THE PHYSIOLOGICAL UNITY

OF

PLANTS AND ANIMALS.

A Lecture

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SYLLABUS OF THIS LECTURE.

The progress of science consists in the connection of phenomena previously considered isolated.

The old Three Kingdoms of Nature now seen to be in many points one, in most essential characteristics only two: the Organic and the Inorganic, or Living and Not-Living.

Plants and animals identical in their ultimate chemical constituents; Carbon, Hydrogen, Oxygen, Nitrogen, Phosphorus, Sulphur, Potassium, Iron: in most of their proximate principles; Water, Carbonic acid, Sugar, Starch, Cellulose, Fibrin, Casein, Chlorophyll, Protoplasm.

Structural identity of the lower groups—Häckel's Protista. Functions of living beings.

Identity in Respiration.

Identity in Nutrition, the presence of ferments, pepsin, digestive acid and peptones — The Chlorophyllian property — The Conversion of starch into sugar.

The functions of Relation; Sensation, Nervous action and Motion—The nerve-like action of protoplasm in Drosera—Motion by pseudopodia or cilia.

Reproduction by fission, gemmation and ovulation—Ova and Spermatozoa.

THE PHYSIOLOGICAL UNITY OF PLANTS AND ANIMALS.

ONE of the cardinal laws of the modern philosophy of evolution is that the history of the development of the race is summarised in that of the individual. This is exemplified in the growth of human knowledge, especially of accurate knowledge or science: as a child learns a number of detached words, chiefly nouns, before it can frame a connected train of thought, and notices with unreasoning surprise each phenomenon of nature which it encounters, so in the progress of science the human race learns to trace the general laws which govern phenomena that it once looked upon as isolated and marvellous.

Thus mankind were for ages content to talk of the "Three Kingdoms of Nature," and to look upon minerals, plants, and animals, as three distinct categories having little or nothing in common. We now know, however, that in many respects these three are one, and that in all essential characteristics they can only be considered as two. They are subject to the same physical and chemical laws: plants and animals contain no chemical element not existing in inorganic minerals, even carbon occurring in meteoric stones; their mode of growth is not so radically unlike that of a collection of small crystals in a nutrient fluid as has been supposed; nor are the simple geometrical beginnings of organic structure wholly unlike crystallisation. The words "inorganic" or "unorganised" are as applicable to the lowest animals as to the starch manufactured by chemical synthesis from its elements in the laboratory; for it is a mere contradiction in terms to term that an organism which is absolutely destitute of organs. It would be extremely difficult to show that in life we have more than an assemblage of forces possessed individually, at least in some degree, by the inorganic world; and we still look upon the dead body of plant or animal as being plant or animal when not only is the individual dead, but even when no single tissue evinces lingering vitality by responding to stimulation. Thus the distinction between living and not-living is scarcely more precise than that between organic and inorganic.

Still, however, though the boundary-line be not easily definable, there are distinctions readily perceptible between nearly all things that either do live or have lived and those that have not.

Living beings have curved outlines; they have much of their structure in a soft condition; if alive, they exhibit numerous functions; they consist chiefly of complex carbon compounds.

Between plants and animals, at first sight, there may seem to be distinctions equally simple; but this seeming only arises from our thinking of types rather than of the whole groups, and even popular natural history recognises the difficulty in detail in terming one group of animals "zoophytes," or animal plants.

Plants and animals are identical in their ultimate chemical constituents, *i.e.*, in the elements or simple substances, of which they are composed, the chief of which are carbon, hydrogen, oxygen, nitrogen, phosphorus, sulphur, potassium, and iron. The proportion in which these elements occur varies, however, to some extent in the two groups, carbon being relatively more abundant in the vegetable, and nitrogen, sulphur, and phosphorus in the animal kingdom. These elements occur probably, however, in every plant and in every animal. Oxygen and hydrogen form water (H_2O), which constitutes from 14 to 94 per cent. of plants, 67 per cent. of the human body, and far more in some other animals. Carbon and oxygen form carbonic acid (CO_2), and nitrogen and hydrogen form ammonia (NH_3), invariable products of the disintegration of the bodies of plants and animals. All vital actions in both plants and animals—growth, assimilation, reproduction, nervous action, &c.—are conducted by the complex substances known as albuminoids, which have an average per centage composition of 53 of carbon, 22 of oxygen, 16 of nitrogen, 7 of hydrogen, 1 of sulphur, and a trace of phosphorus. Iron, the great colouring matter of nature, necessary alike to the production of the green chlorophyll of leaves and of red blood, is probably universally present; and potassium, which seems in some way essential to the formation of starch and cellulose—those carbo-hydrates, so abundant in most plants, so rare in animals—occurs, though in small quantities, probably in all animals.

Many of the chief compounds or proximate principles are also common to the two groups. Not to mention further such products of decomposition as carbonic acid and ammonia, or water, in the absence of which vitality is impossible; starch ($C_6 H_{10} O_5$) has been detected in the human brain and elsewhere; cellulose ($C_6 H_{10} O_5$) occurs in the "mantle" of the Tunicata, or marine Ascidians; fibrin, the chief ingredient of blood and meat, is all but identical with the gluten of cereal grains; casein, the curd of milk, it represented most closely in those most concentrated of vegetable foods, the seeds of peas and lentils; chlorophyll even, that green colouring matter which we look upon as so characteristic of the vegetable world, not only exists in a score of animals belonging to most varied groups,[1] but in them has the same marked effect upon the atmosphere that it exerts in plants; and lastly, that protoplasm, or sarcode, which Professor Huxley has so well termed "the physical basis of life," appears absolutely identical in both divisions of the organic kingdom. In either case it would seem to be very probably a combination of a *phosphamide* and a *sulphamide* of some highly complex base containing carbon, hydrogen, oxygen, and nitrogen.

If we leave composition and pass on to structure, looking, as rational philosophy teaches us, at the base of the diverging branches rather than at their summits, we find the identity so close that the shrewdest naturalists are baffled in their attempts to draw a boundary line; so that Professor Häckel has been led to cut the gordian

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[1] The following list of these chlorophyllian animals has been drawn up by Professor Ray Lankester:—

Foraminifera.
Radiolaria.
  Rhaphiophrys viridis.
  Heterophrys myriapoda.
Infusoria.
  Stentor Mulleri, &c.
Spongida.
  Spongilla fluviatilis.
Cœlentera.
  Hydra viridis.
  Anthea smaragdina.
Vermes.
  Mesostomum viride.
  Bonellia viridis.
Chætopterus Valenciennesii.
Crustacea (Isopoda).
  Idotæa viridis.

knot by establishing the intermediate group of Protista, neither plants nor animals, thus simply doubling the difficulty.

I hope to show to-day that, without confining our attention to these lowly forms, we may see an identity in function superadded to these identities in composition and structure, each leading physiological function of the animal being represented among plants, and *vice versâ.*

Now the functions may be classified into three main groups: those of nutrition, of primary importance, and co-extensive in time with life, as being necessary to the support of the individual; those of relation, useful in bringing the organism into relation with its environment (primarily evolved, no doubt, as aids to nutrition and self-defence); and lastly, those of reproduction developed when a mature size has been reached, or, as it has been well put, when nutrition becomes discontinuous and secures the permanence of the race.

Subsidiary to nutrition is the important function of respiration, by which the body is supplied with atmospheric oxygen which is utilised in the breaking up or waste of effete complex compounds in the body, and by which also the resulting carbonic acid is exhaled. This function, which it is convenient to discuss first, is universally identical in plants and animals.

We are not concerned with the mechanism of respiration whether it be lungs, as in our own bodies, or gills, or the general surface, as in many of the lower animals. In both plants and animals oxygen is taken from the inhaled air, and carbonic acid is exhaled. This breathing continues as long as life lasts, by night as well as by day, and even under the influence of anæsthetics, such as chloroform. Among plants it is clearly observed in the case of germinating seeds, as in the evolution of carbonic acid in the artificially-produced sprouting of corn, known as "malting;" in the action of fungi (which it would be absurd to class as other than plants) upon the air, as seen in the like evolution from brewers' yeast; in the effect on the atmosphere of any ordinary green plants during the night or in the dark; and lastly, as we learn from the luminous experiments due to the marvellous acumen of the lamented Claude Bernard, in the effect on their atmosphere of such ordinary green plants when put under the influence of anæsthetics.

Green plants in the daylight, not under anæsthetics, have an effect upon the atmosphere the converse of that of animals, and have accordingly been said to inhale carbonic acid, and to exhale oxygen.[2] This is, however, to render the physiological term "respiration" meaningless; and is moreover conclusively disproved by Claude Bernard's experiments, which show that a true respiration is continually going on in these plants, and polluting the air with additional carbonic acid, though the effects on the atmosphere of this function are masked by the more powerful chlorophyllian property which has a diametrically opposite effect. This remarkable action of the green colouring-matter of leaves, under the influence of sunlight, in causing the removal of carbonic acid from the air, is part of the nutritive functions properly so-called, and, though more general among them, is by no means confined to plants, as shown by the table of animals belonging to most distant groups which contain chlorophyll, as evidenced in several cases by the specific name of "viridis." (*See* note [1] p. 5.) This animal chlorophyll has, moreover, been recently shown to produce the same effect upon the air as does that of the plants. Many plants, too—namely, the whole of the fungi—are without chlorophyll.

This leads us to the functions of nutrition, to which respiration is merely subsidiary. Most plants derive their food from two sources: water, and saline substances dissolved in it, from the soil, through their roots, and carbon, from the carbonic acid of the atmosphere, absorbed by their green leaves. Their nitrogen they undoubtedly derive chiefly from nitrates in the soil; their phosphorus from phosphates. Most animals, on the other hand, are unable to build up the complex compounds of which they consist from inorganic materials, subsisting entirely on food previously assimilated by plants or other

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[2] I cannot at all agree with Dr. J. H. Gilbert, when he says (Presidential Address to the Chemical Section of the British Association at Swansea): "It may, I think, be a question whether there is any advantage in thus attempting to establish a parallelism between animal and vegetable processes."

See Mr. Corenwinder's researches in "Revue Scientifique," 1874.

animals. This apparent contrast will not, however, hold universally. Fungi and all parasitic plants depend, either wholly or in a great measure, on food already assimilated; whilst, on the other hand, those animals which contain chlorophyll appear to be able to assimilate inorganic matter.

The identity of the nutritive processes can, however, be shown in much greater detail if we describe that even of one of the higher animals, such as man, and refer in the comparison partly to those plants which have been termed "carnivorous."[3] The food of a man, consisting of previously elaborated animal and vegetable matter, is first *ingested* or taken into the alimentary tract. In the mouth it is masticated and mixed with saliva, a neutral or alkaline watery fluid, containing a small quantity of *ptyalin*, a nitrogenous substance, which, acting as a *zymase*, *i.e.*, in a manner similar to that of yeast and other ferments, converts the insoluble starch into soluble glucose or grape sugar ($C_6 H_{12} O_6$). The food than passes into the closed stomach, the glands of which secrete an acid gastric

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[3] This term may be applied more or less fully to the following plants belonging to widely different groups:—

Accidentally.
e.g. Lychnis (Campion). Caryophyllaceæ.
Saxifraga tridactylites. Saxifragaceæ.

Saprophagous, i.e., only absorbing the products of decomposition — ? Dipsacus (Teazle). Dipsaceæ.

With pitchers — Sarracenia. Darlingtonia. Heliamphora. — Sarraceniaceæ.

With utricles — Utricularia. Polypompholyx. Genlisea. — Lentibulariaceæ.

Digesting.
? Helleborus. Ranunculaceæ.
? Parnassia. Saxifragaceæ.

Cœlenterate.
Cephalotus. Saxifragaceæ.
Nepenthes. Nepenthaceæ.

Motile.
Pinguicula. Lentibulariaceæ.
Drosera (Sundew). Drosophyllum. Roridula. Byblis. Dionæa (Venus' Fly-trap). Aldrovanda. — Droseraceæ.

juice, containing *pepsin*, another nitrogenous ferment or zymase, which acts upon the albuminoid constituents of the food, rendering them soluble, or digesting them, when they are known as *peptones*—substances that readily ooze through a membrane. The entrance of food into the stomach stimulates the nerves in its walls, and the neighbouring arteries swell so as to produce a blushing of the surface. After quitting the stomach the conversion of starch into sugar is completed by the *pancreatin* in the intestinal juice of the small intestine, which is neutralised by the alkaline bile. At the same time, the fatty portions of the food are *emulsionised*, *i.e.*, separated into fine particles suspended in the fluid, and to some extent *saponified*, *i.e.*, rendered more soluble by a conversion into soap by the alkaline bile, just as animal and vegetable fats and oils are converted into soap, in the arts, by treatment with caustic alkali; whilst any remaining albuminoids are also digested.

The nutrient matter passes through the membranes of the alimentary canal into the *capillaries*, or finest blood-vessels, and by the blood, the vehicle of circulation, it is conveyed to every part of the body to be *assimilated*, or taken up, by any organs requiring repair. Any subsequent changes it may undergo are comprehended under the term "*metastasis*."

In making this comparison we must not lose sight of the fact that in the lowest animals we have no specialised organs or structures to perform these varied functions.

Now, if we turn to plants in general, we find that the watery solution taken in by the roots penetrates through the cell-membranes, as the peptones do through those of the alimentary canal in the animal, and that it is caused to ascend to the leaves and growing parts by the evaporation from the surface. The air enters the *stomata*, or pores, in the epidermis, and penetrates the cell-membranes, as it does in the air-cells of the bronchial tubes in our own lungs. The primary product of the union of this gaseous with this watery food seems to be the formation of protoplasm, that complex albuminoid containing not only carbon, hydrogen, oxygen, and nitrogen, but also sulphur and phosphorus. Only plants that contain chlorophyll are able to utilise the carbon of the air in forming protoplasm or assimilation, others must obtain it elsewhere. Chlorophyll is formed in the protoplasm, only in the presence of iron, and generally in daylight; plants grown in the dark being bleached by its imperfect formation. The presence of chlorophyll is necessary to the formation of starch, though the latter is a very simple substance. Starch is therefore absent from the fungi. Recent researches[4] point to the conclusion that starch is formed by the protoplasm under the influence of light filtered, so to speak, through chlorophyll. Though insoluble, starch seems to be readily rendered soluble, as, though chiefly formed in the leaves, it is rapidly transferred to the stem, the seeds and other parts, where it is stored up as a food-reserve. It is from these stores that man obtains some of the most important of his food-stuffs—the flour of wheat, the sago from the stem of the sago-palm, and the starchy tuber of the potato. Agricultural chemists have come to the conclusion that animals derive their fat from the carbo-hydrates of their food,[5] *i.e.*, from cellulose, starch, and sugar—more especially from the two latter; and it would seem highly probable that the similar fatty oils in fruits and seeds, such as the olive and the oil-palm, are due to the transformation of starch. A more important change is that into glucose and soluble starch in germination, in the spring sap, and such cases, which is brought about by a ferment or zymase, known as *diastase*, all but identical with the similarly acting ptyalin of our own saliva.

While starch is formed by day, by night the protoplasm originates cellulose, the cells divide and the plant grows. Assimilation thus proceeds mainly by day; growth by night. Some new evidence on this part of the subject has been educed by Dr. Siemens's experiments on plants under the electric light.

In germinating seeds the albuminoids are converted into substances closely resembling the peptones of animal

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[4] Those of Pringsheim, remarkably confirmed by Mr. George Murray, of the British Museum, who has shown that *lichenine*, a form of starch occurring in lichens, is formed not in the chlorophyll-containing "gonidial layer," but in the subjacent cells.

[5] *See* Dr. J. H. Gilbert's Presidential Address to the Chemical Section of the British Association at Swansea.

digestion; and in the transfer of these, of soluble starch, dextrine, and sugar, to the growing parts, we have a close analogy to animal circulation.[6]

In the various complex processes of change, known as metastasis, acid-salts and free acids are formed in plants, with instances of which we are all familiar, such as the rhubarb, apple, gooseberry, and orange. Now free acids are nearly always deleterious to organic tissues. These acids are therefore either metamorphosed or neutralised, or to some extent excreted by being stored up in glands near the surface, as in the orange. Such embedded glands are very common, as are also the thin-skinned glandular hairs, which often have a viscid secretion, as in the catch-flies or campions of the genus *Lychnis* in *Saxifraga tridactylites*, in *Pinguicula* and in most *Droseraceæ*. Mr. Darwin has shown[7] that these hairs in Saxifrages, Droseras, Primula, and Pelargonium, will absorb ammonia from a solution; hence they might obtain it from dew, in which it occurs in small quantities. It is also probable that they derive some benefit from the nitrogenous matter in the bodies of flies, with which *Saxifraga tridactylites* is always covered.

Flies are constantly drowned in the pitcher formed by the two united leaves of the common teazle, into which Dr. Francis Darwin thinks he has detected delicate protoplasmic threads protruded from the cells of the stem, like the *pseudopodia* of a Foraminifer.[8]

Several plants, belonging to widely separated orders, have their leaves modified into pitchers, or utricles, in which insects get drowned and decay, the products of decay being absorbed by glands on the inner surface of

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[6] The presence of a pepsin-like ferment, or *peptogene*, which might have been inferred from the transference of albuminoids from one part of the plant to another, has been shown in the seeds of Vetch by Gorup-Besanez. A similar substance occurs in the milky juice of the papaw (Carica Papaya), which, like the gastric juice of animals and the secretion from the leaves of the sundew (Drosera), has the two-fold property of acting as an *antiseptic* by destroying the *microzymes*, or organisms that induce putrefaction, and of acting as a solvent or peptogene on albuminoids.

[7] "Insectivorous Plants." London, 1875.

[8] Quarterly Journal of Microscopical Science, 1878.

the organ.[9] Such is the case with the *Sarracenias* and their allies, an order related to the water-lilies, and with the *Utricularias* or bladderworts, which are related to the butterwort, *Pinguicula*, and less closely to the primrose tribe. In the true pitcher-plants, however, the *Cephalotus* and the *Nepenthes*, plants in no way related morphologically, we reach a much higher physiological grade. The leaves in this case develope pitchers strictly comparable to the animal stomach. The glands on the inner surface of these pitchers secrete a watery fluid which is slightly acid. Albuminoid matter, whether animal or vegetable, immersed in this fluid, even when removed from the pitcher, is converted into soluble peptones, as in the gastric juice, and this change occurs so rapidly that we naturally infer the presence of some pepsin-like ferment. Mere acidulated water, without a ferment, takes several days to digest albuminoid matter; though Professor Frankland has shown that, though differing in the intensity of their action, nearly all acids will effect such a digestion. After absorbing albuminoid matter the glands of these pitchers become a bright red colour, strangely reminding us of the blushing of the walls of the stomach.

In *Pinguicula* and in the *Droseraceæ*, though we have no stomach-like pitchers, we have a somewhat higher grade in the introduction of motion to aid in the nutritive processes. The simple leaves of the butterwort are covered with viscid, glandular hairs, the secretion from which exerts a remarkable effect upon milk, coagulating it; whence the name butterwort. When flies stick to the hairs the leaves roll up at their margins, the secretion becomes acid, and the albuminoid matter is digested and absorbed. The absorption is shown by the fact that the protoplasm in the cells of the glands becomes *aggregated* or contracted. If milk is left on the leaves it is first coagulated, and then its casein is absorbed.

We then come to a most interesting group, the *Droseraceæ*—a group not represented by any considerable number of forms, but of world-wide distribution. A

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[9] *See*, on the subject generally, Dr. (now Sir Joseph) Hooker's Address to the British Association at Belfast, in 1874, in "Nature," vol. X., and Mr. Darwin's work before referred to; on Cephalotus, Dr. Dickson, in the "Journal of Botany" for 1878.

large proportion of the species are natives of Australia; but they occur also in Patagonia, whilst our British species range throughout Europe, Siberia, to the Himalayas, in Kamschatka and in America, from the Arctic Circle to Florida and Brazils. So we may safely say that they have been successful in the struggle for existence. It affords a strong confirmation to our views as to the source of their main food-supply that *Sarracenias*, *Utricularias*, *Pinguiculas*, *Nepenthes*, and the *Droseraceæ* are in all cases either submerged aquatic plants, or inhabitants of marshes, where they are often seen growing on pure sand which can only yield them pure water. Their roots are very small; in *Aldrovanda* they are altogether absent.

The round-leaved sundew of our own marshes, which grows under the protection of the Board of Works on Hampstead Heath, in Epping Forest, and on Keston Common, whence Mr. Darwin has procured his specimens, has its leaves prolonged into glandular hairs or *tentacles*, each surmounted by a drop of viscid secretion to which they owe their name of sundew. The stickiness of this secretion will amply suffice to detain a small fly by the leg. On doing so, not only does that particular drop become acid, but all the other glands instantaneously become aware of the capture of some nitrogenous matter; their secretions become acid, and they bend forward till the fly is carried to the centre of the leaf, covered by the glands. Complete digestion then ensues, occupying a time which varies according to the size of the prey, and the peptones and other soluble results are absorbed by the glands of the leaf, the protoplasm of which becomes aggregated. A substance analogous to pepsin has been detected in the secretion by Dr. Lawson Tait, who terms it *droserin*, and the acid has been determined to be either propionic ($C_3\,H_6\,O_2$), or a mixture of acetic ($C_2\,H_4\,O_2$), and butyric ($C_4\,H_8\,O_2$). It is noteworthy that the secretion has also antiseptic properties, herein also resembling gastric juice. Chlorophyll is but scantily developed in the mature leaves, suggesting that organised food renders that derived directly from the atmosphere to a large degree unnecessary. That the plant derives a decided advantage from this leaf-absorbed nitrogen is conclusively proved by Dr. Francis Darwin's comparative experiment, in which he grew some hundred meat-fed plants side by side with a like number of others not so fed, the former proving the superior in weight, number of off-sets, of flower-stalks, of flowers, and of seeds, and in the weight of their seeds.

It is, however, in the exotic ally of our sundew, the Venus's fly-trap *(Dionæa muscipula)* of North Carolina, perhaps, that we have the highest degree of specialisation for nutrition in the direction we are considering. In this plant, rapid movement produced by an electro-magnetic change in the condition of the blade of the leaf on stimulation, takes the place of a viscid secretion. The blade of the leaf is orbicular, divided by a hinge-like midrib, and surrounded by spinous prolongations corresponding to the tentacles of *Drosera.* Its upper surface is covered with glands, and bears long sensitive hairs, generally three on each lobe. These, from their action, I think I may venture to term *vibrissæ, i.e.*, rudimentary sense-organs. These vibrissæ are extremely sensitive to the touch, the two halves of the leaf instantly closing, their spinous tentacles becoming interlocked like the teeth of a gin. Dr. Burdon Sanderson has shown [10] the existence in the leaf of a normal electric current precisely similar to that of animal muscle; and that, on the vibrissæ being touched, a deflection of this current, which can be observed with the galvanometer, is produced, precisely as in the contraction of muscle under nervous stimulation. Though it is an anticipation of the next division of my subject, I must here call your attention also to the remarkable analogy we have here presented with that deflection of a normal electric current in the optic nerve which has been recently shown by Professors McKendrick and Dewar to be produced by the action of light on the eye in most animals. The motor impulse, both in this plant and in *Drosera*, is transmitted not only by the vascular tissue, but also by the cellular. The glands are both secretive and absorptive, but do not secrete until stimulated by absorption. The acid secretion in the temporarily-formed stomach acts like that of *Drosera.* In neither case is fat absorbed, nor — which is rather remarkable — casein, though cheese produces an abundant flow of the acid

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[10] Proc. Royal Society, vol. xxi., and 'Nature,' vol. x.

secretion. In digesting this albuminoid, the butterwort (*Pinguicula*) is more active; but perhaps we should look upon the leaf-digestion in plants as a recently-acquired function—geologically speaking—so their digestive powers may as yet be weak. Over-feeding seems to have a fatal effect either on leaves or on whole plants.

In leaving the subject of nutrition, I hope it will not be supposed that in dwelling thus at length upon these plants, I look upon their functions as exceptional. They are well exhibited for purposes of experiment and comparison in these so-called "carnivorous" plants; but they are represented in the processes of assimilation and metastasis throughout the plant-world.[11]

The functions of relation are motion, sensation, and nervosity. Some few animals lose the power of moving from place to place, a power possessed only by the very lowest plants. Higher plants, however, are carried as winged fruits or seeds to a distance, and in many cases possess as much power of *relative movement*, *i.e.*, the movement of certain of their parts as do many animals, *e.g.*, the *circum-nutation*, as Mr. Darwin has termed it, or revolving motion of tendrils, twining plants and shoots, and the *irritability* of stamens, as in the barberry, or of carpels as in the balsam. Motion is effected by *pseudopodia* in the Myxomycetes and some other Thallophytes, as much as in the lowest animals, and by *cilia* in somewhat higher members of both groups, whilst muscles are, of course, as absent in the Protozoa as in plants.

The definitions of sensation, given in most manuals of physiology, presuppose the existence of nerves and nerve-ganglia. These occur in no animals lower than the Jellyfishes; yet, I think, most naturalists would rather look upon protoplasm as a diffused nerve-matter, as suggested by the late Dr. Bowerbank, than deny sensation altogether to the Protozoa. Leaving out of consideration the remarkably rapid action of the sensitive-plant (*Mimosa pudica*) and the related movements in various compound leaves, known as "sleep," as being still problematical, I would ask whether the instantaneous reaction of the secretion in *Drosera* (its becoming acid) on stimulation, or

[11] I endeavoured to elucidate this point in an article on 'Plant Nutrition' in the *Gardeners' Chronicle* for 1878, vol. ix., p. 202.

the electric action of *Dionæa*, is not entitled to be considered as the same in kind with animal sensation.

The function of reproduction is performed in three different ways: by *fission*, by budding or *gemmation*, or by *ovulation*. Each of these processes is represented both among plants and among animals, though fission and gemmation are termed *vegetative* functions—functions, that is, of mere discontinuous growth as distinguished from ovulation or *sexual* reproduction. Fission, or *cell-division*, is the normal method of reproduction among the lowest cellular plants (*Protophyta*), and even a sea-anemone, when cut in half, has healed to form two perfect individuals. Gemmation, or the production of off-sets more or less distinct, familiar to us in ferns, bulbs, and strawberry runners, occurs also in the freshwater polyp (*Hydra*) and other animals higher in the scale.

In the processes of sexual reproduction we have, however, perhaps the most striking of all the parallelisms beween plants and animals. In both we have the impregnation of a *germ-cell* or *ovum* by a *sperm-cell*, the male element: in Cryptogamic plants, and in animals, this male element is a minute body furnished with one or more cilia, known as a *spermatozoid:* in both kingdoms the ovum is a single cell originated within its parent cell by what is termed *free-cell formation:* in both this ovum subdivides to form the *embryo;* and in the egg of the one, as in the seed of the other, there is often, in addition to the embryo, a food-supply for its early nourishment. In fairness it must be noticed that the animal ovum is *segmented* into four, eight, sixteen or more segments, whilst that of the plant forms in general a filament (*hypha* or *suspensor*), at the end of which the embryo originates; and secondly, that flowering plants have perhaps advanced a grade beyond animals in substituting the *fovilla* of pollen for the spermatozoid.

I have thus in detail endeavoured to trace a fundamental identity, in nutrition, in relation, and in reproduction, in plants and animals. My object in so doing has been to extend, as far as our knowledge permits us, the reign of law and uniformity; and to show that the study of the physiology even of plants may not be without its practical lessons to so exalted an animal as Man.

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