SCIENCE

A WEEKLY JOURNAL DEVOTED TO THE ADVANCEMENT OF SCIENCE, PUBLISHING THE OFFICIAL NOTICES AND PROCEEDINGS OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

EDITORIAL COMMITTEE: S. NEWCOMB, Mathematics; R. S. WOODWARD, Mechanics; E. C. PICKERING, Astronomy; T. C. MENDENHALL, Physics; R. H. THURSTON, Engineering; IRA REMSEN, Chemistry; CHARLES D. WALCOTT, Geology; W. M. DAVIS, Physiography; HENRY F. OSBORN, Paleontology; W. K. BROOKS, C. HART MERRIAM, Zoology; S. H. SCUDDER, Entomology; C. E. BESSEY, N. L. BRITTON, Botany; C. S. MINOT, Embryology, Histology; H. P. BOWDITCH, Physiology; J. S. BILLINGS, Hygiene; WILLIAM H. WELCH, Pathology; J. McKEEN CATTELL, Psychology; J. W. POWELL, Anthropology.

FRIDAY, MAY 9, 1902.

CONTENTS:

*THE ORIGIN OF SPECIES BY MUTATION.**

FORTY years ago Darwin's 'Origin of Species' was given to the world. The number of those who witnessed its appearance gradually diminishes year by year. Few are left to remember the condition of things at that period, and the shock which its publication caused. We had grown up firmly convinced of the invariability of species. The precepts and commands of Linnæus reigned supreme over our thoughts and deeds alike. To take the last specimen from a locality, no one would have dared, not even in the seclusion of the forest primeval. Far less would any one have had the temerity to give even a single thought to those phenomena whose study he had forbidden. Many an interesting variation did I meet with on my walks when a student, but, obedient disciple that I was, left uncollected.

With the appearance of Darwin's book came the complete overthrow of the old doctrine. What formerly had been *the* science now became merely its primer. New demands were made upon investigation, interest was now directed into entirely new channels. An endless field was

* Address before the second general meeting of the eighth congress of the 'Nederlandsche Natuur- en Genuskundige Vereeniging,' held at Rotterdam. Translated from the 'Album der Natuur,' Mei, 1901, by H. T. A. Hus, Assistant in Botany, University of Amsterdam, and revised by the author.

opened for thoughts, for observation, or comparison and the drawing of conclusions. The result was a hard-fought war, openly carried on against Darwin, and ending in his complete victory. But before we were able to declare ourselves advocates of the new doctrine, the bonds which held us were to be severed, and we had to break loose from the old prejudices.

Of the present generation none have known this internal struggle. They have been brought up in the new doctrine. The common descent of species and genera is for them a dogma, as much as the creation of species was for their fathers. With different eyes they watch the progress of science in this new territory. They neither feel the pride of the victor, nor have they the personal example of Darwin's untiring labor. It is much to be regretted that everywhere, in the manner of both working and thinking, we find evidence of this. Deductive treatment has taken the place of observation and investigation. An immense superstructure of speculative science has risen on the foundation of Darwin's selection theory. The possible influence of selection in past times has been discussed for numerous cases, but its actual influence at the present time was left uninvestigated. Thought, instead of Nature, became the source of theory, and the latter consequently became farther and farther removed from the truth.

At last the tide is turning. Conn, in a recent book on evolution, exclaims: 'Let us leave our books and return to Nature,' adding, 'leave speculation and turn to observation.' The necessity of this is making itself felt everywhere. The time of contemplation is past. We no longer ask how things *might be;* how things *are* is the question of the hour.

De Varigny, the well-known French translator of Wallace's book on 'Darwinism,' formulates as the first requisite, viz., that we should see species originate. It is no longer sufficient to be convinced that it is so, we must know it from experience. During the last decade a few investigators have sought the paths which lead to this goal. It is but recently that the results they obtained have been published. And though the paths followed are very divergent, and the results differ greatly, yet for all the initial point was Darwin's book; none were influenced by subsequent speculations. Darwin's theory of adaptation led to the investigations on the origin of species in the Alps by Kerner and von Wettstein; Darwin's selection theory to the statistical investigations of variability by Galton and Weldon, and to the mathematical studies of Karl Pearson. And likewise finding its origin in Darwin's great work, stands the study of discontinuous variability, the study of the single variations or mutations,* and the question whether in these must be sought the origin of species.

Only a single case has been discovered in which it is possible to actually see species originate; and this not accidentally, but experimentally, so that one can watch and carefully follow the manner of their origin.

Three kinds of evening primroses occur in Holland, all three introduced from America about a century ago, but since escaped from cultivation. The youngest of the three, or rather the one most recently introduced, and at the same time the most rare, is the large-flowered evening primrose, described at the beginning of the nineteenth century by Lamarck, and named after him *Oenothera Lamarckiana.* It is a beautiful, freely branching plant, often attaining a height of five feet or more. The

* Sudden variability, comprising the deviations from the rules of heredity in the wider sense, as opposed to fluctuating variability, *e. g.*, the degree of variability peculiar to each character of a species. Hugo de Vries, 'Die Mutationstheorie.' Leipzig, Veit & Co. 1901.

branches are placed at a sharp angle with the erect stem and in their turn bear numerous side branches. Nearly all branches and side branches are crowned with flowers, which, because of their size and bright yellow color, attract immediate attention, even from a distance. The flowers, as the name indicates, open towards evening, shortly before sunset, and this so suddenly that it seems as if a magic wand had touched the land and covered it with a golden sheet. Bumble bees and moths, especially those of *Plusia gamma* and of *Agrotis segetum*, are the principal visitors. During the hot weather the flowering period is limited to the evening hours. In daytime often nothing is to be seen but faded and half-faded flowers and closed buds. Each flower bears a long style with four or more stigmas, which protrude at some distance above the eight anthers, and would therefore, as a rule, not be fertilized without the help of insects. When the flowers, including their apparent stem, the calyx tube, drop off, there remains behind a perigynous ovary, which finally becomes a capsule. At first green, it becomes brown on ripening and finally opens with four valves, setting free the seeds. A stem with ten to twenty, or even thirty or forty, capsules is not rare, nor consequently a plant with a hundred or more fruits. And since each fruit contains more than a hundred seeds it would be quite possible for a plant of this species to reproduce itself several thousandfold, provided all seeds could germinate and grow.

It is this plant, *Oenothera Lamarckiana,* which exhibits the long-sought peculiarity of producing each year a number of new species, and this not only in my experimental garden, but also when growing wild. But in the latter case the new species have as a rule but a very short lease of life; they are too weak and too few in number to survive in the struggle for existence with the hundreds and thousands of their fellows. In the experimental garden, however, they can be recognized at an early stage, and with especial care may be isolated and cultivated. It is thus that in the experimental garden we are readily able to see that which, among wild-growing plants, is lost to observation.

The new species vary but little from the old. An inexperienced eye detects no difference. Only a careful comparison shows that here we have to deal with a new type. There are some, for instance a dwarf species, and species with a peculiar close crown (*O. nanella* and *O. lata*), which at once attract our attention, because they are short of stature. Again, some are more slender and delicate, others low and unbranched, or robust and tall. A difference may be detected in the shape of the leaves, their color and their surface. The fruits vary in the same manner; sometimes they are long, sometimes short, sometimes slender, sometimes stout. The more one observes these plants, the more differences one sees. Gradually it becomes apparent that here we have to deal, not with a chaos of new forms, but rather with a series of sharply defined types. Each of these types originated from a seed produced by the parent species, growing wild, and fertilized in the usual manner, or growing in the experimental garden, and fertilized artificially, with its own pollen.

Here then we have our first result. The new species originate suddenly, without preparation or intermediate forms. But they do not differ from the old species like an apple from a pear, a pine from a spruce, or a horse from a donkey. The deviations are far smaller. But every one knows how difficult it is to distinguish the common oak from *Quercus sessiliflora,* or the lime tree from *Tilia grandifolia.* Yet these are forms which by the disciples of Linnæus are recognized as true species. And what botanist has not been entangled in the species of *Hieracium,* or who is able to recognize at first sight the closely related forms of *Cochlearia?*

Because of the dying out of intermediate forms, more ancient species may be widely separated. On the other hand, more recent species, whose ancestors are still alive, may form narrow groups because of and with these surviving ancestors. Good illustrations of the latter are yielded by roses, willows and brambles, as shown by the facility with which the closely related forms can be cross-fertilized, as well as by the great trouble the numerous bastards cause in determination. Such genera are found everywhere in the plant kingdom; the gentians of the Alps, for instance, or the *Helianthemums,* which with us seem to be composed of fairly distinct types. Everything indicates that in these cases the species are of more recent date, and that only through the dying out of intermediate forms the differences between the remaining ones have attained that degree of distinctness which so greatly facilitates the separation of the other groups.

In this regard the *Oenotheras* agree exactly with what may be observed in nature. Recent forms group themselves around the mother form with minute, hardly perceptible gradations.

Once formed, the new species are as a rule at once constant. No series of generations, no selection, no struggle for existence are needed. Each time a new form has made its appearance in my garden, I have fertilized the flowers with their own pollen and have collected and sown the seed separately. The dwarf forms produce nothing but dwarfs (*O. nanella*), the white ones nothing but white ones (*O. albida*), the *O. gigas* nothing but *O. gigas,* the red-nerved ones nothing but corresponding specimens. But a single form made an exception. This was the small *O. scintillans,* the seeds of which produced but a percentage of *scintillans* plants, but here this inconstancy is and was as much the rule as the constancy of the other species.

As an example I may cite *O. gigas.* The plant is as tall as *O. Lamarckiana* but has a more robust stem, denser foliage, a broader crown of large, widely opening flowers and stouter flowering-buds. The fruits attain but one half the length of those of plants of the mother species and consequently contain fewer seeds. But the individual seeds, on the other hand, are rounder, fuller and heavier. This type originated in my cultures of 1895 as a solitary specimen, which at first was overlooked. At that time I desired to hibernate some plants, and in the latter part of the autumn chose for that purpose twelve of the strongest and best developed. It was only in the following summer, when the plants began to flower, that I noticed that one plant showed differences, the importance of which I did not fully realize until the fruits, on ripening, became much shorter and stouter than ordinarily was the case. It was only then that I placed the raceme in a bag so as to prevent fertilization with other pollen. Afterwards this seed was collected separately and in the spring of 1897 sown in a flower bed between other beds sown with seeds of the normal *Oenothera Lamarckiana.* Immediately subsequent to germination no difference was apparent, but when the third and fourth leaves unfolded it suddenly became evident that a new species had originated. All plants differed from their neighbors, were more robust and bore broader, darker leaves. Though two to three hundred in number, all evidently belonged to one distinct type. Not having, at the time, paid special attention to the mother plant, I was unfortunately unable to compare the latter with the type at this age. But when, during the summer, first the stems and afterwards the flowers and the fruits, made their appearance, the agreement became perfect. All specimens closely resembled the mother, and together they formed the new species, *Oenothera gigas*. This species therefore was at once constant, even though it found its origin in but a single specimen. Evolved with a sudden leap from the mother species, differing from it in general appearance as well as in the character of its various organs, it remained unchanged. It was no rough cast which selection had to correct and polish before it could represent a distinct form; the new type was at once perfect and needed no smoothing, no correction.

My other species originated in the same manner, suddenly and without transitions. We may therefore assume that species, when growing wild, do not appear gradually, slowly adapting themselves to existing conditions, but suddenly, entirely independent of their surroundings. Species are not arbitrary groups, as Bailey, and with him many others, believed should be deduced from the theory of descent, but sharply defined types, unmistakable, for one who has once seen them.

Each species is an individual, says Gillot, having a birth, a lease of life, and an inevitable death. From the moment of birth until the time of death, it remains the same. Only when taking this point of view can we reconcile our daily experience of the constancy of species with the theory of descent. This is fully confirmed by the results of my experiments.

If species originated gradually, in the course of centuries, their birth could never be observed. Were it so, this most interesting phenomenon would forever remain hidden from us. Happily it is not so. Each species as soon as born takes its place as peer in the ranks of the older species. This birth may be directly observed. One can even collect the seeds in which the new types are hidden, and one can observe the first steps in the development of these types. Literally the new species originates at the time of the formation of the seed, but it is born only at the time of germination. But at this period it is not recognizable as such; this only becomes possible after the first leaves have unfolded. The plant can then be photographed, and in this manner we may preserve the type as soon as it becomes discernible and recognizable. In fact, one can study the birth of a species as readily as that of any individual, be it plant or animal.

Yet it shows one important difference. It is not at all necessary that a species should originate in but a single specimen as we saw in the case of *O. gigas*. The same leap, the same mutation may occur again, and actually did so in my experiments, where, in fact, it seemed to be the rule. All that is required is that the cultures consist of some thousands instead of some hundreds of specimens. Two things then become apparent: First, that in each lot several specimens of *O. nanella, O. lata, O. oblonga* and of certain other new species appear; secondly, that it is only a few types (and no others) which make their appearance. The number of new forms is far from unlimited. On the contrary, but few types make their appearance annually, and this among a large number of specimens. There are some that are more rare, as for instance *O. gigas* and a most graceful, small-flowered mutation which put in an appearance during the past year. In the latter, unfortunately, the seeds did not ripen, and therefore, for the present at least, it has disappeared, leaving no trace, with the exception of a plate, a few photographs and some alcoholic material.

To give a general view of the whole course of my experiments on mutation in this genus, I might combine them in the form of a

GENEALOGICAL TREE OF OENOTHERA LAMARCKIANA.

Generations:	*gigas*	*albida*	*oblonga*	*rubrinervis*	*Oenothera. Lamarckiana*	*nanella*	*lata*	*scintillans*
8th Generation, 1899 Annual.		5	1		1700	21	1	
7th Generation, 1898 Annual.			9		3000	11		
6th Generation, 1897 Annual.		11	29	3	1800	9	5	1
5th Generation, 1896 Annual.		25	135	20	8000	49	142	6
4th Generation, 1895 Annual.	41	15	176	8	14000	60	63	1
3d Generation, 1890–1891 Biennial.				1	10000	3	3	
2d Generation, 1888–1889 Biennial.					15000	5	5	
1st Generation, 1886–1887 Biennial.					9			

O. Lamarckiana forms the main stem; all other species originated from its seeds. Descendants of the mutations are not included in the scheme, so as not to make it too intricate.

The first two generations showed but comparatively few types. The reason for this may be sought in the fact that at the time I did not know how to trace them. Hence the fourth generation shows a marked improvement, which continued after the sowing had undergone a great numerical reduction.

O. oblonga appeared by hundreds. All of these plants closely resembled each other. They could be recognized as rosettes of root leaves by the narrow leaves with broad veins, and later on by their delicate, stiff, nearly unbranched, seemingly naked stems. The same is true for the dwarf forms. Our genealogical tree shows of these about 150; in other experiments I have met with even larger numbers. These plants again form a distinct type, which could readily be recognized, whatever the age of the specimens. *O. rubrinervis, O. albida* and *O. scintillans* were far rarer, but as a rule appeared each year, always bearing exactly the same character.

A species therefore is not born only a single time, but repeatedly, in a large number of individuals and during a series of consecutive years.

It is clear that this fact, so apparent in my experiments, must be of enormous importance in the case of wild-growing plants. How small is the chance of a single plant to triumph in the struggle for existence! Only when a number, or rather a large number, of similar individuals do battle together for the same cause is it that this chance acquires a value. *O. gigas* would have been nipped in the bud were it not for my aid. I have never found it growing wild, as I did some specimens of the less rare *O. lata,* and *O. nanella.* But these also meet with too many hardships. Only once have I found a single specimen in flower.

But next to the question of the more or less frequent appearance of a new species stands another which has as potent an influence upon its life. It is of course a matter of pure chance whether a mutation is or is not better adapted to the environment than the parent species. Sometimes it will go one way, sometimes the other, or both may be equally well adapted. Our *O. gigas* and *O. rubrinervis* are, during the flowering period, as robust as the mother species. Perhaps the first is, because of its broader leaves and stouter stem, a little better adapted. Probably both would survive in the struggle for existence if the early stages were not detrimental. *O. albida* and *O. oblonga,* on the other hand, are extremely weak, and it is with great difficulty that they can be persuaded to produce flowers and fruit. When growing wild they could never survive, in fact, they are never met with, though in the garden experiments they made their appearance in large numbers. For *O. nanella* the form is an objection, at least, under existing conditions, though were these different, it might prove an advantage. In regard to *O. lata,* which until now I have hardly mentioned, the plants are low, with a limp stem, bent tips and side branches, all very brittle, but with dense foliage and luxuriant growth. But unlike its relations, it possesses no pollen. It is true there are apparently robust anthers, but they are dry, wrinkled and devoid of contents. Only by cross-fertilization can *O. lata* produce seeds, and so it is unfit to found a wild type. Certain structural characters of this plant are therefore detrimental, or at least useless, and 'useless characters,' as every one knows, were among the earliest objections to the doctrine of the gradual origin of species by selection. For this theory can explain none but useful characters.

These observations are also important from another point of view. They teach us that the variability of species is independent of environment. This hypothesis, already formulated by Darwin, and which for him was the basis of a simple, logical explanation, is fully confirmed by the results of our experiments. Before Darwin published his 'Origin of Species,' it was generally believed to be otherwise; it was thought that environment had a direct influence on species. Changes in environment would call forth various needs and these in their turn would cause gradual changes in various organs. Use would have a strengthening, disuse a weakening, effect; a functioning in a certain direction would fit the organ better for that function. The changes would take place gradually and imperceptibly, but if only the influence continued long enough in one direction, specific differences would finally appear. On this theory are based the attempts already mentioned to make new species by transporting lowland plants to the highlands and *vice versa.* When this is done, great modifications may be observed, even during the first year. In the Alps the plants assume the compact, woody, small-leaved form which we meet with there so frequently; in the plains they are tall, with slender stems and ample but delicate foliage. At first it appears as if these experiments bore out the general opinion, but Bonnier has shown the opposite. He has proved that it is nothing but adaptation, something which any plant can show and which stands in no relation to heredity and the origin of species.

In my experiments the mother species mutates in all directions, in nearly all organs and characters as well as for better or worse. These changes occur, as far as could be learned, on a poor sandy soil as well as on heavily manured garden soil, with careful treatment and plenty of room between the plants. The mutation therefore is independent of environment, its direction is not governed by circumstances. Numerous species originate at the same time, forming a group in the same manner as the above-mentioned genera. The question which of these will persist in the wild state, which, as legitimate species, will some time form part of our flora, does not concern us at present. This can only be decided when the new forms have lived next to the others for a prolonged period, as some of them have done for the last fifteen years. For sooner or later must begin the struggle for existence, and the species which is best adapted will come out triumphant. But it is not a struggle between individuals, as is commonly believed, but war between species. The question is whether *O. gigas* or *O. rubrinervis*, or perhaps *O. nanella* or some other species will be best adapted to the new environment. Only then will be decided which shall remain and which shall go.

Here we have elimination of the weak, selection of the strong. 'Many are called but few are chosen.' In Nature this is true of species as well as of individuals.

The development of the entire plant kingdom points to a gradual progress. Nature passes from simple to complex, from generalities to particulars, from the lower to the more highly organized, from species with few characters to those which possess a countless number. Are our mutations a step forward in this direction? I believe I am able to answer this question in the affirmative, if we except perhaps *O. lata*, which possesses feminine characters only, and the dwarf forms, whose type is too common.

It is exactly because of this peculiarity that I arrive at this conclusion. Dwarfs constitute the only type which is also met with among other species, a type which is found among a large number of plants, such as dahlias, chrysanthemums, ageratums and a long list of species belonging to the most widely divergent families. A dwarf form is therefore nothing new, it is but an old principle under a new guise. The same is true for so many other forms which in horticultural and systematic botany are dignified by the name of variety. White varieties are found among most red- or blue-flowered species; with hirsute or thorny species occur nearly as many glabrous or thornless forms. Such repetitions are evidently no progress. They contribute largely to the great variety of Nature, but are usually retrogressive and not progressive changes. And ordinarily they deviate from the species in but a single character, something indicated as a rule by the name.

Quite different from this are the mutations of *Oenothera*. Recognizable as seedlings, as rosettes differing in shape, edge and color of the root-leaves, and later with stems differing in structure and mode of branching, agreeing in the flowers, varying in the fruits, they possess a type entirely their own, a type quite novel. Neither in other species of this genus nor in other genera belonging to the same family, nor anywhere else in the plant kingdom, do we find a *rubrinervis* or an *albida* with all their distinctive characters. Here we have something absolutely new, something entirely original.

My observations constitute but a first step in a new direction. But that direction is the one demanded by the times.

Any advance in our knowledge depends on the possibility of seeing species originate. Of course this does not refer to present species. Such a thing would be as impossible, as absurd, as expecting to witness the birth of an individual already inhabiting the earth. The species living at present are too old. But they may give rise to new ones. There seems to be sufficient reason for suspecting that this is happening at this very moment, and in our immediate surroundings, only we are not aware of it. Such cases must therefore be searched for with great care and patience. Once found, they must be carefully and extensively studied. The one case which I have mentioned here shows sufficiently the great treasure of new facts which lies within our reach. All that is necessary is to overcome the first difficulties.

Not only would such studies aid the theories of science, but they would also be of great advantage to the practical side of life. Our improved agricultural plants may serve as an illustration. According to Hays the produce of entire districts may be increased ten per cent. by the careful and repeated selection of seed. And these results were reached by the aid of old methods, applied during a few years only. How great is the promise of the new methods, with their larger prospects and greater chances.

Next to new races are new species. Let this be the motto of science and practice alike, for the welfare of agriculture as well as for the welfare of man.

HUGO DE VRIES.
UNIVERSITY OF AMSTERDAM.

SIXTH ANNUAL MEETING OF THE NEW YORK STATE SCIENCE TEACHERS ASSOCIATION.

THE meeting was held December 27 and 28 in the Medical College of Syracuse University. The greater part of two half days was given up to the section meetings which are reported at the end of this article. There were also four general meetings. Friday evening was devoted to a dinner and social reunion, an innovation appreciated by all.

The following papers were read and discussed in general sessions:

The Value of Research Work in Education: Professor SAMUEL J. SAUNDERS, Hamilton College, Clinton.

All education which attains its highest ends is of the nature of original research. The power to apply the research method should be raised to as high efficiency as possible before we stand face to face with the problems of life; it should be cultivated during the whole school career. Much of our modern educational effort fails because the pupil does not test his knowledge continuously and learn 'to do by doing.' The research method in science trains the observation, the imagination and the memory. It increases manual dexterity and skill. It forces the student to stand on his own merits and makes of him a vital factor in the promotion of civilization and national prosperity.

The Study of Types: Professor N. A. HARVEY, Chicago Normal School.

A full abstract of this paper is printed in *School Science,* beginning with February, 1902.

The Report of the Committee on 'A standard College Entrance in Botany,' appointed by the Society for Plant Morphology and Physiology. Presented by Professor FRANCIS E. LLOYD, Teachers College, Columbia University.

This report is discussed in a recent number of SCIENCE (page 409).

Symposium, *What ought the high school teacher in each science to know? What ought he to be able to do? What are his opportunities for self-improvement?* Brief speeches by several members and guests.

Report of Progress of the Committee on Stimulants and Narcotics: Presented by the Chairman, Professor IRVING P. BISHOP, Normal School, Buffalo.

The report comprises: I., A comparison of text-books used in medical colleges and in the public schools of the state; II., opinions of the committee regarding the effects of alcohol; III., opinions of educators regarding present methods of teaching physiology; IV., conclusions of the committee from the preceding investigation; V., recommendations of the committee. The report urges that the state law be modified so as to give more freedom to the writers of text-books and the teachers of physiology 'to decide as to the character and content of their teaching.' It urges that less time be spent in trying to teach the physiological