CHAPTER X.

Physiology of the Living Organism—Function of Nutrition: its Nature and Relations to Tissue-waste — Nutritive Equilibrium and Excess—"Growth:" Nature and Phenomena of —Nutritive Deficiency—Atrophy—Hypertrophy—"Death" as a result of impaired Nutrition—Food of Animals and of Plants—Process of Assimilation: its Nature and Relations—Function of Innervation—Essential Conditions of Correlation — Correlation in the lower Forms — Nerve-tissue in the lowest Organisms—Views of Beale—Innervation in Invertebrata and Vertebrata—Phenomena of "Instinct."

THE function of *Nutrition*, or that by which a living being nourishes itself and contributes to its growth and increase, forms, in the most appropriate manner, the first of the great vital processes which we are, in the present instance, led to consider. The first act of the newly-formed being is nutritive in its character. Its first instincts are directed to the prehension of the matter necessary for the sustenance of life, and to the due maintenance of the nutritive process the function of correlation or innervation may be said, in the first instance at least, to be wholly devoted. As we shall afterwards more particularly observe, the third great function, that of reproduction, is in its nature antagonistic or opposed to that of nutrition; the preservation of the species being, in this way, more or less antagonistic to the preservation of the individual.

We have already remarked that the mode of increase of a living being is invariably associated with the "intussusception" of material from the outer world, or, in other words, with the reception within its body, of matter derived from the medium in which it lives, or with which it is connected. This material we ordinarily know as "food," and the special functions which are respectively

devoted to its prehension, and ultimate "assimilation," are collectively denominated under the general term of "nutrition."

The living organism, in the exercise of those functions, or in the performance of those acts which depend on the presence and possession of vitality, is constantly subject to a greater or less waste of substance. The slightest or most simple action on the part of a living being involves a corresponding loss of vital power, which is manifested by a subsequent and proportional destruction or waste of the textures and tissues of its body. This waste necessitates renewal and repair; and, in this sense and aspect, the vital organisation approaches most nearly that of the mechanical. Just as the machine requires certain conditions, such as those of fuel or applied force, to sustain its mechanical powers, so does the living organism require its own and special conditions to enable it to successfully maintain and renew its vital powers. The failure of the requisite supply of conditions to the machine results in its disorganisation, or simply in the cessation of its functions. The failure of the nutritive supply of the living organism is attended by the same result, manifested, however, in a much more striking degree—namely, in that of complete disorganisation, cessation of vital power, and finally of "death."

At this stage, however, the parallelism between the mechanical contrivance and the living organism may be said to cease. The machine can, of itself, give no outward or visible evidence, or sign, of its wants; it possesses, *per se*, no knowledge of conditions or sensations, and the failure of the necessary conditions would be indicated simply by the stoppage of its mechanism, and by the cessation of its function. But the living organism, in virtue of its vitality, possesses the power not only of giving evidence of its wants, but is also furnished with the means for satisfying these demands; and it moreover possesses the power of elaborating from "raw material" the matter necessary for the nutrition and repair of its body.

Hence the term "nutrition," used after the purely de-

velopmental and earlier phase of the function has been subserved, may be regarded as synonymous with that of "repair;" the function of nutrition in the living organism being thus devoted to the repair and renewal of the tissues after the wasting and destruction dependent on the performance of their appropriate vital functions.

The general term "assimilation" has already been used to denote the more typical phenomena included in the performance of the nutritive function; and the present chapter has for its object the cursory review of these phenomena, and of those less notable actions which spring from or are dependent upon them.

The first observation to which attention may be directed lies in the fact that the living organism appropriates to itself matter from the external world, and of a kind generally foreign to itself, but which it converts, by the assimilative process, into the materials of which its body is composed. There is thus a subtle conversion of material of one kind into material generally of a widely different kind; and, in the performance of this process, organs or tissues varying widely in structure and complexity are engaged.

We have previously noticed, in treating of the "specialisation of functions," that the highest and lowest organisms each nourish themselves after the most perfect fashion, but differ in the manner in which the process is effected. The nutritive function is thus perfectly performed by every organism, whatever its rank in the scale of creation; but in its performance a great variety of means, varying in complexity, is employed. The Amœba (Fig. 1), by means of the nearly structureless protoplasm of which its body is composed, performs the nutritive function, and renews and repairs the waste of its body as perfectly to itself as does the Mammal (Fig. 11), with its complicated digestive system. The difference between these forms, or between all the varying forms of which the organic series is composed, does not therefore concern the *result to the organism* of the nutritive process. Every living being manufactures from its "food," in the most

perfect manner, the material or materials necessary for the sustenance of its life.

We thus reduce to a striking community of type or detail the aim of the nutritive function throughout the organic series; and this ultimate aim is the formation or elaboration from the food-material of a fluid varying in composition, but containing certain nutritive principles, from which the tissues in turn draw their nutritive supply. This nutritive fluid in the higher forms of animal life we know as the "blood," whilst in plants it receives the general name of "sap."

A further consideration of the preceding points will show us that the process of "assimilation" in the living organism, and viewed relatively to the constituent parts of the organism, has a twofold aspect or nature. We find, firstly, the primary process of "assimilation" performed by the organs of digestion; this first process resulting in the manufacture, production, and circulation through the body of the nutritive fluid. This fluid forms the common source whence the nourishment of all the varied tissues of an organism is derived; and hence we recognise the existence of an ultimate or secondary process of assimilation—that of "assimilation" by the respective tissues of the organism, whereby each tissue, from the nutritive fluid, in turn elaborates the special materials necessary for its own and intimate repair. Thus it is, that from the common "blood" conveyed to the tissues of the higher animal, bone-tissue manufactures or renews its own peculiar substance; that nerve-tissue assimilates nervous substance; that muscular tissue manufactures muscle; and that every other tissue forms and elaborates its peculiar substance from the common nutritive fluid, just as this fluid was previously elaborated or manufactured from the food.

A series of actions so remarkable as those involved in the process of secondary assimilation or digestion by the tissues, has afforded, as might readily be expected, matter for much thought and speculation at the hands of physiologists; and to the vital property in virtue of which

living structures possess this wondrous power, the various terms of the "vital property of attraction," or "selection," and the "elective affinity of the tissues," have been applied. The exact nature or *rationale* of the process remains hidden from the furthest research, but we may safely assume its intimate dependence, with many other and similarly subtle processes, upon the possession of "vital force," vitality, or life.

The living organism, then, by means of this twofold process, nourishes itself as a whole, and also sustains the life and vitality of its more intimate and distinct constituents. The act of living or of being, involving motion and the exhibition of force, is accompanied, as already remarked, by a corresponding amount of tissue-waste. Loss of power is thus invariably accompanied by loss of substance; and it is this loss of substance which necessitates the repair, primarily, of the body as a whole, and secondarily of the tissues. So long as the reparation of the tissues keeps pace with the tissue-waste the organism will maintain itself in a state of nutritive equilibrium. Notwithstanding the incessant loss of material, and the equally constant repair, the organism as a whole will present a comparatively unaltered appearance and conformation. But it is conceivable that the nutritive supply may exceed the tissue-waste, and in the earlier periods of existence this relation between the nutritive waste and repair actually occurs. In the young organism the process of nutrition is more than adequate to compensate for the comparatively trivial tissue-waste of early life; and new material being thus added to the body faster than it is expended, we find the tissues, and, through them, the entire organism, increasing in size, or exhibiting in this way the process and phenomena we familiarly know under the name of "growth."

"Growth" thus essentially implies nutritive excess—the addition of nutritive material, and the increase of tissues, of organs, and of the entire body, at an increased rate when compared with that of the nutritive expenditure. This much is meant by "nutritive growth;" but

we may distinguish a second kind of "growth" which does not consist in the increase of already-formed tissues, but in the formation and advance towards maturity of new structures or parts. This latter process, witnessed in the earlier phases of the existence of a living organism, has reference to the *development* of the being; and hence it may appropriately be termed a process of "nutritive development" or of "developmental growth." The conditions and phenomena of this latter phase of the nutritive process will be hereafter investigated under the subject of *Development*.

The balance of waste and repair in the living organism, and the maintenance thereby of the body in a state of nutritive equilibrium, must, however, be viewed in contradistinction to a second and opposite condition—that of nutritive deficiency. The conditions of waste and repair being equal, the living organism maintains a natural and stable position with regard to its own and intimate functional relations, and with regard to the world in which it lives. But if we suppose that the nutritive supply falls short of the demand, we then find the organism to exhibit a corresponding loss and diminution of vital power; and, if the deficiency be carried out to a great extent the death of the organism from "inanition" will result. This result, therefore, concerns the being or body as a whole, but the occurrence of "local" or "partial" death is also to be noticed. This latter phase has reference to conditions of nutritive deficiency, where a limited portion of the organism only, such as a tissue or organ, is affected. The deficient nutrition of such a part produces the death or deterioration of the organ, and it may thus die or become functionally useless so far as the organism as a whole is concerned. And hence the organ or part is said to be locally dead; or when deteriorated by deficiency of nutrition, or by want of functional activity resulting from inefficient nutritive supply, the structure is said to be "atrophied."

Nature not unfrequently is observed to induce the occurrence of "atrophy," by cutting off the nutritive

supply in parts or organs which are no longer required in an animal economy. Thus, at birth, many embryonic structures atrophy and disappear from this natural cessation of nutrition; the process being induced primarily, no doubt, by such organs being no longer required in the discharge of the newly-assumed functions of the being. And similarly in old age the same process of atrophy appears to affect organs and parts, and indeed the body as a whole; although the intimate causes of this "senile atrophy," as it is called, are less susceptible of explanation than those of the ordinary phases of the process.

Nutritive excess, carried to a great extent in consequence of excessive functional activity, or in virtue of other causes, is also liable to induce a condition opposite to that of "atrophy," and known as "hypertrophy." Excessive use of an organ, necessitating increased nutritive supply, is commonly associated with an increase of structure beyond the ordinary and normal limits. When an organ is influenced by such conditions, the result is a "hypertrophy" of the organ or part. "Hypertrophy" is thus merely "nutritive excess" induced to a high or extended degree by the increased use or functional activity of a part, and it may therefore be regarded as simply a form of abnormal "growth."

Lastly, and in concluding these general observations on the process of nutrition, we may refer to the ultimate effect of prolonged activity on the nutritive function, and to the effect of such a condition on the body as a whole. We have previously remarked on the result of the premature failure of the nutritive function; a result synonymous with the "death" of the organism. And it has also been observed that the process of tissue-waste may be regarded as essentially one of "local" death. But a consideration of the cycle of existence in the living organism shows us that a certain period inevitably ensues in its life-history when the nutritive as well as the other functions of the body appear to fail in administering to its wants, and when, as a result, the vital activity of the being entirely and for ever ceases.

Through this consideration we are led to notice the occurrence of this cessation of vital activity in an organism, simply from an apparent deficiency in nutritive power. Apart from the occurrence of abnormal or diseased states or conditions, we have therefore to observe the fact of death occurring naturally, or from a defective nutrient supply. And when we might be tempted to suppose that this latter result is in itself unnatural, it is to be borne in mind that the period of existence in the living organism appears to be bounded by certain limits, not always to be defined it is true, but sufficiently well marked to leave no doubt of their existence.

In virtue of the fact that the existence or life of the living organism is a cycle, repeating itself in all the functions which pertain to the vital state, we may safely assume it as a natural result that, like an ordinary piece of mechanism, the living body should sooner or later wear out and become incapable of further performing its functions, whether these be comparatively simple or intricately complex. And as the parts or organs of the machine become deteriorated by the wear and tear of its work, so the organs of the living organism become affected by the incessant effort of living and being. Why this should be so, physiological science does not pretend to explain; but we may, with all safety, assume that the conditions determining the limits of existence are, like those which regulate the causes of that existence itself, beyond the bounds to which our furthest light and investigation extend.

The relative nature of the food of animals and plants has already been pointed out, and but little remains to be noticed under this division of the subject. The food of plants we have seen to be composed in chief of inorganic materials; and these substances the plant, by its constructive chemistry, is capable of elaborating into compounds of organic nature. The inorganic food-materials of plants are chiefly carbon, nitrogen, oxygen, and hydrogen; these substances being derived respectively from the carbonic acid of the atmosphere, from the

ammonia of the soil, and from the water they absorb. These inorganic compounds are converted within the plant-organism into organic compounds of highly complex nature.

Animals, on the contrary, demand for their due sustenance a supply of already elaborated nutritive or organic material; and this material they obtain chiefly from the plant world. The animal, equally with the plant, possesses a vital chemistry peculiarly its own, and by aid of this chemico-vital action it converts the organic into inorganic material. In connection with the food of either series, we have to notice the general occurrence, as part of the dietary of animal or plant, of certain inorganic or mineral substances. Of these, some few appear almost, if not absolutely essential to the nutrition of the organism, whilst they all bear an important part in its histological or intimate composition. Such inorganic substances as the various salts of lime, silica or flint, iron, phosphorus, etc., appear to enter into the intimate composition, and otherwise to be closely bound up with the nutrition, of the living organism.

To the above broad and general facts and laws regulating the relative nature of the food of animals and plants, there appear certain exceptions, of which it is necessary to take cognisance in the present instance. Thus certain of the lower plants, or Fungi, appear to subsist chiefly, if not entirely, upon organic compounds; living parasitically upon other plants, or upon animals, the substance of whose bodies they appropriate to their own and special nutrition. And in their reaction upon the atmosphere they do not appear to emit oxygen, as is the case with ordinary plants. Conversely too, certain of the lowest forms of animal life—such as the deep-sea Foraminifera—appear to be capable of subsisting upon inorganic materials, and so to imitate the members of the plant series; whilst such forms have been also supposed to present exceptions to the ordinary rule of animal existence, in that they inhale carbonic acid and emit oxygen. But the validity of these latter suppositions appears to

be rendered doubtful from the consideration of more feasible explanations of the conditions of life in these deep-sea forms; which conditions will be more appropriately referred to under the head of "Distribution in Space."

In considering very generally the actual details of the nutritive process, we find it divided into the subsidiary processes of prehension; mastication; insalivation; digestion; absorption; assimilation of the absorbed products of digestion; circulation of the nutritive fluid or blood; nutrition of the tissues; excretion from the tissues; and respiration or the purification and aëration of the blood—that is, the excretion from the body of the substances evolved from the tissue-waste, and the simultaneous absorption of fresh oxygen into the nutritive fluid.

In animals we find the food-material received within the body, and generally an internal cavity or stomach is the seat of the essential changes and primary stages in the elaboration of the nutrient matter. Even in the lowest organisms, such as the *Amœba*, we find the function of prehension subserved by the finger-like processes into which it is capable of pushing out its protoplasmic body, and the little particle of food is received within the soft jelly-like mass, and is there subjected to the digestive process. A little clear space is then seen to form around the food-particle, and gradually it appears to be dissolved and incorporated with the contents of the body. In this case digestion, assimilation, and absorption are performed at once and by the same process; which, simple though it may appear, yet partakes, equally with the highly complicated process of the mammal, of the subtle and mysterious nature of a truly vital action.

The process of digestion, or, to use the wider term, of assimilation, is therefore to be regarded as essentially and primarily *vital* in its nature. That many changes occur in the process of elaboration of food into a nutritive fluid, which are explicable on chemical grounds and conditions, cannot be denied; but to assert that the entire action is merely one of chemical separation and re-formation, is to

state what is as far from the truth as to say that there is no chemical action whatever. The chemist, for example, may make us acquainted with the *modus operandi* and results of the influence of solar light upon the functions of plants; but his explanation will leave us as ignorant as before of the more intimate causes or forces from which the very actions he describes take their origin. There is, therefore, a something in the vital actions of plants and animals which a mere chemical theory will not suffice to explain. Chemistry, it is true, will explain for us the *conditions* under which many of the functions of the living body are exercised. Of such conditions it takes due cognisance, and may further elucidate the manner in which they relatively combine to effect a given result; but it does not follow that, although we gain a perfect knowledge of the conditions under which an action may take place, we are also, and at the same time, conversant with the *causes* which give rise to the conditions. The solar beam may thus represent the conditions necessary for the due performance of plant-functions, but of the intimate changes and actions which the plant effects in turn upon the sunlight, chemistry can give no explanation. For, if we are to denominate such actions as purely chemical in nature, there will, even after such an admission, be many points and phases which render these actions entirely different from, and unlike, any processes with which the chemist is acquainted. Such an admission would thus involve the chemist in the difficult position of being unable to account for or explain phases, which, at the same time, he admits to fall within the province of his science. And unless we assume the existence of some other force inherent to, and manifested solely by the living organism, we shall have to leave the question at issue as one which does not admit of any feasible or competent explanation.

Hence, in discussing the probable cause of this and other vital actions, we must bring to light and reproduce the same arguments and considerations which we have already enumerated in investigating the subject of "life" and

"vital force." The presence of a "physical basis" can only serve to supply the necessary *conditions* for the manifestation of these, and of all other vital actions, similarly as we have seen it to be the medium for the exhibition of vital force itself. In any case, we must assume the existence and operation of an additional "force" or "principle," which not only invests the "basis" or "material" with certain properties peculiar to itself; but also constitutes these properties as the primary means for enabling the organism to avail itself of those chemical or physical conditions which affect the living body, and which are, in turn, made subservient to the purposes and ends of its existence.

The process of assimilation may be held to be "chemico-vital" in its nature; and of all the various and conflicting theories, which from time to time have been promulgated regarding the nature of functional activity, this view will be found to be that most consistent with the ascertained results of scientific inquiry. The objection, that to use the term "vital" is merely to avow our ignorance, is of but little weight, when we know that other, and apparently more rational theories, give us no better explanation of the matter, but, on the contrary, lead us into speculations which possess a character far more fanciful than that which is said to appertain to the term "vital" itself. And whilst we thus assume the "vital" nature of these and allied processes, we do not preclude or dispute the possibility of a more satisfactory or feasible explanation being, in the course of time or of scientific progress, arrived at. But in the present state of scientific inquiry, the observer who would wish to escape the odium of being a violent partisan of any party or opinion, has no other resource than to admit his inability to offer any further or better explanation of this wondrous cycle of functional manifestations.

Digestion in the stomach or gastric cavity is, in the higher forms, succeeded by digestion in the intestines, to which latter process succeeds the absorption of the elaborated fluid from the alimentary tract, by a distinct set of

vessels, to which the general names of "absorbent vessels," "lacteals," or "lymphatics," are applied. These latter absorb from the alimentary tract the fluid products of digestion, which are collectively known as "chyle." Already the chyle appears to possess the characters of the nutritive fluid or blood, and in the lymphatic or "absorbent" vessels and analogous glands it undergoes further elaboration; this latter process constituting that known as "sanguification." From these absorbent vessels the nutritive fluid is conducted to the current of the circulation of the blood, with which it mixes and becomes identical. In this way the supply of nutrient fluid is from time to time recruited.

In lower forms, in which the complicated apparatus here described is entirely wanting, we find the nutritive fluid simply elaborated in the stomach and intestine—or in the stomach or digestive sac alone, where an intestine may be wanting—the process of absorption, in such cases, being subserved by the walls of the alimentary tract. The nutritive products in such a case are sent into the general cavity of the body, there to mingle with the contained fluid, and generally to perform a rudimentary or primitive circulation.

The circulatory system is typically represented by a central organ or heart, and by a system of closed tubes or blood-vessels, communicating with the heart. The heart, as the central organ, propels the blood through the vessels, and these latter, in turn, branch and ramify throughout the organs and tissues of the body, until eventually the nutritive supply is brought to the intimate parts of the tissues, which latter structures are thereby nourished. At the same time the products of tissue-waste enter the current of the circulation, and are borne backwards towards the heart. The blood thus latterly becomes a medium for the conveyance from the system of the waste products of vital energy and work; the function of excretion of these products being performed chiefly by the breathing organs in the exercise of the respiratory process.

Those forms, in which the circulatory system is not

specialised, generally possess, as already remarked, a rudimentary or general circulation of the fluids contained in the cavity of the body; this circulation being excited and maintained by the action of the minute, vibratile, eyelash-like filaments, known as "cilia," which very generally fringe the surfaces of the internal membranes throughout the animal series.

The function of respiration is performed generally by distinct organs, known as "lungs," and as "branchiæ," or "gills;" but it may be subserved, as in *Flustra* (Fig. 6), by the tentacles or organs of prehension. In other cases respiration is performed by the ciliated surfaces of the body-cavity, or by the general and external surface of the body. In any case, the absorption of oxygen gas, and the excretion of carbonic acid gas, are the characteristic features in the performance of this function by the animal. The function of respiration in plants is performed by the leaves; carbonic acid gas being, in the case of the plant, absorbed, whilst oxygen is exhaled.

The function of respiration ranks, in point of frequency of occurrence throughout the animal series, next to that of the actual prehension and digestion of food. Even in such forms as the *Amœba* and its allies, there appears to exist a process imitative of the renewal of oxygen in the higher animals; and from the intimate connection between the processes of circulation and respiration, it appears highly probable that the two processes may, in these lower organisms, be subserved by one and the same organ. In this way, the "contractile" vesicles of the *Amœba* and *Infusoria* (Figs. 12, A *b*, and 22 A, *c c*), may be supposed to equally subserve the circulation of fluid, or the renewal of the aërating medium. And in such forms as *Flustra*, together with very many animals of lower organisation, we find the respiratory function specialised, and devolving upon the tentacles (Fig. 9, *a*), before the faintest traces of a circulatory organ are apparent.

The brief sketch here given of the chief processes involved in this important function will serve to give the

beginner in zoological studies a broad, but, at the same time, essential and necessary idea of the mode in which the organisms he will meet with in his systematic studies nourish themselves, and of the manner in which the chief and most apparent processes of life are subserved throughout the animal series. It only remains, in the present case, to say a few words concerning the function of *Innervation*, since we reserve the consideration of the *Reproductive* function for a separate chapter, and for a subsequent period in our biological studies.

The function of *Correlation*, *Innervation*, or *Irritability*, has already been defined as that whereby an organism maintains relations with its fellows, and with the medium in which it lives. The present function is one which has been thought to be essentially peculiar to the animal series. And the functions of relation have accordingly been denominated the "animal" functions; whilst those of nutrition and reproduction, from their community in both plants and animals, are commonly spoken of as the "organic" or "vegetative" functions.

Whilst, therefore, the correlative process is one which is seen to fullest perfection in the animal series, there is good reason for the belief that plants also possess means for maintaining relations with surrounding media, and this in a manner closely analogous to that observed in many animal forms. And when we reflect that in not a few organisms—exemplified by the entire *Protozoa*, and most *Cœlenterata*—the truly animal nature of which cannot be questioned, no distinct or specialised apparatus for carrying on the function of innervation can be discerned, we must admit that the limitation of the function to the animal series is, on reasonable grounds, to be considered as somewhat of an arbitrary nature. Such animal organisms, as are above indicated, despite their want of specialised or distinct nervous centres, exhibit many of the phenomena which we regard as normally taking origin from, and as regulated by, a correlative apparatus. The phenomena of co-ordination of motion, of contractility, and many other processes, which, in the higher forms of

animal life, we know to be dependent upon the operation of the innervative function, are also perfectly exhibited by many of these lower forms. Hence we are led to the belief, firstly, that the phenomena of correlation may apparently be dissociated from a specialised nervous system; secondly, that the specialisation of this function does not partake of that gradual development which we have seen to be characteristic of nutrition and reproduction; and, thirdly, that the innervative process appears to be subserved in the lower forms of animal life and in plant existence generally, by an adaptive or functional development of the ordinary tissues and textures of the body.

The advance in the histological department of morphology, and the close application to, and improved methods of, microscopic research, may in the future enable us to determine with exactitude the curious relations between the function of innervation and the organism in which it resides. Recently, Dr. Lionel Beale has suggested the idea, that not only are means for the performance of the correlative function invariably present in the animal organism, but these means may, in the hands of the skilful microscopist, be traced out to actual demonstration. Thus he tells us that "it might be supposed that we should be able to form a correct idea of the essential structure of a nervous apparatus if we appealed to some of the lowest organisms in which the existence of nerve-tissue might be fairly assumed. In them it would be supposed that we should meet with a nervous system in a very simple condition. But it unfortunately happens that in these lower forms of life the nerve-fibres are so very delicate as to be, under ordinary circumstances, invisible. Nor is it surprising that the difficulty of detecting them has induced some to adopt the hasty and, it must be admitted, unjustifiable inference, that many creatures which exhibit combined and complex muscular movements are altogether destitute of nerve-fibres, but that the nerve matter of their bodies exists in a diffused and fluid state, or in the form of minute disconnected particles disseminated amongst the tissues.

"Now, if the tissue of the arm of an Actinia, or sea-anemone, be carefully examined after successful staining, multitudes of minute oval bioplasts (nuclei), taking different directions, will be observed amongst the muscular fibres, as well as in the external investment. The disposition of these would receive explanation if they were connected together by delicate threads. Here and there, in a very thin specimen, a very delicate film can indeed be discerned passing from one bioplast to its neighbours. . . . . In the peripheral organs of the perfect fly, and in many tissues of the mollusca, especially over some of the muscles, I have been able to separate an extremely delicate tissue, consisting principally of nerve-cells with very fine fibres passing from them, and crossing and interlacing in every direction, constituting what may truly be described as a nerve membrane of extreme delicacy. We shall find in the peripheral parts of the nervous system of man and the higher animals at an early period of development, a precisely similar arrangement. In this delicate membranous structure no separate nerve-cords or fibres can be detected, but delicate tracks crossing one another at various angles may be discerned."

The view thus promulgated is further detailed, with the object of showing that, in all probability, the nervous power, in virtue of which the function of correlation is manifested, may be regarded as an original property of the "protoplasm" or "bioplasm" of which the living organism is composed. And hence Dr. Beale believes in the community of type of nerve-force, as exhibited in the lowest or in the highest organism; this common nature taking origin from the community of the living "bioplasm," in which this nerve-force or correlative power is originally inherent. Thus he says—"Although, therefore, the nerve-current may be due to chemical change, and the arrangement of the nerves might be accounted for by physical actions, both series of phenomena are dependent upon antecedent operations which must be at last referred to the direct influence exerted by the peculiar power which is associated with the matter of the bioplasm during its

living state." And, again, a nervous apparatus is to be regarded "as consisting essentially of fine fibres and masses of bioplasm, which form uninterrupted circuits." And lastly, regarding the primary origin of the nervous system, as affecting the question of its actual presence and form in the lowest organisms, Dr. Beale says, "the formation of the nerve-fibres and cells—the construction of the nerve mechanism, must be referred to the properties or powers of the bioplasm which preceded its formation. The *action* of the mechanism may be said to be due directly to physical and chemical change, but the matter which is changed, it must be borne in mind, was formed by bioplasm, and owed its origin to bioplasm. The higher phenomena of the nervous system are probably due primarily to the movements of bioplasm, by which some part of the nerve mechanism is acted upon."

The ingenious theory thus expressed, may, for the present at any rate, afford an explanation of the occurrence of correlative phenomena in the lower forms of animal life, which has the merit of resting upon a demonstrable basis. And if we accept the main thought of this view, we may form some conception of the mode and means by which an organism—such as the *Amœba*—whose body consists wholly of bioplasm in its simplest possible state, maintains relations in its economy which are undoubtedly analogous to those we are accustomed, in the case of the higher organism, to associate with the possession of nervous centres. In this way, also, we can conceive a probable idea of the non-specialised nature of the nervous apparatus in the lower forms; the progress of specialisation tending to gather together and to concentrate the bioplastic nerve-centres, until, progressively, the highest form of a nervous apparatus is produced.

The essential feature in the function of *Correlation* is the reception by the organism, through its correlative apparatus, of certain impressions derived from the external world, and known as "sensations." These impressions or sensations, through the medium of its nervous system, influence the individual parts of the organism, or the

organism as a whole; and it is thus enabled to re-act upon the media by which it is surrounded. Or, if we state the case in the reverse order of its circumstances and phenomena, and start with the influence of the organism upon the external world, and the reaction upon the organism of external media, the result, to the media and to the organism, will be exactly similar in every way.

The reception by the organism of "sensations," and its reaction upon the medium from which the sensations are derived, therefore constitute the essential and characteristic features in the operation of the correlative function. And in the lower or *Invertebrate* forms of animal life the nervous apparatus may be considered to be almost wholly occupied in the reception of the ordinary "sensations," which minister to the wants and necessities of existence, without any active or intelligent appreciation of the causes or results of the sensations thus conveyed. Or, to use the words of Dr. Carpenter, "the type of psychical perfection among Invertebrated animals, which is manifested in the highest degree in the Social Insects, consists in the exclusive development of the *Automatic* powers, in virtue of which each individual performs those actions to which it is directly prompted by the impulses arising out of impressions made upon its afferent nerves, without any self-control or self-direction; so that it must be regarded as entirely a creature of necessity, performing its instrumental part in the economy of Nature from no design or will of its own, but in accordance with the plan originally devised by its Creator."

In the *Vertebrata*, on the other hand, we find the higher perfection of the correlative apparatus associated with powers which place the organism far above the rank and relations of a piece of automatic mechanism. And we accordingly notice this specialisation of the correlative powers in these higher forms, evincing itself in the possession of a power of appreciation of the origin of sensations, known as "intelligence;" whilst, in virtue of this latter feature, we find another and distinctive power super-

added, which is devoted to the regulation of the movements of the body, and which is known as the power of "volition" or "will."

Such a development of functional powers and attributes is accompanied by a corresponding specialisation of the nervous centres; and accordingly we observe the correlative apparatus of the Vertebrate to evince a division into distinct parts, each part having to deal with special processes in the performance of the correlative function. The "cerebro-spinal axis" of the vertebrate (Fig. 11), consisting of the brain (*b c*) and spinal cord (*s s*), thus constitutes the chief nervous axis of the body. The brain, or collection of nerve-centres, or "ganglia," is the seat of those directing and guiding powers which raise the vertebrate above the lower or invertebrate forms; whilst the "spinal cord," or continuation of this chief nervous centre, forms the medium through and from which the nervous supply of the body generally takes origin, and along which the guiding impulses of the brain are transmitted to the various organs or parts of the system. And, lastly, from the brain and spinal cord the various nervous trunks arise, and are distributed throughout the body.

In addition to this chief nervous axis we find a second series of nerve-centres present in Vertebrata. This latter system has been denominated the "sympathetic," or "ganglionic" system of nerves (Fig. 11, *p p*), and consists of a chain of "ganglia" or nerve-centres disposed along the under surface of the spinal column, and connected with the "cerebro-spinal" axis. The operation and regulation of this latter system of nerves is, to a great extent, independent of, and without the influence and command of, the will. The functions of the "sympathetic" system appear to be those of regulating the movements and processes of digestion, circulation, and respiration, and of influencing the various secretions connected with these processes.

In *Invertebrata* the nervous axis generally consists of a series of nervous centres or "ganglia," arranged after various fashions, and connected together by nervous cords

or bands. Such a system, whilst it may be shown to be partly homologous with the "cerebro-spinal" axis of the Vertebrata, nevertheless corresponds in general function to the "sympathetic" system of the latter forms. The *Invertebrate* apparatus of correlation may therefore be regarded as a general medium for the regulation of the vital processes of the body, together with the administration of the correlative power necessary for the functional exercise of the organs of sense, in cases where these are present. The "excito-motor" movements of the Invertebrate, together with those which, from their affecting the organs of sense may be termed "sensori-motor," are essentially and solely of an automatic kind; since, however perfectly adapted to surrounding circumstances these movements may be, they want the directing and guiding intelligence of the higher forms.

In *Invertebrata*, accordingly, the nervous axis may be regarded chiefly as constituting a mere connecting and controlling medium to the various parts of the organism. Its various centres may be regarded as semi-independent factors in the constitution and performance of the correlative function. In the *Vertebrata*, on the other hand, the process of specialisation tends to develop as chief and independent factors, certain parts of the nervous axis; these latter parts serving, as we have seen, to direct and control, in virtue of an inherent intelligence, all the functions and processes of the organism.

The occurrence amongst certain Invertebrate forms—typically exemplified by the "social" insects—of a remarkable development of apparent intelligence, directing and guiding the special impulses of these creatures, is entirely and satisfactorily explicable according to the ordinary facts and laws which regulate the correlative function in the Invertebrata as a whole. This adaptation of action to special ends, we ordinarily know as "instinct;" and the exhibition of this power or phase occasionally includes phenomena of the most remarkable kind, which would, at first sight, seem to be suggested, directed, and controlled, by the operation of an

animated intelligence analogous to that which controls the operations of the higher and Vertebrate form.

The phenomena, for example, which are noticed in the performance of the many and complicated functions that make up the life-history of the ant, wasp, or bee, and the consideration of the wondrous exactitude with which their many labours and duties are performed, would, and not unnaturally either, almost force upon us the impression and belief that this so-called "instinct" must be nearly allied in nature to the higher powers of reasoning and of intelligence. Yet the most marvellous exhibitions of instinctive powers simply consist of movements induced chiefly by external impressions—"sensori-motor" movements—but in which neither reason nor intelligence, as evinced in the higher animals, participate.

The wasp, ant, or bee thus constructs its abode, and performs the duties incidental to its highly-organised existence, primarily, as a result of the "adaptive" nature of their nervous organisation; the surrounding circumstances of the insect's life being the undoubted and exciting causes of the "sensations," and through these latter of the "movements" which together make up the cycle of "sensori-motor" or "instinctive" acts. And this assertion receives support from the mere circumstances and essential conditions under which the instinctive power operates. Thus the same series of actions and labours is undertaken and performed by all the members of the colony, or by the entire species; a community of impulse being thus associated with a similarity of conditions. And the insect may therefore be compared to a highly-perfect piece of automatic mechanism, which derives its impulse from the conditions by which it is surrounded, and which invariably executes or performs the same round or cycle of duties with an exactitude due simply to the harmonious and unaltering nature of the surrounding media.

And similarly with the relations of instinct to the educative power we familiarly know as experience. The higher organism progressively, and through the teachings and instructive power of experience, attains from im-

perfections in the performance of duties and labours to their due and perfect execution. Its progress, influenced and carried on by its high psychical development, is necessarily at first of a slow and gradual character; but, once having attained to the knowledge and execution of the task, succeeding efforts will only tend to further improve or perfect the knowledge which has thus been acquired. Not so, however, with the form which performs its duties in virtue of the possession of merely instinctive powers. The bee or wasp, after arriving at maturity, at once enters upon the performance of the most complicated duties, without any previous knowledge or educative effort; and the task or labour will be none the more perfectly performed at the close of existence, and after countless repetitions, than it was at the commencement of active life. The bee, similarly with the automatic machine, thus requires no preliminary education or experience, but enters upon its duties at once, and as naturally as the mechanism of the machine, once perfected and set in operation, fulfils the function for which it was destined and prepared.

And, lastly, as remarked by Dr. Carpenter, "the very perfection of the adaptation, again, is often of itself a sufficient evidence of the unreasoning character of the beings which perform the work; for, if we attribute it to their own intelligence, we must admit that this intelligence frequently equals, if it does not surpass, that of the most accomplished Human reasoner."

The phenomena of contractility and movement of the leaves observed in many plants have been referred to in commenting upon the apparent limitation of the correlative function to the animal world. Such movements are witnessed in widely different degrees of perfection throughout the vegetable world; those observed in the *Mimosæ* or Sensitive plants, in the Venus' Fly-trap (*Dionœa muscipula*), and in the Moving Plant of India (*Desmodium gyrans*), exhibiting the phenomena in their most typical aspect. The leaves in the first-mentioned plants exhibit a high degree of irritability; the slightest touch or irritation

causing them to exhibit the movements of folding in and of drooping the irritated organs. Whilst in the Venus' Fly-trap the surface of the leaf-blade is provided with sensitive hairs, which, on being touched or irritated, appear to cause the closure or folding-together of the two halves of the leaf-blade. In the Moving Plant of India, the individual leaflets of which the leaf is composed exhibit a constant oscillatory movement, and in this way they are seen to wave from side to side, and also from above downwards.

The seat of these movements appears to exist in cellular nodes or swellings situated at the base of the leaf-stalks or "petioles" in the sensitive plants; the sense of irritation being apparently conveyed by these sensitive expansions to the cellular structures of the plant. By botanists the cause of these movements is therefore referred to the contraction and expansion of the cells and cell-contents; and although such an explanation might account for the purely mechanical movement of the leaves, there yet remains to be elucidated the nature of the conditions in virtue of which the cells become thus sensitive to the action of stimuli. The inference, that these conditions may take origin from the presence of a correlative apparatus of a lowly-specialised nature, does not, in the face of the considerations previously enforced, become of an improbable or unwarranted nature. And recent physiological researches—among which those of Dr. Pettigrew stand conspicuous—have given to this latter opinion a nature and status above that of a merely hypothetical statement.