INSTINCT AND INTELLIGENCE

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PREFACE

The meaning of the term Education is "to draw out what is in a child"; it therefore includes the training of his inherited instinctive disposition or character, as well as the "putting in" needful knowledge, or the "instruction" of his intellectual faculties. Educationists of the present time appear to exaggerate the importance of training the intellect, and are apt to overlook the fact that each individual possesses certain instinctive qualities which to a large extent determine his behaviour throughout life. These qualities, which no human power can eradicate, may, however, be favourably modified by appropriate training.

In the following pages we have endeavoured to give an outline of the evidence, and the reasons upon which we rely to prove that the instinctive behaviour of human beings depends on work performed by definite parts of the brain; consequently, education has not only to deal with the training of something immaterial which we call mind or consciousness, but has first and foremost to deal with the proper development of the nervous substance of that part of the brain the orderly working of which is essential for the occurrence of instinctive, and intellectual phenomena. In the majority of healthy children this purpose can be attained by means of the appropriate exercise of their eyes, ears, and other sensory organs; for, as we explain, energy derived from this source stimulates and develops the living substance of those parts of the brain directly concerned in the elaboration of an individual's instinctive and intellectual processes; we may thus hope to lay the foundation on which to build up a chaste, self-reliant character combined with a clear and strong intellectual capacity.

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In the following pages we shall frequently have to refer to the molecules and atoms constituting the basic substance of living matter. It may be well, therefore, to define the meaning we attach to these terms. Let us suppose we proceed to subdivide a drop of water into its smallest conceivable particles, we should in time come on a single unit particle, or molecule of water, the smallest particle of water that can exist. It could not properly be described as the atom of water, because, although it represented the limit of conceivable mechanical subdivision, it can be decomposed into its constituent elements—hydrogen and oxygen. The word molecule is thus employed to represent the smallest single particle of any substance, whether elementary or compound that has a separate existence; whilst the word atom denotes a constituent elementary particle of a molecule.[1] Atoms are now held to consist of a central nucleus around which multitudes of electrons constantly revolve.[2] The structural arrangement and motion of atom-clusters are all important as being the directing agents of the kind of work performed by various kinds of matter. For instance, the molecules of the two substances known as benzonitrile and phenylisocyanide each contain seven atoms of carbon, five of hydrogen, and one of nitrogen. There is a small difference in the arrangement of the atoms of these two substances, and this slight difference in their atomic

[1] *Matter and Energy,* by Frederick Soddy, F.R.S., p. 48.

[2] "Electrons have been described as immaterial in the sense that they are not matter, but something at once finer grained and endowed with fundamental qualities which distinguish them from any known kind of matter; they revolve thousands of millions of millions of times per second, so that it might be supposed impossible to measure the electron; but as a matter of fact no magnitudes in science are known with greater exactitude."—*Matter and Energy*, pp. 170, 175, 187.

architecture completely alters their character, one being a harmless aromatic fluid, the other an offensive poison.

Atoms and molecules are far too small to be seen under the highest powers of the microscope; nevertheless, their size and the velocity of their movements are accurately known. We may perhaps form some mental picture of their movements, by watching the perpetual motion of inorganic particles seen in a drop of turbid water when placed under a good lens. Hour after hour these particles may be seen to be in a lively state of movement; each particle contains millions of molecules and infinitely more atoms, all of which are in constant motion similar to that observed in the drop of water.

But we know that one of the fundamental properties of matter is its inertia; that is, its disinclination to move when at rest, and to stop moving after it has once been started. What, then, is the cause of the constant motion of atoms and molecules? In answer to this question we reply "energy" is the cause of all these and every other kind of movement; as Professor

Soddy remarks, before any object can start, what we call "energy must be supplied to the matter, and before it can stop this energy must be taken from it."[1]

At present it is an open question as to whether energy possesses an atomic character; like matter, we know it is conserved, and what is conserved has physical existence; in other words, when energy appears it must come from somewhere, and when it disappears it must go somewhere. Energy has been defined as that which has the power of changing the properties of bodies; it is the cause, change of condition the effect, "the capacity for doing work." For instance, to keep a grindstone in motion a certain amount of, say, muscular energy must be expended to overcome the resistance opposed by the air, axle bearings, etc. If a piece of steel is pressed against the stone while in motion the steel soon becomes warm. If a vulcanite tyre be placed on the grindstone, and the rim pressed with a piece of flannel electricity will be developed, which can be reconverted back into mechanical motion. Heat and electricity are

[1] *Matter and Energy*, by F. Soddy, pp. 19, 78, 91, 171.

well-known concomitants of chemical action. Hence we infer that heat, electricity, mechanical motion, and chemical action are a few among many other different kinds of one distinct entity-energy.[1]

Observation has shown :—

I. That one form of energy can be transformed directly or by intermediate steps into any other form.[2]

II. When any quantity of one form of energy is made to disappear, an equivalent quantity of another form or forms of energy reappear.

III. We recognise energy in two forms: Kinetic free or available, and Potential or possible energy; the first depends on motion, the second on the position of the body under consideration. Thus, when a marble is set rolling, it has the power in virtue of its motion of changing the state of motion of any other

[1] *Text Books of Physical Chemistry*, edited by Sir William Ramsay. Volume on Chemical Statics and Dynamics, by J. W. Mellor, D.Sc., p. 21.

[2] "The mechanism by means of which stimulating waves are converted into heat in the body acted on is still a mystery. That waves should cause the electrons to vibrate is perfectly clear, but how vibrations of the electrons are converted into those vibrations of the atoms and molecules which constitute heat is still unsolved." —P. Phillips on *Radiation*, p. 57.

marble which it might strike; it therefore possesses kinetic or free energy in virtue of its motion or active condition.

Potential energy, on the other hand, is associated with a body in virtue of its position. Thus, when a stone is lifted above the ground, the energy expended and the work done in lifting it are measurable quantities of energy stored up or rendered passive in some way, and this energy can be recovered or set free in a measurable form. Coal represents an accumulation of light and heat energy derived by plants in bygone ages from the sun, which has been transformed by means of the living basic substance of these plants into chemical energy. In order to liberate this potential or latent energy another chemical substance in the shape of oxygen is required, which acts on the molecular structure of the coal and sets its latent energy free in the form of heat, light, etc.

We have given an example (p. 10) of a change in the arrangement of the atoms in an organic substance which completely alters the character of the work it performs; the same rule holds good for inorganic matter. For instance, the structural arrangement and motion of the elements which form a piece of iron wire is such, that they can act as a means of transmuting magnetic energy into electrical or into mechanical energy. A thread of platinum is so sensitive that it reacts by a variation of electric conductivity when struck by a ray of light of so feeble an intensity, that it can produce an elevation of temperature amounting to only one hundred-millionth of a degree. Hertzian waves which have travelled over hundreds of miles, and are therefore extremely feeble, nevertheless so modify the structure of the metal they reach as to produce marked changes in its electric conductivity. Again, it has been shown that metals become for a time less sensitive after constant excitation, but regain their irritability after an interval of repose; while their peculiar qualities may be excited or depressed or even abolished by chemical substances.[1]

The structural arrangement of the molecules which constitute the basic substance of living protoplasm makes it peculiarly sensitive to

[1] *Annual Report of the Smithsonian Institution for* 1903, p. 288. Also *Human Speech*, by N. C. Macnamara, p. 13.

energy changes, and thus capable of taking up energy in one form and transmuting it readily into another. For example, when a healthy plant is excluded from that form of energy which we call sunlight, its green leaves lose their colour, but if this plant is removed into the light the protoplasmic elements of some of its cells undergo changes which result in the re-appearance of the natural green colour of the leaves.[1] This colouring matter is contained in what are known as chlorophyll bodies or corpuscles, the basic substance of which is derived from the living matter of the protoplasm of the cell in which the chlorophyll appears. Our chief interest in these green corpuscles is, their elements are so arranged that they act as specialised energy-transformers. Chlorophyll corpuscles if treated with alcohol soon lose their green colour; the chlorophyll being dissolved out of them by the alcohol, there remains a colourless corpuscle which gives the reaction of proteid substance, and is doubtless of a protoplasmic nature. The chlorophyll is not actually

[1] Prof. B. Moore on *The Origin and Nature of Life*, pp. 178, 183. Also *Lectures on the Physiology of Plants*, by S. H. Vines, pp. 153, 157.

combined with the protoplasm, but is retained mechanically within it. The function of chlorophyll is to absorb certain rays of light, and enable the protoplasm with which it is intimately connected to avail itself of radiant energy of the sun's rays, for the construction of organic substance from carbon dioxide and water.

Every kind of healthy living matter possesses the power of helping to convert the nutrient matter which, as a rule, is carried to it by the circulating fluid into such a form as can be incorporated with its protoplasmic elements, thus replacing its worn-out particles; this process is technically known as Metabolism. Professor Huxley, when referring to this power, describes the incoming atoms as being piled up in the cell under the action of chemical force, while before they leave it they tumble down into smaller heaps. The energy set free in the tumbling down of these atom groups affords a constant store of working energy to the cell-contents.

The human brain, for our purposes, may be described as consisting of an innumerable multitude of fully-charged nerve cells, exposed to a constant flow of incoming energy derived from internal and external sources. This flow effects a discharge of part of the latent energy of the cells in the form of nervous energy, and may become manifest in instinctive and intellectual processes.

With regard to Instincts, more than a century ago Sydney Smith wrote as follows : " The most common notion now prevalent with respect to animals is that they are guided by *instinct*; that the discriminating circumstance between the minds of animals and of man is that the former do what they do from instinct, the latter from reason. When I call that principle upon which the bees or any other animal proceed to their labour the principle of instinct, I only mean that it is not a principle of reason. However the knowledge is gained, it is not gained as our knowledge is gained. It is not gained by experience or imitation. . . . It cannot be invention, or the adaptation of means to ends, because as the animal works before he knows what event is going to happen, he cannot know what the end is to which he is accommodating the means :

and if he be actuated by any other than these, the generation of ideas in animals is very different from the generation of ideas in men. Ants and beavers lay up magazines. Where do they get this knowledge that it will not be as easy to collect food in rainy weather as it is in summer? Men and women know these things, because their grandpapas and grandmammas have told them so; ants, hatched from the egg artificially, or birds hatched in this manner, have all this knowledge by intuition, without the smallest communication with any of their relations."[1]

Professor Lloyd Morgan defines "instinctive behaviour as that which is, on its first occurrence, independent of prior experience; which tends to the well-being of the individual and the preservation of the race; which is similarly performed by all the members of the same more or less restricted groups of animals; and which may be subject to subsequent modification under the guidance of experience."[2] He holds

[1] *Sketches of Moral Philosophy, by Sydney Smith,* pp. 240, 244, 247.

[2] *Instinct and Experience,* by C. Lloyd Morgan, D.Sc., Professor in the University of Bristol, pp. 5, 28, 79, 204.

that such behaviour is a more or less complex organic or biological response to a more or less complex group of stimuli of external and internal origin; and depends upon the *inherited structure* of the nervous system of a definite part of the brain.

It would be difficult to devise a clearer definition of the term Instinct than that given by Professor Lloyd Morgan; the nervous matter through whose agency action of this kind is brought into play is inherited. The energy attached to its molecules being set free by various stimuli received from external objects, and internal movements becomes manifest in definite action. That matter having instinctive properties has been derived from a common ancestral source, and has developed under the laws of natural selection, is apparent from the fact that the same kind of movements are made in similar environmental conditions, without being taught, by newly-born beings belonging to the same species, located in widely separated parts of the world.

The exciting agent or mode of energy is called a stimulus, which is always due to a change of environment. Internal stimuli result in part from energy derived from the sensory organs of ligaments, muscles, and other structures in contraction, pass by afferent fibres to motor areas of the cerebral cortex, and by releasing a portion of their potential energy bring "motorial" or "kinæsthetic" sensations into play. Beyond this various biochemical stimuli known as "hormones" are formed in various glands of our bodies; they enter the blood stream and activate among other structures the instinctive sensori-motor elements of the central nervous system. It seems possible that some of these hormones, by exciting the basal nervous matter of a new-born infant's instinctive elements, may lead to the movements which guide his limbs to seize and direct the nipple of his mother's breast to his mouth.[1]

Instinct is in fact a fundamental property of certain inherited forms of living matter, as is demonstrated by the behaviour of some of the

[1] An Essay on Character in Relation to the Emotions and Instincts, *Science Progress*, No. 36, April, 1915, pp. 683–685, an Introduction to the Study of the Endocrine Glands and Internal Secretions. By Sir Edward Schäfer.

simplest kinds of organism, such, for instance, as the Amœba proteus.[1]

Amœba are of microscopic size, and may be found moving about on the mud at the bottom of many ponds and ditches; each one of these unicellular beings contains a single minute speck of nucleated protoplasm. The protoplasm forming the substance of these unicellular beings consists of a network of proteid elements, the interspaces being occupied by semi-fluid contents. The Amœbæ do not possess a nervous system, eyes, locomotor, or any other permanent organs; their nucleus, however, is composed of a somewhat different variety of protoplasm from that which forms the body of the cell. The worn-out elements of these living cells are replaced by metabolic processes (p. 17), and it is thus supplied with a constant reserve

[1] For half a century the author of this volume has been more or less occupied in studying, under the highest magnifying powers, the life-history of some of the simplest organisms; his attention having been directed, when serving in India, to this subject in an effort to define the specific germs which he was convinced gave rise to Asiatic cholera. (*A Treatise on Asiatic Cholera,* by N. C. Macnamara, Calcutta, 1869.) It would be out of place here to recapitulate the results of his work, especially as reliable descriptions of the behaviour of lower organisms, including that of the Amœba, are now at command, written by impartial and acknowledged authorities in this department of science. (Prof. H. S. Jennings, *The Behaviour of Lower Organisms,* New York, 1906.)

of chemical energy. When an Amœba has grown to a definite size its nucleus and body-substance separate into two parts which move away from one another, and two young Amœbæ are formed exactly resembling their parent.

Amœbæ from time to time, in response to certain stimuli, extend outwards retractile processes from their body substance known technically as pseudopodia. By aid of these feelers an Amœba is able to move about over the mud forming the bottom of the pond it inhabits. When an Amœba comes in contact with solid particles, Dr. Dendy[1] writes, we notice that it has the power of distinguishing one particle from another, and that one which is good for food adheres to a pseudopodium and is carried into the body of the animal, where it is digested.

Professor G. C. Bourne, when describing Protozoa, or single-cell organisms, remarks that they must exercise some sort of selection in ingesting solid matter; for if they did not they would take in every particle of convenient size that they meet, and they do not. He further

[1] *Outlines of Evolutionary Biology*, by A. Dendy, D.Sc., F.R.S., p. 16.

states that an Amœba living in water containing numerous diatoms of relatively large size, may be seen to engulf a number of these apparently inconveniently large objects almost to the exclusion of other substances, thus making a discrimination between things good for food and things not good. Moreover, if watched for a long time, the movements of an Amœba are seen to be of a purposive character; that is to say, they are adapted to the necessities of the organism, as is evident when an obstacle is met with, or when the animalcule endeavours to seize and ingest some object that rolls away from it, or attempts to capture a smaller member of its own kind for food.[1]

Professor Jennings on one occasion saw a large Amœba seize a small one and encircle it by means of pseudopodia which were then retracted; but the embrace of the small by the large Amœba not being complete, the former animal escaped; upon which the large Amœba reversed the course it was following and pursued its prey. Professor Jennings states with

[1] *An Introduction to the Study of the Comparative Anatomy of Animals, by* Gilbert C. Bourne, M.A., D.Sc., Professor of Comparative Anatomy, University of Oxford, Vol. I., p. 134. Second edition.

reference to this performance that it is difficult to conceive each phase of action of the pursuer to be completely determined by a simple present stimulus. For example . . . after Amœba *b* had escaped completely and was quite separate from Amœba *c*, the latter reversed its course and recaptured *b*. What determines the behaviour of *c* at this point? If we can imagine all external physical and chemical conditions to remain the same with the two Amœbæ in the same relative position, but suppose at the same time that Amœba *c* has never had the experience of possessing *b*, would its action be the same? Would it reverse its movements, take in *b*, then return on its former course? "One who sees the behaviour as it occurs hardly resists the conviction that the action at this point is partly determined by the change in *c*, due to the former possession of *b*, so that the behaviour is not purely reflex, but partly the result of memory."[1]

[1] *Behaviour of Lower Organisms,* by H. S. Jennings, p. 24. New York, 1906.

Prof. W. B. Hardy, when discussing the nature of the movements made by Amœbæ, observes: "They manifest discrimination, imperfect no doubt, but as the choice is beneficial it contains an element of purpose."—*Science Progress,* October, 1906, p. 182.

From the above evidence, which we can confirm by our own experience, we hold that the behaviour displayed in response to appropriate stimuli by the simplest forms of animals is instinctive, employing that term as defined by Professor Lloyd Morgan (p. 19). The behaviour, however, of the Amœba above referred to was to some extent the result of memory. Huxley, in his well-known address to the British Association in the year 1874, referring to this subject, remarks that impressions made on certain kinds of living matter leave behind molecules competent on being stimulated to their reproduction—"sensigenous molecules," so to speak, which, he adds, "constitute the physical foundation of memory." We thus arrive at the conclusion that not only instinctive behaviour, but also memory, is a fundamental property of living animal protoplasm. This idea is substantiated by the following evidence:

Sir Francis Darwin, in his address as President of the British Association in the year 1908, not only concurs in Huxley's views on this subject, but quotes Regnano, Hering, and Semon as postulating the existence in living protoplasm of elements possessing the basis of memory and inheritance. For example, Stentor, although its body-substance and nucleus are structurally of greater complexity than those of Amœba, is nevertheless a unicellular being. The movements effected by the protoplasm of this animal have been carefully studied by Asa A. Schaeffer; he gives in detail a clear account of his experimental work, and arrives at the following conclusions :—[1]

1. Stentor cæruleus excises a selection among particles that are brought to its food-pouch; certain particles are rejected, others are carried to the mouth and ingested; in selecting food it probably reacts to physical properties only or chiefly, and not to chemical properties.

2. Stentor discriminates very accurately between organisms and indigestible particles, the latter of many sorts which have for thousands of generations not come in contact with Stentor are nevertheless rejected.

[1] *The Journal of Experimental Zoology*, Vol. VIII., No. 1, January, 1910, pp. 894–5.

Prof. A. J. Ewart remarks, when referring to the movements of organisms possessing locomotory organs, that they have "acquired the power of directing and controlling the natural forces to their own benefit."—*Physics and Physiology of Protoplasmic Straining in Plants*, p 1'2.

Difflugia, one of the simplest of unicellular beings, when it has reached its full size, protrudes long pseudopodia which move over the mud at the bottom of the water it inhabits. If its pseudopodia come in contact with grains of sand they contract with the sand adhering to them, and pass it into their body. These grains of sand are subsequently employed as materials to form a new shell for the Difflugia's offspring. Professor Verworn, instead of grains of sand, placed small fragments of coloured glass near a Difflugia; some time afterwards he noticed a heap of these fragments on the bottom of the shell. He then saw a protrusion of protoplasm issue from the shell in the shape of a new Difflugia. Thereupon, the material collected by the parent organism—the fragments of coloured glass—were used to envelop the substance of the young animal, and came to form a shell similar to that enveloping the parent. Behaviour of this kind seems guided by instinct and memory.

Before leaving the Protozoa we may refer to the Volvocinæ, which appear to occupy an intermediate position between unicellular and multicellular beings. In this genus the cells in place of simply dividing, as in the Amœbæ, into independent organisms unite and form a colony consisting, it may be, of as many as 1,200 cells; each cell consists of a mass of nucleated protoplasm which is united to its neighbour by means of processes formed from their body-substance; from each cell two flagella project by means of which the colony is paddled through the water. (Fig. 1.)

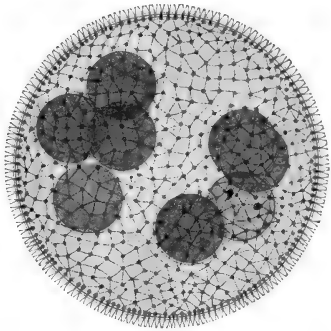

FIG. 1.—Volvox, showing the small ciliated somatic cells and eight large germ cells. (Drawn from life by J. H. Emerton. See E. B. Wilson, *The Cell in Development and Inheritance, p.* 123.)

The cells of a Volvox multiply by a process of division, but after a time they appear to become exhausted; or at any rate, some of the cells fuse to form one or more large or female organ cells; at the same time other cells of the colony develop smaller flagellated male cells, which escape from the parent colony and swim about in the water until they meet with one of the female cells, into which they pass; fertilisation takes place by changes similar to those which characterise the reproduction of the germ cells of the higher orders of plants and animals. From our point of view the interesting feature in reference to the life-history of some of the Volvocinæ is the evidence it affords that, with structural modifications in their protoplasm, there is a corresponding alteration in the nature of the work it performs.

CHAPTER II

Multicellular animals—Sex—Hydromedusæ—Hydra—Appearance of nerve cells—Medusoids—Their nervous system—"Eye-spots"—Purposive movements of Hydra according to stimulus—Purposive movements of Medusoids dependent on existence of nervous system—Purposive movements of unicellular organisms accounted for—Development of sensory organs—Light as stimulus.

Our attention thus far has been fixed on unicellular beings with the exception of Volvox, which consists of an aggregation of cells foreshadowing the structural arrangement of all multicellular animals, since, besides the aggregation of individual cells to make up its body, the germinal elements of some of these cells separate from the rest of its substance so as to produce male and female cells. The individual is no longer reproduced by the simple division of a parent cell into two young beings, but depends mainly on the conjugation of male and female cells.

It is well in passing from the consideration of unicellular to multicellular beings to bear the above principles in mind, for they apply to the reproduction of all multicellular animals. Germinal cells alone possess the power of giving rise to a being resembling more or less closely in the structural, and potential powers of the stock from which these cells have been derived, powers which they pass on to succeeding generations. The mass of cells which form the various tissues and organs of an animal's body, including the nervous system, are known as *somatic cells;* worn-out or injured somatic cells are replaced by fresh cells produced by asexual division of neighbouring like cells, but are incapable of giving rise to new beings. At the same time, we must never forget that the living protoplasm of every form of animal cell possesses a certain proportion of elements having mnemic and instinctive functions.[1]

[1] It has been assumed that a fertilised cell, such, for instance, as that of a human being, which has a diameter of about $\frac{1}{20}$ mm., is too minute in size to contain a sufficient amount of matter to produce a man with all his structural and mental qualities. This idea, however, is not entertained by those best qualified to form an opinion on the subject. Prof. J. G. M'Kendrick states that taking the average cubical diameter of a

The simplest type of multicellular animal (Metazoa) is to be found among the Sponges.[1] Only a slight degree of co-ordinate action exists between the cells forming the bodies of these animals, and they thus represent a primitive grade of organisms beyond which other Metazoa have passed. (See Appendix at end of Chap. VII.)

Following the Sponges, in the ascending scale of the animal kingdom, we come to the

human ovum at $\frac{1}{20}$ mm. and an atom at $\frac{1}{10000000}$ of a millimetre, and assuming that about fifty exist in each organic molecule (proteid, etc.), the cube would contain at least 25,000,000,000,000 organic molecules. Again, the head of the spermatozoid, which is all that is needed for the fecundation of an ovum, has a diameter of about $\frac{1}{200}$ mm. Imagine it to be a cube; it would then contain 25,000,000,000 organic molecules. When the two are fused together, as in fecundation, the ovum starts on its life with over 25,000,000,000,000 organic molecules. If we assume that one half consists of water, then we may say that the fecundated ovum may contain as many as about 12,000,000,000,000 organic molecules. Clerk Maxwell's argument that there were too few organic molecules in an ovum to account for the transmission of hereditary peculiarities does not apparently hold good. Instead of the number of organic molecules in the germinal vesicle of an ovum numbering something like a million, the fecundated ovum probably contains millions of millions. Thus the imagination can conceive of complicated arrangements of these molecules suitable for the development of all the parts of a highly complicated organism, and a sufficient number to satisfy all the demands of a theory of heredity. Such a thing as a structureless germ cannot exist. Each germ must contain peculiarities of structure sufficient to account for the evolution of the new being, and the germ must therefore be considered as a material system.—See *Nature*, September 26, 1901, p. 547.

[1] *Treatise on Zoology*, edited by Sir Ray Lankester, Part II., p. 2, by Prof. E. A. Minchin, F.R.S., on Sponges.

Hydromedusæ. This class of animals is of particular interest, as it includes the lowest order of beings possessing nerve cells, together with definite sensory organs, or structures specially adapted to receive, and transmit to nerve cells various modes of energy acting on the surface of the animal's body, the result of which frequently becomes manifest in instinctive movements.

The Hydromedusæ present two main forms, the non-sexual polyps or Hydra, and the sexual Medusæ, such as jelly-fish and sea anemones; as an example of the former we may refer to the small yellow or light brown fresh-water polyps known as *Hydra fusca.* The body of this creature consists of a cylindrical sac, its walls being formed by an outer and inner layer of cells, with an intervening gelatinous contractile substance. This Hydra is commonly found attached by one end of its body or foot to some solid substance, such as a water plant; the other end of the body opens to the exterior by an orifice which leads to the central cavity or digestive department of the animal. Round the Hydra's mouth from six to nine tapering processes of the animal's body, known as its tentacles, act as feelers and prehensile structures. The external surface of the body and tentacles of Hydra are covered by minute bristle-like projections, some of which are

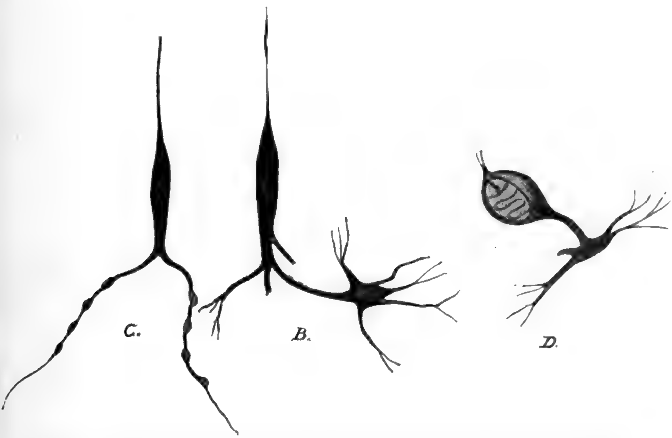

FIG. 2.—Sensory organs or cells connected with a nerve cell. *C*, Protoplasmic fibre of a tactile sense-cell forming nodular enlargements. *D*, Cnidoblast connected with nerve cell by a protoplasmic fibre.

named palpocils; they are formed of an outgrowth of the protoplasm of the cylindrical cells which constitute the ectoderm or outer skin layer of the animal. (Fig. 2.)

Palpocils, projecting as they do from the outer free surface of cylindrical cells, are well adapted to receive, and transmit any tactile impressions made on them to the protoplasmic contents of the cell of which they form a part. In this way the palpocils with their cells constitute a rudimentary sensory organ or receiver of energy from the outer world; they act somewhat after the fashion of a trigger, and when stimulated discharge a part of the potential energy stored in the living substance of the cylindrical cells. These cells are constantly kept primed with energy derived from the metabolic processes carried on by their protoplasmic elements. Energy thus released from the cells becomes manifest in definite movements of the Hydra's body or tentacles; because the deep or attached part of these cells is prolonged into a system of nerves and contractile structures.

Beneath the ectoderm of Hydra nerve cells have been detected. These cells are in direct communication with—in fact, are a part of—the living substance of cylindrical cells, and possess therefore, in common with other kinds of protoplasm, inherent mnemic and instinctive elements. Part of the energy set free by stimuli acting on the palpocils and the living substance of their cylindrical cells passes to corresponding nerve cells, and by means of their instinctive elements is transformed into purposive nerve force, which extends to groups of muscle cells, causing them to contract in a co-ordinate manner, and thus to give rise to instinctive movements of certain parts of the animal's body. It is, therefore, through the instrumentality of a system consisting of a sensory organ, nerve cell, and muscular fibres, that the automatic or instinctive movements of the animals to which we have referred take place.

Between the bases of the cylindrical cells of Hydra are a number of ovoid cells, some of which become developed into germ cells, others are so much elongated at one end as to form a fibre armed at its base with a sharp spine. (Fig. 2.) By a process of introversion of the wall of the cell this fibre comes to assume a spiral form within the cell, with one of its ends projecting outwards on the surface of the animal's body. This apparatus is described as a cnidocil, and, with the palpocils, forms a delicate bristle-like covering to the body and tentacles of Hydra. If a small living animal happens to come in contact with these processes as chemically to irritate the free ends of its cnidocils, their barbed fibres are released, and darting out of their cells sting the intruder to death; the prey is then seized by the Hydra's tentacles, carried to its mouth, and passed into its body cavity, there to be digested and assimilated.[1]

Hydra fusca, like many of the Hydromedusæ, is reproduced by a process of budding; but other genera of this family, such as the small *Obelia geniculata* often found attached to the oar-weed, give rise by sexual processes to Medusæ commonly known as "jelly-fish." The various phases in the reproduction of the Hydroids and Medusoids, although a subject of great interest is outside the province of this work; we, therefore, pass on at once to consider the structure of a typical form of Medusa,

[1] *Quarterly Journal of the Microscopic Society*, February, 1905, p. 615. Mr. G. Wagner on "Some Movements and Reactions of Hydra."

in relation to the automatic or instinctive behaviour of these animals.

The Medusoids are generally bell-shaped. As a typical example of these animals, we may refer to a jelly-fish known as Sarsia (Fig. 3), which may be said to consist of a tubular body and manubrium with a mouth or opening, from which a passage leads to its digestive cavity. From this cavity canals pass outwards to terminate in a passage which extends round the margin of the bell. In Sarsia and many other Medusoids a shelf or velum projects inwards from the margin of the bell, and at the junction of the velum and rim of the bell tentacles hang downwards. (Fig. 3.)

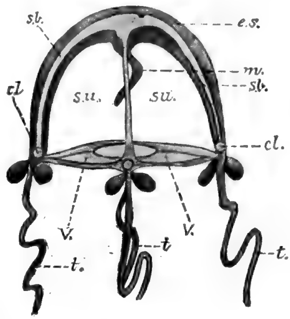

FIG. 3.—Diagram of a Medusoid (Sarsia). *m*, manubrium; *es*, external surface of bell; *sb*, subumbral surface; *v v*, velum; *su*, subumbral cavity; *cl*, circular canal; *t t t*, tentacles. (After Lankester's *Treatise on Zoology*, Part II., p. 17, The Hydromedusæ.)

The ectoderm or outer surface of this Medusa is formed by a layer of flattened cells. Muscular fibres surround the manubrium and extend outwards over the inner surface of the bell; they may be followed into the velum, which is essentially a muscular structure.

We find, in connection with the ectoderm of the under surface of the bell and its muscular fibres, a complex arrangement of nerve cells and fibres. (Fig. 4.) Mr. G. J. Romanes compares the network of nerve fibres of the inner subectodermic layer of a Medusoid's bell with a "disc of muslin, the fibres and meshes of which are finer than the closest cobweb."[1]

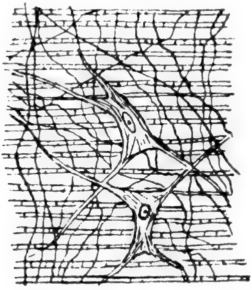

FIG. 4.

The nerve cells originate, as in Hydra, p. 36, from the sensitive protoplasmic substance of the outer layer (ectoderm) of cells forming the margin, and under-surface of the bell. In some Medusoids a double circle of nerve cells and fibres extends round the structures constituting the margin of the bell; from these nerve cells numerous fibres are given off

[1] G. J. Romanes on *Jelly-fish, Star-fish, and Sea-Urchins*, pp. 17, 20.

which terminate in the muscular structures of the manubrium and other parts of the animal.

In connection with the nervous system of Medusoids we find tactile sensory organs, similar to those which exist in Hydra, spread over their tentacles and over certain regions of their bodies. In addition to these sensory organs some of the Medusæ present definite structures derived from the ectoderm or living substance of the outer layer of cells, which are described as statocysts and ocelli; these organs are for the most part located on the margin of the bell, at or near the base of the tentacles.

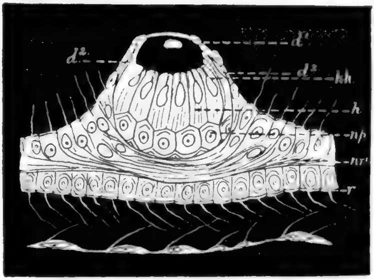

FIG. 5.—Statocyst. d^1, superficial layer of ectoderm; d^2, deeper layer; *h*, specialised cells of ectoderm; *hh*, supporting filaments; *np*, nervous structures; *npr*, upper nerve ring; *r*, endoderm ring of circular canal. The calcareous body and cavity of sense-organ seen above. (Hertwig.)

The statocysts consist of minute masses of organic and calcareous matter, supported in a cavity containing sensory fibres, which communicate vibratory impressions to subjacent nervous structures. (Fig. 5.) Their function appears to be that of adjusting the balance of the animal's swimming-bell in its passage through the water.

The ocelli consist of an arrangement of sensory and pigment cells grouped into a definite organ, in which some of the ocelli project above the surface of the ectoderm in the form of a cuticular lens. (Fig. 6.)

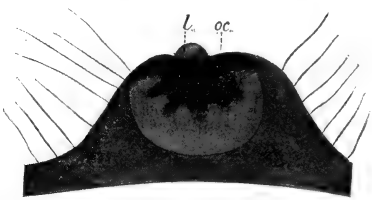

FIG. 6.

Ocelli are sometimes alluded to as "eye-spots," in consequence of the part they play as receivers of the waves of light which reach the animal from the outer world. Mr. Romanes has proved that Medusoids are influenced in their movements by the stimulus of light; if the animal is vigorous and swimming freely in water, the effect of a momentary flash of light thrown upon it during one of its natural pauses immediately starts a bout of swimming.[1] He states that when the margin of the bell, together with all its ocelli are removed, the swimming bell, although still able to contract, no longer responds to luminous stimulation of any kind or degree. But if some of the ocelli are left *in situ*, light induces an unfailing response of the entire animal.

We may now pass on to consider the movements of Hydra in order to determine how far they are directed by instinctive processes. Although a Hydra is usually attached by its foot to some solid substance, its body and tentacles undergo constant contractions and expansions; these movements are augmented by any vibrations, such as those caused by slamming the door of the room in which the aquarium containing the Hydra is placed.[2] Reaction to stimuli of this kind leads to movements which enable the Hydra's tentacles to explore the surrounding water, and thus increase its chance of capturing any suitable object which

[1] *Jelly-Fish, Star-Fish, and Sea-Urchins*, by G. J. Romanes, M.A., LL.D., F.R.S., p. 39.

[2] *The Quarterly Journal of Microscopic Science*, New Series, No. 192, p. 585, G. Wagner on "Some of the Movements and Reaction of Hydra."

may be floating about within its reach. Hydra can move from one spot to another without difficulty. These movements are effected as follows: the animal's body and tentacles expand and bend over to one side; as soon as the tentacles touch the solid substance to which its foot is attached they become fixed to it; they then contract, the animal's foot relaxes its grasp, and its body moves so that the Hydra comes to stand on its tentacles; the body then bends over until its foot reaches something to which it can fix itself, the tentacles loosen their hold, and the animal resumes its former upright position. In other cases the foot of the Hydra glides along the surface it is attached to until it comes close to the tentacles, which then leave their hold, with the result that the Hydra moves forward. When mechanically stimulated, the body of a Hydra contracts at the same time as its tentacles, as if to offer a smaller surface to the cause of irritation; if, however, the mechanical stimulus is continued, the animal relaxes its foothold and moves away slowly in the manner above described.

If a Hydra is kept without food for a week or ten days, and then a particle of raw meat is placed near one of its tentacles, it at once fastens itself on the meat, and then the other tentacles close round the food and contract; in this way the particle is conveyed to the Hydra's mouth, which opens to receive it, and closes again as the food passes into the body cavity where it is digested. If a particle of meat is dropped by a Hydra when being conveyed to its mouth, the animal does not appear to make any effort to recover it, although its tentacles may continue to move about in an excited manner for some little time. If a piece of filter-paper is placed near a starving Hydra, the animal does not attempt to seize it. "A mechanical stimulus alone, then, cannot call forth a food reaction."[1] In addition to the mechanical stimulus to produce such a reaction, the object must possess chemical properties of a definite kind. For instance, a Hydra will seize and swallow a morsel of filter-paper which has been soaked in beef-tea.

From the above facts we learn that Hydra

[1] *The Quarterly Journal of Miscroscopic Science*, New Series, No. 192.

when undisturbed can move from one to another position; when any part of the surface of its body or tentacles is mechanically or chemically stimulated, it responds by contracting more or less completely according to the intensity of the stimulus. A localised stimulus applied at brief intervals is at first followed by corresponding contractions, but after a time the stimulus loses its effect and contractions cease to occur; though if the cause of irritation is continued the Hydra loosens its foothold, and, if possible, moves away from the cause which is irritating it. Hydra only reacts to the stimulus of food when hungry, and then the complex, and to some extent co-ordinate movements of its tentacles and mouth necessary to enable it to seize, and swallow its food require a combination of mechanical and chemical stimuli to produce an efficient response of the structures concerned in the action.[1]

The fact to which we desire to draw special attention is that the most conspicuous movements made by the animals referred to are pur-

[1] *Am. Jour. Physiol.,* Vol. VIII. p. 29, "The Animal Mind," by M. F. Washburn, p. 214.

posive in character, and could not have been acquired by imitation or from having been taught. That these motor effects are, however, due to a common cause is shown by the fact that in whatever part of the world Hydroids exist they respond in like manner to stimuli, and the response is repeated by succeeding generations of these animals.

We may now pass on to consider the behaviour of Medusoids. The origin of the nerve cells of this order of animal is similar to that of Hydra; both of them being derived from, and remaining in close connection with the living substance of the ectoderm, out of which also the various sensory organs are developed.[1]

With sensory organs and a nervo-muscular system such as those we have described as entering into the structures forming the body, and tentacles of Medusoids, we can understand how it comes to pass that, if we stimulate a point situated on the under surface of the margin of a jelly-fish's swimming-bell, its

[1] *A Treatise on Zoology,* Edited by E. Ray Lankester, Part II., "The Anthozoa," by Prof. G. C. Bourne, p. 10.

manubrium first contracts, and with unerring aim brings its mouth to the point stimulated. If another spot is irritated, the manubrium leaves the first and moves to the second spot; and when left to itself visits first one and then another irritated point, dwelling on those most severely irritated. (Fig. 7.)

If the tentacles or the margin of the swimming-bell of a Medusa (*Gonionemus murbachii*) be stimulated by a weak electric current, a series of rhythmical contractions and expansions of the structures forming its body and velum takes place, which enable the animal to swim away from the source of irritation. If a small bit of meat is placed in the water near one of these Medusæ, so as to touch more than one of the animal's tentacles, they move simultaneously to the food; at the same time the manubrium stretches out to meet the contracting tentacles, and the food is thus taken into the animal's mouth and passed on to its digestive cavity.

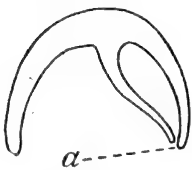

FIG. 7.

The movements made by the manubrium and swimming-bell of the jelly-fish above referred to clearly show that, when definite parts of its sensitive surface are appropriately stimulated, its body-substance responds by well-ordered and distinctly purposive movements, that is to say, by instinctive behaviour calculated to promote the well-being of the animal and the species to which it belongs. When the entire margin of the bell of a living jelly-fish, including therefore the whole of its sensory organs and system of nerve cells is excised, neither mechanical nor any other form of energy applied to the remaining part of the bell produces any movement in it or in the manubrium. In place of excising the margin of the bell, Romanes made an incision above the situation of its nerve cells, parallel to its margin. Under these conditions the movements of the manubrium became uncertain; it no longer bent down to the seat of irritation, but dodged about from one to another part of the margin of the bell; it had seemingly lost its power of localising the spot irritated.[1] The manubrium, under these conditions, being acted

[1] *Jelly-fish, Star-fish, and Sea-urchins,* by G. F. Romanes, p. 33.

on by a diffused nervous force, is impelled to wander first here and then to another spot, in place of taking a decisive instinctive action.

From these experiments we learn that the definite co-ordinate action of the different parts of a Medusoid's body takes place through means of its nervous system.

The ordinary swimming movements of a Medusoid depend on the regularly recurring contraction and relaxation of the muscular fibres of the bell and velum. This action in its turn depends on a constant flow of energy from its surroundings to the sense-organs, and from thence to the nervous and muscular systems, which are charged with potential force derived from metabolic processes carried on by their living protoplasm. A discharge of energy from a series of nerve cells having thus been released, their living matter for the instant is exhausted, and until it receives a fresh supply of energy derived from metabolic processes it cannot act on the muscular fibres. During the instant, therefore, that the supply of potential energy is being renewed, the kinetic energy received from the sense-organs is suspended, and the tension of the muscles of the bell and velum is relaxed; but when the potential energy of the cell is restored, external stimuli produce another discharge of nervous energy, followed as before by contraction of muscular fibres. So long, therefore, as the fundamental properties referred to are carried on by the living matter of the system, and a supply of potential energy is secured, regularly recurrent contractions and relaxation of the muscular fibres of the bell and velum take place, whereby the swimming movements of the animal are effected.[1] We thus come to appreciate the force of Professor Lloyd Morgan's oft-repeated remark that the instinctive behaviour of animals "depends upon the inherited structure of their nervous system."

It is, however, evident that unicellular beings such as Amœba, Stentor, and Euglena, although they do not possess a nervous system, nevertheless respond by appropriate purposive movements to various forms of energy applied to their body-substance or living protoplasm,

[1] Halliburton's *Handbook of Physiology,* p. 191, Seventh Edition.

which must therefore contain elements capable of transforming ordinary modes of energy acting on them into purposive movements. We hold that in the course of the evolution of the ascending classes of animals purposive elements such as those governing the behaviour of unicellular beings have separated, or become differentiated from the rest of the protoplasmic elements, so as to constitute a very important part of the living matter of the nerve cells of more highly organised beings; elements of this description in the course of time have become the instruments whereby energy derived from external and internal sources is transmuted into force, which becomes manifest in purposive or instinctive movements of animals.

The delicate structures forming the various sensory organs of Medusoids are of a distinctly higher order than those of lower orders of beings; and we find a progressive evolution of these tissues in advancing families of animals. Doubtless the evolution of these structures, like those of other parts of the body, is largely attributable to natural selection; but these changes of structure in a continuous series throughout vast periods of time, appear to demand the intervention of some more specific mode of energy than that implied in the hypothesis of the survival of the fittest. We seem to require the aid of some definite and persistent underlying force which has gradually moulded the living matter of these structures into forms adapted to receive, and modify the different kinds of energy acting on them, so that it becomes capable of stimulating corresponding centres of nervous matter into purposive action. We can best illustrate our meaning by referring to the development of visual sensory organs.

The simplest known form of an organic visual apparatus is that of an "eye-spot," such as exists in Euglena, a unicellular being constituting a link between animals and plants. Near the anterior end of the cell forming one of these beings a bright red spot exists, which consists of a meshwork of sensitive protoplasm containing a number of red particles. Externally this spot is covered by one or more granules adapted to receive, and concentrate waves of light on the subjacent pigmented sensitive mass. There can be no question as to the fact that the movements made by Euglena are influenced by the stimulus of light; it is, however, uncertain how far the structures forming the eye-spot determine these movements; but in the case of Volvox each cell possesses a well-defined refracting lens behind which is a layer of coloured sensitive matter. The movements of this organism are clearly influenced by the stimulus of light, and its eye-spots are essential to these movements.

It is by no means difficult to follow the transitional stages of the structures constituting the eye-spots of Euglena and Volvox into the forms these tissues have assumed in the ocelli of the Medusoids and the eyes of Mammalia. The pigmentary elements in each of these orders of beings give precisely similar reactions to light, and their dioptric arrangement is built up on the same general plan; so that we are disposed to hold they originally proceeded from a common ancestral stock.[1] The regular evolution of structures of this description could not have been effected, much less maintained, by

[1] *Comparative Anatomy of Animals,* by Gilbert C. Bourne, Vol. I., p. 192.

the play of an ever-varying environment. It could only have been brought about by some definite and persistent force underlying or working with that implied under the term of natural selection. (See Appendix.) As regards the development of the structures forming the organ of vision, it appears to us we have in that mode of energy we call light a force capable of moulding, on general lines, living substance so as to adapt it to the needs of the various ascending orders of beings. It is evident that waves of sunlight must have acted constantly on organic matter from the time this substance first came into being. It is, therefore, conceivable that light might, in the course of time, have moulded the molecules of primitive forms of organic matter into structures which gradually became adapted to its own incidence, as well as to that of the environment. The similarity of the structure constituting the visual organs of different classes of animals can thus be accounted for, their living substance having responded in like manner to a direct and never-failing similar form of energy. The more and more complex structures forming the eyes of ascending orders of animals would thus be something akin to a deeper and deeper impression of light on a substance which, being organised, possesses a special aptitude for receiving and rendering it hereditary.[1] Professor F. Soddy, when referring to this subject, observes that the human eye has become adapted through long ages to the peculiarities of the sun's light, so as to make the most of that wave-length of which there is the most.[2] In the following chapter we hope to show that in the Star-fish the connection between its visual sensory organs, their corresponding nervous system, and the instinctive behaviour of these animals is even more conclusive than that which exists in the case of their allies the Medusoids.

[1] *Creative Evolution*, by H. Bergson, p. 73.
[2] *Matter and Energy*, by F. Soddy, p. 193.

CHAPTER III

The nervous system of the Star-fish—Purposive movements dependent on presence of sensory organs—Development of head in animals—Earth-worms—Rudimentary brain—Hereditary instinctive movements—Crayfish—Increased complexity of brain corresponding to higher order of instinctive movements—Labyrinth experiments—The brain of insects—Their sensory organs—Highly developed instinctive processes in Ants, etc.—Automatic processes.

In the preceding chapters we have endeavoured to show that some of the elements of living protoplasm possess a special aptitude for becoming adapted to the incidence of recurring modes of energy; in this way the sensory and nervous structures of the ascending classes of animals have become moulded on a uniform plan. The changes in structure thus effected have led to corresponding modifications in the work which these structures perform, the movements of the advancing orders of animals thus becoming adjusted to their environment. In the following pages we shall show this adaptation between structure and instinctive processes in those classes of beings which succeed the Hydromedusa in the ascending scale of animals, viz., the Echinodermata, including star-fishes; the Annelida, to which worms belong; and lastly the Arthropoda, including crustacea, such as crayfish and insects.

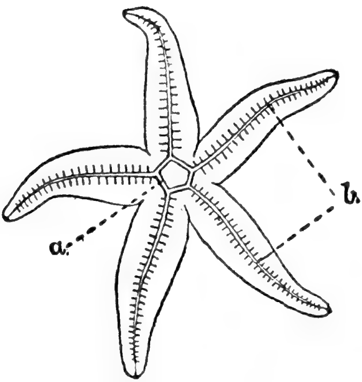

Fig. 8.—Diagram of the nervous system of a star-fish. *a*, central nerve-ring surrounding the mouth; *b*, peripheral nerves of the arms.

A typical star-fish (Fig. 8) possesses a central body from which five radiating arms extend outwards; on their upper surfaces are numerous calcareous nodules supporting short spines. Between these nodules there are a number of processes or stems terminating in pincer-like structures, worked by muscular action.[1] The under surface of a star-fish's body has an opening or mouth leading to the gullet and digestive organs, from which there is an outlet on the upper part of the body. The under surface of each arm is grooved, and has rows of contractile tubular organs each terminating in a sucker, known as the "tube feet." These structures are worked by the contraction and relaxation of the muscular fibres which surround the tube, and are thus under the control of the animal's nervous system.

The nervous system of a star-fish is derived from and is in close connection with the protoplasmic elements of the ectoderm. The central part of this system is composed mainly of two rings of nerve cells and fibres which surround the animal's gullet. From these circum-oral rings radial nerves extend throughout the length of each of the animal's arms; they supply branches to its entire muscular system, and also to the sensory organs. In addition to the radial system of nerves, although doubtless

[1] *Jelly-fish, Star-fish, and Sea-urchins*, by G. J. Romanes, p. 255.

intimately connected with it, a plexus of nerve cells and fibres exists beneath the ectoderm, corresponding to that found on the under surface of the swimming-bell of Medusoids.[1]

The sensory organs of a star-fish are derived from the ectoderm, and consist of an abundance of tactile organs situated on the spines and pedicels of the animal's arms; in some species of star-fish a bright red spot exists on the terminal tentacles of each of the five arms, which indicates the position of the animal's visual sensory organs, these are of a higher order than those we have referred to as the eye-spots of unicellular beings and of Medusoids. The outer surface of the visual organs of Echinoderms is formed of one or more layers of transparent cells, and beneath this layer a refractive lens-like structure rests on a mass of deeply pigmented cells. In connection with these colour-bearing cells, club-shaped nucleated cells may be demonstrated which receive at their base fibres from terminal branches of a radial nerve; in this way a communication is established between the animal's visual

[1] Romanes on *Jelly-fish*, p. 292.

organs and its circum-oral or central nervous system.

With reference to the instinctive behaviour of Echinodermata, an ordinary star-fish is able by the use of one or more of its arms and sucker feet to hold on to the bottom or to the sides of its tank; the muscles of the arm then contract and draw the animal's body up to the point its feet have grasped; it thus moves forward, either along the bottom or up the side of the tank. When a star-fish reaches the surface of the water it comes to a stand, as its sucker feet can only act efficiently beneath the water. Under these conditions a star-fish stretches out its uppermost arms along the surface of the water so as, if possible, to meet with something it can cling to; if it succeeds in doing this, it relinquishes its hold on the side of the tank and swings itself on to the object it has grasped. Mr. Romanes remarks with regard to behaviour of this kind that the activity and co-ordination manifested by the animal's acrobatic movements are surprising, and have almost an intelligent appearance.[1]

[1] Romanes on *Jelly-fish*, p. 269.

As the sucker feet of a star-fish are only found on the under surface of its arms, the animal, if turned over on its back upon a flat surface, is unable to secure a fixed hold by which to drag its body into its natural position. In these circumstances the animal inverts the tip of one or more of its arms until some of its feet can gain a hold on the surface upon which it has been placed; from this fixed point the animal turns over so as to regain its normal position.

If a star-fish is moving in a certain direction and one of its foremost arms is pricked or pinched, the animal instantly reverses its course, apparently with the object of escaping from further injury. A hungry star-fish will follow food moved slowly from one to another part of its tank; if it succeeds in grasping the food, it is carried to its mouth, the other arms of the animal, if necessary, coming to assist in this action.

So long as a star-fish's organs of vision are in working order the animal evinces an inclination to move towards and remain in the light; but if these organs have been destroyed movements of this kind are hindered or altogether abolished. If both the visual and tactile sensory organs of one of these animals are removed the creature ceases to move, but if fed it may continue to live.

Although it is difficult for star-fish to move from one place to another unless by means of their sucker feet, it is possible for them to shuffle along when placed on their backs. They accomplish this movement by aid of their pincer-like spines, which under these conditions act together in a remarkable manner so as to push the animal along in a continuous direction. If while progressing in this manner a lighted match is held near the animal, as soon as the heat reaches it the whole of its spines reverse their movement, and work in the opposite direction.

Movements similar to those above referred to take place in the recently amputated arm of a star-fish. They are distinctively purposive in character, and depend on energy set free by external stimuli acting through sensory organs on the sub-ectodermal plexus of nervous matter, to which we have referred. In a short time after an arm of a star-fish has been amputated, its circulation and consequently metabolic processes cease, and with this change the potential energy of the nerve cell fails, and all instinctive or any other movements of the amputated arm cease. If the sensory organs of an amputated arm are removed, or if they are not appropriately stimulated the limb remains motionless.

From experiments made on various species of living star-fish we learn that the function performed by its central nervous system is to bring about the co-ordinate working of the arms and various parts of its body in a purposive manner. If the circum-oral rings are removed the animal completely and permanently loses all power of co-ordinating its arms or their sucker feet.

The result of excision of the sensory organs of jelly-fish and star-fish leads us to conclude that the exciting cause of the animal's instinctive behaviour depends, to a large extent, on work performed by these organs; for if they are destroyed all such action is abolished, although the animal may continue to live. This means that the prompting cause of purposive action is energy derived from external or internal sources acting through sensory organs, which, by practice have become sufficient to provide for the necessities of the classes of animals we have referred to in their struggle for existence, and for their reproduction.

Professor Preyer informs us that on slipping a piece of rubber tubing over the middle part of one of the arms of a star-fish, belonging to a species in which those members are very slender, he found that the animal tried successively various devices to get rid of the foreign body; by rubbing it against the ground, trying to shake it off; holding the tube against the ground with a neighbouring arm, and finally, as a last resort casting off the limb together with its rubber ring.[1] Action of this kind is probably due to the overflow of nervous energy set free by the stimulus excited by the pressure of the rubber tubing on the sensory organs of the limb. Most people, however, refer these movements to "spontaneous action," which is,

[1] *The Animal Mind,* by Margaret F Washburn, p. 215.

at best, as Prof. Huxley remarks, a term employed "when we do not know anything about the cause of any phenomena."[1] It would be well for science if we could rid ourselves of such phrases, for modern scientific ideas can accept no theory which is not founded upon continuity of phenomena, whether physical or psychical.

The bodies of jelly-fish and star-fish have neither a head nor tail, neither right nor left side, an arrangement which is sufficient to meet the needs of beings whose food is brought to them floating in the water by which they are surrounded. But when from geological or other changes in their environment animals of this description have been compelled to pass from an aquatic to a terrestrial mode of life, and therefore to search for their food, or for a mate, and to protect themselves from enemies, the various kinds of protoplasm constituting the basic substance of the structures of the "fittest" of these beings must have responded adequately to the incidence of the forces acting on them, and thus gradually developed a nervous

[1] Huxley's *Essays*, p. 216, Everyman's Library Edition.

system and sensory organs which enabled them to meet the demands of the conditions to which they were exposed.

The class of beings (Vermes) which include the various orders of worms follow the star-fish in the natural ascending classes of animals; of these we may refer to the common earth-worm to illustrate the link which exists between the structural development of a central nervous system, and the growth of instinctive processes. It is probable that earth-worms have been developed from fresh-water, and these from marine, ancestors.[1] When these animals came to dwell on the land they must have begun to move with one part of their bodies in front, and thus acquired an anterior end or head, and sides to their bodies. The head of the organism being thus brought into constant contact with external objects, its sensitive elements, including nerve cells connected with its skin layer, were developed by use, and at the same time became protected by passing from the surface deeper into the head; in this way an aggrega-

[1] *Comparative Anatomy of Animals,* by Gilbert C. Bourne, Vol. II., p. 43

tion of nervous matter was effected, forming an organ which we recognise as the animal's brain.

The body of a large earth-worm contains a series of from 100 to 200 segments or somites, each of which is furnished with four pairs of bristles or chætæ movable by muscles, and constituting the animal's chief locomotory organs. An earth-worm's mouth is situated on the under surface of its head; at the posterior extremity of its body is a terminal opening or anus. The nervous system of these worms consists of two masses of nerve cells and fibres (ganglia) situated just above the passage leading from the animal's mouth to his stomach (Figs. 9 and 10). These ganglia give rise to the nerves passing forwards to the head and to a ganglion situated below the gullet, from whence a cord of

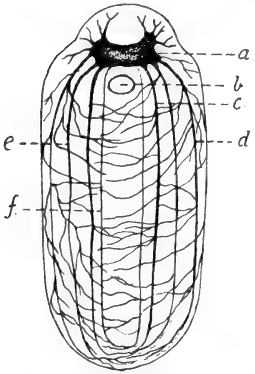

FIG. 9.—*a*, cerebral ganglia; *b*, mouth; *c*, ventral nerve tract; *d* and *e d f*, respectively marginal, dorsal, and medio-dorsal nerve tracts.

nervous matter extends along the length of the body; at each somite the cord swells into a ganglion from which nerves pass to neighbouring structures. These nerves contain incoming (afferent) fibres or paths, by which impressions made on the surface of the animal's body are conducted to the central ganglion, and outgoing fibres (efferent) commencing in the ganglion and terminating in effective structures such as muscles or glands. The class of beings to which worms belong, affords us not only an example of the way in which their

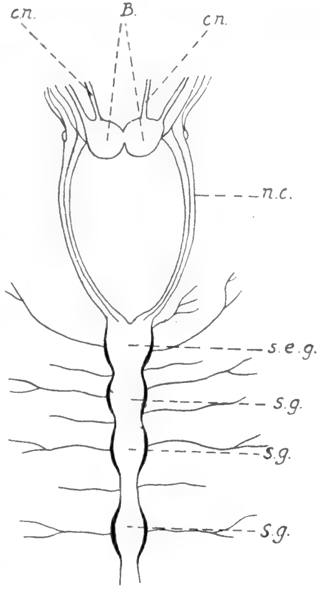

FIG. 10.—Diagram of nervous system of Annelida. *B*, brain; *c.n.*, cephalic nerves to supply sense organs of anterior end of the worm; *n.c.*, nerve cord passing from the brain to *s.e.g.*, the sub-œsophageal ganglion; *s.g.*, segmental ganglia giving off nerves to the corresponding segments of the body. (*Human Speech*, Fig. 30, p. 126.)

sensory organs have been evolved by natural modes of energy acting on differentiated living matter, but they also illustrate the gradual loss of these organs when deprived of their appropriate modes of stimulation. For instance, some aquatic worms have visual organs, but in the common earth-worm, living as it does without sunlight these organs have disappeared. But although these animals do not possess eyes, when the anterior ends of their bodies are exposed to a stream of bright light the worm speedily retreats into its burrow, while if other parts of the animal's body are alone illuminated it remains perfectly passive. It would seem that the energy attached to waves of light affects the ending of cutaneous nerves of the animal's head, and reaches its cerebral ganglia, thus setting free some of their latent purposive energy, which becomes manifest in the co-ordinate action of certain groups of muscles, and so to instinctive movements of the animal's body. Some fishes and reptiles are influenced by light which falls on the skin alone; a frog whose eyes have been removed will, if light of suitable intensity be allowed to fall on the animal, turn its head and jump towards the source of light.

There is a great contrast between the more prominent instinctive movements displayed by worms, and those of beings which possess neither head nor tail, their central nervous system consisting of two subdermal rings of nerve cells and fibres, in place of a rudimentary brain such as that which exists in the head of an earth-worm. For example, the common earth-worm displays remarkable purposive behaviour in the way it plugs the external opening of its burrow. The animal emerges from its burrow at night, and drags dry leaves, the petals of flowers, paper, or other light materials, squeezing them into its burrow. A leaf when being dragged to the burrow often becomes folded or crumpled. When another leaf is drawn in, this is done exteriorly to the first one, and so on with the succeeding leaves; and finally they all become closely folded and packed together; the interstices between the leaves being filled up by means of a viscid secretion ejected from the animal's body. Darwin describes the way in which an earth-worm almost invariably lays hold of leaves by their tips, so that the thin part of the leaf can be easily drawn into the burrow, leaving the thick foot-stalk projecting outwards from the mouth of the hole. He observes: "Although the habit of dragging leaves into their burrows is undoubtedly instinctive with worms," nevertheless these purposive movements are so accurately adapted to fulfil their ends, that it is difficult to distinguish them from movements guided by intelligence.[1]

Darwin refers to the fact that the instinctive behaviour of earth-worms is hereditary, for he had watched a very young one born in one of his pots, dragging for some distance a Scotch fir leaf, one needle of which was as long and almost as thick as its own body. No species of pine was endemic in the part of England where this incident occurred; it is therefore incredible that the proper manner of dragging pine-leaves into the burrow could have been learnt by this worm; its behaviour was clearly instinctive or innate, for so young an individual could not

[1] *The Formation of Vegetable Mould,* by Charles Darwin, pp. 27, 56.

have carried out a series of movements such as those referred to as a result of its own experience; the only kind of action which Mr. Romanes believes can be accepted as an indication of intelligence.[1]

The burrows of the ordinary earth-worm are carefully lined by leaves and earthy materials, and terminate in a chamber in which one or more worms pass the winter rolled up into a ball, kept warm by the lining of the passage and the effective plug they have constructed to exclude external cold, and the danger of being flooded.

It thus appears that with the development of a brain or aggregation of nervous elements in the head of a class of living beings, their instinctive behaviour rises to a higher level than that displayed by more lowly organised animals. This state of things can be understood, if we admit that the functions performed by certain of the elements of nervous matter is to transform energy acting on it into instinctive processes. The evidence we have thus far advanced supports this idea, and, still further, points to the fact that the purposive movements

[1] *The Formation of Vegetable Mould,* by Charles Darwin, p. 90.

of the animals we have referred to are proportionate to the completeness with which the protoplasmic elements of their nervous system has responded to the divers modes of energy acting on it, that is to the environment.

Passing from the Annelida to the higher class of the Arthropoda, which includes the Crustacea and Insecta, we find the instinctive movements of these orders of animals to be in harmony with the ideas we have endeavoured to inculcate in the preceding pages, which in our opinion are competent to explain the phenomena in question.

We may refer to the crayfish as representing the Crustacea. These animals abound in many of our streams and harbours; they are rarely more than three or four inches long, and in appearance are not unlike small lobsters; they may often be seen walking along the bottom of shallow streams by means of four pairs of jointed legs.[1] At other times a crayfish appears at the mouth of a burrow he has excavated in the banks of a stream; he lies at the entrance to his hole, barring it with his

[1] *The Crayfish*, by T. H. Huxley, pp. 6, 9.

claws and feelers, keeping careful watch on the passers-by. Larvæ of insects and tadpoles, small frogs, and other objects which come within the animal's reach are seized and devoured. In the spring of the year female crayfish are found to be laden with eggs attached to their tails; when hatched they give rise to minute young beings which are sometimes seen hanging on their parent's body, under whose protection they spend the first few days of their existence.

Scattered over the surface of the body of a crayfish there are a multitude of tactile sensory organs, known technically as setæ: they are particularly well developed on the animal's antennules or feelers. The setæ arise from cells of the ectoderm, and at their attached surface receive terminal fibres which originate in the nerve cells of the animal's mid-brain. On the under side of the outer branch of the antennule sensory structures exist, which there is reason to think form part of an olfactory apparatus. The eyes of a crayfish consist of highly complex structures, arranged so as to bring waves of light to bear upon the fore ends of two bundles of optic nerve fibres; thus forming an apparatus which, as Huxley observes, sorts out the rays of light into as many very small pencils as there are separate endings of the fibres of the optic nerve, and in part serves as the medium by which luminous waves are converted into molecular nerve changes. It is evident that the sensory organs of crayfish are much more highly organised than those of worms, or of any of the lower classes of animals. Accompanying this increased complexity of structural arrangement in these receptors of energy is an increased development of the cerebral nervous centres, or areas from which the nerve fibres supplying these organs originate. Fig. 11 is a drawing made from a section of a crayfish's brain, showing its anatomical division into anterior, middle, and posterior sections or lobes.

The brain gives off fibres which form the optic and antennary nerves, as well as the nerves which supply the viscera and certain muscular structures. The sensory organs are in close connection with the nervous matter of the animal's mid-brain, which seems to exercise a controlling influence over the rest of the cerebral system, and thus over the behaviour of the animal.

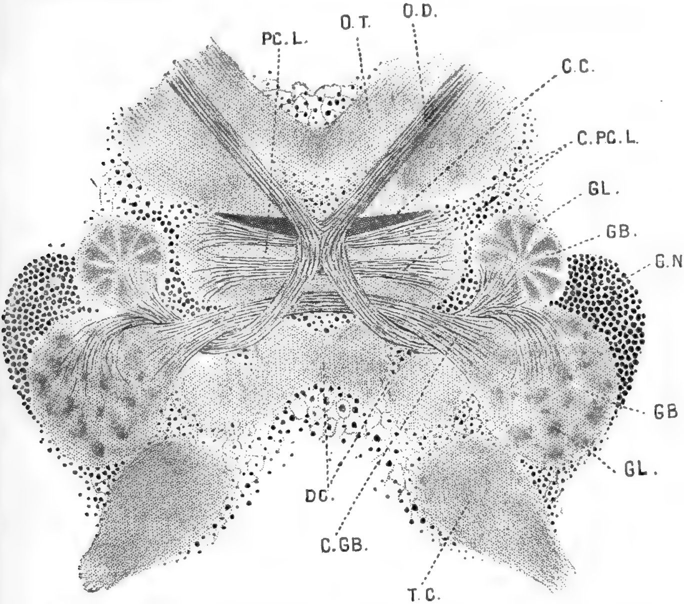

FIG. 11.—Horizontal section through the brain of a crayfish. ×40. *C.C.*, corpus centrale; *C.GB.*, commissure of globuli; *C.PC.L.*, commissures of protocerebral lobes; *DC.*, mid-brain; *GB.*, globulus; *GL.*, glomeruli; *G.N.*, ganglionic nuclei; *O.D.*, decussating bundle of optic tract; *O.T.*, optic tract; *PC.L.*, fore-brain; *T.C.*, hind-brain. (*Cat. Physl. Series, Museum Roy. Coll. Surgeons*, Vol. II., p. 22.)

As a consequence of the more complex structural arrangement and development of the central nervous system, and sensory organs in crayfish than in earthworms, the ordinary instinctive movements of the former animals are of a distinctly higher order than those displayed by the latter. For instance, a crayfish with its head, claws, and long feelers protruding from its burrow keeps a careful watch on the divers objects floating near it in the surrounding water, and whatever these may be, they are seized by the animal's claws, torn to shreds by its capacious jaws, and passed into the creature's mouth. It is said these animals even devour their own spouses. Crayfish exercise no discrimination in the choice of their food; anything floating within its reach acts as a stimulus on the animal's visual nervous system, a stimulus which becomes manifest in the purposive movements of certain groups of muscles, leading to the effective grasping of the object which set the neuro-muscular machinery in action. The adjustment of such movements to the incidence of external stimuli is doubtless facilitated by the excitation of the animal's tactile sensory organs or setæ which abound on his antennæ. These feelers are constantly waving about in the surrounding water, and are thus liable to come in contact with floating bodies, causing a discharge of some of the potential energy of nerve cells of the brain, and thus bringing about the contraction of the muscles controlling the use of the animal's prehensile organs.

Professors Thorndike and Yerkes have done much good work in testing the instinctive reactions of certain of the lower animals, by what is known as the labyrinth method. This plan consists in ascertaining the facility with which an animal learns the correct road to take through a labyrinth, interposed between its home and its food. In the case of crayfish, a labyrinth offering only a single choice of passages was placed between the animal's aquarium and its food. "About half-way down the interposing box a partition, put in longitudinally, divided it into two passages, one of which was closed at the end by a glass plate. In sixty trials the animals, which had originally chosen the correct passage 50 per cent. of the time, came to choose it 90 per cent. of the time. A second series, with a single animal upon which more tests a day were made, resulted in the formation of a perfect habit in 250 experiments. The glass plate was then shifted to the other passage, and the crayfish was naturally completely baffled for a time, but ultimately succeeded in learning the new habit."[1]

From these and similar experiments it is evident the functions performed by the nervous matter constituting the lines of communication between sensory organs, nerve centres, and their efferent fibres improve by use. Thus the purposive movements of the crayfish, after the animal had been subjected for a number of times to the same form of stimulus, became so perfect that other less energetic stimuli failed at the moment to elicit a response, or to influence the behaviour of the animal. Movements of this kind are often ascribed to experience gained by the animal during repeated trials to attain desired or pleasurable ends. Mr. Romanes was of opinion that we can only infer intelligence in an animal when we see the individual profit by his own experience. But what is the meaning to be attached to the terms experience and intelligence? Behaviour, when

[1] *The Animal Mind*, by M. F. Washburn, pp. 220, 319, 323.

the result of personal trial or experience, is attributable to the re-excitation of impressions made by repeated similar kinds of stimuli on the mnemic elements of nerve cells. Intelligent behaviour involves the modifications in the action of those elements which constitute the agency by which instincts become manifest.[1]

Among invertebrates, instinctive movements have reached their highest point of perfection in ants and bees, and we find a corresponding development of their central nervous system, for if there is one organ of the body more than another which increases in complexity as evolution proceeds it is the brain.

The central nervous system of insects consists of a brain and a chain of ganglia extending along the ventral part of the animal's body, which in many instances are found to have undergone concentration longitudinally. From this chain of nervous matter sensory and motor nerves pass to the structures forming the animal's body; it is continued upwards into the lower brain.

[1] *Psychology*, "The Study of Behaviour," by William McDougall, F.R.S., p. 164; also "Instinct and Experience," by Prof. Lloyd Morgan, pp. 7, 9, 12, 27, 32.

The fore-brain in insects is formed by the optic ganglia together with two masses of nervous substance united by communicating fibres. In connection with these lobes we find aggregations of small granule nerve cells from which fibres pass to the mid-brain. Similar masses of nerve cells exist in the brain of the sea-mouse, and are more highly developed in crayfish (Fig. 11, G.N.), but they attain their highest state of perfection in insects. For instance, in the working bee nervous structures of this description form two masses, situated near the dorsal surface of the brain. Within the same order of beings these structures increase in size in proportion to what we judge to be the instinctive capabilities of the animal, they are larger in the worker than in the drone or the queen bee.[1]

The mid-brain or antennary lobes of insects consist of two masses of nerve cells united by bands of communicating fibres. From this part of the brain nerves pass to the antennæ; it is also the meeting-place of nerve fibres proceed-

[1] Mr. R. H. Burne, *Catlg. Phys. Series of Compa. Anatomy*, Royal Col. Surgeons Museum, p. 35.

ing to and from the various sensory organs of the animal's body. The mid-brain, therefore, of crayfish and of insects corresponds to that part of the brain of vertebrates to which we shall subsequently refer as their basal ganglia.

The hind-brain of insects gives off nerves to supply the animal's alimentary canal; it forms, as it were, the head of the chain of ganglia alluded to in our description of the central nervous system of crayfish.

We may now turn our attention to the sensory organs of insects, which consist of structures derived for the most part from the ectoderm, specially modified either in the form of single or groups of cells, which act as the receptors of energy derived from visual, olfactory, and tactile impressions.[1]

The visual sensory organs of insects consist

[1] "It is probable the structures of the various sensory organs that first receive the external stimulus act like a sieve, arresting certain qualities of the exciting energy and permitting certain other qualities to pass on, so as to act on the specialised living nervous substance of the various sensory centres. These receptors of energy have thus a certain power of selection or natural fitness developed by means of the action of their environment or struggle for existence."—(Professor T. Ziehen, *Introduction to Physiological Psychology*, pp. 40, 42.) As we have shown, after leaving a sensory organ by nerve paths energy becomes subjected to further selection through the action of an interrupted system of dendrons, so that by the time it reaches the living matter of the corresponding cerebral cell it has assumed a specific form.

of many eyes, each with its own retina and dioptric apparatus separated from its neighbours by pigment-cells.[1]

The visual power of these beings depends largely on the form and the number of facets possessed by the outer surface of their eyes; for instance, the prominent convex eye of the dragon-fly is said to contain from 12,000 to 17,000 facets. We can form an idea of the acuteness of vision possessed by these insects if we try to catch one of them when hovering over a pond. The dragon-fly will allow us to approach our net just near enough to miss catching it, when off he darts, seeming able to measure the length of the handle of our net, for the insect repeatedly flies off in spite of our efforts to capture it. Wasps can judge the size and colour of inert objects by the aid of their eyesight. Thus if some dead flies are placed together with other insects on a table in a room where there are wasps, a wasp will soon fly down and without hesitation alight on a dead fly, which he will carry off, and this process is

[1] R. H. Burne, Asst. Curator, Roy. Coll. Surgeons of England, *Cat. R.C.S. Museum, Physiol. Series,* Vol. III., p. 302.

repeated over and over again without the wasp taking any notice of the surrounding dead insects.

The *olfactory* sensory organs of insects consist of structures adapted to receive and transmute a special form of energy into one which, on reaching certain cerebral centres, becomes manifest in the sensation we designate odour. By the sense of smell, therefore, we mean the response made by a specialised system of living matter to definite modes of energy derived from certain bodies.[1] The olfactory sensory organs of insects are located on their antennæ among the tactile setæ; they are supplied by terminal branches of the antennary nerves which arise from nerve cells located in the animal's mid-brain.

The different genera of ants, which under ordinary conditions are natural enemies and fight to the death when they meet, after having had their antennæ excised may be kept together in the same box, where they live on

[1] There are hardly any metallic or other bodies which do not manifest, especially on friction, odour of their own. Berthelot calculates that one gram of iodoform only loses the hundredth of a milligram in a hundred years, though continuously emitting a flood of odoriferous particles in all directions.

friendly terms. Having no antennæ, and therefore no sense of smell, they can no longer distinguish friend from foe. Male insects after their antennæ have been removed do not recognise the female; they will pass close to their favourite food without noticing it; they guide themselves by the sense of smell, and when their antennæ are removed fail to retrace their way home from a distance or to recognise their companions when they reach their nests.[1]

If an ant is smeared with matter pressed from the bodies of its nest companions, and then put back among the latter, they take no notice of the stained insect. But if an ant is smeared with fluid pressed from the bodies of a hostile nest, and then returned among its companions they at once attack and kill it. Evidently it is the odour of the fluids in the two cases which affects the actions of the ants through impressions made on their olfactory sensory organs, impressions which pass through the antennary nerves to the olfactory lobes of the insect's brain and re-

[1] *The Senses of Insects,* by A. Forel, translated into English by Macleod Yearsley, F.R.C.S., pp. 69, 129.

excites those previously established in its nervous substance.

In order to substantiate the fact that the organs of smell are located on the antennæ of flies and other insects, we may refer to one among the numerous experiments which Monsieur Forel has made. He placed the body of a decomposing mole under a hemispherical wire gauze cover. A fly soon arrived and tried to gain access to the dead animal. Forel caught the fly, and after destroying its eyes let it go. The insect flew about the room knocking itself against the ceiling and walls, and finished by falling on the floor in a helpless state. Forel then removed one of the fly's wings, and afterwards placed it near the mole, which he uncovered; the fly immediately set to work to feed on the dead animal. He then removed the insect's antennæ; from that moment, despite oft-repeated trials, the fly paid no more attention to the mole than to a piece of stone or a bit of wood.

Taste.—Insects as a rule possess the power of distinguishing between the quality of certain non-volatile substances before swallowing them.

For instance, if morphia or strychnine is mixed with honey, ants attracted by the smell of their favourite food begin to eat the mixture, but after taking it into their mouths they leave the tainted honey. When the antennæ and palpi of wasps were removed and the animal's mouth then brought in contact with honey mixed with quinine, after tasting it the insect immediately turned away from the honey. From experiments of this kind it appears certain that in insects the sensory organs of taste are located within the animal's mouth, and consist in all probability of a series of cup-like depressions, connected with the terminal distribution of subjacent fibres proceeding from nervous centres located in the subœsophageal ganglion and the mid-brain.

Touch.—The sensory organs of touch in insects consist of structures similar to those described as existing in Hydroids (p. 37). They are scattered over the surface of their bodies, and are well developed on their antennæ.

Hearing.—With the exception of crickets and a few other insects, there is no evidence to show that this class of animals possesses the sense of hearing.

From the preceding statement it is evident that insects possess visuo-sensory and olfactory organs, also sensory organs of touch, taste, and the muscular or kinæsthetic sense; some few of them have the power of hearing. Leading directly from each of these receptors of energy, nerve fibres pass to corresponding nervous centres located in the brain. These cerebral nervous centres are in intimate communication with one another by means of protoplasmic fibres, and the whole of this system of sensory organs and cerebral centres is brought into close relation with the nervous matter of the mid-brain.

That insects possess memory is demonstrated by their actions. For instance, Professor J. Loeb states that there was a wasp-hole in a flower-bed in his front yard. Towards noon he saw a wasp passing along the side walk of the street in front of his yard, carrying a caterpillar in its mouth; the weight of the caterpillar prevented the wasp from flying. The yard was separated from the street by a cemented stone wall, up which the wasp repeatedly made an attempt to climb, but kept falling back. The insect, failing to scale the wall, then ran round the bottom of it until it reached an opening, through which it crept into the yard. Then crawling through the fence which separated the two yards, it dropped the caterpillar near the root of a tree and flew away. After a short zigzag flight it alighted on a flower-bed in which were two holes. The wasp soon left the bed and flew back to the tree, stopping twice on the road. It then landed on the caterpillar it had left and dragged it into its hole, which it covered with sand.

As an example of instinctive processes in insects we may refer to the slave-making ants which are incapable of tending their young, and even of feeding themselves. At a particular period of the year, when the nests of the black ants contain the neuter brood, at a given signal made by certain of the leaders of a nest of red ants, an army of these insects leave their nest and advance in fairly straight lines, the vanguard, which consists of eight or ten ants, continually falling back to the rear. In some cases the whole army separate in search of nests of black ants. At last a nest of these latter species having been found, a signal is given by striking the forehead of a neighbour; this signal is passed from one red ant to the other, and the army re-forms. On arriving at the black ants' nest a desperate conflict ensues, which ends in the defeat of the negroes; and the red ants then enter the nest and leave it almost instantly, each insect holding a larva or pupa in its mandibles, which it carries home with all speed. In the return of the army there is never any hesitation; the olfactory and visual memory of the outward journey is sufficient to make known to each ant the exact road. Having reached home the red ant hands over the stolen larva to a slave, and as a rule sets off immediately to the pillaged nest if it still contains more larvæ, or they may put off the return journey until the following day. Forel states this return journey is never made if the pillaged nest has had the whole of the larvæ removed; he remarks: "The fact appears to me to furnish irrefutable proof of their memory. They must remember if the pillaged nest still contains pupæ or not; that is to say, if there are many or few. Neither reflexes, nor odour, nor polarised tracks can explain the thing."[1] The stolen pupæ are treated by the red ants with great care, and when grown up spend their lives in excavating passages, collecting food, carrying larvæ, etc., for their masters as if this had been their original destination; in fact, they fulfil the office of slaves.

Bees appear capable of receiving and communicating to their companions impressions derived from other bees. Thus if a queen bee is removed from her hive, the workers soon miss her and raise a prolonged and plaintive sound. The queen bee, having been secured, was placed in a wire case and returned to the upper tier of the hive. The working bees immediately changed their note from a doleful into a joyful sound, which was taken up and repeated by bees in the most distant part of the hive. When about to swarm, before the queen is allowed to leave the hive, scouts are sent out to seek for a suitable locality for the swarm to settle in. After having

[1] Forel, p. 239.

chosen a spot the scouts return and conduct the swarm to the place they have selected, showing not only a memory of places, but also remarkable instinctive power, if not intelligent action, in their movements.

From this series of observations and experiments it is evident that the purposive movements of insects are brought into play by means of external and internal modes of energy passing through the various sensory organs to corresponding nervous centres constituted of cells, a part of whose living matter contains purposive and mnemic elements. We also learn that automatic processes effected by a system of this kind are sufficient to maintain the existence and reproduction not only of insects, but of the whole kingdom of Invertebrates. It has been shown that the behaviour of this vast mass of the lower orders of animals is controlled by instinctive action.

CHAPTER IV

Nerve cells and nerves—Spinal cord—Motor and sensory nerves—Reflex action—The brain—The Amphioxus and its nervous system—Fish—The Lamprey and its brain—The basal or instinctive ganglia—The development of the cerebral cortex—The Mud-fish—The Stickleback, Salmon, Perch, instinctive processes of, shown in traits of character—Their existence depends on presence of basal ganglia—Amphibians, brain of—Location of centre of instinctive movement—Reptiles, sense organs of—Birds.

It has been shown above that the effective working of the living substance forming the body of a nerve cell depends on its metabolic properties, whereby the cell is kept primed with working energy. One of the functions of these charged elements is to respond to the streams of energy which reach them through sensory organs, and to transmute this energy into purposive instinctive action. Automatic action of this kind is all that is necessary for the preservation and reproduction of invertebrates and the three lowest classes of vertebrates; it often reaches so high a level that it is difficult to distinguish it from acts commonly attributable to the work of intelligence. In the following pages the origin and mode of action of a form of nerve energy which is capable of infusing intelligence into instinctive processes will be explained.

Nerve cells consist of a minute mass of nucleated protoplasm. From the body-substance of the cell fibres of two kinds extend outwards; one set of these fibres soon after emerging from the cell divides into several branches, which either unite or come into relation with similar fibres from neighbouring cells; these fibres are called dendrites or dendrons. Other fibrils passing from the nerve cell constitute what is termed its axis cylinder; these fibres often extend for a considerable distance from the cell in which they take their origin, and in their passage through the brain and spinal cord give off branches to other cells, and ultimately break up into a plexus of fibrils which are distributed to muscle cells or other

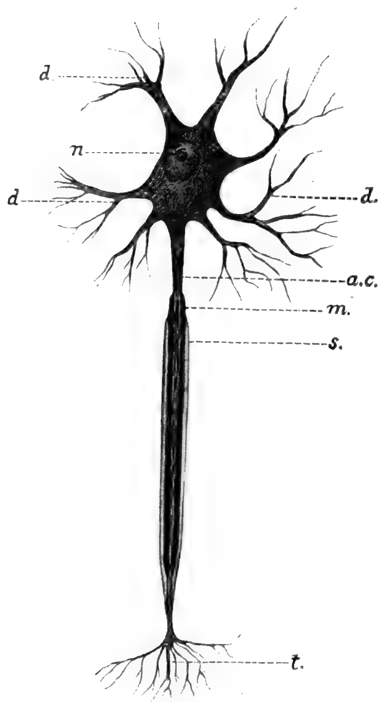

FIG. 12.—Diagram of a ganglionic nerve-cell (neuron). *d d d*, dendrons; *n*, nucleus and nucleolus; *a.c*, axis-cylinder; *m*, medullary sheath; *s*, neurilemma; *t*, terminal branches. (*Human Speech*, p. 147.)

effective structures. Soon after leaving its cell the axis cylinder becomes encased by an inner sheath of fatty matter, and an outer sheath known as its neurilemma; it is along the central axis or conducting core of the fibre that impulses travel to and leave the body of nerve cells. Until the axis cylinder of a nerve cell has, in the course of its development, become enclosed in its protecting sheaths (or, technically, myelinated) it is functionally imperfect as a conductor of nervous energy. (Fig. 12.)

The central nervous system of vertebrates consists of the spinal cord and brain; the former is enclosed in the vertebral column (backbone) and the latter in the skull. The spinal cord is formed of a cylinder of nervous substance extending throughout the length of the spine; it has a deep fissure in front and another behind, the two halves of the cord being connected by a strand of nervous substance which contains a canal extending throughout the length of the cord, and continued upwards into spaces in the interior of the brain. Each half of the spinal cord is divided longitudinally into three columns, by the line of attachment of two parallel series of filaments which constitute the roots of the spinal nerves. If the anterior root fibres are irritated the muscles to which these fibres are distributed contract, but no pain is felt; this is therefore known as a motor root. If the posterior roots are irritated pain is felt, referable to the area of the skin to which the nerve fibres of these roots are distributed; the posterior spinal roots are therefore known as being sensory in function. An irritant applied to parts of the skin containing tactile organs travels along sensory or afferent nerve fibres to corresponding central nerve cells, thus releasing a part of their potential energy which extends to a motor cell, and thus reaches muscles or other structures to which the motor fibres are distributed, becoming manifest in a definite kind of work. A system of this kind is known as being a nervous arc; when stimulated it gives rise to what is termed *reflex action*, which, though strictly automatic, is generally adapted to promote the well-being of the organism.

The spinal cord after entering the skull expands to form the hind-brain; this is prolonged upwards by means of strands of nerve fibres into the "most constant portion of the brain of vertebrates, the mid-brain."[1] (Figs. 11 and 13.) This latter part of the brain is continued onwards into the fore-brain. The cerebellum is situated above the bundles of nerve fibres which connect the hind- and mid-brain.

[1] *The Nervous System of Vertebrates*, by Prof. J. B. Johnston, pp. 223, 261.

DIAGRAM FROM J. B. JOHNSTON'S *Nervous System of Vertebrates.* FIG. 13.—*A*, the spinal cord, is prolonged upwards into *B*, the ***medulla oblongata*** (myelencephalon). In this region the spinal cord seems to widen out into a thin membranous roof covering the central canal (fourth ventricle). The lateral walls of the medulla oblongata contain aggregations of ganglionic nerve cells, which form the nuclei or place of origin of some of the most important nerves of the body. *C*, the metencephalon, forms a short section of the brain, its roof is known as the cerebellum, the arms of which encircle this section of the brain (Pons Varolii). *D, the **Mid-brain*** (mesencephalon), consists of ventral and lateral walls of nervous matter enclosing a narrow canal (Aqueduct of Sylvius). Its dorsal walls form the two optic lobes. *E, the Inter-brain* (diencephalon) constitutes, by means of its thickened lateral walls, the ***optic thalami;*** the dorsal wall is also thickened at one point by fibres which connect the two knot-like portions of nervous substance known as the nuclei trabeculæ. *F, the **Fore-brain*** (telencephalon) consists of paired lateral lobes from the anterior end of which processes pass to the olfactory lobes. A membranous roof connects and covers the lateral lobes of the Fore-brain ventricle, which divides anteriorly into a Y-shaped cavity and is continued into the olfactory bulbs. The common cavity with that of the inter-brain (diencephalon) constitute the third ventricle of the brain; the lateral or olfactory portions are comparable with the lateral ventricles of the mammalian brain.

The term cerebrum is applied to the largest section of the brain; it consists of the two halves into which the fore-brain is divided, known as the cerebral hemispheres, united to one another by connecting nerve fibres.

In the Amphioxus, a small fish-like being, we have an example of a living primitive vertebrate. These animals inhabit shallow seas in almost all parts of the world; although fish-like in appearance, they have neither the structure nor habits of a true fish.[1] An elastic cartilaginous rod (the notochord) extends throughout the length of the body of an Amphioxus, giving support to its muscular and other structures. The animal's central nervous system is formed of a thick-walled tube, nearly co-extensive with the notochord. The bulk of the cord is made up of longitudinal nerve fibres; it contains a central canal, round which are nerve-ganglion cells, some of them of considerable size. At the anterior end of the cord the central canal widens to form a space known as the cerebral vesicle. The nervous matter constituting the

[1] The Introduction to the *Study of the Comparative Anatomy of Animals,* by Prof. Gilbert C. Bourne, Vol. II., pp. 173, 188.

walls of this vesicle contains cells of a similar character to those found in the grey matter of the basal ganglia; they give off sensory fibres which terminate in the epidermis of the anterior end of the animal's body; otherwise an Amphioxus has no brain.[1] Motor and sensory nerves are given off in pairs from the central nerve cord to each section of the animal's body.

An Amphioxus is able to swim through the water by sinuous movements of its body; it has no fins, head, or jaws. It habitually rests with the greater part of its body buried in the sand, its anterior end projecting into the water. In this position the animal obtains nourishment from minute organisms, drawn inwards by means of a current of water created by a ciliated apparatus surrounding its mouth. If alarmed the animal buries itself in the sand.

The class of animals which in the ascending scale succeeds that to which Amphioxus belongs includes the Fishes, which are divided into two main groups: first, those having a cartilaginous, and secondly a bony skeleton; the former are represented by lampreys, dogfish, and sharks;

[1] The Introduction to the *Study of the Comparative Anatomy of Animals*, by Prof. Gilbert C. Bourne, Vol. II., p. 282.

among the latter are perch, sticklebacks, salmon, and the mudfish.

The brain of a sea lamprey consists of a slight enlargement of the anterior end of the spinal cord accompanied by a corresponding increase in size of its central canal, and its partial transverse division into three spaces or ventricles. Upon this foundation certain excrescences have been developed in connection with the animal's sensory organs of vision and smell.[1]

The walls of the hind-brain are slightly thickened by the aggregation of nerve cells to form the nuclei, or place of origin of the nerves which supply the animal's respiratory, alimentary, and circulatory organs. The hind-brain passes forwards by means of bundles of nerve fibres which extend into the walls of the mid-brain; above these fibres is a part of the brain known as its cerebellum, which in cartilaginous fishes is of small dimensions. The dorsal walls of the lamprey's mid-brain are marked by a longitudinal furrow which separates them into

[1] *Catalogue of Museum of Royal College of Surgeons of England,* Vol. II., p. 65.

two lateral portions known as the optic lobes, they receive fibres coming from the animal's retina. The lateral walls of the mid-brain (or more correctly the diencephalon) are known as the optic thalami, in the substance of which some of the fibres of the optic nerve terminate together with numerous fibres derived from the animal's olfactory lobes, and tactile sensory organs.

The mid-brain is prolonged anteriorly into the fore-brain, which in cartilaginous fishes consists of paired lateral lobes known as the cerebral hemispheres. These at the anterior end are prolonged forward as slender cylinders of nervous matter, terminating in the olfactory bulbs, which receive fibres from the animal's olfactory sensory organs. (Fig. 13.) The fore-brain contains a cavity known as the third ventricle, whose lateral walls are thickened so as to form the two corpora striata; these, with the optic thalami, constitute the stem of the brain or its basal ganglia.[1] The nervous matter

[1] In a recently published article on the anatomy and physiology of the corpus striatum, bearing specially on its motor functions, Dr. S. A. Kinner Wilson remarks that, "from a consideration of the anatomical data, obtained by experiments on apes, and known to be in part, if not entirely, identical in man, it is clear the

of these basal ganglia is all-important, in that a large part of their living substance is formed of inherited nervous matter, which under appropriate stimuli regulates the behaviour of the lower classes of vertebrates; energy derived from external and internal sources being transmuted by the elements of these centres into instinctive movements. (See footnote.) The behaviour of these lower classes of animals may therefore be said to depend on the nature of the structural arrangement and motion of the elements forming the nervous matter of their basal ganglia. In some invertebrates, such as the Crustacea (p. 77), nervous structures exist which control the instinctive movements of these animals, and we shall find that similar organs are present in the brains of amphibians,

corpus striatum is an autonomous centre; in other words, whatever its function, that function is exercised independently of the cerebral cortex."—(*Brain: A Journal of Neurology,* May, 1914, pp. 477, 482.) He adds, its nerve fibres become myelinated comparatively early in fœtal life; that phylogenetically it is a very old structure consisting of the basal part of the fore-brain. Dr. Wilson further observes that in fishes the corpus striatum is comparatively simple in structure, but in function acts as a "miniature brain"; in reptiles and birds there are additions, and in apes and man it consists of a complex organ closely connected with the optic thalamus "and beyond." Prof. Elliot Smith regards the corpus striatum as that part of the original cerebral hemisphere whereby impressions from sensory organs are brought to bear on the nervous mechanism regulating an animal's movements, or, in other words, its behaviour.

and throughout all classes of vertebrates, including human beings; in fact, it constitutes a kind of matter which has passed through long ages of evolutionary changes, and has thus assumed a form which when brought into play becomes manifest in instinctive action. In the higher classes of animals by appropriate treatment, the structural arrangement and functions of this part of the brain may be modified; one of the main objects of education is to effect this purpose, and thus to improve the innate disposition or character of an individual.

Almost every part of the walls of a lamprey's fore-brain contains nerve fibres proceeding from the olfactory lobes, and terminating in primordial cortical cells, "by means of which smell impressions pass indirectly through the intermediation of another part of the hemispheres"[1]; thus showing a disposition towards the differentiation on the part of certain of the nervous elements of the hemispheres of the brain in this, the lowest genera of true vertebrates. In the ascending classes of animals

[1] Prof. Elliot Smith's Arris and Gale Lectures, reported in the *Lancet* for January 15th, 1910, p. 150.

these pallial or cortical nervous elements gradually become developed, and ultimately assume the structural and functional character of what is known as the *neopallium*. Nerve fibres can be traced from these cortical cells, as well as directly from the olfactory, visual, and tactile sensory organs to the basal or instinctive ganglia. Consequently, we find in the brain of the most primitive class of existing true vertebrates nervous structures whose main function it is to elaborate instinctive processes; it also contains elements having a tendency to become differentiated into rudimentary pallial or cortical nervous structures, which in the higher animals are indispensable for the occurrence of psychical processes.

The instinctive behaviour of a rudimentary form of brain, such as that possessed by a lamprey, is of a correspondingly low type. This animal has a circular mouth armed with numerous hard tubercles which serve as teeth, by which the animal is able to hold on to the body of its prey; its tongue acts like a piston in its mouth, and enables the creature to draw in as well as expel water through its gills, and to respire while clinging on to another fish and sucking its blood. Lampreys pass from the sea up rivers during the summer months for the purpose of spawning. Sharks form another genera of cartilaginous fishes; their instinctive behaviour is somewhat more pronounced than that of the lamprey, for if attacked they will defend themselves with great determination; and it is well known they follow the same ship at sea for many days, swallowing almost anything thrown overboard. Many sharks are ovoviviparous, while others produce eggs having a long filament attached to them, which is apt to become entangled in sea-weed and held there until the egg is hatched; the parents do not appear to take any interest in their young.

The brain of bony fishes affords a favourable field for the study of the development of cerebral nervous structures, there being a marked tendency for its living matter to become, as it were, sorted out so as to perform distinct kinds of work, and thus to reach a higher standard of organisation than that attained by cartilaginous fishes. This tendency is marked by the numerous connecting links established between the different parts of the brain, whereby energy coming from one part is readily able to modify the activities of some other part. This higher organisation of the brain is effected by the extension, and constant exercise of all the sensory paths leading from the receptors of energy up to their corresponding cerebral nervous centres, nature thus indicating clearly the means that should be followed in any attempt to develop the structural perfecting, and thus the efficient working of the cerebral nervous centres and their associative and mnemic elements.[1]

[1] The gustatory apparatus in many of the bony fishes is well developed, the terminal nuclei of its sensory organs being located in the basal ganglia in association with those of the tactile, olfactory, and visual organs; a state of things tending to facilitate the correlation of tactile, gustatory, and olfactory impulses, and thus the control of the animal's movements for the capture of food. (The Arris and Gale Lectures, by Prof. Elliot Smith, see *Lancet,* pp. 169–174, for the year 1910.) The sensory organs of taste in not a few bony fishes are scattered over the surface of their bodies, and helps them to detect the presence of food. In other fishes these organs are plentiful near their mouth, and are used by these animals in search of food; hence the differentiation of the nervous matter constituting the nuclei of their cerebral gustatory centres, the taste organs being located in the mouth of terrestrial animals are rarely employed in their search for food. This explains the relatively slight importance of the sense of taste, and the comparative insignificance of its nervous apparatus in the higher vertebrates as compared with their visual, auditory, and other sensory nervous systems.

The brain of the South American mud-fish is an example of the highest state of development reached by this organ in bony fishes; the pallial formation of its hemispheres contains a fairly compact layer of cortical nerve cells, its lateral extremities show signs of commencing specialisation to form the pyriform lobes into which olfactory tracts penetrate, and its mesial extremity forms what are known as rudimentary hippocampal lobes. Beyond this the grey superficial strata lining the basal ganglia contain a layer of pyramidal cells (the epistriatum); which receives terminal fibres from various sensory organs, and passes into, and possibly constitutes an important element in the development of the neopallium. But the cortical structures of the highest orders of fishes, as well as those of amphibians and reptiles, can only be taken as indications of the first stage of the labour attending the birth of a true neopallium, such as that which exists in the cerebral hemispheres of the Mammalia.[1]

We may now refer to the instinctive be-

[1] *The Nervous System of Vertebrates*, by Prof. J. B. Johnston, pp. 255, 297, 310, Fig. 152. Also the Arris and Gale Lectures, pp. 151–2, the *Lancet*, January 15, 1910.

haviour of the mud-fishes of Guiana, possessing as they do a somewhat higher type of brain than that of the cartilaginous fishes; it is interesting to find the instinctive behaviour of these animals is also of a superior character to that displayed by any of the lower orders of the same class of beings. For instance, the mud-fish of South America is in the habit of constructing a nest in the banks of the stream it inhabits, which it makes from grass and the leaves of water-plants. These it binds together so as to form a secure place in which the female can deposit her eggs. The male fish keeps watch over the eggs, and the young fish until they take to the water and begin an independent existence. These fish travel for a considerable distance over the land dividing one stream from another; during the dry season they bury themselves in the bed of a stream, and remain there until the return of the rains, which soften the earth in which they have slept and thus release them from their temporary grave.

The small animal with which most of us are familiar, commonly known as the stickleback, is another nest-building bony fish. During the spawning season the male assumes a metallic green hue, the lower part of his throat being a bright crimson colour. The fish constructs his nest in the water it inhabits by collecting a quantity of grass-stalks, which he cements together with a layer of mucus exuded from the surface of his body. In this way a dome-like hollow structure is reared in the side of which a hole is left, its edges being strengthened and rounded off with great care. The fish then seeks a mate, and conducts her to the nest he has made; she enters it, and in a few minutes has laid some eggs. This process is repeated day by day until the nest contains a considerable number of eggs. The male then takes up a position for a period of about a month to defend the nest from invaders. During this time he has frequently to fight with larger fish than himself; in making these attacks the little creature seizes their fins and strikes furiously at their head and eyes. As the young fish appear and grow they are apt to stray; the male brings them back to their allotted precincts until such time as they are able to protect themselves, when he ceases his guardianship and returns to freedom.

The action taken by salmon in the preparation of spawning-beds, and the care of their young is remarkable; after passing from the sea the female deposits her eggs in shallow furrows in the gravel, to which they adhere by a thin coating of glutinous matter. The trenches in the sand are made by the female throwing herself at intervals of a few minutes upon her side, and while in that position, by a rapid action of her tail, she digs a receptacle for her eggs a portion of which she deposits, and turning on her side she covers them over with sand. The male seems to take no part in this work, but after it is completed he acts as a sentry over the eggs, for which he has at times to fight fiercely, for other male fish are anxious to appropriate his charge. He is thus kept incessantly on the alert until the eggs are hatched, and the fry able to take care of themselves.

Mr. Pennell states that in company with Mr. Bartlett, Superintendent of the Zoological Gardens, Regent's Park, he visited the house in which perch are kept; the keeper of these fish was also present. So long as the keeper walked about in front of the aquarium occupied by the perch they took no notice of him; but on Mr. Bartlett directing this man to walk away from the tank towards the cupboard where the net was kept by which food was introduced into the tank, the fish became intensely excited the instant the keeper made this movement and rushed to and fro across their tank, erecting their fins and exhibiting unmistakable emotional movements.

Much more evidence might be adduced to establish the fact that the instinctive movements made by the animals included in the three lowest classes of true vertebrates result from purely instinctive processes, and generally become manifest in definite traits of character which we are accustomed to attribute to self-preservation, parental affection, anger, jealousy, fear, self-reliance, and sympathy in a low form. That these traits of character are the outcome of instinctive processes is evident, in that to a greater or less extent they are common to all the orders of animals included in the three lower classes of vertebrates; that they are hereditary is shown by the fact that they are manifested by the young of the same orders of beings in all parts of the world. That they depend largely on work performed by the nerve cells of the mid-brain, including its basal ganglia or lower nervous centres, is shown by the fact that after the destruction of this part of the brain, although an animal may continue to live, its instinctive powers are abolished. Prof. Pagano observes, as the result of numerous experiments on adult and new-born animals, that after their basal ganglia had been destroyed their movements of expression distinctly attributable to emotional states were abolished. He asserts that the physiological preorganised mechanism of instinctive and emotional reactions are to be found at birth and in after-life in the basal ganglia.[1]

We may now pass on from the class of fishes to the Amphibians as represented by frogs and lizards. It is evident the sensory organs and brains of many of these animals are of a somewhat higher order than those possessed by car-

[1] *Archives Italiennes de Biologie*, 1906.

tilaginous or bony fishes. For instance, the common bull-frog, in addition to a membranous labyrinth such as exists in the auditory apparatus of fishes, possesses the rudiments of a structure known as the cochlea, which plays an important part in the appreciation by the animals of differences in sound. From experiments made by Prof. Yerkes, it seems that frogs appreciate differences in sound, as demonstrated by their movements, and in an alteration in the rate of their respiration when exposed to differences of range of auditory vibrations. That these movements depend on the action of the auditory apparatus, and corresponding cerebral centres is shown by dividing the auditory nerves of these animals—that is, by destroying the connection between their ears and auditory cerebral centres; after this has been done, the animal's movements in response to vibrations of sound are abolished.

Having in part adopted a terrestrial mode of life, the olfactory organs of Amphibia have become somewhat modified in response to the altered nature of their environment; they afford a direct passage for air to the animal's lungs, and have developed specialised olfactory sensory organs. To a large extent, however, this class of animals has to depend on their visual apparatus to enable them to gain their supply of food and to warn them of approaching danger. Their central nervous system has evidently responded to this demand, for it has become so far developed as to enable the Amphibia to appreciate between differences in colour. This is demonstrated by forcing a frog to follow a certain track in a labyrinth in order to obtain a supply of food.[1] At a point in the labyrinth where a choice between the right and wrong paths was necessary "a red card was placed on one side and a white card on the other side. When the frog had learned to take the correct path towards the white, the cards were exchanged without any other alteration in the conditions, and the decided confusion of the animals indicated that they had discriminated between the red and white cards, and had learnt to react with reference to this discrimination."[2] The small green tree-frog,

[1] *Journal Comp. Neur. and Psych.*, Vol. XV., p. 279.
[2] *The Animal Mind*, by M. F. Washburn, p. 142.

after a hundred trials, learned without a fault to follow the right path by which to obtain its food in a simple labyrinth.

Professor Flourens found that after he had removed the cerebral hemispheres of a frog the animal continued to swim when thrown into the water. Movements of this kind are due to stimuli received by the tactile sensory organs of the animal's body, which pass to the nerve cells of the spinal cord and through their motor fibres to the muscles concerned in the act of swimming. The neuro-muscular system of these animals has acquired the power of executing these movements in virtue of the hereditary structural arrangement of its elements, which had been exercised and thus improved during the previous lifetime of the animal. But, as Professors Goltz and Schrader have shown, if, together with the cerebral hemispheres, the basal ganglia are destroyed, the animal loses all power of instinctive reflex action; a frog thus mutilated will, if left to itself, remain motionless until in the course of time it dies. If the cerebrum of a frog is removed *exclusive* of its basal ganglia, instinctive actions are retained. If an obstacle is placed in the path of an animal which has been thus mutilated, and it is then excited by a prick in its foot, it moves away so as to avoid the obstacle. The mere act of leaping away may possibly, in case of necessity, be regarded as a reflex action; but the fact that the frog avoids the obstacle shows that its instinctive elements are still at work, and are located in the nervous substance of the basal ganglia.[1]

Reptiles form the lowest class of vertebrates which lead a wholly terrestrial existence, their lives depending on the perfection of their visual, auditory, and tactile sensory organs and the corresponding cerebral centres. The living substance of these organs has, among the "fittest" of this class of beings, responded to the streams of energy derived from new and varied external sources. For instance, the eyes of reptiles have developed structures whereby they focus on their retina waves of light proceeding from near and distant objects. Their

[1] Professor Schrader concludes from the result of his experiments on frogs, that their central nervous system can be divided into a series of sections, each of which is capable of performing an independent function.

retina consists of an outgrowth from the brain which terminates in a cup-like receptacle for the dioptric apparatus of the eye. In some reptiles the vestiges of a pair of eyes located on the upper surface of the animal's skull exist in addition to their lateral organs of vision. The auditory sensory organs of many reptiles possess structures which greatly facilitate the transmission of waves of sound to the auditory nerves and brain centres. The nose of reptiles also consists of an elaborate arrangement of structures adapted to present an extensive surface for the growth, and development of sensory organs connected with the olfactory nerves and cerebral centres.

The flow of energy from the outside world, and from internal sources passing to the central nervous system through the sensory organs of reptiles, has exercised a stimulating effect on the development of their terminal nerve cells and pallial structures, which have thus become more pronounced than those possessed by the two lower classes of vertebrates.[1] The con-

[1] *The Nervous System of Vertebrates,* by Prof. J. B. Johnston, pp. 257, 314.

necting fibres of these centres and of the spinal cord form a complex arrangement of paths by which pre-existing mnemic impressions are brought into harmonious action, and become manifest in purposive instinctive movements. For example, Prof. W. H. Wilson has found that "stimulation of the optic lobes of the large Egyptian iguana produces movements of various parts of the body, and that there is a definite and precise motor localisation in the mid-brain of these reptiles—a localisation which is determined by the ending of the tactile tracts (from the body generally) in this part of the brain." [1]

But as with the two lowest classes of vertebrates, so also with reptiles, their brains cannot be said to contain structures to which we can properly apply the term "neopallium"; the development of their cortical or pallial elements has been effected by the flow of energy which reaches them, but the crowning achievement of this process, consisting in the development of a true neopallium, has not been effected by the reptilian brain. The behaviour of this class of

[1] Arris and Gale Lectures, by Prof. Elliot Smith.

animal depends on the nature of the hereditary instinctive qualities of the nervous matter constituting their basal ganglia and mid-brain. From experiments made by Prof. Yerkes it appears that these movements may, in certain reptiles, become altered if the animal is subjected to appropriate treatment; in other words, the behaviour of reptiles is capable of being modified by proper training. Thus turtles, when subjected to labyrinth training, gradually learn how to follow rather complicated paths in order to reach their food. If an inclined plane is so placed as to intercept their path, to shorten the journey turtles on reaching the summit of the obstruction, systematically throw themselves over its edge so as the more speedily to reach the food contained in the water of their feeding tank.[1]

Among the class of birds the brain is remarkably constant in its outward form; its most characteristic feature is the great size of the basal ganglia as compared with other parts of the brain. The increased development of these structures is the result of the constant use

[1] *The Animal Mind,* by M. F. Washburn, p. 222.

necessarily made by birds of their visual, auditory, and tactile sensory apparatuses in order to maintain their existence. The evolution of the basal nervous system of birds, in response to the action of their environment, accounts for the surprising instinctive qualities displayed by many of this class of animal; the careful provision they make for their young, their self-reliance, jealousy, and other instinctive qualities are so well known that it seems unnecessary to dilate on this subject. That these qualities are hereditary, and become manifest without having been learnt or gained by experience, is well illustrated in the account Prof. Lloyd Morgan gives of a young moorhen which he had hatched in an incubator, and watched from day to day, almost from hour to hour.[1] When about nine weeks old this bird was swimming in a pool at the bend of a stream. A puppy ran down to the stream barking, and made a feint from the bank towards the young bird. In a moment the moorhen dived, disappeared from view, and soon partially reappeared, his head just peeping above the water beneath the

[1] *Instinct and Experience*, by C. Lloyd Morgan, p. 4.

overhanging bank. This was the first time the bird had dived. Mr. Lloyd Morgan observes that he had repeatedly endeavoured to elicit this characteristic piece of behaviour, but had failed. But now the blundering puppy succeeded in causing the small bird to execute a series of complex movements which, on their first occurrence, were independent of prior experience, and were directed towards the well-being of the individual. He adds: "Such behaviour is, I conceive, a more or less complex organic or biological response to a more or less complex group of stimuli of external and internal origin, and it is, as such, wholly dependent on how the organism, and especially the nervous system and brain centres, have been built through heredity under that mode of racial preparation which we call biological evolution."

From the basal ganglia of a bird's brain numerous nerve fibres pass to the superficial layer of cells forming the pallium of its hemispheres; the structures entering into the formation of this layer are more distinctly differentiated and of a higher type than those of the corresponding areas of the reptilian brain.[1] If definite spots of a bird's pallium are stimulated certain groups of muscles of the animal's limbs and body are brought into action, thus showing that the energy released from this part of a bird's brain passes to motor centres, and thence through the spinal cord to the contractile elements of the muscle cells.[2] After the complete removal of a bird's cerebrum, although the animal may continue to live for some time if fed artificially, it loses all instinctive powers; it, however, responds to tactile impressions by reflex action. But, as Prof. Elliot Smith observes, birds possess such a highly specialised and diversely modified cerebrum that they seem to have left the path leading to the formation of a true neopallium, such as that which forms a characteristic feature of the Mammalian brain.

[1] *The Nervous System of Vertebrates,* by J. B. Johnston, p. 149, Fig. 74.

[2] *The Evolution and Function of Living Purposive Matter,* by N. C. Macnamara, p. 100.

CHAPTER V

The Neopallium in Mammalia, extinct and surviving—The Tasmanian Devil—The Duckbill—Release of energy in response to stimuli—The folds of the Mammalian brain—The functions of the cortex—Cortical areas—Intelligence in dogs—Macaques—Areas of Neopallium—Learning by imitation—Baboons—Limits of intelligent action.

Before attempting to explain the evolution and functions performed by that part of the brain which is directly concerned in the manifestation of intellectual processes, it is well to observe that, as Professor Elliot Smith remarks, in each successive epoch it has become incumbent upon every mammal either, on the one hand, to adopt some eminently safe mode of life or some special protective apparatus to avoid extinction; or, on the other hand, to "cultivate" a larger cerebral cortex or that part of it known as the neopallium which, as the organ of associative memory, would enable it to acquire the cunning and skill to evade danger and yet adequately attend to its needs. In many of the Eocene Mammalia the neopallium is reduced to such diminutive proportions that the brain resembles the reptilian type, and in each successive generation the neopallium becomes larger or the creature in self-defence is compelled to adopt some safe form of life. The Hippopotamus and the Sirenia are examples of animals which have not kept pace in the fierce race for neopallial supremacy, but survive by adopting habits of life which are eminently safe. The condition of the human brain represents the other extreme. Here the neopallium has attained its maximum development, and its possessor has not had to seek refuge either in a retired mode of life, or by protective specialisation of structure either for offence or defence, but has attained the dominant position in the animal kingdom by means of the development of his intellectual powers, while retaining his animal or instinctive nature.[1]

We have noticed (p. 67) that in animals so

[1] *Cat. of Comp. Anatomy*, Vol. II., p. 465, Roy. Coll. Surgeons of England.

low in the zoological series as worms the effect of exposure of their nervous system to an increase in the complexity of the stimuli acting on it, has tended to develop the growth and organisation of its nerve cells. Under like conditions the cerebral cortex of some bony fishes is of a higher order than that possessed by the lamprey; in reptiles and birds it becomes differentiated structurally and functionally. The brain of some of the Marsupialia or pouch bearing animals structurally consists of something between that of reptiles and the more typical mammals. The "Tasmanian Devil" affords us an example of this order of beings; it possesses well-developed basal ganglia, into which nerve fibres extend from the various sensory organs; from the terminal cells of these ganglia numerous fibres extend to a rudimentary neopallium, from which lines of communication pass to motor cells controlling the action of the muscles of the animal's body and limbs. The behaviour of this, one of the lowest orders of mammals, is evidently governed by instinct, its fierce nature, strenuous efforts for self-preservation, and the fondness it shows for its young confirm this idea, and agree with the anatomical structure of its brain.

The snout of the Duckbill is an extremely sensitive organ; from it nerve fibres pass to terminal cells located in the basal ganglia; innumerable fibres extend from these ganglia to the nerve cells of the cerebral cortex, and to motor cells of the lower brain and spinal cord, so that impressions made on the animal's snout pass to its instinctive and cortical centres, and by releasing a part of their potential energy cause a discharge of combined nerve force which, acting on motor cells, become manifest in the purposive and intelligent movements of the animal's body and limbs. This point may perhaps be more clearly understood by reference to the following diagram :—

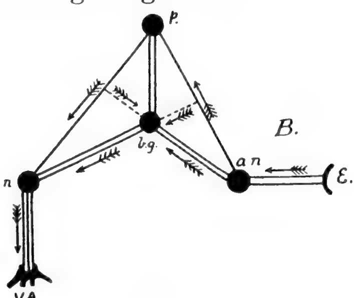

FIG. 14.

E represents energy derived from tactile impressions; *a n*, the receiving or sensory tactile organ from which energy passes to *b.g.*, a terminal tactile nucleus located in the basal ganglia; a part of the instinctive working energy attached to the living matter forming the cells of this nucleus being set free, passes to *mn.*, a motor centre. At the same time some of the energy set free by the nucleus *b.g.* extends to *p.*, a tactile cortical or neopallial centre setting free a part of its nervous energy which extends to the motor cells *mn.* and infuses a certain amount of nerve force into that derived directly from the instinctive elements of the basal ganglia, the result being manifest in the skill or cunning of the muscular movements made by the animal which are represented in the diagram by the letters *VA*.

The increase in the size of the cerebral cortex in the ascending orders of mammals seems to have outgrown that of the unyielding skull by which it is enclosed, so that its surface layers have become crumpled up so as to form a number of infoldings, or sulci, as they are termed; on the exterior of the hemispheres the sulci show as sharply-cut fissures; the intervening brain-substance is known as forming its convolutions. The pattern which the principal sulci and convolutions of the brain assume in the various orders of mammals is fairly constant, so that anatomists, by inspecting the surface of a series of brains, is able to state to which class of animals each of them has belonged.

The upper and lateral surfaces of a dog's brain present several well-defined infoldings of its cortex; on the base of the brain a part of its basal ganglia is conspicuous; they project into the lateral ventricles or space which exists in the brains of all the higher orders of animals. These ganglia, in fact, as in the lower classes of animals, constitute the receiving central and dispatching centres for incoming and outgoing streams of energy, derived from the animal's nervous sensory organs.

After a dog has been completely anæsthetised if certain areas of his cerebral cortex are stimulated by an electric current, contractions of definite groups of muscles of his body and limbs take place. At one spot excitation of the cortex is followed by movements of the muscles of the upper limbs; and so on with other groups of muscles. These cortical areas are known as motor centres; like areas on being stimulated induce similar action in every species of the canine family. Stimulation of other areas of a dog's cerebral cortex leads to movements which, there seems reason to think, depend on work performed by the cortical nervous matter governing the animal's feelings or sensations; but as it is impossible to arrive at any accurate conclusions regarding a dog's feelings, it is well to defer this subject until we come to consider the functions performed by certain areas of the neopallium of human beings. There are considerable spaces of the cerebral cortex in a dog's brain situated between its motor and sensory centres, which make no response to any form of stimuli applied to them. These regions of the cortex furnish lines of communication between the various cortical and other nervous centres, and transmute the energy it receives into a form which so acts on motor centres as to impart an intellectual character to the animal's movements. These so-called association areas of a dog's brain as compared with those of a human being are of a rudimentary type; nevertheless, dogs certainly possess a certain amount of intelligence or reasoning power. For instance, Darwin, when referring to this subject, gives the following details regarding the sagacity displayed by a dog belonging to a Mr. Colquhoun; this gentleman when out shooting winged two wild ducks, which fell on the opposite side of a stream. His retriever tried to bring over both birds at once, but could not succeed; she then, though never before known to ruffle a feather, deliberately killed one of the ducks, brought over the other, and returned for the dead bird. Colonel Hutchinson relates that two partridges were shot at once, one being killed, the other wounded; the latter ran away, and was caught by the retriever, who on her return came across the dead bird; she stopped, evidently greatly puzzled, and after one or two trials finding she could not take it up without permitting the escape of the winged bird, she considered a moment, then deliberately murdered it by giving it a severe crunch, and afterwards brought away both birds together. This was the only known instance of this dog ever having wilfully injured any game. Darwin adds : "Here we have reason, though not quite perfect, for the retriever might have brought the wounded bird first, and then returned for the dead one, as in the case of the two wild ducks."[1]

Behaviour such as that displayed by these dogs certainly indicates something more than mere automatic or instinctive action, and which is attributable to work accomplished through means of the living substance of the association areas of the animal's brain. We rest this belief on the fact, that if these parts of the brain are destroyed while the animal's basal ganglia remain, such an animal's intelligence and memory for all it had previously learnt are abolished; but its instinctive powers still continue and become manifest in instinctive behaviour.

It is impossible to draw a hard and fast line between instinctive and intelligent processes, the molecular structure of the living substance constituting the association areas of the neo-

[1] *The Descent of Man,* by Charles Darwin, Vol. I., p. 48, edition 1871.

pallium have been evolved from instinctive elements, raised as it were to a higher level in response to the increasing complexity of the environment imposed on the ascending orders of animals in their struggle for existence.

Although there is much to interest us in following the evolution of the brain of the Ungulates and Cetacea, it does not enlighten us much as to the connection which exists between the organisation and growth of the neopallium, and the development of an animal's intellectual powers; we therefore pass on to the order of the Primates, including the Macaque, whose brain has been extensively explored by physiologists, and its neopallium mapped out into well-defined motor and other centres which closely correspond with those of the higher orders of Primates.

The development of the association areas of a Macaque's brain do not reach the same plane as those which characterise the brain of the baboons; nevertheless, they are of a higher type than that possessed by a dog; consequently the reasoning powers displayed by some monkeys are more pronounced than those of a lower class of beings. Thanks to Mr. Kinnaman we can form fairly accurate ideas concerning the instinctive and intellectual capacities possessed by Macaques. He finds that the animals soon learn to discriminate between different colours, and also to appreciate the difference between the size and form of a vessel containing their food. Mr. Kinnaman had no difficulty in teaching his Macaques to follow the right path through a labyrinth constructed on the plan of the Hampton Court maze. He placed food in a cage which was closed by means of an elaborate set of fastenings, which his monkeys had to open before they could gain admission to the cage; the animals soon learnt how to open the cage, and evinced no small amount of pleasure when they had successfully completed their task. The question then arose as to whether a Macaque could, by watching its companion perform certain movements, and observing the consequence be able to accomplish a similar set of movements from a desire to effect similar results. The test used consisted of a closed box containing food; this box was fastened by means of a plug; one of the Macaques failed to work the mechanism and gave up trying in despair. Its companion, however, came out of her cage, the first one following her; number two went to the box, pulled the fastening about and ultimately seized the end of the plug with her teeth and pulled it out of its clasp. The box was again set; the first animal made a rush for it, seized the plug as number two had done, and got her food. She repeated this act several times.[1]

In our opinion the behaviour of this family of apes is attributable to instinctive processes fertilised, as it were, by nervous energy derived from the living substance of the association areas of their cerebral cortex, and therefore possessing a tinge of intelligence.[2]

The neopallium of Baboons and Anthropoid Apes is largely developed in all directions as compared with that of their lower brethren, and with this structural development their instincts and intellectual powers have risen to a higher standard. For instance, the author was out with a shooting expedition among the hills near a

[1] *The Animal Mind,* by M. F. Washburn, pp. 238–10.

[2] *Psychology,* "The Study of Behaviour," by W. McDougall, p. 164.

place called Colgong, on the River Ganges. Returning home in the evening we saw a troop of Baboons seated on a ledge of rocks; among them was a female with a young one close beside her. One of our party, without a moment's thought, fired and killed the young ape; its body rolled down the rock, and was instantly followed by the older ape, evidently the young one's mother. On reaching the dead body she took it up in her arms, fondled it, and uttered the most piteous wail, which attracted a crowd of her companions, several of whom joined her in her lamentations. The behaviour of these apes indicated a distinctly high tone of instinctive action; grief, and, as we have stated, sympathy, being innate qualities common to the same orders of animals under like conditions in all parts of the world. Thus, on Darwin's authority, the traveller Brehm, while in Abyssinia, encountered a troop of Baboons which at the time were crossing a valley. Some of them had already ascended the opposite rocks, and some were still in the valley; these latter were attacked by some dogs and driven away with the exception of one young animal, who was left behind on a ledge of rock and called loudly to its companions for help. One of the largest males of the troop came slowly to the youngster's aid and led him to a place of safety. Behaviour of this kind seems to imply intelligence, the old ape's instinctive action becoming modified by energy discharged from his visual and auditory neopallial centres by stimuli derived from cries, and the apparent peril in which his young companion was placed. Most of us have witnessed or heard of the surprising antics which performing apes go through at a sign or command of their keepers; but it is doubtful if they utilise acquired habits of this kind for their own advantage or to promote the well-being of their fellow-creatures.

CHAPTER VI

The hereditary qualities of the Neopallium and basal ganglia contrasted—The brain of Tertiary man—The brain of a microcephalous idiot—The arrest of human intelligence when sense organs are absent—Education through a single sense organ—Association nervous centres—The *modus operandi* of a sensation—Memory and sensation—Ideas and impressions—The mechanism of reading—Sensory cortical centres.

While the ordinary movements of invertebrates and the three lower classes of vertebrates are regulated by energy derived from their basal instinctive nervous substance, a part of this matter has undergone evolution in consequence of the constant action on it of the new kinds of energy to which the ascending orders of animals have been exposed in their struggle for existence (see Appendix). In this way a part of the cerebral cortex has become developed into what is known as a neopallium, consisting of specialised layers of nerve cells and fibres possessing intellectual properties. The nervous substance and functions of the instinctive or basal elements of the brain are strictly hereditary, having a pedigree extending over long geological periods and therefore difficult to alter and almost impossible to obliterate.[1] On the other hand, the association or neopallial elements of the brain are, philogenetically, of recent origin; their hereditary qualities are not so firmly ingrafted in its substance as those inherent in the instinctive centres; psychical nervous substance is

[1] Mr. W. McDougall is of opinion that modifications of instinctive action may be effected, *first,* by an animal learning to discriminate by experience gained from success or failure of its instinctive behaviour. *Secondly*, an animal may learn to react with one of its instinctive modes of behaviour to an object of a kind towards which it at first remained indifferent. The *third* type of modification of instinctive behaviour consists of a modification of the bodily activities that are directed upon the object of the instinct. He remarks that "when the behaviour of an animal exhibits modification of a purely instinctive mode of behaviour of any one of these kinds, we say that it has profited by experience and behaves intelligently. All animal behaviour is, then, either purely instinctive or intelligent; and when we say intelligent, we mean that it is such as implies some degree of modification of the innate structure of the mind through experience of success or failure, pleasure or pain, in the course of purposive activity. Intelligent behaviour thus always involves modification of instinctive modes of behaviour, and intelligence presupposes instinct, for unless a creature possessed instinct of some kind, all basis for the play of intelligence would be lacking, there would be no tendencies to be modified, and modification of pre-existing tendencies is the essence of intelligent activity."—(*Psychology,* "The Study of Behaviour," pp. 163, 164.)

therefore more amenable to training than that which constitutes the basal ganglia.

Our knowledge of the functions performed by different areas of the living substance of the neopallium is based on a study of its structure, and on experiments made on the brains of apes and other animals. As regards human beings, it is derived mainly from the destruction of definite areas of the brain as the result of disease or injury. The cerebral cortex, or neopallium, in man consists of five layers of nerve cells, and a subjacent mass of nerve fibres which connect together the whole of the complex structures forming the central nervous system.

The convoluted cerebral cortex of the existing races of human beings is far more extensive in proportion to the rest of the brain, and the surface of their bodies than that of any of the lower animals. In this respect the nearest approach to the human brain is that of the gorilla, which, although much inferior to man's brain in superficial area, and especially as regards its motor centre of speech, otherwise conforms structurally to the type of the human brain. With a well-developed neopallium these man-like apes show a considerable amount of intelligence and capacity for education, although their behaviour as a whole is markedly governed by their hereditary instinctive centres. There can be no doubt that between the type of brain possessed by apes and human beings there are missing links, which might possibly have been filled in to some extent, if we possessed the skull of a Dryopithecus as well as the animal's lower jaw.[1] One of these missing links is, however, supplied by the skull, and some of the bones of an ape-like human being (the *Pithecanthropus erectus*) discovered by Dr. Dubois in Java in a Tertiary geological stratum. These bones were found close to one another in the same geological formation, and were all in a similar condition of fossilisation, and therefore in all probability were part of one skeleton. Dr. Dubois brought these bones to Europe and submitted them for examination to our leading anatomists. After much controversy it is now generally admitted that they are part of an ape-

[1] The Dryopithecus of Lartet, which was closely allied to the anthropomorphous Hylobates, existed in Europe during the Upper Niocene period; it was nearly as large as a man.—*The Descent of Man,* by C. Darwin, Vol. I., p. 199, First Edition, 1871.

like human being who lived in the later Tertiary period. Dr. Dubois holds the opinion, from impressions he finds on the inner surface of this skull, that the brain it once contained possessed that portion of the cerebral hemispheres in which Broca's organ of speech is located. He holds that this area of the brain, in the Tertiary period human being was less than half the size of the corresponding portion of the brain of existing Europeans.

This statement suggests the idea that this being possessed to some degree the power of articulate language, but from the capacity of his brain as a whole we feel convinced that his intellectual powers were of a rudimentary character, as compared with those of civilised human beings of the present day.[1] We make this statement on the estimated capacity of the Java skull, which amounts to 950 c.c. as compared with that of average educated Englishmen, who have an average cranial capacity of 1,500 c.c. The capacity of a full-grown male gorilla's skull is some 600 c.c., the weight of

[1] The capacity of the skull is commonly expressed in cubic centimetres.

this animal's body being about the same as that of an average adult human being; this great difference in the capacity of a human and a gorilla's skull represents the difference that exists between the size of their brains.[1] (Fig. 15.)

Although it is impossible to ascertain the exact form of the brain possessed by Tertiary human beings, the brains of a certain class of idiots are of such a size and form as would fit well into the Java skull-cap. We published some years ago a case of this kind, in order to show what the probable habits and behaviour of primitive human beings would have been, possessing, as we may presume was the case, brains having about the same superficial area and configuration as the class of idiots to which we refer.[2]

In the case which came under our notice the individual was four feet eight and a half inches in height, and broad in proportion to his stature;

[1] Prof. T. H. Huxley, *Evidence of Man's Place in Nature*, p. 136. See also *The Origin and Character of the British People*, by N. C. Macnamara, p. 28.

[2] *Journal of Anatomy and Physiology*, January, 1903, Vol. XXXVIII., p. 258. See also *Scientific Transactions of the Royal Dublin Society*, Vol. V., Series II.; "The Brain of Microcephalic Idiots," by Prof. D. J. Cunningham.

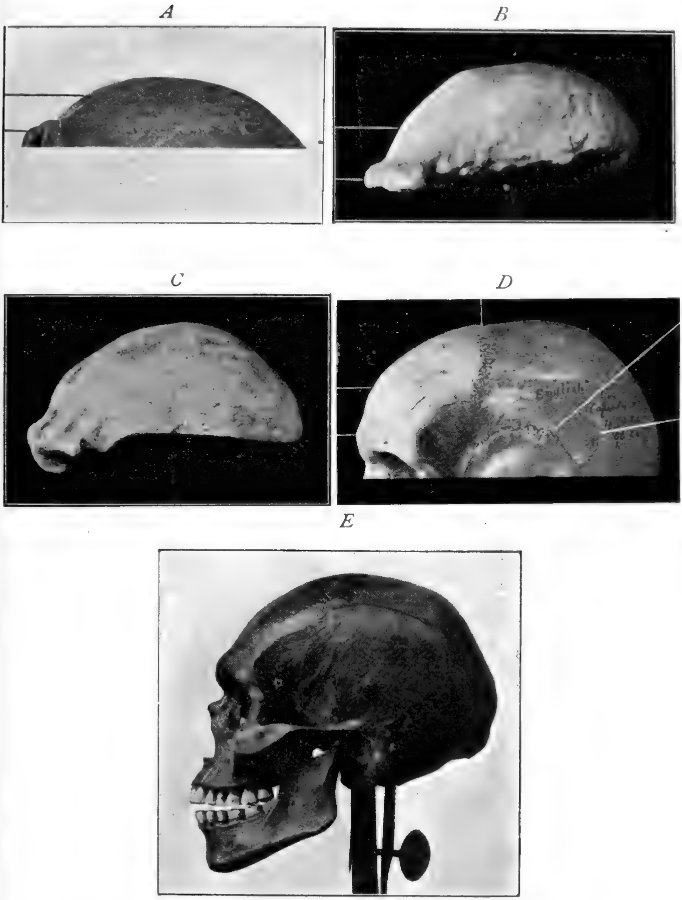

FIG. 15.—*A*, Skull-cap of a Chimpanzee. *B*, Skull-cap of a Neanderthaler. *C*, Skull-cap of the Java skull. *D*, Skull-cap of an existing European. *E*, Skull of a native of Australia. See *The Hunterian Oration* for the year 1901, by N. C. Macnamara.

his features were large, coarse, and devoid of expression. His long arms and small head with its receding forehead gave him an ape-like appearance. (Fig. 16.)

This poor lad had never been able to speak, but expressed such wants, and any ideas he could formulate by signs and inarticulate sounds. He attached himself to persons who were kind to him and followed them about from place to place. His power of sight, hearing, touch, and taste were all good; but it was impossible, notwithstanding the most patient efforts to teach him to speak or do such work as that of sweeping out a room. The intellectual power possessed by this individual was inferior to that of some of the lower animals. His habits were dirty, and he was very passionate; when out of temper he became violent, throwing himself on the ground and uttering loud inarticulate sounds. His general health was good until he reached the age of twenty-one, when he contracted disease of the lungs, from which he died some twelve months later.

After death it was found that the weight of this youth's brain was under 20 ounces (the average weight of adult Englishmen's brains being from 48 to 50 ounces), and that the part

FIG. 16.

of the frontal lobe in which the "organ of speech" is located had not been developed, so that the part of the brain (Island of Reil) which in man is covered by the posterior part of the third frontal convolution, was, in the case of this idiot, exposed. It is unnecessary for us to enter into a further anatomical description of this brain, which has been elsewhere fully described. But we may observe, that the form and size of this idiot's brain differs less from that of the brain of an anthropoid ape, than it does from the cerebrum of a normal adult European. We may go beyond this, and state that the brain of this individual was more nearly allied structurally to that of an adult male chimpanzee than to that of an average human cerebrum.[1]

Our object in drawing attention to the form and dimensions of the skull and so of the brain of anthropoid apes, as compared with that of our human progenitors and existing races of men, is in order to show that, with about the same weight of body their intellectual capacities have advanced in proportion to the increase in the size of their cerebral hemispheres; for it is owing to the growth of this part of their brain that its bulk has advanced from that of a chimpanzee of 600 to 1,500 c.c. This increase of

[1] *Human Speech*, by N. C. Macnamara, pp. 226–7.

man's neopallium has probably resulted to a considerable extent from the development of his motor cerebral area of speech, and the power he has thus gained of expressing his thoughts in intelligent language. If, as in the case of the idiot we have referred to, the motor area of the brain regulating the action of the muscles of articulation has not been developed, and the cerebral hemispheres as a whole are imperfect, the intellectual powers of such an individual are of a low order, and he is unable to express his thoughts in articulate language. The size of the brain, however, is by no means the only thing which determines the standard of an individual's intellectual powers; its inherited qualities, state of nourishment, and the training its nervous substance has undergone in early childhood are factors which influence the kind of work it is able to perform. To appreciate this fact at its true value we must endeavour to understand the nature of the mechanism, the orderly working of which is the essential requisite for the occurrence of intellectual processes.[1]

[1] *The Brain in Health and Disease*, by Dr. J. Shaw Bolton, pp. 51–123.

On referring to Fig. 17 it will be seen that considerable intervals exist between the sensory and motor cortical centres; in the brains of ordinary human beings these spaces are occupied by nerve fibres and cells which constitute

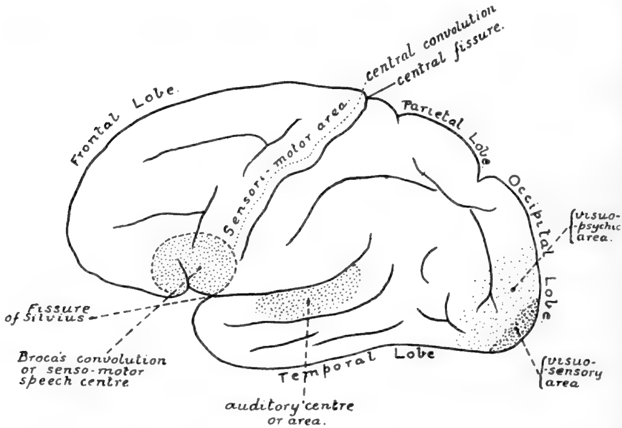

Fig. 17.—Diagram of left cerebral hemisphere (outer surface) of human brain. (From Halliburton's *Handbook of Physiology*, p. 688.)

its psychical or *association* areas. It is in these parts of the cerebrum that energy passing from sensory to motor cortical centres is transmuted into intellectual processes, and in that form stimulates the motor centres which control the action of the muscles of our bodies and limbs.

In order to comprehend the working of this system, it is well in the first place to remember the part taken by the sensory organs of our bodies as receptors, and modifiers of energy derived from external and internal sources, by which energy the system we have above referred to is ordinarily kept in action. To illustrate this point we can hardly do better than study the effects produced on the normal development of a child's intellectual powers when, in his early life, the principal portals by which energy passes to his brain are destroyed.

Laura Bridgeman was a healthy infant, and grew in body and in intelligence until she had reached her second year of age, when she was attacked by fever which completely destroyed her eyesight and her power of hearing. Laura's mother, in spite of all her efforts, was unable to teach her child to speak or to notice any sound. Laura Bridgeman, in fact, from her second until between her seventh and eighth year of age was dumb as well as deaf and blind. Dr. Howe states, that until Laura was over seven years of age she "occupied a place in her home no higher than that of an intelligent animal upon whose instruction much labour had been bestowed." Her intellectual capacity, so far as an opinion could be formed, remained undeveloped; her sense of touch, however, was unimpaired, and she was thus able by the use of her hands to feel her way about the house in which she lived. Before entering the institution for the blind, which she did when seven years of age, L. Bridgeman had been taught by means of her sense of touch—that is, through moving the tips of her fingers over raised letters—to recognise words which were attached to a number of articles in common use, such as knives, forks, spoons, and so on. She had, however, no conception of anything beyond this mechanical form of knowledge, the result of which, Dr. Howe observes, "was about as great as if one had taught a number of tricks to a clever dog." After long and patient teaching, so as to exercise her sense of touch as highly as possible, Dr. Howe states, Laura B. seemed to have gained ideas that the symbols she was employing meant definite things.

"Immediately she realised this her countenance beamed with human reason; she could no longer be compared to a parrot or a dog."

Another remarkable case of a similar kind to the above is reported by Mr. E. Chamberlain, and subsequently by H. Keller herself.[1]

H. Keller when she was nineteen months old was seized with a fever, through the effects of which she completely lost her sight and hearing. Her other special senses were unimpaired. From the time of this illness until she reached the age of seven years, H. Keller states that her life was a blank, meaningless, and concerning the events which took place before she reached the age when her regular education commenced she remembers little or nothing; she lived during this period, as she expresses it, in a condition of mental fog. Those who knew H. Keller during these years state that the predominant features in her character were her excitable, passionate nature and love of mischief. When she was rather over seven years of age she came under the influence of a wise and experienced teacher, and under

[1] *The Story of the Life of Helen Keller*, by H. Keller, 1903.

her instruction she passed through a preliminary course similar to that followed by Laura Bridgeman. As her sense of touch became more delicate, her tutor, by signs made with her fingers in the palms of her pupil's hands spelt the names of things in common use. Referring, however, to this period of her life, H. Keller remarks that "in the still, dark world in which I lived there was no sentiment, no tenderness." The signs made and received were, as in the case of Laura Bridgeman, mechanical, the outcome of work done by the living matter of her basal ganglia; the hemispheres of her brain were as yet hardly brought into play through the cerebral centres of touch. This condition of things continued for a considerable time. One day, however, H. Keller and her tutor came to a stream of water, into which the latter placed her pupil's hands, and while there traced on the palms of them the letters w-a-t-e-r. H. Keller states: "My whole attention being fixed upon the motion of the water and the motion of my instructor's fingers, I recognised a connection between the two, and that water meant something that was flowing over my hands, the thing had a name." From this beginning H. Keller's knowledge of things rapidly increased, and in the course of time she acquired the power of lip-reading and of articulation.[1]

From the history of these individuals we learn, that from their second to their eighth year of age they were unable to name things either in silent or articulate language. Their power of memory or of forming ideas was rudimentary. H. Keller states that for six years before her education commenced her intellectual faculties were in a condition which she likens to that of a dense fog. We conclude that after these children had lost their sight and hearing, and consequently their power to receive impressions and gain ideas regarding external objects through their eyes and ears, their intellectual powers had ceased to develop. We say ceased to develop, because until they lost their sight and hearing they were as intelligent as most other children of the same age.

[1] From *The Story of the Life of H. Keller,* written by herself, we learn much that is most interesting regarding her mental development, which attained to so high a standard as to enable her to gain a university degree.

Taking this fact, and also that of their subsequent histories into consideration, we conclude that the brains of these beings possessed the mechanism by which they might have expressed their thoughts in intelligent speech, but that the machine failed to work. Their sensory, motor, auditory, visual, and tactile centres were, in conjunction with the association areas of their cerebral hemispheres, capable of performing their ordinary functions, but the two former important receptors of energy had been destroyed, so that the sensations and ideas which children usually acquire through these sense-organs were not formed; the consequence was that the functions of the association areas of these children's brains remained undeveloped, until they had been brought into action by the skilful training of their tactile sense-organs, and corresponding sensori-motor nervous centres. This training consisted in the persevering exercise of the nervous matter forming the tactile sense-organs of their fingers, and thus in bringing their corresponding sensori-motor cerebral centres into a high state of physiological perfection. By a process of this kind the dormant intellectual powers of these children were brought into play, and they gradually came to comprehend that external things could be specified by definite symbols or movements made with their fingers, *i.e.*, that it was possible to express their thoughts in manual signs.

It was the exercise of their sense organs of touch, and the motion of their fingers which brought the inherent power of their association nervous centres into healthy action.

Passing from the eyes, ears, and the other sensory organs of our bodies, ingoing or afferent fibres may be traced which extend to, and terminate in relation with aggregations of nerve cells known as the sensory cortical centres, located in definite areas of the cerebral hemispheres; in their passage to these centres the fibres give off branches to the basal ganglia. (See Fig. 14.) The nerve cells forming the sensory centres are brought into relation with motor cortical centres by means of association fibres. From the motor centres fibres extend to the lower brain and spinal cord, and in their passage give off branches to the nuclei of nerves terminating in effective muscular and other organs, by which energy is distributed to the contractile elements of muscles, and to gland cells.

Energy derived from any object, such for instance as a rose, passing to our retina releases a part of the energy attached to its nervous elements; the energy thus set free extends along fibres to corresponding sensory cortical centres, and is followed by a visual sensation or feeling; at the same time the incoming stream of energy makes an impression on some of the mnemic elements of the sensory centre, in the form of a visual image of the colour and form of the flower.

The visual, auditory, tactile, and other cortical centres, however, are constituent parts of the cerebral hemispheres which possess psychical functions. When the potential energy of a sensory centre is liberated by the re-excitation of its charged or impressed elements, part of its energy is liberated and sets free from surrounding association centres a certain amount of nerve force which gives reality to the sensation, that is to an *idea* of the form and colour of the rose. There is reason to believe that a sensation is a purely automatic process; it is only when the potential energy attached to its nervous elements in the form of an impression is released by a fresh stimulus of its mnemic elements, and passes to surrounding association nervous matter that an idea or intelligent image of the constituent parts of the object which has caused the impression becomes a reality.

For instance, when we first saw a rose we may have smelt it and have plucked it from its stem. In this way, at the same time as our visual mnemic elements received an impression of the form and colour of the flower, our olfactory and tactile sensory centres also became impressed by its odour and feel. Energy discharged from any one of these charged centres releases energy from the other centres, and leads to a real and complete idea of the rose. The sensation imparted by a rose that we have once seen is not totally lost after the flower has disappeared, for if we again see a similar flower we recognise it as one we have seen.

Take another example. We see a friend and greet him. In this case the form of our friend produces a visual sensation and impression; the salutation is the result of its action on motor centres *plus* an intercurrent stream of released psychical nervous force. (See Fig. 14.) It is evident the sensation produced by the external stimulus is not alone a sufficient cause for the salutation, because if in place of a friend we had met someone we disliked we should not have saluted him. It is plain that a latent image of our friend had been re-excited when we met him; a psychical image stored in our brain had been brought into action, and the contents of the idea thus produced has assumed an intelligent form in the association areas of our cerebral cortex, and, guided by the result of experience, is followed by the contraction of definite groups of muscles.[1]

An idea, therefore, means the thing or movement which has produced the sensation, and the contents of the idea consist of energy derived from the characteristic features possessed by the object or movement which has caused the sensation. Latent impressions thus

[1] Introduction to the *Study of Physiological Psychology*, by Prof. Theodor Ziehen, pp. 20, 285.

formed remains dormant until the elements upon which they have been established are re-excited, when their potential energy being set free, is transmuted into nerve force and becomes manifest in a real image of the object or of the movement which has caused the impression. In order, therefore, that an idea should assume the form of a real image of the object or movement which has caused the sensation, the elements on which the principal features of the object have been established must be re-stimulated by a similar or kindred form of energy to that which produced the sensation. Prof. Ziehen illustrates this point by comparing the living matter of the impressed nervous centres to the wheels, stars, etc., formed out of gas-pipes as we see them in illuminations. Unlit, they resemble the so-called latent ideas; the charged materials are there, but a spark must first light the gas that escapes from many holes of the pipe in order that the latent form may become a reality.

The act of reading aloud illustrates our meaning as regards the association of ideas in operation. Energy derived from the concentration of our eyes on printed words passes to our visual and auditory word centres; a part of their mnemic energy is thus released and excites neighbouring association nervous elements, followed by the discharge of nerve force which by practice travels along association fibres offering the least resistance to psychomotor centres, and leads to the utterance of word sounds corresponding to those from which the original visual impression was derived.[1] The efficient working of a system of this kind is gained by its exercise; any fault in the sensory organs or in the nervous apparatus hinders its perfection, but under favourable conditions the more regular the exercise of the materials involved the more readily do they respond to the energy acting on them; physiological and pathological science corroborates this statement. It has been proved that after the excision of the association nervous substance surrounding a dog's visual centres, or the destruction of the corresponding part of the cortex by disease in human beings, the dog

[1] Halliburton's *Handbook of Physiology* (eleventh edition), p. 741; also *A Text-book of Physiology*, by Landois and Stirling, Vol. II., pp. 962, 988, 996.

or the individual becomes mentally blind; that is, he can still see, as appears from his following objects moved in front of his eyes and avoiding obstacles placed in his path, but he no longer recognises what he sees. The dog no longer crouches when threatened with a whip or attempts to avoid a stone thrown at him; the man stares at the most familiar objects as if they were wholly unknown to him, and recognises them only when he touches them. Again, the auditory sensory cortical centres are located in well-defined areas of the cerebral hemispheres (Fig. 17). The functions performed by a part of their living substance is to retain the impression made on them by word sounds spoken by another person; this part is recognised as constituting our auditory word centres. When these charged centres are re-excited, part of their energy is released, and extends to the motor centres which order the action of muscles controlling the vocal apparatus. If, however, these auditory word centres are destroyed by disease, the latent word sounds established upon them perish and cannot be replaced, and a person affected in this way is therefore dumb, not because he is unable to articulate, but because he has no words at his command; he may still be able to see, feel, and smell, and, as far as possible without the help of words, think and reason.[1]

Dr. J. Shaw Bolton gives an excellent account, in the eighth chapter of his book on "The Brain in Health and Disease," as to the probable mechanism of the cerebral association processes which, in human beings, result in the elaboration of articular language and thought. The employment of words as articulate symbols to express the contents of impressions made on cortical sensori-motor centres must release a form of energy peculiar to human beings which probably tends to aid in the evolution of the psychical elements of their brains.

[1] *The Evolution and Functions of Living Purposive Matter*, by N. C. Macnamara, p. 140.

CHAPTER VII

The cerebral cortex and insanity—The inherited instinctive powers of the new-born—Development of cerebral hemispheres and formation of conceptions of space, etc., due to stimulation from without—The nervous element in reflex action—Acquired reflexes—Their seat in the Neopallium—Development of this and basal ganglia the physical basis of education—Hereditary development of basal ganglia cells—Emotional expression in children born blind and deaf—Heredity in an Andaman tracker—Hereditary qualities capable of being modified—Training of animals—Instinctive qualities to be cultivated or repressed—Instinct usually more to be relied on than intellect—Early training essential—Free play to children's actions advocated—Training of association areas of the brain—The Montessori system—Misdirected education of to-day—Aim of education—Classification of pupils—Cadet courses with technical training.

We have shown that energy, after passing through sensory organs exerts a powerful influence on the development of those parts of the brain whose function it is to associate the contents of ideas and to transmute them into intellectual processes. The following pages will further show, that the neopallium also constitutes the organ by which the movements of the higher orders of animals become speedily adjusted to changes of their environment. In conclusion, we indicate the lines on which the results of a study of the nature and functions of the brain may be applied in forming sound ideas as to the education of children.

It is found that the nerve cells of the neopallium of imbeciles are structurally defective when compared with those of right-minded people; in fact, in proportion to the deficiency of the cerebral cortex in this respect so is the intellectual deficiency.[1] One of the earliest symptoms of a disease known as the general paralysis of the insane, which depends on the degeneration of the nerve cells and fibres of the cerebral cortex, is a peculiar hesitation and irregular movement of the lips and other muscles concerned in the production of articulate speech, which indicates an impaired action of the terminal nerve cells constituting the

[1] *The Brain in Health and Disease,* by Dr. J. Shaw Bolton, pp. 37, 86.

sensori-motor cortical centres of speech. At the same time an individual suffering from this disease unconsciously drops syllables in the attempt to form spoken sentences or in writing. In like manner, when trying to think he finds that his memory for certain words is defective, so that even in the early stages of general paralysis a person may be incapable of managing his own affairs. We thus have proof that there is a corresponding loss of the individual's intellectual powers in persons born with a defectively developed neopallium, or in those whose nerve cells and fibres, of this part of the brain, degenerate.[1]

If we turn to the other side of the picture we find that the intellectual capacity of a healthy child is in proportion to the perfection of the structural development of the nerve cells and fibres of his cerebral cortex.

Those of us who, as medical practitioners, have had an opportunity of watching the movements of a new-born infant, can have arrived at no other conclusion than that a child immediately after birth possesses inherited instinc-

[1] *The Brain in Health and Disease*, by Dr. J. Shaw Bolton, p. 375.

tive and emotional powers; for if the infant is brought within reach of his mother's breast he seizes the nipple, directs it to his mouth, and begins to suck; if thwarted in this action the child gives vent to his emotional feelings by crying. (See foot-note, p. 185.) When a lighted candle is brought near an infant's face it acts as a stimulus to his visual nervous centres, and leads to reflex contractions of groups of muscles as shown by his outstretched arms towards the flame regardless of the consequences; a young infant fails to make any reasonable attempt to remove anything which may be causing him pain.[1] The reason for this is, that the nervous structures entering into the formation of an infant's spinal and basal system are more fully developed (myelinated), at the time of his birth than his cortical cerebral substances; so that reflex and automatic instinctive movements are then possible through the base and stem of the brain, while at this early age the structures forming the association areas of the child's cerebrum are immature, and consequently his intellectual powers are defective.

[1] *The Dawn of Character*, by E. R. Mumford, pp. 27, 29, 43. See also p. 21.

A healthy infant will lie for hours moving his limbs about in an aimless manner. These movements, however, tend to promote the growth, not only of the child's bones and muscles, but also of the nervous substance of his cerebral hemispheres, because the constant movements bring numerous muscular sense-organs into action, thus leading to a discharge of energy which passes to sensori-motor centres, and by exercising their elements promotes their organisation and also that of the cerebral cortex as a whole. That this is the case is shown by the fact, that an infant four or five months old not infrequently ceases crying to be fed when he hears his nurse's voice, showing that he has come to associate the sound of her voice with the relief of the cause of his distress.[1]

Infants when about six months old, as a rule, make persistent but ill-directed efforts with their arms and hands to reach any near object, especially if it happens to be of a bright colour; movements such as these depend to a large extent on reflex automatic action. When a child is a little older he guides his hands so as to seize

[1] *Instinct and Experience*, by C. Lloyd Morgan, pp. 20, 33.

a near object; no sooner, however, does he grasp it than the muscles of his hands and arms contract, and the object is carried to his mouth. Action of this description depends on the stimulation of the tactile sense-organs of the child's fingers and hands when grasping the object. At first the combined action of both visual and tactile impressions is necessary to effect these movements; but when a system of this kind has been constantly exercised, it is only necessary that the tactile sense-organs should be stimulated to bring the muscles of the child's hands and arms into co-ordinated action, the movement has become a *habit.* The child is henceforward occupied in attempting to execute new movements, which lay the foundation for processes of selection or choice, and ideas of the greater and the less.[1] The young child as yet cannot distinguish the difference between his woolly ball and his wooden bricks, but he comes by experience to contrast the sensations derived from soft and hard things; he stretches out his hands, but there is nothing to feel or

[1] *Physiological Psychology,* by Prof. Ziehen (Third Edition), pp. 58, 273.

which he can pull towards himself; repeated movements such as these lead to the adaptation of the nervous substance of tactile and other centres to impressions made on them through the sense organs; in this way a child begins to appreciate distance and space, and to recognise the fact that his body is something apart from the rest of the world. These rudimentary conceptions of his own being, or "Ego ideas," by a child develop rapidly, especially during that period of his existence when he is passing from crawling to walking in the erect position. This fact is confirmed by microscopic examination of sections of the brain at this period of child-life; the nerve cells and fibres of its cortical substance will then be seen to be more completely developed than they are at an earlier period of life.[1] We conclude that a child's intellectual powers come into effective operation simultaneously with the development of the struc-

[1] Halliburton's *Handbook of Physiology* (Tenth Edition), p. 734. See Quain's *Anatomy*, p. 178. "A man can think of those things only of which he has learned to think; and this learning to think of an object is a process of gradual building up of that capacity by successive efforts to think of the object more adequately; and that which endures between the successive acts of thinking of this object is a potentiality (disposition) of thinking of it again."—*Psychology the Study of Behaviour*, by William McDougall, p. 81,

tures which form his cerebral cortex; and that the effective working of his brain, like that of other organs of his body, depends on the structural arrangement of the elements which form its underlying basic substance; while any improvement of its functions implies a similar improvement in the structures which minister to their performance. Sensations derived from the outer world or else from internal sources form the material from which intellectual processes are derived; as Aristotle long ago stated, "Nihil in intellectu quod non fuerit prius in sensu"; we know, and learn from what we see, feel, hear, taste, and smell.[1]

We may now pass on to consider the evidence on which we base the opinion that, in addition to the above stated functions, specialised areas of the neopallium control the movements of animals so as speedily to adapt them to their environment.[2]

Nervous action is reflex; that is, it depends on the effect produced by energy applied to a

[1] See *The Nineteenth Century and After,* "A Physiological Basis of Education," by N. C. Macnamara.

[2] A "Lecture on the Investigation of the Higher Nervous Functions," by Prof. T. Pawlow, *Brit. Med. Journ.,* p. 973, October, 1913.

system of living matter. This system consists of a sensory organ from which ingoing (efferent) nerve fibres pass to end in a central nerve cell; from this cell (afferent) outgoing fibres extend to effective organs such as muscle fibres and secreting cells. Stimuli derived from sensory organs travel to a central cell, and thus release a part of its potential energy, which is conducted along afferent nerve fibres to an effective organ. For instance, a particle of dust falls into our eye, it acts as a local source of irritation, and thus excites corresponding central nerve cells, from which energy is discharged which, passing to the muscles of the eyelids and to its lachrymal gland, sets up spasm of the lids and a flow of tears.

Professor Pawlow, of Petrograd, has for many years been engaged in studying what he terms acquired or "conditional" reflexes; while movements of the lower classes of animals are controlled by innate, simple, or "unconditional" reflexes; under the influence of evolution and the adaptability of living matter to its surroundings, the higher orders of beings have acquired the power of forming new reflexes by which they become adapted to the ever-increasing complexity of their environment, new relations being thus established under new conditions to the advantage of the organism.

As an example of a simple reflex action we may refer to the increased flow of saliva which accompanies the stimulus of food taken into an animal's mouth; there is no difficulty in collecting the saliva which ordinarily finds its way into the mouth, so that the quantity of fluid secreted by the salivary glands can be measured under varying conditions. While a dog is eating his food there is, by reflex action, an increased flow of his saliva. While this is taking place we may proceed to pinch or otherwise stimulate the skin of a definite part of the dog's body. If, when the dog has finished eating and the increased flow of saliva ceases, we then irritate the previously stimulated skin, a fresh flow of saliva takes place, produced this time by a tactile impression made on sensory organs of the skin, in place of one caused by the contact of food with the mucous membrane of the mouth. Again if, while a dog is being fed and his salivary glands thus stimulated, we prick or otherwise painfully stimulate the animal's skin, he naturally shrinks from our treatment; after a time, when the dog has ceased eating, if we again apply a painful stimulus to his skin he no longer shrinks from it, but there is a marked increase in the secretion poured out from his salivary glands.

From these and many other like experiments it seems clear, that a nervous impulse resulting from a stimulus which naturally passes to corresponding central nerve cells may, under new conditions, be diverted to another centre—that is, it is easy by changing the conditions to divert an impulse from one to another path. It can be shown that processes of this kind depend on the action of the living substance of certain areas of the neopallium; for if these parts of the brain are removed during life, no new or conditional reflexes can be established, but if at the same time the basal and spinal systems have been preserved, the animal responds to stimuli by simple, or it may be automatic, reflexes.

Professor Pawlow has also shown that certain areas of the neopallium form a "fundamental mechanism," whereby new reflexes are analysed. Such analysers are, he believes, incessantly at work controlling the reactions of living beings to their ever-changing environment. He finds that if the anterior half of the cerebrum is removed all the conditional reflexes which may have been previously established are obliterated; the animal appears to have lost all its normal relations with the outer world; from a psychological point of view such an animal is a perfect idiot. After work on these lines extending over a quarter of a century Professor Pawlow has arrived at the conclusion that, "the cerebrum is the organ for the analysis of sensations and for the construction of new reflexes and new movements." [1]

If the evidence referred to in this and the preceding chapters is trustworthy, and the hypo-

[1] Dr J. B. Johnston, in his exhaustive work on the *Nervous System of Vertebrates,* p. 292, remarks that the evolution of the cerebral hemispheres is associated with the mode of life of the animal; and the greater its size and internal complexity, so in proportion is the perfection of the organism's adjustment to its environment.

theses founded on it reasonable, it follows that any effort made to develop the moral and intellectual capacities of young people should be directed towards the efficient training, and nurture of the nervous substance upon which the manifestation of these faculties depend; to be more precise, our efforts should be directed towards developing the nervous instinctive basic substance of the basal ganglia, and of the association areas of the neopallium.

The development of a child's character may be conveniently considered, *firstly*, with reference to the training of his hereditary instinctive qualities, which depend on work performed by the nervous substance of his lower or spinal system, including the basal ganglia (see Chap. IV.); *secondly*, with reference to the development of his intellectual powers, the result we conceive of work performed by the higher or association areas of his cerebral hemispheres (Chaps. V. and VI.). It is, however, to be borne in mind that when we refer to higher and lower centres, these, together with all the other parts of the central nervous system constitute a single organ which in health work in unison.

If from one part of this system energy is set free, an equivalent amount replaces it from some other part by a process of irradiation or overflow, by means of which the system is maintained in a state of equipartition of energy.

We cannot obtain the same kind of evidence regarding the functions performed by the human basal ganglia as that procurable in the lower animals, (see p. 133) but the clinical evidence we possess on this subject tends to confirm the idea, that specific forms of energy on arriving at this part of the brain are transmuted into instinctive and emotional action, and that this form of matter is passed on from one to succeeding generations of beings through the medium of germ cells. This fact is illustrated by the histories of the blind and deaf children we have referred to, whose psychical capacities remained dormant from infancy until they had reached their tenth or eleventh years of age; their hereditary dispositions during this period of their lives dominated their behaviour, and led to frequent outbursts of uncontrolled passion, at other times to fits of meaningless laughter. Having been blind and deaf from infancy, these children could not have learnt from seeing or hearing other people how to give expression to their feelings by muscular movements of the kind referred to; it is evident their behaviour was the result of inherited qualities brought into action probably by stimuli derived from their tactile sensory organs.

As an example of the inheritance of hereditary instinctive qualities we may refer to an account in the *Westminster Review* (December, 1900) of an Andamanese lad who, in the year 1872, came under our observation. The primitive inhabitants of the Andaman Islands, in order to find their way about the dense jungles they inhabited, were in the habit of forming a trail marking certain trees, and carefully noting irregularities and objects on the paths they traversed. Their power of observation was thus cultivated, and in the course of many generations had become extremely keen. An Andamanese infant, having been deserted by his parents, was reared on the premises of the Chaplain residing at the central station of the

Andaman Islands. When this lad was ten years old he was brought to Calcutta; the day after his arrival, while walking with him and his master over the open plain (maidan), we were suddenly enveloped in one of the dense fogs common to Calcutta; our party halted, and were discussing the advisability of remaining where we were until the fog cleared; the Andamanese lad, hearing what we were discussing, said he thought he could show us the way home along the path we had traversed. He pointed to a stone a few feet from us and said we had passed it, and a little further on a clump of grass; and so, like a dog on scent, he followed on until we came to the public road which led to our house. The lad said he had paid no particular attention to the various objects he recognised on the ground, but that he must have seen them and had no difficulty in recognising them again. It seemed to us that this boy had inherited a sense of observation similar to that possessed by his progenitors—a development, in fact, of the instinctive power possessed by many of the lower animals—which had remained dormant in his case, until surrounding conditions brought these faculties into play.

The instinctive powers displayed by this lad, in conjunction with the previous histories of the deaf and dumb children, strengthens the idea we have advocated, that the brain of human beings contains a nervous mechanism possessing innate qualities which, when stimulated by appropriate energy, become manifest in instinctive action. The evolution of this mechanism can be traced upwards through the ascending classes of animals, and constitutes a prominent feature of the human brain. We thus come to realise the fact that the animal side of man's nature results from a specific arrangement of elements entering into the formation of his central nervous system which he has inherited from his progenitors, and cannot therefore get rid of or permanently alter. Nevertheless, it seems possible to modify the kind of work which the nervous substance of the basal ganglia performs by educating or influencing its action through means of the sensory organs, and still more directly, by energy derived from association areas of the brain. We know that the instinctive behaviour of many animals under the influence of selective breeding and domestication becomes greatly modified, and that even wild beasts, if taken in hand when young, may by the exercise of patient and kindly treatment have their inherited dispositions much altered, although their savage natures can never be altogether abolished. Probably no one ever had a larger experience as to what can be done in training wild animals than Carl Hagenbeck, who, when referring to this subject, observes that all carnivorous animals "when they are caught young and are properly treated are capable of being brought up as domestic pets"; he adds that among animals, as among men, good and bad are mixed, and that while the good will develop itself, the bad can be suppressed.[1] With regard

[1] *Beasts and Man,* an abridged translation, by H. S. R. Elliot, of Carl Hagenbeck's experience of half a century among wild animals. Like human beings, animals differ much in their capacities to be influenced by training. Thus Mr. Bartlett informs us that having some monkeys for sale, a trainer came to him to offer a certain price for the lot; but he said: "If you will permit me to have them for a week or ten days, I will keep two or three of the animals and send you back the remainder, for it is only those who are attentive that I can train; the inattentive animals whose eyes are constantly watching a fly or anything moving about the room are of no use to me; no amount of teaching will induce them to learn the tricks I require them to perform."

to domestic animals, believing as we do that our instincts and emotional expressions have been derived from animal progenitors, it seems reasonable to suppose that the method employed by many generations of sportsmen to train pointers, for instance, might give us an idea of the kind of treatment likely to succeed in developing the living nervous matter of our basal centres. In the year A.D. 1621 a well-known sportsman, Gervase Markham, observes regarding the training of pointers that no one should attempt to take this business in hand unless he has a real pleasure in the work, and a natural liking for dogs. He writes as follows: "You shall beginne to handle and instruct your dogge at four months old; if deferred longer it will make the labour greater; make him most loving and familiar with you, taking a delight in your company, also mix with this familiarity a kindly awe and obedience which you shall procure rather by tenderness than by terrefieing him, which only maketh him sly. When you have got thus far in his training you may begin to teach him the work you desire him to perform." Markham is quite clear in his instructions regarding the necessity for patience on the part of a trainer; he observes that it is wrong "ever to hurry your young dogge, give him time to fix himself and much liberty of movement, handle him firmly but tenderly."[1]

It would be difficult to lay down in general terms principles better adapted for the training of a young child's instinctive powers than those given by Markham for the training of pointers. In other words, a system of education pursued on these lines is calculated to develop and improve the working of the nervous substance on which the individual's character depends.[2]

If commenced in early childhood it is possible by careful training habitually to curb the instinctive and emotional activities displayed by young people. But teachers who have had large experience in educating children, and who have lived sufficiently long to see their pupils grow up to middle age, assure us that children whose character they had fondly hoped to have

[1] *The Pointer and his Predecessors,* by W. Arkwright, p. 154.

[2] This principle is applicable alike to individuals and to the various races of men. *Origin and Character of the British People,* by N. C. Macnamara. Also by the same author, *The Evolution of Purposive Matter,* p. 191.

moulded into all that could be desired showed by their subsequent behaviour that their hereditary instinctive qualities had only been subdued when children, and by no means eliminated. The unreliable, sly child, when he reached the prime of life, in too many instances was an untrustworthy and scheming individual, and so on with the other instinctive faculties.[1]

In spite, however, of these somewhat pessimistic views as to the *permanent* results to be obtained by the ordinary means employed to educate young children, we are convinced that if a healthy child is adequately fed and placed in a fairly favourable environment, many of his more desirable instinctive qualities may be developed, such, for instance, as those of parental affection, respect for superiors, sympathy, and disinterestedness, out of which an individual's moral sensibilities are derived. In like manner we can regulate, but cannot abolish, an individual's undesirable hereditary tendencies, such

[1] The branch of science known as bio-chemistry has within recent years shown that effective states of mentality depend much on the circulation in the blood of certain materials derived from the ductless glands of our bodies, the destruction of one or other of the glands being followed by various abnormal conditions of the nervous system. See also p. 21.

as those of fear, jealousy, envy, hatred, and malice, qualities which ancient philosophers fully recognised as forming a part of human nature which no device of man could wholly eradicate, a residuum of the wild beast, liable at any moment to assert itself, a fact of everyday experience, and one which history has over and over again proved to be true.[1]

Before undertaking the care and training of a child it is desirable, as far as possible, to gain sound ideas concerning his hereditary qualities or natural disposition. There are two main sources from which to obtain information on this subject; we know the child inherits many of the qualities possessed by his immediate progenitors; and from about the third year of child-life his hereditary qualities will be recognisable from his behaviour, which we can study without difficulty.

Most people belonging to the upper and middle classes of society are capable of forming fairly correct ideas regarding their own hereditary qualities which, if they understood the im-

[1] When making use of the term "young children" we mean children from some three to five or six years of age, the psychical nervous substance of whose brains is gradually being matured.

portance of the subject, they would utilise in the training of their own children and in guiding those to whom they entrust their care.[1] It has been our aim to show that instinctive action is phylogenetically both older, and often to be relied on with greater confidence, in the common affairs of life than conclusions reached by intellectual processes. In the case of many women their instincts have been, and always will be, their true and unconscious guide to action; it is this which confers on them the exasperating sway of often being in the

[1] In an article published in the *Westminster Review* for December, 1900, p. 638, on the importance, from an educational point of view, of rightly understanding the development of the innate character of young people, we endeavoured to show that parents, guided by their own experience, can comprehend the nature of the inherited mental qualities of their own children, and are bound to make use of this knowledge in their home training. The same principle, in our opinion, applies with even greater force to the case of schoolmasters, many of whom receive lads from eight to ten years of age under their charge. A master has seldom any real knowledge as to the innate qualities of the lads he undertakes to educate; he may make inquiries from a boy's parents as to the infantile diseases from which his pupil has suffered, but it rarely occurs to him to inquire concerning the boy's disposition. If any thought is given to the subject, it is taken for granted that the lad's character will soon make itself manifest by his conduct. There is much truth in this idea. Nevertheless, we are convinced that if parents and masters came to an understanding as to the real innate and fixed character of the boys they have to deal with, it would assist much in right education. Not a few self-respecting natures are in early life driven into habits of sullenness, deceit, and untold anguish by treatment and punishment misapplied from ignorance and want of appreciation of a lad's character.

right in matters which reason fails to solve correctly.

As it is with the lower animals, so also in the training of young children; it should be commenced early in life—that is, when the child has reached his third year of age—and to be effective the nurse or any other person entrusted with the care of a child ought to possess an innate love for children. Such a person would soon acquire, from a child's ordinary behaviour, a fairly accurate idea of his hereditary instinctive qualities; this knowledge should be fortified by information on this subject derived from the child's parents, and, if possible, supplemented by an acquaintance with the elements of the physiology of the central nervous system, such, for instance, as that to be found in Huxley's small work on this subject; the object being to enable those entrusted with the training of a young child's character to realise the nature of the living matter with which he has to deal, and the importance of employing appropriate stimuli to his various sensory organs in order to develop what is good and suppress any evil qualities possessed by the child. Armed with knowledge such as this, a nurse or teacher will soon gain by the exercise of patience, justice, and unfailing kindness, the affection and confidence of a child, and may then proceed to guide his innate qualities into correct modes of action.

A young child should be allowed freedom of action in order to give full play to his natural tendencies, guided as they ought to be by the kindly precepts and example of those entrusted with his management; through liberty a child comes to recognise the extent of his own strength and weakness, and thus learns a self-discipline and consideration for the feelings of other people which by practice become habitual, and constitute a sound foundation on which to rear a satisfactory moral character.

Parental affection is a strongly developed instinctive faculty. It is the greatest possible help to a child to feel that his parents take a genuine interest in him, being at all times ready to help him in his real or imaginary troubles, and to participate in his pleasures. The simple prayers learnt by a child at his mother's knees are for him no mere repetition of words, but the means of developing his innate striving for communion with a Being upon whose love and tender care he unconsciously relies, and in after-life transfers to a supremely wise and loving spirit—his God. Reserve on the part of parents, or on the other hand of children, is often attributed to shyness, but in truth as a rule depends on the play of a far more difficult instinct to deal with successfully—that is, pride. It is, however, beyond our province to attempt to enter into details concerning the training of young children, the more so as it is within our power to recommend to the reader an excellent work on this subject written by Edith Reed Mumford, under the title of *The Dawn of Character, a Study of Child Life*.[1]

Having given the reasons which lead us to conclude, that the basal ganglia constitute the basic substance on the working of which instinctive character or behaviour of an individual mainly depends, we pass on to consider that part of education which is principally con-

[1] M. A. Wood's book, *Thoughts of the Training of Your Children,* is the result of five-and-twenty years' experience; it contains much valuable information on the subject and may be highly recommended.

cerned in instructing, or influencing from without the development, and working of the association areas of the neopallium on which we conceive the occurrence of an individual's intellectual processes depend. This part of the brain, being of later philogenetic evolution than its more stable instinctive elements, under the action of appropriate stimuli more readily undergoes variations and mutations of structure; it has developed nervous centres which not only possess psychical properties, but also motor centres which control the muscles of the vocal apparatus, enabling men to think and to express their thoughts in intelligent speech.

Whether Froebel's Kindergarten, or the Montessori system is best adapted for training the intellectual powers of children attending our elementary State-supported schools is an open question; there can be no doubt as to the value, especially of the latter system, in helping to increase the intellectual and physical powers of children; the freedom of action inculcated is of great value, and the employment of the didactic materials recommended by Madame

Montessori are well devised to promote the development of the instinctive and the association areas of a child's brain.[1]

The structure and quality of the nervous substance of all classes of Englishmen are derived from a common Anglo-Celtic stock, and are therefore amenable to the same kind of training. The difference between the intellectual qualities of the children of the manual labouring classes, and their more prosperous neighbours is not in the innate quality of their nervous systems, but depends on the difference in the conditions under which their nervous matter, and that of their immediate progenitors has been reared; in other words, on the environment in which from infancy to childhood and adult age most of these people have had to live.

At the age of fourteen years a lad belonging to the labouring classes is obliged to leave school, and endeavour to earn his own living. Not having been trained how to think or to do any useful kind of work, he finds it difficult to get any permanent occupation, and probably

[1] *The Montessori Method*, by Maria Montessori, M.D., p. 216.

wanders from one employer to another during the following three years of his life, learning little, if anything, likely to advance his future career. His earnings are insufficient to enable him to feed or clothe himself properly, consequently many a lad drifts into the ranks of the unemployable class.[1] That this is not an overdrawn picture of the career of many town-bred lads is proved by the result of Mr. Arnold Freeman's history of seventy-one typical examples of boy-workers between their fourteenth and nineteenth years of age. He seems to have had no great difficulty in obtaining sufficient details concerning the career of these lads at school, and of their parentage and home conditions to enable him to form a fairly accurate opinion as to their hereditary qualities. Mr. Freeman believes that the life-history of these seventy-one individuals is representative of well above a half of the juvenile population of the City of Birmingham after they had passed through a ten years' course of instruction in elementary State-supported schools. But he rightly lays stress on the fact that throughout their school-

[1] *The Nineteenth Century and After*, 1912, p. 962.

days the majority of these young people had lived in houses defective from a sanitary point of view, and in an extremely unsatisfactory environment. The extent and depth of the home-life differed, of course, from one dwelling to another, but in none of them was there any real assistance given to forward the work of the school.

Mr. Freeman found that three years after leaving school only six of these seventy-one lads had emerged into the position of skilled workmen; forty-four of them were doing unskilled work, and twenty-one were unemployable on account of physical or intellectual inefficiency.[1] Much of the physical weakness under which many of these young people suffer results from the premature decay of their teeth, a state of things we conceive, to be mainly due to the pernicious practice which has sprung up during recent times, of mothers rearing their children on various kinds of artificial food and adulterated cow's milk, in place of feeding them as nature intended from their own breasts.

[1] *Boy Life and Labour*, by Arnold Freeman, p. 13.

With regard to farm labourers, we learn from a report issued by the Board of Agriculture that many of these men assert, apart from reading, writing, and arithmetic, that the education they received at school had proved to be of no possible use to them.[1]

From evidence such as that above given it appears, that a large percentage of the youths of this country are at present living under social and industrial conditions which render them incapable; when they have reached the age of manhood of earning sufficient to support a wife and family in a clean and comfortable home.

A certain class of politicians, some fifty years ago were intent on persuading people that if the nation would supply the necessary funds to build school-rooms, and provide the teachers necessary to give free education to every one of the children of our labouring classes, poverty and crime would disappear from the country; they went so far as to assert that, under a system of compulsory free education, if any man re-

[1] *The National Review*, August, 1910, p. 937.

mained poor he would have only himself to blame for it. These "radical philosophers" gained their object, and board schools were established throughout England, conducted on the principles advocated by those who brought them into existence. The system of instruction thus established, with certain modifications, has now been at work for forty years, with a result such as that above indicated. We cannot, however, altogether agree with those who blame the teaching provided in the board schools as being mainly responsible for the existing state of things; nor does it seem to us that a system of "compulsory continuation of education" after a lad has passed through an elementary school is likely to improve matters, so long as these young people are obliged to live in homes such as those in which a large majority of our labouring classes are, from economical and other causes compelled to reside. The home and its environment is at the root of much of the evil complained of; let the training followed in elementary schools be ever so perfect, but little can be done, so long as most of the children have to dwell in filthy sunless houses, towards moulding them into beings other than such as those described by Mr. Freeman in his admirable work on *Boy Life and Labour*. What we require at present is a Government which will carry through measures calculated to improve the housing of the poor, to amend our poor laws, including boy labour; when this work is accomplished it will be time to take seriously into consideration the kind, and scope of instruction to be given in State-supported elementary schools throughout the country.

The main object to be kept in view in educating the children of our labouring classes, is to mould the instinctive and association areas of their brains into a form which, under proper stimuli, will become manifest in a self-reliant, loyal character, steadfast in honest good work, in whatever state of life the individual may be placed. This purpose, as we have endeavoured to show, may be accomplished by the continued employment in early childhood of appropriate stimuli through sensory organs, and thus of securing the co-ordinate working of the higher and lower nervous centres of the brain. The efforts of our elementary school teachers should be directed, not so much towards cramming their pupils with bookwork, but in fitting them to carry on with satisfaction to themselves and their future employers, the various kinds of work they are likely to have to perform during their subsequent lives. The test of efficiency on leaving school should be to demonstrate what a lad or girl can do rather than what he knows. We are told that the ancient Irish people were in the habit of handing their children over for instruction to foster-parents, who had legal charge of their pupils until they were seventeen years of age, when a lad was compelled to return home; and if it was then found that he had not become efficient in his calling, obedient, and otherwise properly instructed, the foster-father was heavily fined; the amount of the fine was given to the pupil, because, as the Brehon Law states, it was "upon the pupil the injury of want of learning has been inflicted." This practice is never likely to be revived, but there is something very refreshing in the idea of making the teacher responsible for the shortcomings of his pupils.[1]

In every elementary school a certain number of the pupils respond readily to the instruction given them; these lads in after-life will probably become skilled workmen and earn a fairly competent living wage. A much larger proportion of the lads attending the school are more or less inattentive, slow to learn, their instinctive qualities dominating their behaviour; in after-life they take to various kinds of low-class labour which, if they are physically strong, enables them to earn fairly good wages during prosperous times; otherwise, especially in unseasonable weather, they have great difficulty in making both ends meet. Then we have a third class of lads who are slow to learn, stupid, and troublesome to manage; these are those who in after-life drift from one job to another, too many of them passing sooner or later into the class of the unemployed, with all its attendant misery. Of the seventy-one boy labourers whose histories Mr. Freeman records, twenty-

[1] *The Story of an Irish Sept, by a Member of the Sept* (N. C. Macnamara), p. 13. See also *The Ancient Laws of Ireland*, Vol. II., p. 155.

one belonged to this latter class. He states that they were so deficient in mental, moral, or physical capacity, and sometimes in all three, as to make it exceedingly probable that at manhood in competition with other adult workers they would tend to be rejected for regular employment.

Uninteresting and difficult to teach as the latter class of pupils is, they form a class which requires the special attention of their teachers. An inquiry should be instituted regarding the parents, and hereditary instincts of each one of such lads, and also into the homes and environment in which they live; their teachers, armed with knowledge of this kind, should, in consultation with the school's medical officer, then recommend the course of treatment to be adopted in each case. If insufficient food, a filthy home, want of sunlight and fresh air are at the root of the evil, they can only be overcome by removing a lad into a more salubrious atmosphere, or by forcing his parents to take better care of him; it is hardly likely that confinement in a board school for five or six hours a day would tend to promote the development of either his mental or moral powers. It may, we believe, be safely stated that if in childhood a boy or girl belonging to the class referred to is placed under fairly favourable hygienic conditions and properly trained, he or she would grow up to be a useful member of the working classes.

By far the majority of lads attending our elementary State-supported schools are thrown on their own resources to gain their living after they have reached the age of fourteen years. As Mr. Freeman has shown, it is during the following three years that, having no settled employment, and frequently unwholesome wretched homes, they too often fall into bad company and lazy habits, thus as they grow up to manhood becoming unprofitable members of society. To avoid this state of things it seems to us that if within a year of leaving school a boy has not obtained some fixed and fairly remunerative employment, he should be compelled to undergo a course of training as a military cadet or be sent to a training ship; during these years he should be taught a trade or some other occupation which would enable him subsequently to gain a living By treatment of this kind a healthy, well-ordered, and useful labouring population could be secured, who, in time of emergency would be ready to defend their country and in all probability save it from even the threat of invasion by an enemy.

APPENDIX

The origin of structural variations in living organisms, and their adaptability to the environment.

During the first half of the nineteenth century naturalists had become dissatisfied with the then current ideas regarding the origin of species. Lamarck completed his well-known work "Philosophie Zöologique" in the year 1809. He believed in the spontaneous generation of living organism from inorganic matter; that life consists of an order, and state of things which permit of organic movements, and that these movements are the result of the action of a stimulus which excites them. He held that a progressive change from lower to higher orders of beings had been and was constantly taking place, and that to effect these changes "*time* and favourable conditions are the two principal means which nature has employed in giving existence to all her productions."

Towards the middle of the last century biologists, working with improved lenses, advanced beyond the knowledge (possessed by Treviranus) of the structure and functions of the cells which, either separately or collectively constitute the bodies of living beings, and came to recognise the fact, that however complicated the conditions may be under which vital phenomena become manifest, they may be split up into processes which are identical in their nature with those taking place in non-living matter.

Sir Charles Lyell, in 1836, although declining to accept Lamarck's theories regarding the descent of human beings from anthropoid ancestors, held that new species originated through the development of pre-existing ones.[1]

Alfred R. Wallace, after spending four years in South America and some eight years in the Malay Archipelago in collecting specimens, and studying the distribution of plants and

[1] *The Coming of Evolution,* by John W. Judd, C.B., LL.D., F.R.S., p. 109, Vol. I. of the Cambridge Manuals of Science and Literature.

animals, was, in the year 1858, attacked by fever and confined to his bed. His thoughts wandered to the problem he was engaged in solving when, as he writes, "in a sudden flash of insight the idea of *natural selection* presented itself to my mind." After a few hours' thought he noted down the views he had formed on the subject, and forwarded them by the next mail to C. Darwin, requesting him to show this communication to Sir C. Lyell. Darwin at once complied with this request, although realising to the full that this paper of Wallace's forestalled the ideas contained in a work on "The Origin of Species" he had in hand, and which he published in the year 1859. In this work Darwin proved from facts of the most varied kind, the truth of the idea he had formed regarding natural selection or the survival of the fittest. He held that animals have descended from at most only four or five progenitors, and plants from an equal or lesser number, which were gradually modified in structure in response to changes in their environment caused by geological, climatic, and other influences—beneficial or harmful. This led him to the belief that all animals and plants have descended from some one prototype. He states that in consequence of the struggle for existence any variation however slight, and from whatever cause it proceeds, if it be in any degree profitable to an individual of any species in its complex relation to its environment, it will tend to protect that individual, and generally will be inherited by its offspring. Darwin calls the principle by which each slight useful variation of an organism is preserved the principle of natural selection, in order to emphasise its relation to man's power of selective breeding. For it is well known that by careful selection of the stock we can adapt organic beings to our own use through the accumulation of slight but useful variations. Natural selection, however, is a power constantly ready for action, and is as immeasurably superior to man's efforts as the work of nature is to that of art.[1]

Darwin repeatedly insists on the fact, that natural selection could not be effective unless

[1] *The Origin of Species by Means of Natural Selection*, by Charles Darwin, M.A., 1859, p. 63.

very long periods of time were allowed for its complete action. It is evident that time must have been an all-important factor if we are to suppose, that by the interaction of the inherent properties possessed by the elements of living matter its structural arrangement became gradually modified in such a way, that existing classes of animals and plants have been evolved out of it.

Charles Darwin's great work on the *Origin of Species* was published in 1859, and was followed by the first part of Herbert Spencer's *Principles of Biology* and Huxley's *Man's Place in Nature*, both of which appeared in the year 1863; the evidence and opinions set forth in the writings of these three Englishmen gave a great impetus to scientists engaged in experiment on the influence of mechanical, and other forms of energy in modifying the character of plants and animals.

In the sixth edition of the *Origin of Species*, published in 1872, Darwin had arrived at the opinion, that the physical condition of organisms lead to new sub-varieties without the aid of selection. In a letter to a friend, dated 1876, he observes, "that in my opinion the greatest error which I have committed has been not allowing sufficient weight to the direct action of the environment, *i.e.*, food, climate, etc., independently of natural selection. When I wrote the 'Origin,' and for some years afterwards, I could find little good evidence of the direct action of the environment. Now there is a large body of evidence." In this opinion we fully concur.

Professor E. Warming, referring to the xerophilous character of desert plants, observes: "The question arises whether these adaptations to the medium should be regarded as a result of natural selection, or whether they owe their origin to the action of the conditions of the medium in modifying forms exercised directly; I adopt the latter view. The character of adaptation thus directly acquired has become fixed and hereditary."[1]

Professor G. Henslow has bestowed many years of careful study on this subject and arrived at the conclusion that, we have now abundant proof both by induction and ex-

[1] *Æcology of Plants, p.* 373.

periment, that the form and structure of the organs of plants are due to the immediate response of living protoplasm to the influence of the environment, and that it, or rather the nucleus, builds up just those cells and tissues which are conformable to the conditions of life. Then after a few years they become hereditary, and so fix the varietal or specific characters by which they are distinguished.[1]

Mr. R. Ruggles Gates, when referring to this subject, remarks that "it seems clear that the plasticity and adaptability of organisms is one of their main properties which has made evolution possible; on the other hand, the 'tenacity' of heredity in perpetuating even small differences for long periods is essential if evolution is to have any cumulative effect."[2]

The most reliable evidence as to the progressive evolution of the animal kingdom is derived from a study of their fossil remains in the various geological strata of our own and other parts of the world. The length of time these strata have taken to form is an open question, but we

[1] *The Journal of the Horticultural Society*, August, 1915.
[2] *The Mutation Factor in Evolution*, pp. 221–321, by R. Ruggles Gates.

may be sure that our chalk rocks, for instance, consist of the shells of marine species of animals, and that these remains of once living beings must have taken long periods of time to have been deposited layer upon layer at the bottom of the sea. Darwin states that the fineness of gradation in the shells of successive substages of the chalk formations led him to maintain the gradual, as against the sudden evolution of species. The fossil shells of these rocks have been thoroughly investigated by Mr. A. W. Rowe, who observes that "the white chalk of England offers an almost unique field for observation on account of its thickness (considerably over 1,000 feet), its slow, uniform, and continuous deposit in a sea of moderate depth, with no closely adjacent land, the abundance and wonderful state of preservation of its fossils, together with the facility with which they can be cleared of their chalky covering."

Among the most common chalk fossils is the flattened heart-shaped Sea-Urchin. These are first found in their shelled sparsely ornamented forms, from which spring as we ascend the zone all the other species of the genus. The progression is unbroken and minute in the last degree. We can connect together into continuous series each minute variation, and each species of a gradation of structure so insensible that not a link in the chain of evidence is wanting. The bearing of this evidence upon the question of continuity or discontinuity in evolution is of paramount importance. Nowhere has evidence been collected so fully as in the case of the white chalk; nowhere have such conclusive proofs of continuity in evolution been established.

Prof. W. B. Scott, referring to the evolution of the existing species of horses, states that in the Lower Tertiary deposits of North America each one of the different Eocene and Oligocene horizons has its characteristic genus of horses, showing a slow, steady progress in a definite direction. This series of fossils points to the fact that existing species of horses are derived from individuals less highly capable of evading enemies and obtaining food; that is, they point to progressive improvement through long periods of time in the structural arrangement of this species of animals.

Again, the well-known fossil of Archæopteryx found in a series of slates in Germany, seems to constitute a link between groups now widely separated by divergence in evolution from the same ancestors. This animal is at once a feathered flying reptile and a primitive bird with many reptilian structures. Although Achæopteryx was a primitive bird, it is in a true sense a "link" between reptiles and the group of modern birds; the gap between these types is filled up by fossil forms like Hesperornis, whose remains are found in strata of a later date. That these links are not alone is proved by the numerous other examples known to science, such as those which connect amphibia and reptiles, ancient reptiles and primitive mammals, as well as those which come between the different orders of certain vertebrate classes. The important element in these examples of evolution is, first, their adaptation; secondly, the origination of new parts; and, thirdly, the retention of the better invention.

Another kind of evidence favouring the idea of the progressive evolution of human beings from simpler orders of animals is the presence of what are known as non-functional vestigial structures, relics of past phases of existence such, for instance, as the unused external muscles of our ears and rudimentary third eyelids, the gill clefts of reptiles, birds, and mammals, and the hind limbs in whales. The study of these vestigial structures is of importance in showing that ancestral features have a great power of hereditary persistence. Our firm conviction is, that the origin of variations in the structure of organisms is, in every case, due to the power which their protoplasmic basic substance possesses of responding to the action of the environment. Those organisms which thus become most perfectly adapted to external and internal stimuli, are those which survive in the struggle for existence.

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