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CONTENTS OF THIS NUMBER:

EVOLUTION OF VEGETAL LIFE

How Life Begins.

BY

WILLIAM POTTS

*The eye reads omens where it goes,
And speaks all languages the rose;
And, striving to be man, the worm
Mounts through all the spires of form.*

—Nature, i., 7.

THE fossil strata show us that Nature began with rudimental forms, and rose to the more complex as fast as the earth was fit for their dwelling-place; and that the lower perish as the higher appear. Very few of our race can be said to be yet finished men. We still carry sticking to us some remains of the preceding inferior quadruped organization. . . . The age of the quadruped is to go out, —the age of the brain and of the heart is to come in. And if one shall read the future of the race hinted in the organic effort of Nature to mount and meliorate, and the corresponding impulse to the Better in the human being, we shall dare affirm that there is nothing he will not overcome and convert, until at last culture shall absorb the chaos and gehenna. He will convert the Furies into Muses and the hells into benefit.—*Culture.*

—RALPH WALDO EMERSON.

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EVOLUTION OF VEGETAL LIFE

BY

WILLIAM POTTS

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1889

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PREFACE.

THE publication of the series of essays on Evolution, delivered under the auspices of the Brooklyn Ethical Association, is undertaken in response to a general and increasing demand for a correct statement, in popular form, of the leading ideas, inferences and tendencies involved in the acceptance of the Evolution Philosophy, together with a clear statement of the main lines of evidence or proof by which the conception of Evolution is sustained. The plan of the series involves not only the treatment of the physical and biological phases of the subject, but also its ethical, social, religious and philosophical aspects—the whole to be introduced by biographical sketches of the two great men of our own time whose names are most intimately associated with the Evolution hypothesis.

As to the selection and arrangement of topics in the programme of the Ethical Association, Mr. Herbert Spencer says : "The mode of presentation seems to me admirably adapted for popularizing Evolution views"; and Mr. John Fiske writes, "I think your schedule attractive and valuable." The essayists have been selected with care, with special reference to the character of the topics to be treated. It is hoped that the publication of these lectures may aid societies and individuals throughout the country, in organizing and conducting classes in the study of Evolution, and thereby prepare many minds for an intelligent and systematic perusal of the more voluminous and scientific works of Darwin, Spencer, and other standard authorities.

The different phases of the subject are treated in this series in a certain natural order of succession, which the student and reader will do well to follow in the perusal of the lectures.

L. G. J.

EVOLUTION OF VEGETAL LIFE.*

IN touching the question of development, even as it affects the most insignificant plant, we are feeling the pulse of the deepest mysteries:

“To me the meanest flower that blows can give
Thoughts that do often lie too deep for tears.”

On the 26th of last July I was wandering around among the rocks where Cape Ann thrusts her granite arm out into the turbulent Atlantic, and bears from hour to hour through the ages the buffeting thunder-strokes of its mighty surf. The breeze was fresh; bright sunlight was reflected from the orange-gray rocks; and the air was full of the perfume of the bay-berry. But perhaps most lovely of all, where all was charming, was the myriad of wild roses which covered the bushes springing from the stony soil. We all know and love these delicate blossoms, which everywhere make our roadsides so attractive at midsummer. Professor Gray enumerates six species as growing in the Northern United States, and some varieties of these are to be found in almost every locality where there is a trace of wildness left. I have here roses from a bush of a different character, but we shall hardly say that they are less lovely. I want to ask you to follow me in an inquiry into the stages of the development of the bush from which they were taken; the different steps of growth which occurred before I could place before you these royal blossoms.

In what shape did it first appear as a growing plant? Probably as a short cutting from a branch, bearing a few buds, and inserted for a part of its length in sandy loam: that is, it was simply a part of another bush. The bush from which it was taken doubtless originated in the same way, and so back for many generations, or quasi-generations,—for, as a matter of fact, we have here no change by generation, but simply the prolongation of the life of a single

plant, by cutting off the root, and bringing the branch into immediate contact with the soil and its contained fluids. By this means its life may be prolonged far beyond what is ordinarily its duration if left to grow from the original root, but not always, perhaps, beyond what is possible in such case: of a rose-bush still living at Heldersheim, in Germany, it is said that, 800 years ago, Bishop Hepilo caused a trellis to be erected to support it.

For the purpose of my illustration, I can most safely go far back of the plant which produced the roses before us, and perhaps may as well take one of those in the thorns of which I became entangled by the margin of the sea. Those of you who are familiar with botany will pardon the introduction of some rudimentary facts, which are essential to the systematic development of the idea which I am to present to you.

We find, then, upon the summit of the flower stem, a little green urn or cup, dividing into five leafy points, and supporting upon its inner edge the five pink petals and a numerous colony of stamens crowned with yellow anthers; while within the cup are many tiny sacks, to each of which is attached a pistil having its summit slightly changed into what is called the stigma. When the flower is completely developed, we find that the anthers open and drop golden pollen-grains upon the stigmas below; and sufficient subsequent examination under a microscope shows us that from each live pollen-grain there grows a slender thread, which gradually penetrates to the little sack or ovule beneath. We next find formed, within the ovule, a minute cell: a membrane called cellulose, consisting chemically of carbon, oxygen and hydrogen, containing a semi-fluid drop of a substance called protoplasm, and consisting of the same elements, with the addition of nitrogen. I cannot tell you just how large this cell may be, but the ordinary diameter of cells in vegetable tissue varies between 1-240th and 1-1200th of an inch. If we take the largest of these, a cubic inch would contain about 14,000,000 of them. But whatever its size, this cell carries the promise and the potency of the plant which is to be. It is not the primary form of vitalized matter, for this matter exists as mere protoplasm alone, without a membrane. In its earliest condition we should be unable to tell whether this protoplasm is the initial step in the formation of a microscopic being

not distinguishable either as plant or animal,—or whether it is to be a rose, a violet, a palm or an oak,—a worm, a fish, a lion or a man. Its future is absolutely unpredictable, and yet upon it have been impressed or within it are contained the influences which determine which of these forms it shall take, in what way it shall resemble other beings, and in what way be distinguished from them: whether it shall live a stationary life, rooted to a rock or to the soil,—accepting the fate which the winds and the waters bring it,—or whether it shall have the power of flying to “fresh woods and pastures new”; whether it shall be a characterless automaton, or whether it shall speculate upon the origin of things, and upon life and death, the infinite and the absolute.

If we follow the changes in this cell, we find it gradually becoming larger, and dividing by a partition into two, into four, and so on, until a tissue is formed; into a substance having perceptible length, breadth and thickness. At last we recognize it as a seed: two minute leaflets attached to the rudiment of a stem, all enclosed within a surface membrane. This is now distinctly the beginning of a plant, and with numerous others it is contained within the orange-colored “hip.” In this state it is quiescent, but if after a time we place it in the earth, we shortly find it burst its sheath: the stem lengthens and pushes downward; the leaflets, reaching toward the surface, separate, and from between them there rises a sprout. How is this done? Simply by the increase in size, and the multiplication of the cells already formed, by absorption of the necessary chemical constituents found in the soil. But these cells now have a more definite arrangement. Some form a white root, and some a stem also white, until it thrusts into the air and light the point of a leaf, which immediately takes a tint of green.

From this time on subsistence is not drawn from the soil alone, but from the air also. The leaf is not simply the right bower of the plant; it is its essential, I might say its only essential organ. There are, it is true, some plants which get along without leaves; such, for example, as the bright orange-colored dodder, common in our meadows and by the brooksides, trailing its long thread-like stems over shrubs and herbs, a golden network, with never a leaf, but with clusters of white blossoms. But these are lazy rogues,

mere parasites, which do not even remain rooted in the ground, although they start there, but which attach themselves to other plants, and, too indolent to manufacture their own sap, plunder the vegetables, to which they have affixed themselves, of the material which they had provided for their own growth. There are numerous other plants not growing from the soil, such as the air-plants, with their gorgeous, or their fantastic insect or birdlike flowers; but these, to do them justice, are not so wholly idle and degraded: they are provided with leaves with which they earn their own living; they do not draw nourishment from the trees upon which they are found, but merely use them for support.

As the cells become more numerous, they also become more and more diversified in structure. In different parts they are different in form, in size and in their nature; some are very beautiful; most are small, but others take the form of tubes, and are enormous, having a length in some instances as great as one-sixth of an inch! But this is an extreme case. The crude ingredients for the sustenance of the plant are absorbed by the root, and transferred from one closed cell to another, through many millions it may be, until they reach the leaves, where they are mixed with the constituents of the atmosphere, and elaborated into the protoplasm from which the plant is built up. The rapidity with which this transference may take place you have yourselves noticed, when you have taken a drooping flower and placed it in a vessel of water. How soon the stem, leaves and blossom regained their firmness, their rigidity, their elasticity, their "life"!

The plant now sends up a stem upon which appear buds; these unfold into leaves; branches grow from the axils of the leaves, and leaves appear upon these in turn, and thorns form, by which the plant is defended. A flower is no necessary part of a plant; it is but one means of providing for a continuance of the series. The flower itself is but a series of modifications of a cluster of leaves, some of which have become sepals, some petals, some stamens, and some pistils. At a recent meeting of the Royal Horticultural Society in London, an Alpine strawberry was shown in which all parts of the flower were more or less represented by leaves. The strawberry is a near relative, a sort of cousin-german as it were, of the rose.

We have now completed the cycle. Starting from the flower, we have followed the life-steps until we have reached it again. Another course which we might have adopted, the one ordinarily chosen by fruit-growers, is that of budding or grafting. We should then have simply taken a single bud in the one case, a small twig in the other, from the variety which we desired to propagate, and inserted it into a sturdy stock of a nearly related kind, in which we had made an incision, bringing the inner bark into close contact, and excluding the air from the joint. What is the result of this process? Excepting in a few special cases, which I cannot stop to describe, the line of union between the two growths becomes indeed a line of union, but remains a line of separation. It is like the door of the underworld of which Dante speaks, though perhaps the prospect is not so hopeless. Your quince or crab stock is firmly rooted in the ground; it draws thence its juices and transfers them from cell to cell, to those of the new bud; but here they "suffer a sea change into something rich and strange." Your bud multiplies its cells,—becomes a twig,—a branch; it buds, it blossoms, and instead of the woody but fragrant quince, the rosy but diminutive crab-apple, you gather the pear-main, the wine-sap, or the seek-no-further, as you may have elected.

But stop. Do you always gather a fruit exactly like that with which you were familiar? Do you invariably obtain from the seed or cutting of your rose a flower of the same identical tint—of the same form, of the same fragrance? Not so: you find slight differences, for the better or for the worse; scarcely any two are precisely alike; you choose those that you prefer and propagate them; you neglect the others.

We have seen that Gray enumerates six species of wild roses in the Northern United States. There are also a number of wild species in the Eastern Hemisphere—how many I cannot tell you. But their cultivation began at an early date, and they have been developed and crossed inextricably. In 1793 some wild Scotch roses were transplanted into a garden. One bore flowers slightly tinged with red; from this, double roses were developed, blush, crimson, purple, red, marbled, two colored, white and yellow, and differing as much in size and shape. In 1841 the number of varieties in the nursery-gardens near Glasgow was estimated

at 300. In 1829, 2562 kinds of roses were enumerated as cultivated in France alone. Most cultivated roses have become double, and gradually less fertile, and less sure of reproduction in kind by seed, so that propagation by cuttings and by budding and grafting is resorted to, when the same characteristics are desired. Our apples belong to the rose-family. You know how much they vary. If they do not all come from the common crab, there are no wild species living, or of which there is any trace, resembling the present forms, and these are continually being increased in number.

This may be as good a time as any, to speak of another variation,—a variation which sometimes occurs immediately in the fruit produced from the pollen of one plant when placed upon the flower of another, and not simply as seen in the fruit of a plant resulting from seed so produced. As an illustration of this, I will give a single instance.

At St. Valery in France there is an apple-tree which has blossoms with a double calyx having ten divisions, and with fourteen styles, but without corolla or stamens. The flowers therefore require artificial fertilization with pollen from another tree. The girls of the village go annually to "*faire ses pommes*,"—to make their apples, each marking her own fruit with a ribbon, and as different pollen is used, the fruit differs on the tree. This is an exceptional case, but the same thing has occurred where the conditions were not so unusual.

Almonds, pears, peaches, plums, cherries, nectarines, etc., belong to the rose-family. The peach is believed to have been derived from the almond, and the nectarine is supposed to have grown from a peach-stone, in Boston, England. It is certain that peach-trees frequently produce nectarines, while nectarines at times produce peaches, sometimes both kinds of fruit appearing together on the tree. Occasionally a part of a single fruit is peach, and a part nectarine. You know what a vast difference there is in the varieties of grapes. Most of these are supposed to have risen from a single Asiatic species. Of gooseberries there were eight varieties known in 1629; now there are over 300.

Pansies are believed to have been derived from five wild stocks, variously crossed. You are all familiar with their varieties and differences. Dahlias are believed to have all

come from one species since 1802 in France and 1804 in England. With the varieties of these you are likewise familiar. So also with the hyacinths. The original flower, which was brought from the East, had the petals narrow, wrinkled, pointed, and of a flimsy texture. In 1597 there were four varieties; in 1629 there were eight; in 1768 there were said to be nearly 2000. The number has since, it is believed, very much decreased. Of chrysanthemums, "it is said that at least 10,000 seedlings have been exhibited for the first time this year. The diversity of form and color displayed is almost infinite, and the various strains have been so intercrossed that the seeds from a single flower-head will often produce examples of the types most widely separated in structure and size, together with intermediate and kindred forms."

These numerous varieties have been produced first by unconscious, then by conscious as well as by unconscious selection. The least of a botanist among us knows enough to gather the finest cluster of mayflowers which she may find by brushing away the dry leaves with which they are covered in the early spring; the best huckleberries or blueberries that grow upon the mountain top. We all know that there *is* a difference. So in the orchard or in the garden. If there are too many apple-trees, it is not those which bear the finest apples which will be sacrificed; if the rose-bushes need protection from the frost, it is not those which produce the smallest and the most scentless blossoms that will be most tenderly cared for. We know, too, that as we give a more steady supply of moisture and nourishment to the plants which we protect, they improve in quality and increase in variety. *How* they will vary, at the outset we do not know, nor do we know *when* they will vary. But experience has shown us that they *will* vary, and that by protecting such varieties as please us most, and propagating them, and conversely, by neglecting or destroying those which are less satisfactory, the variations once begun can be increased and made definite upon the lines chosen.

From this elementary condition, cultivation has gone forward until it has become the artistic representative of a science, and until it almost seems that due diligence only is required to enable the floriculturist to turn out a flower of any pattern which may be suggested to him.

It must be borne in mind however, that these results are

frequently attained under conditions which are artificial, and which are dependent upon the continued care and attention of the operator. From this it would naturally be inferred that the elaborate productions of the culturist's art, if left to themselves, would either perish from the too cold charities of the common world, or would rapidly change their character, and if they did not return toward the form from which they were derived, would at least become something quite different from that to which they had been trained,—and this is frequently, if not always, found to be the case. I have been particularly interested in noticing the apple-trees growing among the trees of the forest, by the side of country roads: not merely the fruit is different from what it should have been, but the whole character of the tree is changed. The branches, instead of being few and wide-reaching, have become numerous, ascending, frequently divided, angular, and with twigs short and thorny.

Strictly speaking, an organism is that which has organs. Colloquially, however, when we speak of organic life, we use the term in contradistinction from mineral, which we call inorganic. As we have seen, the lowest form of matter of which we speak as living, is composed of carbon, oxygen, hydrogen and nitrogen, which are also found in compounds not termed organic. What, then, is the distinction between the organic and the inorganic, and how and when did this distinction arise?

Huxley gives three points, in which he claims that that which has life differs from that which has not life. *First*: In its chemical composition; the chemical elements are united in a combination called proteine, which, together with a large proportion of water, forms protoplasm. Proteine, it is said, has never yet been found except as a product of living bodies. *Second*: Its universal disintegration and waste by oxidation, and its reintegration by the reception of new matter. *Third*: Its tendency to undergo cyclical changes—that is, to pass through a course of development and decay in a succession of forms, like and unlike.

Probably at the outset many persons would say that motion and growth are the most characteristic attributes of life. But the mineral compounds show both motion and growth. Certainly few things are more definite or beautiful than the growth, of course accompanied by motion, which occurs in

the formation of crystals, and which is shown us in transcendently lovely forms in the frost-work upon our windows upon a winter morning.

It is a most interesting question whether the forces which produce organic life differ from those so-called physical forces with which we are familiar in other phenomena. It is clear that all the complicated processes which we call "vital" in ourselves and other higher organisms, are invariably found in the closest and most intimate relations, apparently of effect and cause, with light, heat, electricity, etc. Modern science has shown these forces to be equivalent, correlative and interconvertible, and it would seem an excess of stupidity did we not mentally connect the elaborate operations which we know with the simpler ones which preceded them, as alike in nature and origin. However we may define it, we are certainly, at present, forced to recognize a distinction between that which we say has life, and that which we say is without life. But this distinction, this parting of the ways, finds us upon a narrow edge. On the side of life, we have an unorganized albuminous substance without definite size, or form, or boundaries,—simply homogeneous matter of intimately united carbon, hydrogen, oxygen and nitrogen. I should note here that Huxley remarks: "It may be safely said of all those living things which are large enough to enable us to trust the evidence of microscopes, that they are heterogeneous optically, and that their different parts, and especially the surface-layer, as contrasted with the interior, differ physically and chemically." He does not, however, mean by this that the difference extends so far as to constitute organs.

How the differentiation between the living and the not-living took place, who shall say? All that we know at present is, that it *did* take place, or that at some time it *was*, and that among the qualities of which so-called organic matter was then possessed, or which at least it has always exhibited since it has been observed by men, were the capacity for change, and the power of transforming inorganic into organic matter.

Protoplasm in masses, as discovered at the bottom of the sea by the Challenger expedition, was described by Huxley under the name of *Bathybius*. Of the same composition we find perhaps the lowest forms of individual life, in what

are called monera;—simple tiny lumps of protoplasm, which have no containing membrane. Their motion consists in a changing of shape by the protrusion and retraction of certain parts, not differing in structure from other parts, and they multiply in a most unmathematical way, by dividing. Are they animal? Are they vegetable? Are they not rather a division antecedent to these, and one which cannot be classed with either of the great kingdoms, which probably diverged from it? Haeckel, with a considerable show of reason, takes the latter position, at least tentatively.

These, and the nearest allied forms, are generally microscopic; some may be said to have organization—there is a certain differentiation of parts; they have motion; some of them, such as the diatomaceæ, have silicious shells or skeletons, with wonderfully beautiful markings. That you might have some perception of the subtlety of nature's handiwork, I should like to show you through my microscope a specimen of one of the species of these. You would see a tiny vessel, for all the world like a canoe turned bottom upward (as I have a chilly remembrance of mine having been once, with myself atop, under the gentle ministrations of a September gale in New York harbor), only with stem and stern gracefully curved sidewise in opposite directions, and regularly marked diagonally from point to point with almost innumerable parallel lines in two series, nearly at right angles. It is magnified 500 diameters,—that is, within the space apparently occupied, could be placed 250,000 of the actual diatoms. Mr. McAllister tells me that he has seen the same object under a magnifying power of 100,000 diameters, or covering seemingly a surface which would enclose ten billions (or, what is the same thing, 10,000 millions) of the vegetable, if vegetable we are to call it. Of course but an extremely small fraction of the object can thus be examined at one time. Under this power, the simple parallel lines become the intersecting paths between continuous rows of hemispherical projections.

Notwithstanding their shells, and notwithstanding their motion, these are usually accounted vegetable. Indeed, it is difficult to find any test by which that which is animal may be separated absolutely from that which is vegetable. Is it incongruous for a vegetable to have a solid mineral

frame-work like that of the diatoms? The Rev. J. G. Wood says of flint in grasses and in the horse-tails or equisetæ, "so plentiful is this substance, and so equally is it distributed, that it can be separated by heat or acids from the vegetable parts of the plant, and will still preserve the form of the original cuticle with its cell-walls, stomata and hairs perfectly well defined." Is it strange that a plant should have motion? Darwin has shown, by multitudinous experiments, that many climbing-plants regularly revolve at their growing ends, from right to left, or from left to right; that these revolutions are made in specific times; that their tendrils, when they have them, likewise revolve, and move forward to avoid clasping the stems upon which they grow; that sometimes, even if touched on one side by a weight no greater than 1-50th of a grain, they will curve toward that side, and subsequently become relaxed; that when they find a suitable object, they will twine around it, and having fastened themselves securely, draw up into a spiral spring, thus holding the plant more safely to its support, and at the same time providing a method by which it can yield to the pressure of the wind without disaster.

Is it in the character of their food? It used to be said that animals could only subsist upon organic matter provided by vegetables, either immediately, or indirectly through the substance of other animals, while vegetables drew their nourishment only from air, earth and water, elaborating organic from inorganic matter. But here again we were at fault. I am the happy possessor of a few rocky acres in the north-eastern corner of Connecticut. At the foot of my slope is a pond, with a meadow and a stretch of marshy ground rich in flowers of many sorts. Among these is the beautiful sundew, with its little round or oval leaves, covered with slender hairs, each holding upon its summit a pure and brilliant ruby drop. There it lies in wait to catch incautious insects, ants or flies, and when once they have ventured upon its shining trap, gently folds them in and holds them in a close embrace, until all their available substance has been absorbed. There, also, in hundreds,—yes, in thousands,—is the curious pitcher-plant, always holding out its cups to catch unwary stragglers, and then using the same cups in which to prepare them for its daily meal. In the South there are other species of these, which have a sugary trail leading over the edge of the cups

and so down to the ground,—a long and narrow road to perdition for uneducated or too dissipated insects. There, also, are the Venus' fly-traps,—more ambitious relatives of the sundew,—greedy plants, which are not always cautious enough about what they attempt to devour. It is said that one of them, being fed by a waggish investigator with a piece of cheese, had a most disagreeable dyspepsia therefrom.

Mr. W. T. Thistleton Dyer, in the "Encyclopædia Britannica," draws this distinction between animals and plants: "If we compare a plant and animal reduced to their simplest terms, and consisting therefore in each case of a single cell, i. e. of a minute mass of protoplasm invested with a cell-wall, while the unicellular plant draws its nutriment by simple imbibition through the cell-wall from the surrounding medium,—a process which implies that all its nutriment passes into it in a liquid form,—the unicellular animal is able to take in solid nutriment by means of interruptions in the continuity of the cell-wall, and is also able afterwards to reduce this solid food, if of a suitable composition, to the liquid state."

We do not have to go very far above the monera to find what we may safely call vegetable forms. And first we discover, for example, the protococcus, "which forms dull crimson patches resembling blood-stains on the northern side of damp rocks or old walls,"—plants of a single cell, of which Haeckel says, "several hundred thousand occupy a space no larger than a pin's head." They belong to the algæ or tangles; and, while these are perhaps the smallest, within the same division at the other end of the scale we find the largest plants, the macrocysts, 300 or 400 feet in length. With the algæ of the sea, in some form, we are most of us familiar, and many of the species which we find upon the shore, where they have been left stranded by the tide, are exceedingly beautiful. It is noteworthy, that some algæ have been found living in hot-springs at a temperature as high as 208 degrees Fahr.,—a quite exceptional condition of life.

Nearly related to the algæ, are the fungi and lichens, the algæ being distinguished from the others by containing chlorophyll, that is, the substance which gives the green color which we see in most plants, and which is supposed to be the principal instrument in the elaboration of the nu-

triment upon which the plant subsists. Among the fungi are the bacteria, the yeast-plants, the bread-moulds, the cheese-moulds, mushrooms, toadstools, rust, smut, and a vast number of others of a related character. These, as is the case with most of the lower forms of life, multiply with enormous rapidity. Together, the algæ, fungi and lichens form the sub-kingdom called *Thallophyta*, the characteristic of which is that the plants are without distinct differentiation of root, stem and lateral appendages.

Another sub-kingdom,—*Cormophyta*,—embraces the remaining vegetable population, which may be arranged approximately in the order of development or of elaboration, thus: mosses and liverworts; ferns; the equisetæ or horsetails; the lycopodiums or club-mosses and their near relations: then the flowering plants, beginning with the coniferæ,—the pines, firs, cypresses, yews, and the cycas, which have naked seeds, usually in cones,—and ending with the multitude of trees, shrubs and herbs having their seeds enclosed in seed-vessels, and divided into those the stems of which increase in size by additions throughout their thickness, like the palms among trees, and the lilies among herbs, and those which increase in size by growth on the exterior of the wood immediately under the bark—thus showing year-marks if they be perennials; this division including such trees as the oak, and such herbs as the violet.

While differing enormously among themselves in every respect except one, the leading difference which runs through this classification is in the method of reproduction, and the structure of the reproductive organs. In the very lowest plant-forms, multiplication seems to depend simply upon the strength of the cell membrane. The single cell increases in size, and a partition is formed across it. If the membrane be weak, the two cells part company, and the number of that species has been doubled. If the membrane be strong, the two cells remain attached, and the process of increase in size and division may continue. The protoplasm of the unicellular plant is frequently broken into fragments, each provided with cilia or filamentous prolongations of the protoplasm, by the aid of which they move rapidly through the water in which they are formed. Gradually each becomes covered with a coating of cellulose, and begins life as a complete plant. Much higher in the scale of vegetation, the power of increase by simple sub-division

is retained, as we have seen in the propagation by cuttings. A more marked instance is to be found in the case of the begonia, which the florists propagate from fragments of the leaves. In some of the garden lilies, perfect bulbs are formed in the axils of the leaves; in other plants, bulbs are formed under ground; in the potato, large stems or tubers are formed upon the roots, and from these new plants are grown.

In the simplest plants formed of aggregations of cells, the independence of the cells seems to be simply limited by their physical attachment to each other; subsequently the functions of the parts become diversified, and a division of labor begins.

The next form of the reproductive process is found in the desmids and diatoms, which, beside multiplying by division, also multiply by conjugation; that is, two cells or plants unite to form a compound plant, the contents of which, taking upon itself a coat of cellulose, begins a new series of individuals. The next is a differentiation in the structure of the plant by means of which certain cells called antheridia, produce antherozoids, which correspond with the grains of pollen in the higher plants, and other cells produce oösppheres which correspond with the protoplasmic contents of the ovules. Then we come to the mosses, which have processes resembling pistils and antheridia, either on the same, or on separate plants. Then ferns, in which the spores, found upon the underside of the fronds or leaves, drop off when ripe, and produce minute plantlets, which contain separate elements which must unite before fertilization is effected. Above this grade are the flowering plants, in which is more or less developed the complete system which I have described in the case of the rose.

In much the greater number of the plants with which we are familiar, the stamens and pistils are found in the same flower; sometimes they are found in different flowers upon the same plant; sometimes some of the flowers upon a plant are perfect, and some are staminate or pistillate only; and sometimes the staminate or pistillate flowers are found upon separate plants. The last form is esteemed the most highly developed. I should note in passing that while in all the higher orders of plants having flowers with stamens and pistils, fertilization seems to be necessary for the maintenance of the race, nevertheless instances have been occa-

sionally observed, in which perfect seeds appear to have been formed without fertilization.

I have said that the leaf is the essential organ of a perfect plant. Many plants consist only of the leaf. Rising above this stage, and reaching that of a stem, with root and lateral appendages, we still find the leaf the most important feature, and upon it is dependent the character of the plant. The leaves appear upon the stem in certain specific relations. They are opposite, or in a whorl around the stem, or with the stem passing through them, or placed like a shield upon its summit, or arranged alternately upon its sides. If alternate, they are arranged in certain spirals, as, in one turn with two leaves, or one turn with three leaves, or two turns with five leaves, or three turns with eight leaves, or five turns with thirteen leaves, etc., before a point is reached exactly above that of starting. Sometimes, instead of their ordinary form, leaves assume those of bracts, of scales, as in buds, of tendrils, of spines, etc., and, as we have already seen, of the various parts of flowers. In flowers they exhibit almost every conceivable variety of form and color: sometimes there is one, sometimes there are two floral envelopes, their leaflets united or separate, few or many; sometimes there are stamens and pistils; sometimes either; sometimes none; sometimes the flower is regular in shape; sometimes irregular, in one or other direction,—any one of the parts occasionally reverting to its normal form as a simple leaf. As the branches usually appear at the axils of the leaves, the arrangement of the branches is governed by that of the leaves.

I have said that plants differ in structure in every respect except one. That one is the cell. As the individual plant starts with a single cell, and, simply by aggregation of cells growing from this one, obtains at last all its varied parts as a perfect whole, so the vegetable kingdom throughout, from the simplest form to the most complex, is but a series of similar aggregations. Under the development hypothesis it is claimed that these forms are of a common stock; are related to each other by lines of descent, all having probably originated in the unicellular aggregation of protoplasm which I have described. As we cannot say how this became differentiated from inorganic matter, so we cannot positively say whether such differentiation can now take place. The problem of spontaneous generation is one to which

much time and thought and careful experiment have been given.

Not many years ago it was supposed that the development of infusoria in water, in which organic matter had been steeped; the swarming of animal and vegetable life in decaying organic matter of all kinds, and where no organic matter was known to exist, and great caution had been used in experimentation,—and other similar facts,—were proof positive that such life may even now be generated spontaneously. But then followed an enormous increase in the precision and care with which experiments could be conducted, and it was believed by most that when all access of the germ-laden air had been made impossible, and other essential conditions had been fulfilled, no such generation occurred. Subsequent investigation made this again uncertain. I have an impression that some one has said,—if not, some one *will* say,—that the struggle here is like that between the manufacturers of big guns, and the builders of mail-clad vessels. As to spontaneous generation at the present time, we can hardly do more than render the Scotch verdict,—“not proven.” (But if it does not now occur, it does not therefore follow that in the long-buried past the conditions may not have been such as to have permitted this.)

In this connection, the theory that the parts of an individual, such as a tree or the individual cells of even complex organisms, may have some sort of independent existence, is most interesting.

Supposing the development theory to be correct, it is to be assumed that the earliest forms of vegetable and animal life must have been the simplest—mere albuminous matter. No such forms are found in the geological record: it is impossible that they should be,—their substance and organization (if we may use such a term) were such that they must inevitably be annihilated by time and mechanical action. Moreover, all the earlier rocks appear to have been exposed to such heat and pressure as must unquestionably have destroyed much more elaborated tissues than those first formed. Even should we ever obtain access to that portion of the record now concealed in the bowels of the earth, or under the waters of the sea, there is scarcely a possibility that we should find evidence of the earliest forms of life. Moreover, we could not expect to find a regular series of forms. Between those deposits in which vegetable remains

are preserved there are the widest gaps. They were usually laid down upon sea-bottoms, or in shallow lakes, or at the mouths of rivers, and vast intervals of upheaval occurred between them. There were also great changes in temperature, and by climatic influences, and the varying connections of islands and continents, alternately elevated and depressed, tribes have been pent within narrow limits, or spread to the four quarters of the globe. Nevertheless, in general, the story that geology tells is the story that we should expect to hear. In the several great geologic periods, evidences of the vegetable life of which have been preserved, certain plant-forms have dominated in turn, and in the order of their complexity as I have already defined them.

First appeared the algæ, in the Primordial Epoch, and with them; apparently, no other. In the Primary Epoch, in which were made the great coal deposits of the Carboniferous Period, there was an enormous development of mosses, of lycopodiums, of equisetæ or horsetails, and of giant ferns in great variety and of great beauty. So far as many of these exist to-day, they are characteristic growths of warm countries. It is noteworthy that plant-life was the dominant life of the Carboniferous Period; that plants grow most luxuriantly in an atmosphere containing an excess of carbonic-acid gas; that the effect of such an atmosphere would be to greatly raise the temperature of the surface of the globe; and that during the Carboniferous Period, this tropical vegetation seems to have been spread throughout the circum-polar regions. If, then, at this period, there was an excess of carbonic-acid gas in the earth's atmosphere, all the facts which we note are harmoniously accounted for.

The latter part of the Primary Epoch and the beginning of the Secondary, saw the development and reign of the palm-ferns and the pines; and then the palms and similar interior growing plants; and finally, in the Tertiary and Modern Epochs, became dominant the hard wood trees and varied flora that now in great part form the royal fittings of the temple of nature in which we dwell. Of old herbaceous forms the remains are, naturally, relatively few, because of the softness of their substance; but so far as they appear, their character corresponds with that of the general record.

I do not mean that all of our present forms are very recent. On the contrary, though not among the earliest, some

of them were developed long ago, and when vegetation generally was of a simpler character. Take for instance the sequoias, once numerous, of which there are now but two living species, both on the Pacific slope, and of which giant trees it used to be said that it required two men and a boy to see to the top of one of them. Nor do I mean that none of our present forms are simple and primary. I have already shown you that the case is quite different. But, as we shall see, there is not only no incongruity in this; on the contrary, it is in strict accordance with the theory which I am attempting to illustrate.

The theory of Evolution, as portrayed by Spencer, describes a progress from the homogeneous to the heterogeneous; from the all-alike, to the greatly varied. This does not *necessarily* imply advance in one direction. The contribution of Darwin to this theory was the proposition of a condition, of an active agent, and of the method of its operation; the struggle for existence, natural selection, and the survival of the fittest: of the fittest, mark you, to comply with the conditions existing,—not fittest in the sense of *best*, which is the interpretation usually put upon the term by those who have not made the matter a study. We have here however a good illustration of the saying that there is always room at the top. The greater the variety, the more certain it is that with complexity of form will come advance on certain lines, because, upward and outward, the possibilities are infinite.

Darwin claimed, modestly but firmly, that the one named by him was the principal, though not necessarily the only cause of the development of all existing animal and vegetable life from simple primary forms. If you have not thought carefully of the matter, perhaps you have not realized that there is any such thing as a struggle for existence in organic life, although those of you who have tackled the world single-handed may perhaps be inclined to make an exception in your own case. Let us see: a few suggestions, only, will suffice.

Experiment has shown that the air contains germs in great variety, in numbers inconceivable. So also the soil. Darwin took three table-spoonfuls of mud, from three different points beneath water on the edge of a little pond, and, placing it under cover in his study, kept it there for six months, pulling up and counting each plant as it grew.

There were 537 of them ! But one other case will tell the whole story. Darwin counted and estimated the seeds of one of the English orchids — orchis maculata : there were 186,000. Taking into account the size of the plant, he found by calculation that if these seeds should all grow, 174,000 of them would be sufficient to cover an acre ; that is, in one generation, or one year, the fruit of a single plant would be sufficient to cover an acre ; in two, sufficient to cover the island of Anglesea ; in three to cover 47-50ths, or nearly the whole, of the surface of the earth ! Yet this plant is not increasing in number : not more than one, then, out of 186,000 of its seeds, is able to maintain itself to the point of producing other seeds, and carrying on the line.

Seeing that such is the condition of life,—that all the “soft places” must be taken almost at the moment the doors are opened, and that standing-room only is to be found by the few that are ready to take the places of those that from time to time fall out of the ranks, is it not inevitable that the slightest advantage in any conceivable direction will be favorable, and that the plant having this advantage will be the one that will live and perfect its seed ?

We have seen that slight variations are the rule in nature. These variations may take any direction. If there are upon a given space all the tall plants that can there find room, smaller ones only can creep in, and vice versa. If all the material required by complicated organisms is already spoken for, those only that can live on an inferior quality can find a chance to exist. There are all possible gradations of these conditions. Experience shows that a spot of ground sown with the seeds of several genera of grasses, will produce a greater number of plants, and greater weight of herbage, than a similar spot sown with a single species. Darwin found on a piece of turf, three feet by four, which had been left for many years under similar conditions, plants of twenty species, from eighteen genera and eight orders, showing a wide difference in character.

Time will not permit me to even enter upon the details which have been gathered illustrating the nature of this struggle for position, which is incessantly going on, or the evidences of its effect, excepting possibly in a single direction. I should like to explain Darwin’s hypothesis of Pangenesis. I should like to show you how seeds and plants are distributed : borne on the wings of the wind ; carried in

the crops or between the toes of birds; floated across waters in old tree-trunks and timbers, or shipped unwittingly in the meshes of sacks or cracks of packing-boxes. I should like to tell how our most troublesome weeds, like the white-weed, or so-called daisy, which trades upon the reputation of the "wee, modest, crimson-tippit flower," and a host of others, are pauper-immigrants,—some of them anarchists, indeed,—naturalized and voters the first year, every one. Against them, high license, local option, and prohibition have been alike unavailing: the American System of Protection has been an utter failure. I should like also to show you the minute degrees by which great changes are usually effected, but perhaps this has been sufficiently done in what I have said in relation to Artificial Selection. Natural Selection is simply the happening, under ordinary conditions, of that which man effects under extraordinary conditions. It is simply that which *must* result, in the nature of things, from the fact that a small fraction only of the whole can survive; and from the two diverse tendencies in the laws of descent, for like to produce like, and for the child to differ slightly from the parent. Of course the enormous extent of the changes presupposes an enormous lapse of time in which they were effected. But that lapse of time geology shows to have occurred.

I will only mention one part of the evidence of adaptation which has been recorded. The conviction was forced upon Darwin's mind, by the results of an immense amount of research, that persistent inbreeding is probably detrimental to any plant: that strength results from the crossing of individuals, if not of varieties or species; and that, with a higher grade in life, comes an increasing tendency to specialization in the reproductive organs, and the interposition of bars to self-fertilization. His most exhaustive study was made among orchids, of which there are some 6000 species. Many of these are epiphytes, or air-plants, and are marked by the strangeness or magnificence of their blossoms. They are also marked by a wonderful tendency to hybridize, which enables florists from month to month to exhibit new forms and colors, sometimes of wondrous beauty, and therefore, I imagine, not closely resembling the dog for which the boy wanted an extra price, because he comprised sixteen different kinds.

Darwin found that in nearly all orchids it is impossible

for the pollen of a plant to reach the stigma of the same, but that fertilization is effected by bees, butterflies, and other insects, which bring pollen from other plants while seeking for nectar, the flowers being usually so constructed as to make it impracticable for them to withdraw without carrying away the pollen-masses from the anthers, or to enter the nectaries of other flowers without placing these masses upon the stigmas. The book in which he explains this process, you will find most fascinating.

Among the trees upon my rocky hillside, I found last summer numerous specimens of a showy, rose-purple orchid,—one of the *Cypripediums*,—called indifferently, wild lady-slipper, Noah's-ark, or moccasin flower. If I were to tell the whole truth, I might have to confess that it was partly because of its presence that I was induced to buy the property. This belongs to a genus which Darwin believes, from its structure, to have been one of the earlier forms, in which the fertilization of the flower by its own pollen, or that of another plant, depends upon whether the insect enters it first by one of the side notches or by that in the middle. In most orchids, there is no option,—the flower must be fertilized from another; and this is the case with one of the most attractive of the smaller species, the lovely little white *spiranthes*, or ladies'-tresses, of our meadows.

Perhaps I might venture to mention just one other instance of complicated relations, of especial interest to our single sisters. Darwin found that the fertilization of red clover depends largely, if not solely, upon the visits of humble-bees; that the number of bees is greatly reduced in a district where field-mice are numerous; and that the number of field-mice is dependent upon the number of cats. Huxley carries the chain one link further, and throws out the suggestion that it is the abundance, or otherwise, of the old-maids who cherish the cats, upon which rests the fate of the red clover,—and indeed, as Carl Vogt says, the fate of the English race, whose staple food is the beef grown from the red clover. So you see that starting with the women, by a devious course we reach the men at last.

(Why do these changes of form occur? I cannot tell you: no man can to-day tell you. We only know that variations are constantly taking place; that one form is developed from another; that these variations result from tendencies

controlling the organic matter, checked and guided by surrounding conditions. We know that these changes occur, as certainly as we can possibly know anything: they are taking place at every instant before our eyes. Whether all changes have been of the same character; whether all forms of life, above the most simple, have come from pre-existing forms, we cannot now prove,—we can probably never prove. The most that we can say is, that the preponderance of evidence in this direction is overwhelming; that the system thus outlined is consistent and reasonable; and that any other system or theory, which has so far been broached, seems arbitrary, artificial and improbable. We cannot say that we can understand it, excepting as a logical process: our minds as developed so far have not capacity for grasping certain ideas, which nevertheless we can express. Whatever theory of creation we may accept, whichever horn of the great dilemma we may adopt,—as, for example, that there was a point which had no antecedent, or that there was no such point,—we are alike landed in the inconceivable: and yet, the inconceivable on the one hand or the other, *must* be the true. This is not saying that we must not speculate; it is simply saying that from the constitution of the mind speculation has its limits, which we shall reach, and which will bring us to a halt willy-nilly: we need not fear lest we transcend these limits; we cannot overstep the boundary until our minds take on new powers. We shall adopt, and properly adopt, that theory which is in closest accord with what our experience shows us to be the facts; that theory which requires us to make the least draft upon the arbitrary and the cataclysmic.

Some weeks ago there appeared, among the waifs in one of our daily papers, the following story: “It is said that when Gen. Grant was in Japan, the Japanese Premier, Prince Kung, desiring to compliment the General by telling him that he was born to command, tried it in English with this result: ‘Sire, brave General, you vas made to order.’” Apparently, in most quarters to-day, as in the past, the great question is, whether things have been made to order. The question of design has been the vital question, whether Paley has been the spokesman upon the one side or Haeckel the spokesman upon the other. During the contest through which the development hypothesis passed before its general acceptance by the great body of scientific men, this ques-

tion of design was probably the principal stumbling-block, and many shades of theory have been advanced, ranging from the idea of an absolute pre-existent plan, carried out with mechanical exactness by a divine artificer residing afar, to that of the occurrence of purely fortuitous and unintended combinations. The latter is that of Haeckel, who supposes all development to result from what he calls natural causes and mechanical laws, without any participation of divine power. But whence come these "natural causes" and "mechanical laws" he fails to explain, and he likewise fails to explain how he knows that no divine power is involved.

It seems to me that there is a different way of apprehending the universe, which accords with the facts more nearly than any of these, from the most orthodox to the most materialistic; and it is the natural outcome of the idea of the one-ness of things carried to its n^{th} power,—to its ultimate.

We know nothing of spirit, except as we find it manifested through matter: we know nothing of matter except as spirit makes it objective. We know nothing of absolute life, except as we see it manifested in ourselves, or in that which is around us, or in that which what is around us and in us records. We know nothing of a primary fiat; we know only development and change. Why should we turn our backs upon that which we know, to guess at that which we do not know, and cannot possibly prove? Why choose an arbitrary theory while the facts before us all point in one direction?

We talk of "natural laws" and "divine laws." We know nothing of the imposition of such laws,—we can know nothing. All that we mean by these expressions is, that we are conscious of an invariable sequence. The Universe holds together: there is no revolt in that which exists.

"Ever fresh the broad Creation,
A divine improvisation
From the heart of God proceeds,
A single will, a million deeds."

Our life is a becoming. *Life* is a becoming. Speaking reverentially, as one must, it seems to me that the Universe with all that it contains is but the outward semblance of one life that is self-developing, and that to speak of design in the ordinary sense is a crude and inadequate way of expressing the condition upon which that life subsists. Noth-

ing is fortuitous; nor does it seem to be any more true to say that it is created, in the mechanical sense. Life is evolving: that is all that we observe, that is all that we know. The meanest thing that we see, the highest thing that we can conceive, are manifestations of that life, whose possibilities are beyond our conception.

"For I have learned
To look on nature, not as in the hour
Of thoughtless youth; but hearing oftentimes
The still, sad music of humanity,
Nor harsh nor grating, though of ample power
To chasten and subdue. And I have felt
A presence that disturbs me with a joy
Of elevated thoughts; a sense sublime
Of something far more deeply interfused,
Whose dwelling is the light of setting suns,
And the round ocean and the living air,
And the blue sky, and in the mind of man:
A motion and a spirit, that impels
All thinking things, all objects of all thought,
And rolls through all things."

With the birth of consciousness we feel life; with the development of mind we are able to recognize it; with the growth of mind, to realize that we are of it; with the refining and exaltation of mind, we can deliberately fall into line and assume our share of the labor which carries that life, of which we are part, ever forward to higher issues.

Is it possible to contemplate any finer or holier relation, any higher destiny than thus exists?

Last 2 or 3 leaves I
think very good. A R

ABSTRACT OF THE DISCUSSION.

DR. MARTIN L. HOLBROOK :—

In my judgment both animal and vegetable life have evolved from forms originally possessing some of the characteristics of both kingdoms. Possibly these forms are now represented by well known micro-organisms. Though scientists, after many years of doubt, now class them as belonging to the lower forms of vegetable life, some of them are as much animal as vegetable. They have no chlorophyll, they do not take carbon from the carbonic acid of the atmosphere, as plants do, but from other organic compounds, as ammonia, sugar, etc. They also require oxygen, which, like animals, they draw from the air. The cell-structure of the albuminous compounds of both plants and animals is almost identical. Some of the epithelia of animal and vegetable organisms are so much alike that I have known very good microscopists to mistake those from leaves found in Croton water for those from the human skin and mouth.

Plants have many qualities in common with animals. The dandelion is as aggressive and capable of self-protection as a human being. It seems to have a sort of intelligence. When it sprouts in poor soil its leaves form a mat extending some distance from the stem, keeping other plants away. In rich soil, among other grasses, it uses its leaves, which are notched as if by design, as an ape uses its hands, to climb up to the sunshine. Other facts showing similarity of nature, make it probable that plants have evolved by the same law as animals.

PROFESSOR WILLIAM B. RIDENOUR :—

The study of botany is, throughout, illustrative of the principles of evolution. The gardener in a few years, by his skill, does what it takes nature centuries to accomplish; but he must do his work over and over again, as there is a strong tendency to deteriorate and revert to the original type. Nature's work, gradually adapting the organism to environing conditions, is more permanent.

MR. JAMES A. SKILTON :—

Human progress is largely dependent on botanical conditions, and the character of a vegetation largely determines the character

of the men of a given locality. The thistle which Adam cursed, according to tradition, is a product of *de*-volution, botanists assure us. By studying the laws and conditions of evolution in its total range, we have the materials for a science of prophecy, which may ultimately enable man to lay hold on the future, and greatly hasten the progress of civilization.

DR. ROBERT G. ECCLES:—

All science in one sense is pre-vision or prophecy. The botanical divisions of plants are arbitrary, and do not indicate an absolute separation of species. The difference between those most alike in different genera is no greater than between some which are classified as belonging to the same genera, but of distant orders. The plants of China and the northern part of America are so much alike as to indicate a common origin in the present Arctic region when the two continents were united, and a warmer climate existed in the polar regions.

DR. LEWIS G. JANES:—

A notable distinction between the organic and inorganic kingdoms is observed in their different methods of growth—the latter by accretion, or simple addition to bulk; the former by intussusception, or displacement and renewal of particles throughout the whole tissue. On the theory of spontaneous generation, science has not yet explained how one method was exchanged for the other, in the passage from inorganic to organic structure.

COLLATERAL READINGS SUGGESTED

IN CONNECTION WITH ESSAY V.

Darwin's *Origin of Species*; *Variations of Plants and Animals under Domestication*; *Climbing and Insectivorous Plants*; *How Orchids are Fertilized*; *Cross and Self-Fertilization*; *Earth Worms and Vegetable Mould*; Gray's *Darwiniana*, and *How Plants Grow*; Nicholson's *Palæontology*; LeConte's *Geology*; Grant Allen's *Evolutionist at Large*, and *Colors of Flowers*; Haeckel's *Creation*; Huxley's *Physical Basis of Life*, *Lay Sermons*, and *Lectures on Evolution*; Spencer's *Spontaneous Generation*; Wallace's *Island Life*, and *Tropical Nature*; Clarke's *Mind in Nature*; Bastian and Tyndall on *Spontaneous Generation*; Powell's *Our Heredity from God*; Dawson's *Geological History of Plants*.

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