian corn arises by a very similar process to the one which gives rise to the embryo in itself. A second nucleus derived from the same pollen grain fuses with the

nucleus situated near the ovum, and to the product of this fusion the endosperm owes its origin. This explains the interesting fact that the distinguishing colour character of grains of Indian corn are apparent in the first generation thus, if a plant of maize is white seeded and is fertilized with its own pollen, or pollen from another white seeded plant, the seeds are white, and similarly with a yellow seeded variety. But if a female flower of a white variety is fertilized with pollen from a yellow variety, the grains are yellow; on the other hand, if a yellow variety is pollinated with a white variety, the grains remain yellow. So yellow is dominant over white.

Now, suppose we have made a cross and have sown the seeds of Yellow x White (the seeds, remember, are yellow, but not pure, because they are the result of a cross, and are, in technical language, termed heterozygous).

When these plants come into flower they are fertilized with pollen from a pure white strain. The result of this experiment, again quoting Lock, “takes us at once to the very heart of the Mendelian theory.” Half the total number of grains obtained are *white* and half *yellow*. On sowing the white grains thus obtained and allowing the plants to fertilize themselves they produce cobs with only pure *white* grains which bred true.

What of the yellow grains produced on our F₂ plant? If they were sown and allowed to go on fertilizing themselves they would produce only yellow grains, because yellow is dominant—but if they were fertilized by white pollen the result would be again 50 per cent. yellow and 50 per cent. white, because the original hybrid had one yellow and one white parent, and white was recessive, only awaiting until its counterpart came in to enable it to show itself.

The meaning of all this is that the germ cells are either pure for whiteness or pure for yellowness.

I might call your attention to what is termed the riddle of the Andalusian fowl—or reversion on crossing. The blue

Andalusian fowl has never bred true—*i.e.*, when a blue pullet was mated with a blue cockerel, half only of the chicks are blue and the other half mongrels, but it has been found that by mating the mongrels, a black one and a splashed white one, in every instance the chicks were blue. This again brings us back to the segregation of the characters in the gametes—the germ cells. Into that I fear I cannot enter.

Some may say all this intense experimenting and observation is very interesting and doubtless fascinating to those who are engaged in it, but it does not appeal to us. I know it does not appeal to everyone any more than the finest works of art do, but its usefulness is undoubted. The laws underlying plant life are applicable in most instances to animal life, and the laws underlying animal life are applicable in most instances to human life. Thus we ascend the scale from the lowest to the highest, and the solution of many social problems may become as much the work of the Scientist as of the Statesman.

ABSTRACT OF PAPER ON THE MENDELIAN LAW AND THE THEORY EXPLANATORY OF IT.

By DR. A. J. HALL.

[Read 13th January, 1909.]

We all know that throughout a large portion of the animal and vegetable kingdoms the new individual comes into being by means of the union of two unicellular bodies called germ cells or gametes.

The fertilised ovum, or zygote as it is called, which results from the coalescence of the two (the male and female) gametes is still a unicellular organism, and is the first stage of the new individual.

If the gametes are typical specimens of the species to which they belong, the new individual is exactly the same as its parents, and in due course will produce gametes exactly the same as those which gave it birth.

All this is true when there is no "variation" in the species under consideration. But we know that in many species there is variation—there are varieties—and this brings us into the region of Mendelism.

We know that most plants are hermaphrodite, bearing male and female organs on the same flower, and that as a rule they are cross-fertilised by means of insects. In the latter