John L. Sullivan

THE BRAIN

AS

AN ORGAN OF MIND

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LIST OF WOODCUTS.

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THE BRAIN AS AN ORGAN OF MIND.

CHAPTER I.

THE USES AND ORIGIN OF A NERVOUS SYSTEM.

A lifeless object makes no appreciable response to external impressions. If we touch a rock or a stone, no answering movements follow. Day and night, summer and winter succeed one another, and yet, though inanimate objects undergo imperceptible molecular changes, they yield no active and visible response either to diurnal or to seasonal vicissitudes.

It is wholly different, as we know, with the members of the vegetable kingdom existing around and amongst these inanimate things. The seasonal changes shown by them are familiar to all. The putting forth of the leaf, the period of active growth, the bloom of flowers, the shedding of seed, the fading and fall of leaves, are so many manifestations of an internal activity which display themselves with never-failing regularity.

Plants respond, however, to more definite external changes than those dependent upon seasonal mutations. Their flowers open and shut at particular hours of the day, in accordance with the varying amounts of heat and sunlight falling upon them. They grow more rapidly by night than by day, though as a general rule the activity of their internal changes is closely related to the degree of heat to which they are subjected. Again, whilst they generally grow best in directions where they meet with most air and light (not because of the latter agency, but rather on account of the heat which goes with it), many of them will, in the course of a few days or within shorter periods, bend very perceptibly, so as to bring themselves more under the influence of this latter agent.

Amongst some representatives of plant life, the correspondence between internal and external changes is undoubtedly less obvious than in many of the instances just referred to. Thus is it with the black or grey film of Lichen which marks as with a patch of paint the damp surface of some weather-beaten rock. Yet, watch it carefully from time to time, and, even in this lowly form of life, responsive though sluggish changes may be detected, sufficient to remove it from the category of inanimate things to which the rock itself belongs.

The comparative complexity of life exhibited by members of the vegetable kingdom is, however, small; and for this two principal causes may be cited.

(1.) As a rule—to which there are only few though interesting exceptions, to be mentioned further on—they subsist on inorganic materials, deriving their food from the gaseous or dissolved mineral elements existing in the air or water with which their surfaces are bathed. In their natural or healthy state plants decompose carbonic acid, fixing its carbon and setting free its oxygen. They decompose water, so as to retain its hydrogen; whilst they also abstract nitrogen either directly from the atmosphere, or indirectly from the nitrate of ammonia formed therein and brought to the soil in refreshing showers. This work of decomposition, under the influence of light and heat, goes hand in hand with one of an opposite kind, resulting in the elaboration of those organic and living compounds which enter into the composition of vegetal tissues.

(2.) Then again, as a rule, plants exhibit no inherent powers of movement other than those connected with their growth. The movements of the Sunflower and its allies are exceptional; and there are very few plants which more or less immediately respond to a touch by a movement, in the way that the Sensitive-plant or the Venus fly-trap is known to do. To this subject, however, and to the causes of such motions in plants, it will be necessary to return. For the present it is of importance to recollect that plants do not move at all in search of food.

The comparative simplicity of the life-processes of plants is in the main due to these two peculiarities. They are also, perhaps, the most fundamental attributes of plants as distinguished from animals. This subject is well worthy of our brief attention, since if its consideration should lead us to anything like a correct appreciation of the mode in which some of the simplest vegetal organisms differ from some of the simplest animal organisms, this insight may—apart from its own intrinsic interest—prove of the highest importance in regard to our present inquiry. It may enable us, in a measure, to comprehend why a Nervous System is absent from Plants, and why it comes into existence in Animals. It may help us further to comprehend why this nerve tissue gradually increases in complexity in ascending to more and more highly organized types of animal life.

* * * * *

In the present day it is commonly admitted that many of the lowest forms of life cannot positively be assigned either to the Vegetal or to the Animal Kingdom. Their characters as living things are not sufficiently specific or constant to enable us to say that they belong to one kingdom rather than to the other. In some of their life-phases such organisms seem to display the attributes of vegetal life, whilst in others those of animal life are no less pronounced. They constitute, in fact, an underlying indeterminate plexus of changeable and more or less related forms, appearing now as animals, now as plants—and they may give rise to descendants, or to a series of them, totally unlike themselves and their own immediate ancestors. Amongst such forms variability reigns supreme. These creatures of circumstance, which become metamorphosed in a most striking and apparently irregular manner, the writer has proposed* to include under the general designation of 'ephemeromorphs.' True 'species,' in the strict acceptation of the term, are not to be found amongst them.

Starting from this neutral and changeable ground, however, forms of life appear that habitually reproduce their like, either directly or indirectly; some of which are unmistakably members of the vegetal kingdom, whilst others are no less characteristic representatives of the animal world.

Owing to the frequency and rapidity with which transitions from vegetal to animal, or from animal to vegetal, modes of growth have been observed to occur amongst

* "Beginnings of Life," 1872, vol. ii. pp. 559, 571.

'ephemeromorphs,' we are compelled to believe that such passages from the one mode of molecular composition and activity to the other, may be determined without any great difficulty by internal chemico-nutritive changes, whether these latter have or have not been in part induced by external influences. Such transitions from vegetal to animal modes of life, or the reverse, are regarded by the writer as comparable with some well-known metamorphoses of form and nature amongst simpler kinds of matter.*

It is certain, as Prof. Graham showed, that one and the same saline substance may exist with its molecules now in the crystalloid and now in the colloidal mode of aggregation, according to the different influences under which it has been produced, or to which it has been afterwards subjected. This, for instance, is the case with silica, with the sesquioxides of chromium and iron, and with other mineral substances. On the contrary, it is also known that certain typical colloids may, under some conditions, be converted into crystalloids.

Again, transformations of a similar order, though of different degrees of complexity, are met with amongst saline and elementary substances, when these assume different 'allotropic' conditions. Well known illustrations of this kind of metamorphosis are met with in the different interchangeable states of carbon, of phosphorus, and of sulphur. The passage from one to the other allotropic state amongst these elementary substances may take place either with difficulty or with comparative readiness, though the ease and celerity with which analogous transformations are effected in the case of certain saline substances is still more interesting in its bearing upon the transformations of simple living units. No better instance

* "Beginnings of Life," vol. ii. pp. 38, 55, 82.

can be selected than the case of mercuric iodide, a substance well known to exist in two totally distinct crystalline forms which differ also in colour. Watts says—"The red crystals turn yellow when heated, and resume their red tint on cooling. The yellow crystals obtained by sublimation retain their colour when cooled; but, on the slightest rubbing or stirring with a pointed instrument, the part which is touched turns scarlet, and this change of colour extends with a slight motion, as if the mass were alive, throughout the whole group of crystals as far as they adhere together."

Thus, it would appear that the phenomena of allotropism and dimorphism, and the fluxes from the crystalloid to the colloid state and the reverse, are strictly comparable with the transformations from the vegetal to the animal, and from the animal to the vegetal, modes of growth so common amongst 'ephemeromorphs.' The members of the animal and the vegetal worlds may be regarded as self-multiplying and progressively varying products, resulting from developments which are continually taking origin from what may be regarded as different allotropic states of Living Matter.

* * * * *

Of the organisms appearing as constituents of the ephemeromorphic assemblage of vital forms, Amœbæ may perhaps be cited as the simplest types of unquestionably animal life; just as some of the smallest Confervæ or Moulds are amongst the simplest known forms of the vegetal type or mode of growth.

Confervæ or Moulds, after the fashion of plants generally, feed upon the inorganic elements existing around them either in water or in air; Amœbæ, after the manner of animals generally, feed upon matter which is either living or which has once lived. This difference between plants and animals in their mode of nutrition is so fundamental, so much depends upon it, that we shall find it worth our while to inquire a little more particularly how the departure from the more primordial mode of nutrition, met with amongst animals, can be accounted for.

If we examine some simple vegetal unit through a microscope—the germ from which a Conferva grows, for instance—we find it exhibiting no distinct changes of form; and, if unprovided with one or more vibratile filaments, it also shows no movements from place to place. It manifests no tendency to seize, nor has it any means of taking, solid food. As soon, therefore, as the changes incident upon the active growth of such a unit have ceased, the outer portion of its substance remains constantly in contact with the medium in which it lives, and shortly becomes modified. It condenses and is otherwise changed into an investing envelope, which commonly goes by the name of a 'cell-wall.' In the Amœba, on the other hand, we have an organism which, like the fabled Proteus, is for ever changing its form. It is composed of a clear jelly-like material, endowed with a superabundance of that intrinsic activity characteristic of animal life generally. Those internal molecular movements, indeed, which are inferred to occur to a marked extent in all living matter, seem to take place in it in a pre-eminent degree. Its whole substance shows a mobility of the most striking kind. It continually moves through the water or over surfaces, by alternate projections and retractions of its active body-substance.

Two consequences flow from this high inherent activity of the Amœba. In the first place, owing to the creature's rapid alterations in shape, no one portion of its substance is continuously exposed to contact with its medium, and, as a consequence, that first step in organization, above referred to in connection with the Conferva unit, does not take place. So long as the Amœba remains in full vigour and constantly changes its shape, a cell-wall cannot be formed.

Secondly, during the movements of the organism from place to place, portions of its projected body-substance come into contact with other more minute organisms, such as unicellular algæ and diatoms, or with small portions of organic refuse, and these are oftentimes drawn into its interior when the projections with which they are in contact are retracted. The activity of the Amœba and its allies is excited by contact with matter of this and of other kinds, though inorganic fragments are subsequently rejected.

The surplus inherent activity of the Amœba being, therefore, one of the immediately determining causes of its absorbing solid food, may also be regarded as one of the causes of its departure from the more elementary mode of nutrition met with amongst the simpler or less vitalized organisms from which it has been derived.

A word, however, is required as to the 'selective' power which the Amœba seems to manifest.

A magnet 'selects' minute fragments of iron or steel from any heap of heterogeneous particles containing such matter with which it may be brought into contact. Certain plants, also, such as the Sun-dew and the Venus fly-trap, 'select,' and seem capable of discriminating, nitrogenous from other substances with which they come into contact. The leaves of these plants, however, possess no nervous tissues of any kind; so that the fact that they seem to 'select' nitrogenous substances merely implies the existence of some relation between the molecular composition and activities of the leaves and those of such substances—by virtue of which mutual contact keeps up a state of excitation in the tissues of the plant. Similarly, there must be some definite molecular relation between a magnet and pieces of iron or steel, leading to their 'selection' whenever they come within certain degrees of proximity. In the latter case we have, unquestionably, to do with problems of molecular physics; and in the case of the affinity which seems to exist between the nerveless Amœba and the organic fragments or minute living things which it absords as food, we probably have to do with an allied problem. There may be differences of degree, but none of kind; all must be included as problems of molecular physics.

At any rate, be the cause what it may, the coming into contact of a fragment of organic matter with projected portions of the substance of an Amœba is followed by the closure of this mobile substance round it. The organic mass is gradually drawn into the interior of our Proteus, where, after being thus appropriated, it slowly disappears by a rudimentary process of 'digestion.' After feeding, in this way, and assimilating the organic matter taken into its interior, the Amœba rapidly increases in size, and perhaps still continues its active movements. Or, as happens at other times, its movements may cease: the creature grows sluggish from over-feeding, and then, as a consequence of its motionless condition, its outer layer soon becomes differentiated into a cyst-wall.

Simple as this mode of nutrition may appear to those who are familiar with it, its initiation in the Amœba is followed by consequences of the most profound importance. The assimilation, after such a fashion, of already elaborated organic matter is strongly calculated to increase that high degree of vitality which originally led the organism to take in solid food. This mode of nutrition, in fact, entails a liberation within the organism of much of the molecular motion which was potential in its food; and molecular motion thus liberated becomes a cause of further active movements in the organism—provided its constitution is, at the time, able to accommodate itself to such powerful internal causes of change. Where it is not in such a condition the assimilation of much solid food is followed by an interval of apparent rest, during which a thorough re-adjustment of the molecular constitution of the organism occurs. In the latter case the encysted mass of living matter may after a time divide into a swarm of smaller though most active Monads. Or else traces of higher organization may reveal themselves in the encysted mass as a whole—so that the previous Amœba shortly emerges from its cyst as an active creature of larger size and higher type.

Ciliated Infusoria, Rotifers, and other forms of animal life of different degrees of complexity, may take origin in such encysted masses of protoplasm, forming the resting stages of previously active Amœbæ.* The extent to which this occurs, however, and the real significance of the processes, are subjects upon which all naturalists are far from being of the same opinion.

Be the interpretation, however, what it may, the fact remains that Ciliated Infusoria, Rotifers, and other organisms may be seen to develop directly from encysted matrices of vegetal or of Amœboid origin. Nay more, any forms of the animal series thus initiated exhibit, in an even more marked degree, the fundamental properties of the Amœba—the power, that is, of executing well-marked independent movements and of feeding upon solid food. And as channels for the reception of such food become more and more formed, we may find the organ-

* "Beginnings of Life," vol. ii., chaps. xxi. and xxii.

ism's increasing powers of movement more definitely ministering to this capacity. Its motions, instead of being wholly at random, show more and more signs of purposiveness—they become, to an increasing degree, subservient to the capture of food.

Look, then, at the differences already indicated both in grade of organization and mode of life, by virtue of which even the simpler kinds of animals become strikingly unlike vegetal organisms.

The unit of vegetal life before it has attained any great size exhibits, by reason of its lower degree of inherent activity, a tendency to undergo the first stage of organization, that is, to develop a cell-wall which imprisons the more active living matter within and causes it to undergo certain secondary modifications. Before this occurs, however, the vegetal unit, if it does not divide, may segment or bud; the bud grows into a unit similar to its parent, and this in its turn may also segment or bud. By repetition of such a process motionless cellular organisms are produced, which, though presenting almost endless differences in form and in the ultimate arrangement of their units, are in the main composed of mere aggregations of similar parts—these being not solid units of protoplasm, but mostly vesicular elements, in which a cavity filled with fluid contents is bounded by a layer of protoplasm and outside this by an inert cell-wall. We may have, in the more simple combinations, long strings of such elements forming cellular filaments, as in the Confervæ and other thread-like algæ; or we may have flat cellular expansions, such as exist and brighten many a rock pool, in the rich green fronds of Ulva. Organisms like this present us with life changes of extreme simplicity. If they move it is because they are swayed to and fro by the elements. They require not to seek their food, since the inorganic materials and simple compounds sufficing for their nutrition habitually exist around and in contact with them.

On the other hand, in animal organisms next above the Amœba—such as the various forms of Ciliated Infusoria and Rotifers—well-marked powers of locomotion are displayed, and we have to do with creatures which, if they do not 'seek,' at all events seize and swallow solid food. We find in the latter of these forms of pond life, distinct channels through which food is taken in and absorbed; we have glandular structures of various kinds; we have organs of locomotion, internal and external. Thus, though we have not yet been able to detect with any certainty even the rudiments of a nervous system, the grade of vitality of these animal organisms must be at once admitted to be notably higher than that of plants. The degree of correspondence existing between such creatures and their surroundings is already much more varied than that existing between vegetal organisms and their medium; and this kind of complexity of relation steadily increases in animal organisms only a little higher than those to which we have already referred. Their responses, moreover, to the varied external influences to which they have become amenable are effected by movements direct, rapid, and comparatively complex—the motions themselves being brought about by muscular contractions, partly simultaneous and partly successive, and mostly occurring in groups which are definitely related to different external impressions. Reference to a few of their common muscular actions will illustrate this.

Conjoined movements of the head and its appendages are needed for the seizure of fragments serving as food; and these motions must be followed by certain others in the upper parts of the alimentary canal before the morsel that has been captured can be swallowed. A series of movements of this kind may occur in response to some touch upon the external surface of such an organism; and, after a rudimentary sense of sight has once been established, impressions produced by an object not in contact may lead to complex locomotions in pursuit, followed by others for capture, and others again for the swallowing of food or prey. The sight of a different object may, however, lead to movements of flight rather than to those of pursuit. The organism may hasten away, to avoid a possible attack—since in the past this kind of experience may often have followed the appearance of a similar object.

Again, the process of digestion in such animal organisms is aided by certain accessory glandular organs, whose activity is stimulated by the contact of food with different portions of the alimentary canal. Absorption of the products of digestion is either simple and direct from the alimentary canal into some general body-cavity whose fluid comes into contact with most of the organs; or it takes place through definite channels, and empties itself into a circulatory system proper in which blood is propelled throughout the body by means of a contractile heart containing one or more chambers. Glands also exist whose office it is to modify the constitution of the blood. There may be either gills or lungs to renovate it by contact with oxygen and to get rid of effete products—though in this latter function the organs of respiration are powerfully aided by renal and other emunctories.

All these are functions having to do with the preservation of the life of the individual, though another set of activities also come into play in animals that have attained a grade of organization of the kind to which we are referring. These new activities pertain to the sexual function—

leading to the union of male and female, the begetting of young, and the consequent perpetuation of the species.

Thus it may be dimly gathered how complex the relation of the animal organism to its environment soon becomes, and also what an amount of interdependence is established between the actions of the several parts or organs of the animal economy. The contrast between the animal and the vegetal organism in both these respects becomes most marked.

It is during the establishment of the complex relations above indicated between an animal and its environment, and between the several parts or organs of an animal, that nervous tissues first take origin, develop, and subsequently increase in complexity. How and why this should be may become a little more plain after a brief consideration of the nature of simple nervous functions and structures, and after some reference to the manner in which these increase in complexity, not only in the individual but (by virtue of the principles of heredity and 'natural selection') during the life of that succession of individuals constituting the race or 'species' to which the organism belongs.

From what has been already said it will be seen that the preliminary conditions necessary for the initiation of a Nervous System are, first, the existence of a living substance whose excitability is high; and, secondly, the possession by such substance of a well-marked contractile power. This statement carries with it the implication that the living matter in which a nervous tissue is to develop must not, in the first place, subdivide itself very minutely into separate units; or, at all events, that it must not become differentiated into cells with fully developed cell-walls. Much of the substance of the organism, if not comparatively structureless, must be composed of plastic units of living matter, not marked off from one another by definite and lowly vitalized cell-walls.

The vegetal mode of growth is, therefore, as already indicated, precisely of such a kind as to unfit it in an eminent degree for developing any notable power of appreciating varied external impressions and yielding immediate and discriminative responses thereto.

The nearest approach to such powers and actions in the vegetal world is met with amongst the so-called "Insectivorous Plants," upon whose peculiarities Mr. Darwin has lately given us much information. If we dwell for a few moments upon these highest manifestions of the kind known to occur amongst plants, the reader may the better comprehend the great gulf which separates the vegetal from the animal world in regard to their respective powers of discrimination and motor response.

When the three hair-like projections on the upper surface of the leaf of the Venus fly-trap are touched, they almost instantly communicate a stimulus to the cells on each side of the mid-rib, whereby some change is induced in them, and the two halves of the leaf are made to approach one another. The nature of the change has not yet been fully ascertained, though the evidence adduced by Darwin seems to show that it is, at least in part, due to the contractility of the cells above mentioned. A similar influence appears to be transmitted from the glands that tip the hair-like projections fringing the leaves of the Sun-dew, to certain cells near the base of these bodies, whereby motion is produced. In this latter plant, a very appreciable interval occurs between the time of irritation and the answering movement. Mr. Darwin has never known the interval to be less than ten seconds, though even in the one case in which it took place so rapidly as this, two and a half minutes were needed for the hair, or 'tentacle' as it has been termed, to move through an angle of 45°. As a rule, the rate of movement is even much slower. The stimulus which provokes movement may come to the base of a marginal tentacle either from its own sensitive tip, or by radiation from some of the shorter hair-like projections near the centre of the leaf whenever their terminal glands have been excited by contact with a foreign body.

The transmission of a stimulus from one of the glands tipping a marginal tentacle in the Sun-dew, to certain cells near its base, though consisting only of molecular movements, becomes in a manner visible, owing to the fact that during its passage the protoplasm within the cells of the tentacle undergoes certain obvious changes. Protoplasm previously in a state of uniform diffusion throughout each cell, is caused to aggregate into masses of different size and shape as the invisible wave of molecular movement passes through it. This 'aggregation' is therefore a visible sign marking the passage of the invisible stimulus. And as Darwin points out, the phenomenon is analogous in certain respects to that which occurs when, after stimulus, an invisible molecular change traverses a nerve in an animal organism.*

The same observer has discovered that the chief delay in the transmission of the stimulus along the tentacle of the Sun-dew is caused by its having to traverse the successive cell-walls which lie across its path. At each barrier of this kind an appreciable retardation occurs, as is evidenced by the interval that elapses between the completed aggregation in one cell and the commencement of the process in the protoplasm of that which stands next

* "Insectivorous Plants." 1875, p. 63.

along the line traversed by the stimulus. It has been found that a stimulus radiated from the centre traverses the leaf in a longitudinal more rapidly than it does in a transverse direction—a circumstance apparently to be explained by the fact that, in the longitudinal direction, owing to the elongated shape and disposition of the cells, the stimulus has to pass through a smaller number of obstructive cell-walls.

The irritability and answering movements just described are, however, altogether exceptional events in plant life; more especially if we refer, as at present, only to cases where there is reason to suppose it possible that the movements are in part due to contractility, rather than to mere disturbance of tension in some of the cells—movements of the latter order being not unfrequent in stamens, seed-pods, or other parts of plants. Yet even in these plants, where contractility appears to exist to a more marked extent than in any other known members of the vegetal kingdom, there is no development of a specialized contractile tissue, and still less is there an appearance of any nerve fibres along which the molecular disturbance constituting the stimulus may be transmitted. The obstacles opposing the passage of the stimulus, to which reference has been made, would indeed also tend to impede the formation of a special tissue along the line of discharge.

In Animal Organisms, however, we have a highly impressible and very active variety of protoplasm, the units of which, particularly as met with in the lowest forms of animal life, do not go on to the formation of a distinct cell-wall, and are for the most part aggregated into mere semi-fluid or gelatinous tissues capable of transmitting vibrations in different directions with the greatest ease.

This is the case, for instance, in Medusæ, which are perhaps the lowest animals in whom a nervous system is met with. The recent investigations of G. J. Romanes* in regard to this subject are particularly interesting, because they seem to show such a system actually in process of evolution. The contractions of the bell-shaped swimming disc of common Medusæ must be familiar to most dwellers by the seaside, and we now learn that this part is lined internally by a very thin layer of highly contractile protoplasm, not yet presenting the definite characters of muscle. We learn also that this contractile layer is permeated by a network of incipient nerve fibres, in connection with rudimentary ganglia, near its free margin. The degree of irritability of these altogether elementary animal tissues, and the rate at which stimuli traverse them, is alike remarkable, and far ahead of what may be met with in the plants in which analogous changes are most marked,—such as the Venus fly-trap or the Sun-dew.

According to Romanes the molecular discharges issuing from a single rudimentary ganglion, in the swimming bell of a large Aurelia weighing thirty pounds, were sufficient to incite vigorous contractions throughout the whole mass —though this mass weighed 30,000,000 times as much as the ganglion itself. When all the ganglia have been removed, he has found that a wave of contraction, starting from any part of the disc which is touched, will travel equally in all directions at the rate of a foot and a half per second, so that the contraction of the whole bell is practically simultaneous—and therefore, in marked contrast with the very slow bending of the irritated tentacle of a Sun-dew.

Thus the preliminary conditions already asserted to be necessary for the initiation of a nervous system are here present to a well-marked degree, and in notable contrast

* "Phil. Trans.," Part I., 1876.

to what obtains amongst the members of the vegetable world.

As to the mode by which, in Medusæ or other low types of animal life, the first rudiments of a nervous system are evolved, only a few brief statements can be made. On this subject inferences have only too often to take the place of positive knowledge. Fortunately, however, the data on which such inferences may be based are now fairly well established, thanks more especially to the writings of Herbert Spencer*—whose speculations on this subject have been to some extent confirmed by the recent investigations of Romanes and Eimer.

In the lower forms of animal life, we have to do with a body substance composed, as already stated, almost wholly of undifferentiated protoplasm. This substance, if not 'sensitive' in the strict sense of the term, is highly impressible—or capable of receiving a stimulus—and is also highly contractile. But neither the impressibility nor the contractility of the protoplasm in lower forms of animal life is localized—both properties are, so far as they exist, uniformly possessed by all parts of the organism. In some of the larger Ciliated Infusoria, in Gregarinæ, and in the hydroid Polyps, distinct rudimentary 'muscles' become differentiated, and such tissues are, moreover, now known to exist in many other organisms in which no traces of a nervous system are to be found. Muscular tissue, therefore, makes its appearance before nervous tissue, and it becomes developed in those situations where the protoplasm is stimulated to undergo frequent contractions.

It is, in fact, one of the most fundamental truths in biology that the performance of functions, or, in other

* "Principles of Psychology," vol. ii. p. 69.

words, the occurrence of actions of any kind in living matter, tends to occasion structural changes therein. Such a fact is implied in the common statement that living matter is an organizable matter. We suppose nothing unusual, therefore, when we imagine that frequently recurring contractions in any one portion of living protoplasm will almost certainly lead to a structural change therein. And, further, we are warranted in supposing that such structural change will be of a kind to favour the occurrence of the actions by which it has itself been produced—that is, that the modified protoplasm will be more highly contractile than the original protoplasm from which it has been produced.

But what, it may be asked, is the cause of these locally recurring contractions, the occurrence of which is supposed eventually to lead to the production of muscular tissue? Contraction so invariably follows upon stimulation, that we may safely say the cause in question can be no other than the incidence of certain stimulations—and we probably shall not be very far wrong if we suppose that these result from, or take their origin in, shocks or other physical impressions upon definite though related parts of the external surface of the organism. Its form or its mode of progression by cilia may lead it to come into contact with external objects most frequently by some particular part of its surface, and such local shocks produce waves of molecular movement, which pass more especially in some one or more directions and act as stimuli.

It is pretty certain that impressions or shocks made upon protoplasm, or even the incidence of physical agents such as light or heat, liberate molecular movements therein, and that these molecular movements may be transmitted from their point of origin through it in all directions. Yet it occasionally happens, owing to the shape of the part struck, or owing to the fact that an impression made upon one region—say a tentacle—is usually followed pretty quickly by a second impression made by the same moving object upon another surface region, that an impression or stimulus comes, as Herbert Spencer points out, habitually to traverse a certain path. Much of the molecular motion consequent upon the 'stimulus' is drafted along this path. This being so, the stimulus necessarily tends to excite contractions in particular parts, and thus leads to the differentiation of the protoplasm of such parts into the more or less definite Muscular Tissue found in some of the lowest animal organisms.

This, however, is not all. The localization of the path of the stimulus leads to structural results of another kind. Whenever external impressions produce molecular movements which traverse with frequency some definite path, the transference of such movements is made easier by each repetition, and there is a tendency to the initiation of a structural change along this path. Just as the frequent repetition of contractions in certain parts of the protoplasm leads to the production of distinct muscular tissues, so the frequent passage of a wave of molecular movement along a definite track through protoplasm or through juxtaposed plastides, leads to the differentiation of the protoplasm thus acted upon. At first the actual structural change may be unrecognizable, although a 'line of discharge' may have become established along which impressions are habitually transmitted with ease, as seems to be the case with the majority of Medusæ. Ultimately, however, by the constant repetition of such a process, we should have the gradual formation of an actual 'Nerve Fibre'—this being a tissue element whose special use and duty is to transmit molecular movement, and which may be seen in its earliest form as a barely recognizable structure in Sarsia.*

From all this it would appear that the primitive ' nerve fibre' is a structure serving to connect impressions made upon the exterior of the organism with certain responsive muscular contractions quickly following thereupon. This is perfectly true, though only part of the truth.

The path taken by stimuli from impressible surfaces to muscles is not generally the shortest and most direct route. In the great majority of organisms these paths are more or less bent upon themselves. Those for ingoing impressions may run nearly parallel with one another towards some central situation; and thence they may be distributed to muscles in various parts of the body—some of these being perhaps not very distant from the surface stimulated. In the latter case the track of the stimulus wave is found to be bent at an acute angle, or ' reflected.'

Fig. 1.—Different kinds of Nerve Cells. (Magnified about 350 diameters.)

At the turning point or ' nerve centre,' whence impressions are distributed outwards in various directions to muscles, what are called ' Nerve Cells ' become developed.

* Since the above was written and in type the observations of Schäfer (Proceed. of Roy. Soc., January, 1878), and of O. and R. Hertwig, have revealed the existence of distinct nerve tissues in several species of Medusæ.

These bodies are interposed so as to constitute part of the actual path of the stimulus wave, and accordingly, they may be, in effect, junctions for ingoing impressions or dividing stations for out-going impressions. The matter composing them seems to be endowed with extreme molecular mobility. It is owing to the multitudinous combinations of these bodies with one another, and with ingoing and outgoing fibres, in modes which will be sketched in the next chapter, that the complex work of the nervous system is enabled to be carried on.

Nerve tissue, in the lower forms of animal life, is essentially subservient to the bringing about of movements in more or less immediate response to external shocks or other localized impressions, or of movements and glandular activity as a result of impressions upon internal surfaces. These various movements gradually become more definitely related and appropriate as responses, in proportion as the organism becomes better able to discriminate the differences between the several kinds of impressions made upon different parts of its surface.

Even amongst Medusæ definite responses to stimuli are occasionally met with. Thus in the hemispherical Tiaropsis, from the inside of which hangs a long funnel-like body or polypite, this structure, as Romanes says, is found to be capable of "localizing with the utmost precision any point of stimulation situated in the bell. For instance, if the bell be pricked with a needle at any point, the polypite immediately moves over and touches that point. . . . If immediately afterwards any other part of the bell be pricked, the polypite moves over to that part, and so on." From this it may be concluded "that all parts of the bell must be pervaded by lines of discharge, every one of which is capable of conveying a separate stimulus to the polypite, and so of enabling the polypite always to determine which of the whole multitude is being stimulated. . . . It is no doubt a benefit to this Medusa that its polypite is able to localize a seat of stimulation in the bell; for the end of the polypite is provided with a stinging apparatus, and is, besides, the mouth of the animal. Consequently, when any living object touches the bell—whether it be an enemy or a creature serving as prey—it must alike be an advantage to the Medusa that its polypite is able to move over quickly to the right spot, in the one case to sting away the enemy, and in the other to capture the prey."*

It is, in all probability, the delicate impressions produced by contact of the sea-water with the surface of the organism, acting through the intermediation of the rudimentary ganglia near the edge of the swimming-bell, which tend to incite its apparently 'spontaneous' movements. At all events, when these little bodies are removed the habitual rhythmical contractions of the swimming-bell cease, and a single stimulation of any portion of the bell is then followed by a single contraction. The contrast between the behaviour of such an animal and one which is uninjured, is very striking.†

Multiply the kind of correlation above typified, and it may be seen that as organisms, or their descendants, increase in their ability to discriminate different impressions made upon them from without, so will there grow up muscular responses suitable to each. And the structural modifications, or 'tissues,' through the intervention of which any of these impressions, discriminations, and responses are rendered possible, are no more isolated from others which the creature is capable of receiving or making,

* "Nature," vol. xvi. p. 290. † Loc. cit., p. 289.

than is any one cause of impressions isolated from others with which it may be associated in the complex web of external occurrences. Each acquirement serves as a stepping-stone to the next, and each new response is made easier by those previously rendered possible. In this way the correspondence between the organism and the outside world gradually becomes, as Herbert Spencer has urged, both more precise and more complex. By slow degrees a more and more harmonious relationship between the two is brought about, the degree of complexity of which we are left to gauge, principally by an estimation of the character of the movements executed in relation to the stimuli from which they immediately or remotely proceed. We have at first to do with mere simple 'reflex' actions; in higher forms of life some of these actions increase so much in complexity as to become worthy of the name 'instinctive'; whilst in still higher organisms we have what are called 'intelligent' actions in increasing proportion, though always intermixed with multitudes of others belonging to the 'instinctive' and to the 'reflex' categories.

CHAPTER II.

THE STRUCTURE OF A NERVOUS SYSTEM—NERVE FIBRES, CELLS, AND GANGLIA.

The Nervous System in all higher animals is composed of nerve fibres and nerve cells, together with an intermediate basis substance in those parts where the latter units are principally clustered together. The whole forms a continuous tissue, variously arranged and distributed through the bodies of animals, and differing notably in its development in accordance with the complexity of organization of the creature of which it forms part.

In all animals a certain order or plan is, however, recognizable in the mode of arrangement of the typical elements of the nervous system. Thus, without exception, we find ingoing nerve-fibres proceeding from sense organs, or from other sensitive parts, to groups of nerve cells more or less freely connected with one another in some 'nerve centre.' These cells are, in their turn, connected with another set of inter-related nerve cells, situated either close to or at a distance from the first; and from this second group of cells a set of outgoing nerve fibres proceed, which are distributed to muscles or to glands in various parts of the body. Nerve elements so arranged constitute the functional units of a nervous system. This is the kind of mechanism by means of which 'reflex actions' are brought about; and these form the groundwork of all simple modes of nervous activity. By an indefinite multiplication of such combinations of nerve units, variously arranged, stimuli or impressions (represented by molecular movements) are conducted from the various sensitive surfaces or parts of the body to related nerve centres, and are thence reflected so as to rouse the activity of related muscles or glands.

The groups of nerve cells above referred to, together with some portions of their related fibres, are usually aggregated so as to form distinct and separate nodules known as 'ganglia.' Those in connection with ingoing (or affe-

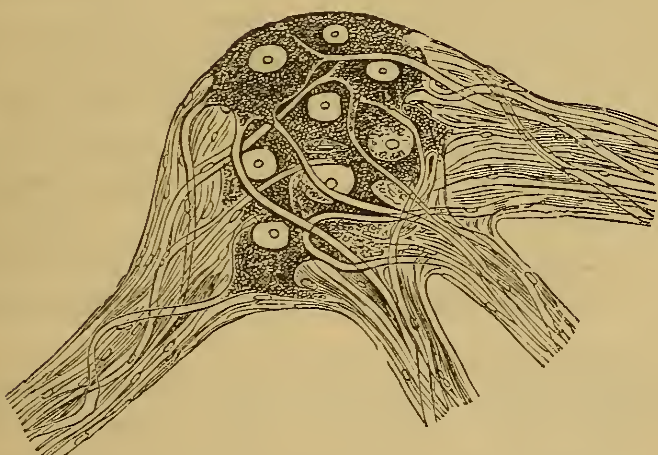


FIG. 2.—Small Sympathetic Ganglion (Human) with Multipolar Cells. Magnified about 400 diameters. (Leydig.)

rent) fibres are commonly spoken of as 'sensory ganglia,' whilst those which lie at the roots of outgoing (or efferent) nerves are known as 'motor ganglia.'

Two or more sensory ganglia, or two or more motor ganglia, may grow together into a single mass; or what is equally common, a sensory and its corresponding motor ganglion, or two or more pairs of these, may fuse into a single larger nodule, which may be called a 'nerve centre.'

The term ganglion is, however, commonly applied to any round or ovoid nodule containing nerve cells, whatever its size or degree of internal complexity. Many ganglia in lower animals, which are typically deserving of the name as regards mere form and separateness, are also, by reason of their compound nature, true nerve centres. The two terms are, therefore, to a considerable extent, interchangeable.

Fusions of ganglia may occur during the development of some animals, especially if they pass through distinct phases of existence, as with Insects (figs. 39–41). Similar changes are also presumed, by believers in the doctrine of evolution, to occur during the development of the race, since in many highly organized animals we may find a large compound ganglion in the place of, and doing such work as falls to, two or more smaller separate ganglia in simpler members of the same class of animals—for example, in different forms of Crustacea (figs. 34–36). This kind of fusion or coalescence of primitive ganglia attains its maximum in the brain and spinal cord of vertebrate animals.

From their naked-eye appearances nerve tissues are commonly divided into 'grey' and 'white' matter. The grey matter of the nervous system is, for the most part, ganglionic tissue, in which nerve cells are more or less thickly clustered. The white matter, on the other hand, such as we find in the brain and spinal cord, is composed of an aggregate of nerve fibres. These tissues are of a soft pultaceous or semifluid consistence, and are composed, in the main, of water, of phosphoretted fats, and of protein compounds. The amount of water varies from 75 to 85 per cent. It is more abundant in the grey than in the white matter; more abundant in lower than in higher animals; and it likewise forms a larger proportion of the nerve tissues of younger animals than of those in whom the nerve centres are more fully elaborated. The chemical compounds, entering into the constitution of nerve tissues, are also extremely complex and very unstable. Thus, both from their physical and chemical composition, it is thought that waves of molecular movement are easily initiated in and easily propagated through nerve cells and fibres. Whether these molecular 'waves' or 'currents' in nerve tissue are brought about by virtue of mere isomeric changes or by actual decompositions occurring in their substance is, for the present, extremely doubtful.*

Our knowledge of the exact arrangement of the anatomical elements of nervous tissues, as well as of their modes of development, is as yet merely in its infancy. We have much to learn concerning the actual relation of fibres and cells, and their different modes of continuity; our knowledge of the structural relations existing between different centres in higher animals is most incomplete; and, concerning the various kinds of peripheral nerve endings, much doubt and uncertainty also prevail. The more difficult questions touching nerve evolution and development are proportionately further from their ultimate solution.

But, whatever the precise mode in which the nerve cell is originally evolved in the race, or developed in the embryo of any particular animal, it is perfectly certain that many of these bodies are subsequently found in organic continuity with nerve fibres and with one another; so that (whatever other function they may fulfil) nerve cells would seem to form meeting-points or termini, in which different nerve currents arriving at and passing through clusters of such bodies, may be brought into relation with one another, and whence they are certainly capable of being diverted into new directions.

* Spencer, "Principles of Psychology," vol. i. p. 20.

Without entering upon any discussion as to the differences existing between the nerve elements of higher and of lower animals, and dwelling but briefly upon the many differences of opinion which exist in regard to the actual structure and relations of these elements, an endeavour will be made to give the reader some notions concerning their most probable arrangement—such notions as may enable him to comprehend the descriptions given in succeeding chapters of the different forms of the nervous system, as well as of the nature and mode of composition of that portion of it known as the 'brain', in various orders of animals till we come to man himself. In this way it will be possible for the reader who bestows an adequate amount of attention, to obtain a good insight as to the nature of some of the most definite and best-grounded notions, which are at present either actually held or warrantable, concerning the structure and functions of the 'Brain as an Organ of Mind.'

Nerve Fibres.—At their commencement near the internal and external surfaces of the body, and also near their endings in muscles and glands, nerves are represented by extremely fine, almost transparent 'fibrils' from $\frac{1}{60000}$th to $\frac{1}{100000}$th of an inch in diameter. These fibrils freely interlace with one another, so as to form minute loops and plexuses, and, within short distances, they often vary considerably in diameter (L. Beale).

Much might be written were we to attempt to discuss the various modes in which the fibrils commence or terminate, and their precise relation to other tissue elements in various parts of the body; but, in spite of the great interest attaching to these questions, they cannot be entered upon in this work. A slight reference to the subject is, however, made (p. 67) in the next chapter.

The ultimate bundles of elementary 'fibrils' are gradually aggregated into larger bundles, or 'fibres,' as they recede from their seats of origin or termination and approach the nerve centres with which they are in communication. These smaller bundles soon become enveloped in a very delicate membranous sheath (Schwann), whilst the component fibrils fuse more or less completely, so that the fibre appears either structureless (fig. 3), or merely shows signs of fibrillation. A little further on these still small fibres become enveloped by a layer of white semi-fluid 'medullary substance,' which lies beneath the membranous sheath of Schwann, and forms a white border to the nerve as it is seen on microscopical examination. Thus a *dark bordered, white,* or *medullated* nerve fibre is formed.

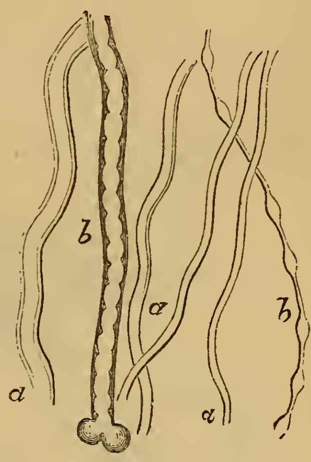


FIG. 3.—Human Nerve Fibres of different sizes (Kölliker).
a, a, a. Healthy fibres, the largest of which is 'dark-bordered.' *b, b.* Fibres altered by exposure. Magnified 350 diameters.

Such dark-bordered fibres are at first very slender; but by coalescence with others of the same kind larger fibres are produced (fig. 4), varying in man from $\frac{1}{12000}$th to $\frac{1}{2000}$th of an inch in diameter. The central portion of such a nerve fibre, viz., that lying within the white medullary sheath, is its most important constituent; it is almost translucent, and is known as the *axis band* or *axis cylinder.* In the perfectly fresh state it shows faint traces of fibrillation, but unless examined with care it may appear structureless, and yield no evidence to the microscopic observer as to its compound nature. Under the influence of slight traction, or by imbibition of water, these medullated nerve fibres speedily undergo change. They then not unfrequently assume an irregular or varicose appearance—

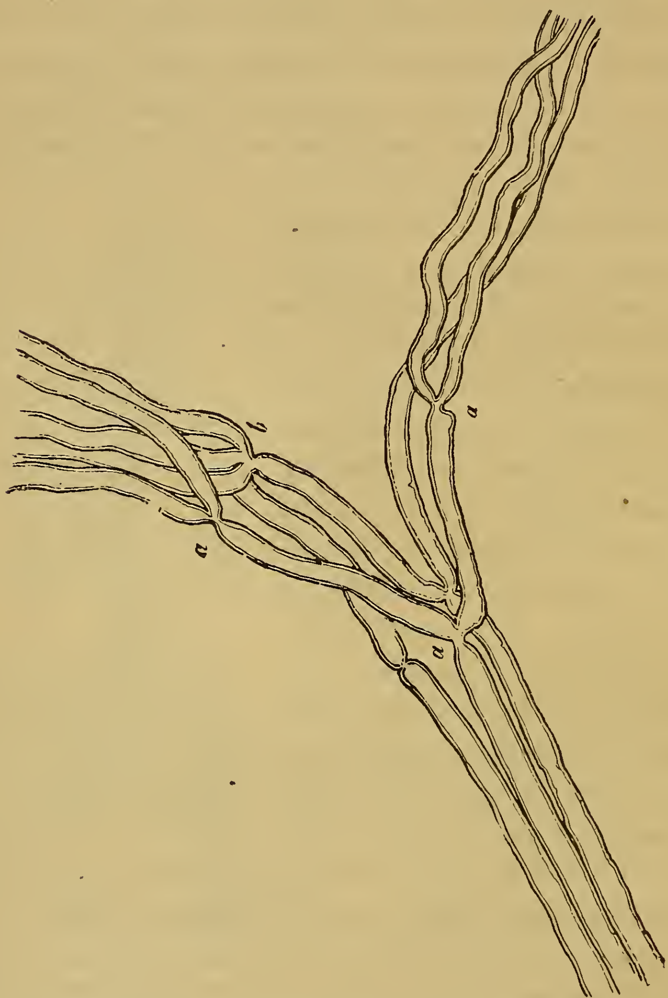


FIG. 4.—Small Branch of a Muscular Nerve of the Frog, near its Termination, showing divisions of the Fibres. Magnified 350 diameters (Kölliker). *a*, into two; *b*, into three.

principally owing to changes in the white medullary sheath (fig. 3, *b*, *b*).

The use of this white investing substance is not known.

It is absent from the peripheral extremities of the nerves, and it is absent also from their central extremities, at the points where the fibres approach or depart from the nerve cells. Both it and the membranous investing sheath have been of late ascertained to be regularly interrupted at comparatively short distances, so that such nerve fibres have the appearance of being constricted in these situations (Ranvier).

Nearly all visceral nerves, as well as the fibres of the olfactory and some others, do not possess this medullary sheath, to which the dead white colour of the great majority of nerve fibres is due. They are, therefore, semi-translucent or grey in tint, and are commonly known as the *pale*, *gelatinous* or *non-medullated* fibres (fig. 5). Their average thickness is about $\frac{1}{6000}$th of an inch; and they differ from the dark bordered fibres principally in the absence of the medullary sheath. They present a distinct appearance of fibrillation, are surrounded by a delicate membranous envelope, and the larger fibres are similarly formed by the running together of fibrils and smaller fibres.

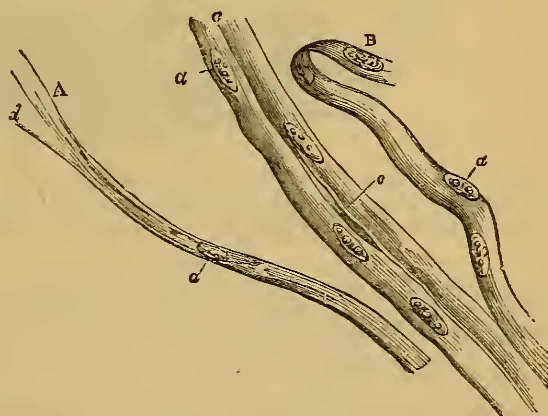


Fig. 5.—Gelatinous Nerve Fibres from the Calf (Henle). Magnified about 400 diameters. A, Fibre showing its constituent fibrillæ (*d*); *a*, *a*, Nuclei in membranous sheath.

Nerve fibres thus compounded, both dark bordered and pale, similarly tend to aggregate into cords or bundles of different sizes, the fibres of which run parallel to one another, and are invested by a sheath. These again, in their course towards the centre, collect into larger and larger bundles, the different elements of which are all bound together into one white trunk or 'nerve' (fig. 6), by means of a firm connective tissue envelope, which sends thinner investing prolongations in amongst the constituent cords.

These 'nerves' of various sizes frequently contain within the same bundle both ingoing and outgoing fibres, and are then known as 'mixed nerves'. Others contain only 'sensory', or only 'motor' fibres. In their course nerves often communicate freely one with another by

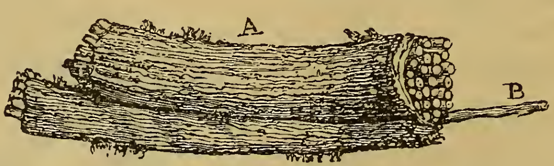


Fig. 6.—Portion of the Trunk of a Nerve, consisting of many smaller Cords wrapped up in a common Sheath (Quain after Sir C. Bell). A, the nerve; B, a single cord drawn out from the rest. Magnified several diameters.

means of branches. Such communicating branches are especially numerous in the course of the visceral nerves, and, when many occur amongst some particular set of cords, what is termed a 'plexus' is formed (fig. 7). In these plexuses the individual nerve fibres do not undergo division. Some of them merely leave one bundle or cord and pass to another, with the fibres of which they are ultimately distributed, either to muscles or to nerve centres.

The smaller medullated nerve fibres unite, so far as we know, only near their commencements, and the larger motor fibres only undergo bifurcation near their terminations in muscles or glands (fig. 4). The fibrils or elementary constituents of the fibres probably do not divide at all. They are to be regarded as single channels (however devious their course may be), along each of which separate stimulus-waves are capable of being transmitted. We can

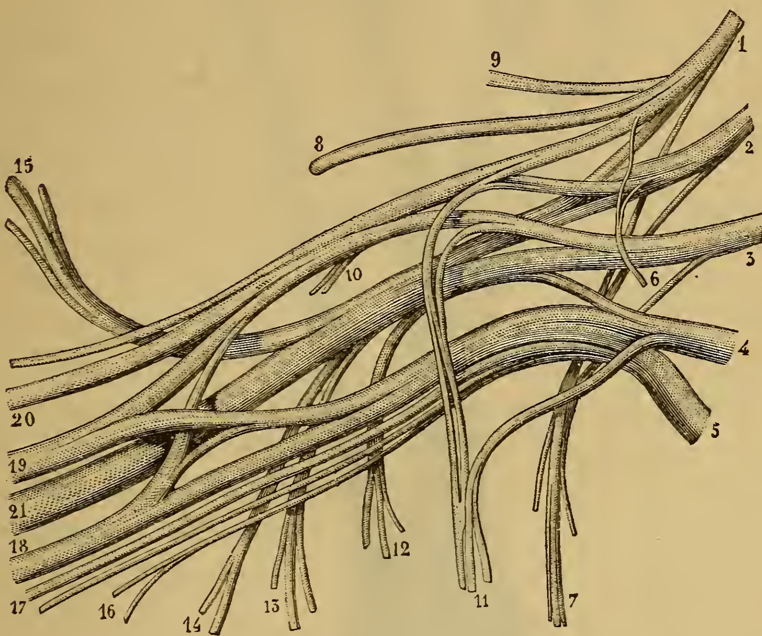


Fig. 7.—The Cervical Plexus, composed by interlacements of the last four cervica (1, 2, 3, 4) and the first dorsal nerves (5). The various branches (6–21) are distributed to the shoulder, arm, fore-arm, and hand. (Sappey after Hirschfeld.)

speak here only of probability, as this is a subject necessarily beyond the reach of actual observation.

Nerve Cells vary much in size and shape—the smallest being about $\frac{1}{3000}$th, whilst the larger may be $\frac{1}{300}$th of an inch or more in diameter. They are more or less granular bodies, each of which contains a large nucleus, and within this an unusually distinct 'nucleolus' (figs. 1 and 8). Near the nucleus a heap of yellowish or orange coloured pigment granules may often be seen. The substance of the cell is continued into two or many 'pro-

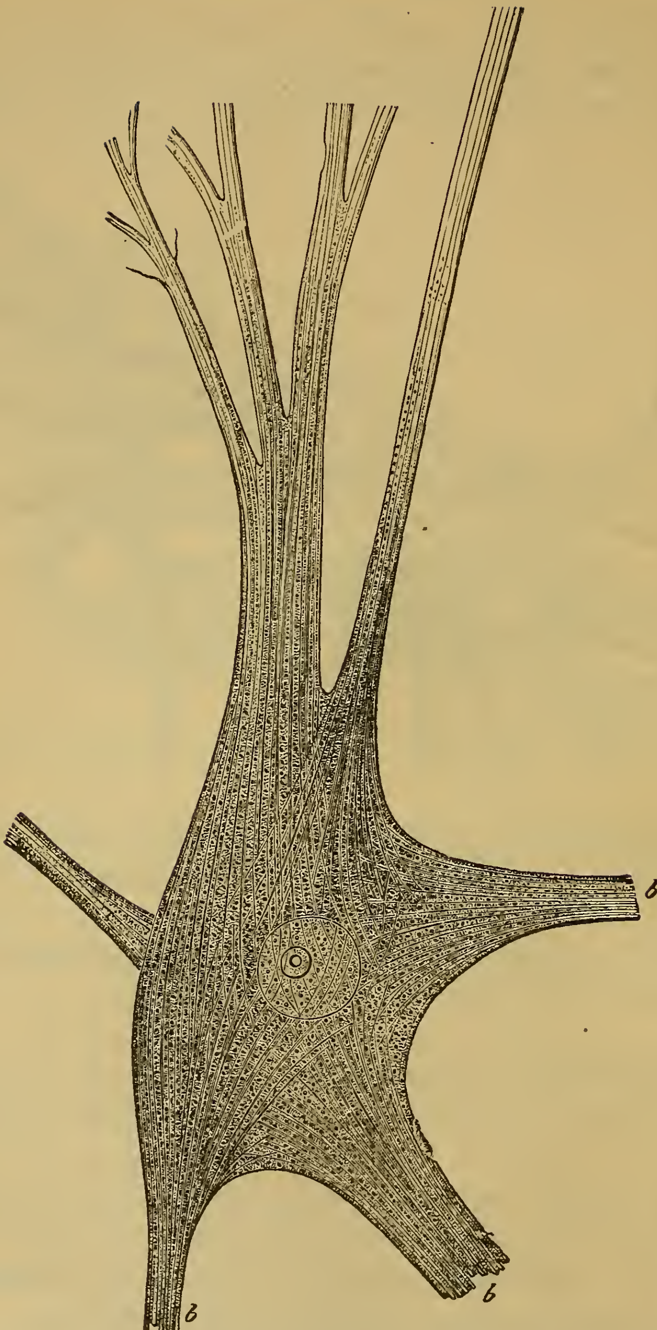


FIG. 8.—Ganglion Cell from anterior Horn or Cornu of Grey Matter in the Spinal Cord of a Calf. *b*, Processes abruptly broken off. *a*, The axis cylinder process. Magnified about 800 diameters. (Max Schultze.)

cesses,' which are either much branched (fig. 12) (ramifying processes) or simple. It is by means of these different kinds of processes that nerve cells are united to the central extremities of the nerve fibres and to one another. It is worthy of note that the substance, both of the nerve cell and of its processes, when examined under high magnifying powers can often be seen to be distinctly fibrillated in the same manner as the 'axis band' of a nerve fibre, with which, or with the ramifications of which, some of these processes are continuous.

If the fibrillations of the axis band, and of the nerve process into which it may be continued, correspond with functionally if not structurally distinct fibrils—that is, with separate paths for stimulus waves—so, in all probability, the fibrillations of the nerve cells will indicate as many distinct paths of stimulus waves through them in different directions. The appearances presented by the cells are quite consistent with this view (fig. 8). Fibrillations, for instance, can be seen passing from one nerve process in a curved direction through the body of the cell and into another process; whilst others in the same process can be followed through the cell in quite different directions. There is no difficulty in supposing that many nerve currents may pass through one of these compound nerve fibres, just as many electric currents might pass simultaneously through a single telegraphic or telephonic wire.

These fibrillations of the nerve cell are probably sequential to, and gradually differentiated in the course of, its functional activity. It is not unreasonable to expect that there would be a gradual marking out of the paths of habitual nerve currents, through the previously structureless though slightly granular substance of the nerve cell, during their passage from fibre to cell and from one of these bodies to another.

In accordance with this view, we should not expect to find in the majority of ganglion cells terminations or origins of such fibrils—whether in the nucleus or free in the body of the cell. If the fibrillations are the structural correlatives of nerve currents, they should be generally as continuous and unbroken as the latter, and just as devious, winding and irregular in their path.

We should scarcely look for free ends or beginnings to such fibrils elsewhere than at the periphery. And if the semblance of free ends are ever recognizable within the body of the cell, it will probably be in young cells in which the functional (and therefore the structural) current lines have not yet been sufficiently developed by constant repetitions. Much obscurity, however, still reigns in regard to all these matters. We do not, indeed, know definitely how far this kind of fibrillation of the nerve cells is general, and whether there may not be whole groups of them in which no such arrangement exists. It is quite conceivable that in some nerve centres, where 'spontaneity' of action appears to prevail (or, in other words, whence widespread and sudden irradiations of motor stimuli may emanate on slight provocation), we might have a different kind of action altogether. The nerve cells of such centres may approach nearer to H. Spencer's ideal, and be true 'libero-motor' elements.

The Neuroglia, or intermediate substance, exists most abundantly in the larger nerve centres, such as the Brain and Spinal Cord. It has been most commonly regarded as a comparatively insignificant connective tissue, though some few physiologists have always been willing, and even anxious, that it should be credited with higher developmental and functional capacities.

It is composed in part of minute corpuscles or cells, united to one another by means of a network of slender ramifying fibrils (fig. 9), and in part of an interspersed homogeneous or simply granular basis substance. It has been long known to contain some small branched corpuscles, almost indistinguishable from young nerve cells; and of late the much branched processes of many fully developed nerve cells have also been thought to have a structural continuity with this minute network of the neuroglia. If these observations are correct, portions of the 'intermediate substance' would often constitute part of the circuits traversed by nerve currents in their passage through the centres.

FIG. 9.—Portion of Neuroglia from the Spinal Cord. Open meshes are seen with small nuclei or cells at intervals, but at two places close lamelliform interlacements are shown. (Kölliker.) Magnified 350 diameters.

This intermediate tissue is, in short, the probable matrix wherein and from which new nerve fibres and new nerve cells are evolved in animals, of whatsoever kind or degree of organization, during their advance in reflex, in instinctive, or in intellectual acquirements. Some such process must take place, *pari passu* with the acquisition of new knowledge and powers, of all kinds and howsoever acquired: whether it comes, as in lower animals, from mere intercourse with natural phenomena; or, as amongst ourselves, from similar means, supplemented by individual application in the mastery of educational or professional pursuits and of all kinds of handiwork; or whether the new knowledge and powers come to us as a result of that more general education or 'experience' which is gained by daily intercourse with the pleasures, troubles, turmoils, and exertions inseparable from social life. The acquirement of new powers or accomplishments must correspond either with more or less alteration of old, or with the development of new structures, in one or more of the various nerve centres.

The Structural Relations of Nerve Cells with Nerve Fibres, and with one another.

Nerve cells are supposed to communicate with nerve fibres and with one another in the following modes:—

1. The nerve cell occurs as a round or elongated swelling in the course of a nerve fibre, as may be seen in figs. 10 and 11.

Here an undivided nerve fibre swells more or less abruptly into the nerve cell, and similarly emerges therefrom, so that the cell in this case is only a nucleated expansion of the fibre. The fibrils of the axis band may be seen passing through the cell in a divergent and re-convergent fashion, having the finely granular basis substance of the cell between them. The sheath of the fibre, though usually not the medullary substance (fig. 10), also passes over the cell.

A point which will be found more doubtful in other cases is most distinctly illustrated here: viz., that a structural continuity exists between the substance of the cell and that of the nerve fibre. There is no distinct line of demarcation between the two. But, so far as we know at present, this particular relation of fibre and cell exists principally in ganglia peculiar to the ingoing nerves and situated near the great centres to which these are attached. There is, it is true, some reason for believing that a similar relationship may exist in some of the ganglia on

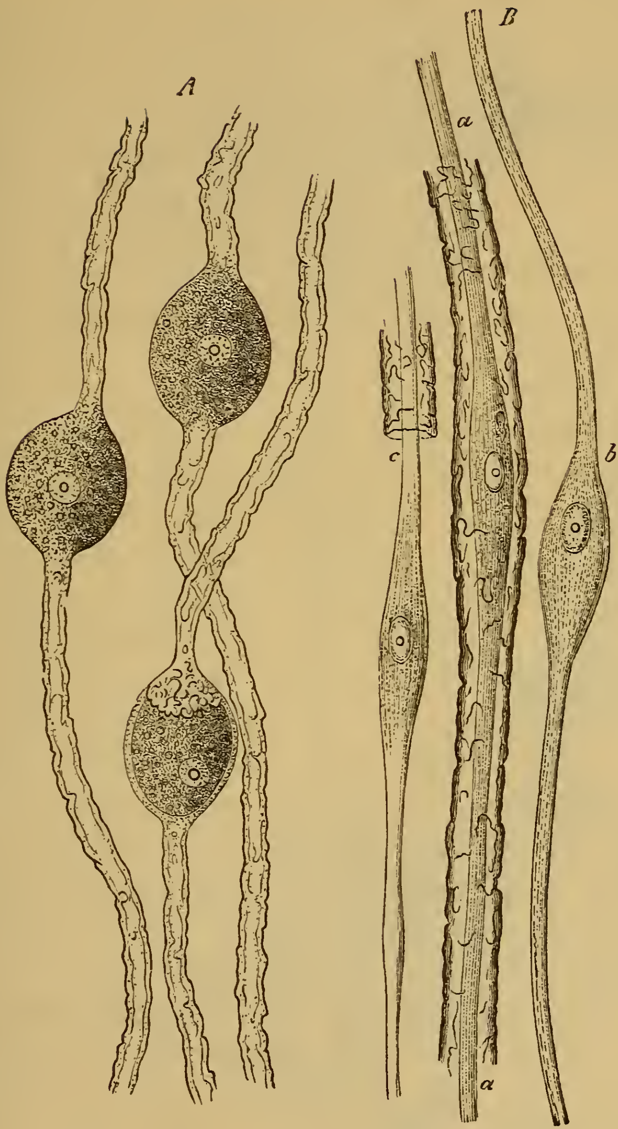


FIG 10.—Three bipolar Ganglion Cells from the fifth nerve of the Pike (Stricker after Bidder).

FIG. 11.—Three bipolar Ganglion Cells from the auditory nerve of the Pike : *a*, entirely enclosed within the medullary sheath ; *b*, entirely, and *c*, partially, exposed, to show that these ganglion cells are only expansions of the axis band.

the visceral nerves, and that something like it also exists,

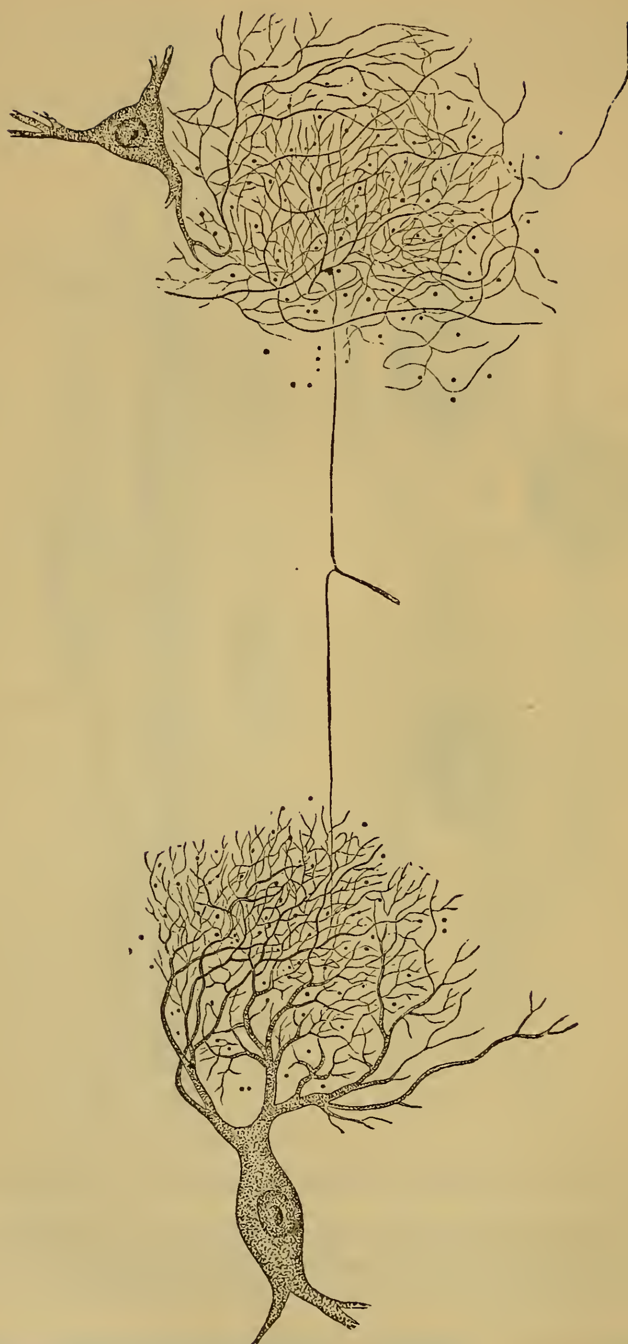


Fig. 12.—Division of a very slender Nerve Fibre, and communication of its branches with a plexus of fibrils in connection with the much-branched Processes of two Nerve Cells. From Spinal Cord of Ox. Magnified 150 diameters. (Gerlach.)

though on a much smaller scale, in the course of ultimate peripheral nerve fibres (Beale).

2. The ingoing nerve fibre, on subsequently reaching its centre, divides into its elementary fibrils, and these become structurally continuous with a fine network of fibrils (Gerlach) forming the rootlets of ramifying nerve processes belonging to one or more contiguous nerve cells (fig. 12).

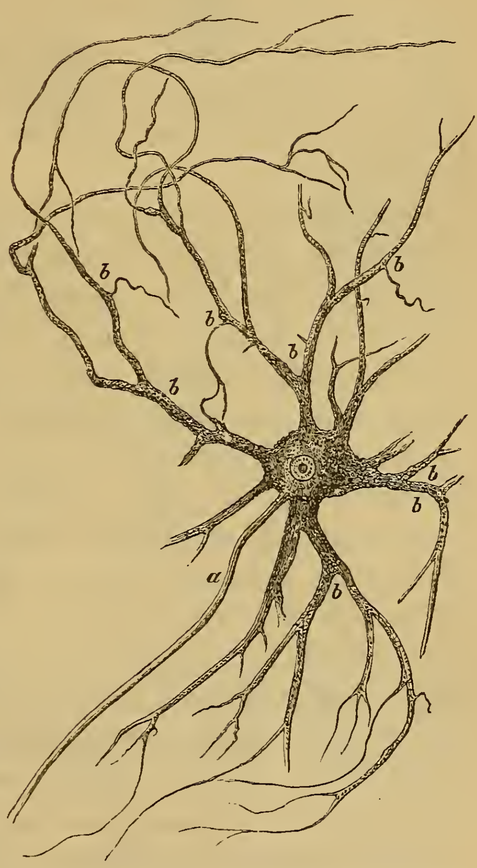


FIG. 13.—Multipolar Ganglion Cell from anterior grey matter of Spinal Cord of Ox. *a*, Axis cylinder process; *b*, branched processes. Magnified 150 diameters. (Deiters.)

This kind of connection is thought to exist not only in the spinal cord, but also in the superficial grey matter of the brain (both cerebrum and cerebellum), though it is by no means certain whether the fibres which unite with the cells in this fashion in the latter organs constitute ingoing or outgoing channels.

It is into such a union as this that the fibrils and corpuscles of the 'neuroglia' (fig. 9) seem to enter. Certainly its network cannot be distinguished or clearly separated, in many nerve centres, from that formed by the ultimate nerve fibrils and the branchlets of ramifying cell processes.

3. In other nerve cells, furnished with many ramifying processes, one long simple process may be seen (figs. 13, *a*, 14), which is occasionally traceable into direct continuity with the entire axis cylinder of a nerve fibre (Deiters). This mode of union is now generally admitted to exist, and it is not improbable that nerves so arising are, usually at least, outgoing fibres. Whilst this view cannot be definitely verified, it is a fact that such processes have been found principally in the spinal cord in connection with the nerve cells of the anterior, or motor, regions of its grey matter.

There is thus some ground for believing that ingoing fibres, in the majority of cases, swell in the posterior spinal ganglia and their analogues into nerve cells (fig. 10); that within the larger nerve centres these fibres, which convey ingoing currents, break up into a pencil of ultimate fibrils, and that these ultimate fibrils may be partly in structural continuity with the neuroglia, and partly with the radicles of a much branched nerve process (fig. 12), the divisions of which unite (like the radicles of a vein), till they are gathered into one or more branches directly continuous with the substance of the nerve cell. Such arrangements may suffice to break the force of Ingoing Currents as they impinge upon highly excitable centres; or their diffusion therein may thus be facilitated, and as a consequence they may be enabled to come into relation with the ultimate ramifications of processes pertaining to several cells.

On the other hand, there is ground for believing that Outgoing Currents leave the cells of the spinal motor centres by undivided processes, which are directly continuous with the axis-bands of dark bordered nerve fibres.

Should these suppositions be correct as to the mode in which currents impinge upon the sensory side, and subsequently issue from the motor side of a nerve centre, then, in order to complete our mental survey of the path of a stimulus wave through such a nervous arc as is called into play in one of the higher animals during the performance of a 'reflex action,' it only remains to consider the modes of connection existing between the several cells of sensory groups and of motor groups, together with the kinds of communication existing between these two orders of nerve units.

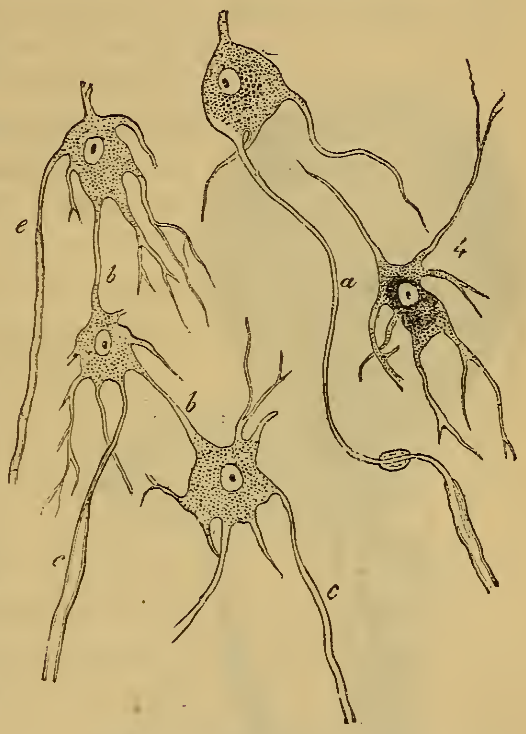


FIG. 14.—Motor Nerve Cells connected by intercellular processes (*b*, *b*), and giving origin to outgoing fibres (*c*, *c*, *c*, and *a*). 4. Multipolar cell containing much pigment around nucleus. Diagrammatic. (Vogt.)

4. Between the contiguous cells of a motor and perhaps also of a sensory group, union is brought about in some cases by means of a short simple *intercellular* process, such as we see represented in figs. 1 and 14. But whether this is the most frequent means of union, or whether, in the majority of cases, especially amongst sensory groups, it is not rather by the inosculation of the rootlets of ramifying processes (with the possible intermediation of the neuroglia) we cannot at present say. There is reason to believe that both modes of union may exist.

5. The cells of a sensory group are united with the

cells of a motor group by one or other of these modes—though in regard to this point we have even less certain knowledge than concerning the last. Of the existence of such connecting or 'commissural' fibres—which are either short or long according to the proximity or remoteness of the two groups of cells—there can be no doubt. Uncertainty exists, however, with regard to the precise mode of their connection with the sensory nerve cells on the one side and the motor on the other—whether at either extremity they are continuous with undivided cell-processes, or break up and inosculate with ramifying cell-processes.

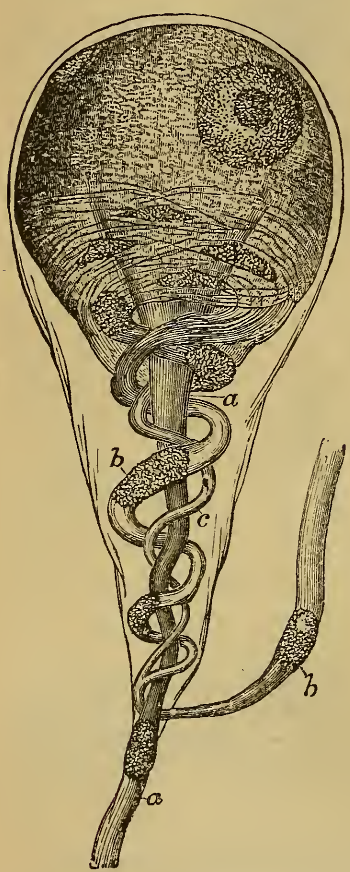


Fig. 15.—'Sympathetic' Ganglion-cell of a Frog, very highly magnified; according to Beale. Reduced and adapted from one of his figures. *a a*, straight fibre; *b b*, coiled fibre; *c*, smaller one joining it. (Quain.)

More room for doubt, therefore, exists in regard to the precise modes in which stimulus waves traverse nerve centres, than concerning the manner in which they impinge upon or depart therefrom.

6. In the 'sympathetic' or visceral ganglia of the Frog and other animals another kind of relation between fibres and cells has been shown to exist (Lionel Beale). The cells are pear-shaped and the narrow extremity of each of them is continued into a process which in turn becomes continuous with a dark-bordered fibre, whilst one or, it may be, two or more smaller fibres seem to arise from

the surface substance of the same extremity of the cell, whence, after twisting round it and the straight process several times, they pass away in different directions. Occasionally L. Beale has seen the spiral process continuous with a dark-bordered fibre, though in such cases it is not certain whether the straight process is or is not continuous with a fibre of the same kind. J. Arncld has also described cells of this type, and believes that the processes are in connection with the nucleus of the cell, an arrangement which has not been confirmed by other observers. The figures given by Axel Key and Retzius agree closely with those of Beale.

7. But in the 'sympathetic' or visceral ganglia of man and other higher vertebrates it is most common to find many simple processes issuing from large and very granular ganglion cells. Whether each is directly continuous with a single nerve fibre, after the fashion diagrammatically depicted in fig. 2, or whether some of the processes end differently, has not as yet been sufficiently ascertained. These large multipolar ganglion

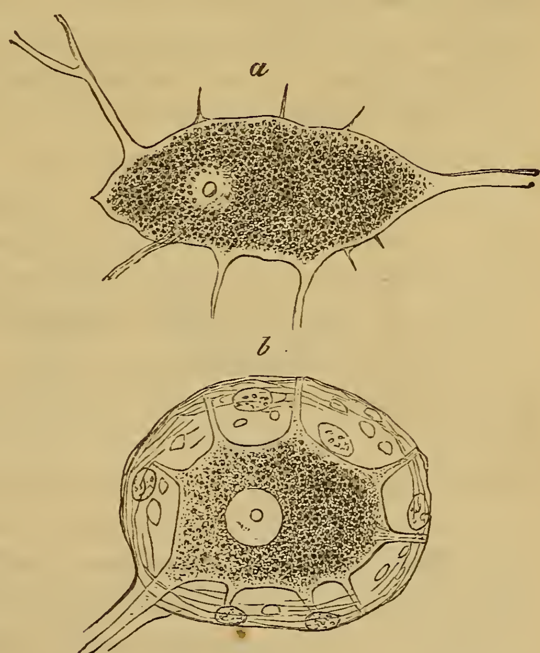


FIG. 16.—Multipolar Ganglion-cells from 'Sympathetic' of Man (Max Schultze). Highly magnified. *a*, freed from capsule; *b*, enclosed within nucleated capsule. The processes of both broken off.

cells of the sympathetic, like those last described, are enveloped by a fine membranous sheath dotted with many nuclei, and the sheath is continued for some distance along each of the nerve processes, in the form of a loose envelope.

8. Lastly, unipolar nerve cells—that is, nerve cells situated at the end of a single nerve fibre—are alleged to exist in the ganglia on the spinal nerves and elsewhere. They have again recently been figured by Axel Key and Retzius, though many modern observers have been very sceptical as to the existence of such bodies. Beale, for instance, maintains that all nerve cells have at least two processes. Without attempting to explain their use or mode of action, it seems to the writer that such unipolar nerve cells certainly exist in some of the lower animals. He has himself seen and figured such bodies as they occur in Ascaris (Phil. Trans. 1866, Pl. xxiv.); and in many other animals nerve units of the same kind have been likewise recognized by competent observers.

Many of the so called *apolar* nerve cells may, as G. H. Lewes suggests in a recent work,* be nothing more than imperfectly developed ganglion cells, in which the processes, if not absent, are so abortive as to escape observation. All who have examined nerve centres with the microscope know that multitudes of such bodies are to be found, though they are often very small—not much larger than mere nuclei—and therefore liable to be regarded as belonging to the neuroglia rather than to the nervous tissue proper. And if some of the cells and nuclei usually assigned to the 'neuroglia' are, in reality, potential or embryo nerve cells, the importance of this intermediate tissue as a formative matrix in which new developments may take place, will at once appear.

* "The Physical Basis of Mind," 1877, p. 234.

Thus far concerning the simplest elements of a nervous mechanism. It should now be stated, however, that even when the Nervous System consists of a mere multiplication of the simplest combinations necessary for the excitement and execution of 'reflex actions,' the groups of these nervous arcs are almost always arranged in pairs, one on each side of the middle line of the body. The body of an animal is for the most part divisible by a median longitudinal plane into two symmetrical halves, and the integral parts of the nervous system are, in the main, similarly double. In some lower organisms, such as certain Mollusks, Worms, and Crustacea, these halves of the nervous system are distinctly separated from one another (figs. 23, 32, 34), though in Vertebrate Animals they are always more or less fused into one axial 'cerebro-spinal' system (fig. 20).

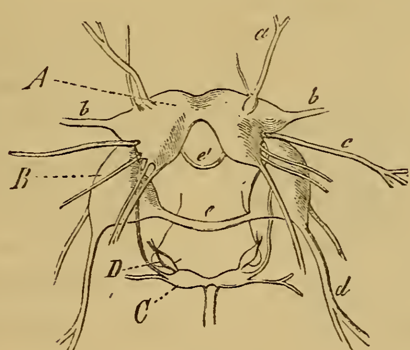


FIG. 17.—Nervous System of one of the Eolidæ (*Fiona atlantica*). (Gegenbauer after R. Bergh). A, Supra-œsophageal sensory ganglia, composed of two pairs of ganglia fused, the cerebral in front and the branchial behind; each pair united by its own commissure. B, Great motor ganglia, in connection with the sensory ganglia, and with one another by the commissure *e*. C, Buccal ganglia. D, Gastro-œsophageal ganglia. *a* and *b*, Nerves from the sensory tentacles. *c*, Nerves from the genital organs. *d*, Principal motor nerves of the body. *e'*, Commissure of the branchial ganglia.

These lateral halves of the nervous system are connected with one another by means of shorter or longer transverse fibres, which, gathered into thick or thin bundles, are known as 'commissures.' Such transverse commissures always unite similar ganglia, whether these are so close as to be more or less continuous, or distinctly separated from one another. Two or three illustrations will suffice to make these bilateral arrangements more intelligible to the reader.

In some of the Nudibranchiate Mollusks so common on the sea-shore, there is in front and on each side a large roundish though functionally compound ganglion receiving numerous ingoing nerves and connected with its fellow by means of a very thick and a thin commissure (fig. 17). The sensory ganglion is also connected on each side by means of a short commissure with its own motor ganglion, from which outgoing nerves proceed to the muscles, and the two motor ganglia are in their turn connected by a longer transverse commissure (fig. 17, *e*).

Thus, in each half of the body of one of these animals there is a complex aggregate of the mechanisms for reflex actions—represented by ingoing fibres entering a sensory ganglion in connection with a motor ganglion, together with outgoing fibres issuing from the latter. Whilst in addition, the two halves of the nervous system are united to one another by the above-mentioned transverse commissures. It is by virtue of these connections between the respective ganglia of the two sides that a properly co-ordinated activity of the whole body is rendered possible, in response to sensory stimuli.

In other animals, such as the Grasshopper, whilst the bilateral symmetry of the nervous system (fig. 18) is just as obvious, it is much more complex and more developed longitudinally. The sensory and motor ganglia are numerous and are arranged side by side in serial order, though many of them are more completely fused with one another and with those of the opposite side than is the case with the two pairs of ganglia of Eolis. Thus median compound ganglia (fig. 18, *g*) are formed, connected with one another by single, or it may be by double (*e*, *h*) commissures. The terminal double group (A) represents the brain of the animal, and this is probably capable of receiving stimuli by some fibres from the sensory portion of each single or double ganglion throughout the body of the Insect. It can probably also transmit motor stimuli along other commissural fibres to each motor division of the same body ganglia.

In the Grasshopper the brain is not more than three or four times as large as one of the compound ganglia in communication with the legs and wings.

In Vertebrate Ani-

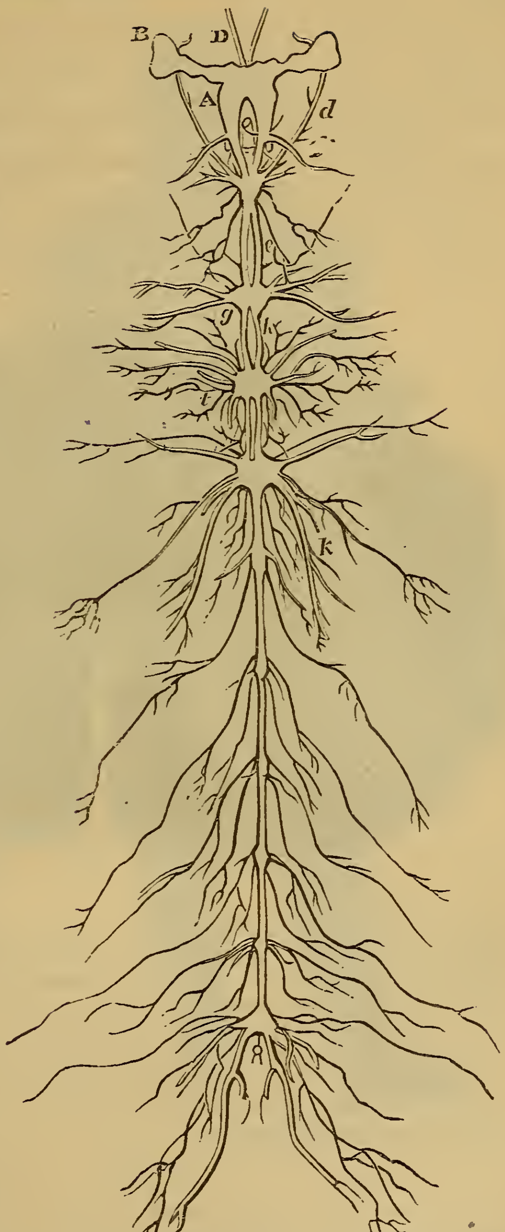


FIG. 18.—Nervous system of the Great Green Grasshopper (Newport). A, brain; B, optic nerves; D, antennal nerves; *d*, motor nerve of mandible from sub-œsophageal ganglion; *g*, first thoracic ganglion, connected to the second, as the second is to the third, by two commissures.

mals we have a still farther concentration of the nervous system. In lower terms of the series, such as Fishes and Amphibia (fig. 56), this concentration is seen to the most marked extent in the chain of ganglia pertaining to the thorax and abdomen. In these animals and in all other vertebrates they are most completely fused into

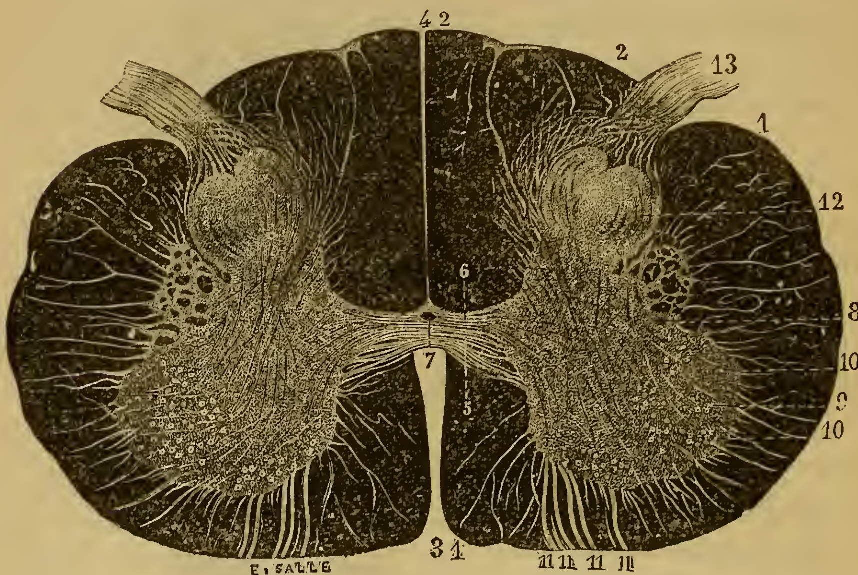


Fig. 19.—Transverse section through Human Spinal Cord in cervical region, showing the organ to be composed of two symmetrical halves. (Sappey after Stilling.) The black portions correspond to regions containing longitudinal fibres ; the lighter portions represent the central Grey Matter and the horizontal roots of nerves ; 5, 6, commissures connecting the symmetrical halves of the grey matter ; 11, 11, 11, anterior or motor roots of spinal nerves, coming from anterior Horns or Cornua of Grey Matter, in which are numerous groups of large ganglion cells ; 13, posterior or sensory roots of spinal nerves, entering the posterior Horns of Grey Matter. Magnified about eight diameters.

a more or less cylindrical column known as the 'spinal cord.' This cord constitutes a double and fused series of nerve centres in relation with the superficial as well as with the deeper structures of the greater part of the body, including all the great nerves of the limbs.

In higher vertebrates, such as Birds and Mammals, we have this same fusion of ganglia in the spinal cord (fig. 19), whilst a similar process also displays itself to a more marked extent in the brain. In the higher forms of this series, and above all in Man himself, the ganglia of the brain become more and more integrated, and some of these parts also take on an enormous development.

FIG. 20.—General view of Nervous System of Man, from behind. 1, Cerebrum; 2, cerebellum; 3, upper part of spinal cord. (Mivart.)

The weight of the entire Brain, as compared with that of the Spinal Cord, indeed, undergoes a great increase in each division of the vertebrates. In the Lamprey this relation is said* to be as ·013 to 1; in the Newt as ·55 to 1; in the Pigeon as 3·5 to 1; in the Mouse as 4 to 1; whilst in

* Marshall's "Outlines of Physiology," vol. i. p. 406.

Man it is about 40 to 1. Thus, whilst the Cerebrum and the Cerebellum, which together constitute the Brain, is actually much lighter in the Lamprey than the Spinal Cord, these same parts in Man are found to attain comparatively enormous dimensions, and greatly to exceed in weight the inferior, though highly important, spinal centres.

CHAPTER III.

THE USE AND NATURE OF SENSE ORGANS.

Heat and light are physical influences to which even the lowest units of living matter respond, whether their mode of life and nutrition be most akin to that of Plants or to that of Animals. These influences act upon such organisms, either by stimulating, retarding, or otherwise modifying the chemical changes occurring in their interior, and upon the existence of which their Life depends.

Where the vital processes of the organism are stimulated by these physical agencies, their incidence may, in many instances, become the cause of so-called 'spontaneous' movements. And some sort of foundation exists for this popular mode of expression. A movement which follows immediately upon some localized external stimulus is not said to be 'spontaneous:' the term is generally applied where the cause of the movement is not distinctly recognizable. In some of these cases—as when we have to do with the influence of a diffused physical agent such as heat—an undetected or unconsidered external cause really exists, which, by stimulating the vital processes, gives rise to movements seemingly spontaneous. Whilst in other cases, movements apparently spontaneous are to be referred to internal states or changes, that is to impressions emanating from some of the internal organs which, after passing through one or more ganglia, are transmitted along outgoing nerves to some of the organs of locomotion.

Heat often acts upon organisms upon all sides alike; consequently, though it may stimulate their life-processes generally and, in some instances, give rise to movements —the latter are not determined in one more than in another direction. It is well known to stimulate the 'to-and-fro' or the gyratory movements of Bacteria, and other of the lowest organisms; and whilst it also renders more striking and rapid those changes of form which all Amœboid Organisms are apt to display, the movements evoked are similarly random and devoid of purpose.

It is not altogether similar with the influence of Light. This agent almost always, and of necessity, falls more on one side of an organism. Consequently it often suffices to induce movements of the lower forms of life in definite directions, just as it causes similar responsive movements to be executed by the parts of any higher plants which may come fully under its influence. In each case the movement, or altered position, is due to some nutritive change—that is, to some alteration, whatever its nature, in the activity of the life-processes taking place in the part impressed by the light. So that, whether we have to do with the movement of a Sunflower or with the locomotions of minute living units, the essential mode of production of the movement is probably similar.

Of such locomotions of minute living organisms under the influence of light many instances might be cited; it will suffice, however, to mention the fact that green Zoöspores, which may have been uniformly diffused through the water, are very apt, when the vessel containing them is placed near a window, to collect on the surface of the water at the part where most light falls, and the same would hold good also for many Medusæ. Minute animal organisms are, however, often affected quite differently by this agent. They may move away from rather than towards its source, and to this extent may be said to 'seek' the shade rather than the glare of sunlight.

The operation of such influences and their results, form the beginnings or substrata, as it were, of other phenomena with which we are now more particularly concerned. The unilateral influence of Light and the movements to or from its source to which it gives rise, afford a connecting link between diffused causes like Heat, which operate generally and produce purely random motions, and those more localized influences now to be considered, by which, and the intermediation of a more and more complex Nervous System, the various definite or responsive movements of organisms have been gradually evoked and potentially organized.

Touch.—The first to be considered—because it is the simplest—of these localized influences, is a shock on mechanical impact of some kind falling upon the external surface of the organism. This is the primordial and most general of all the modes by which the surface of an organism is impressible. Its sensitivity to such stimuli is—both in the stage of impression and in that of reaction—closely akin to the general organic irritability of protoplasm, which unquestionably constitutes its starting point. These modes of impression and reaction are the first links towards the establishment of a correspondence between the organism and the most common events or properties of the medium in which it lives and moves. It is, consequently, the kind of impressibility most extensively called into play in all the lower forms of animal life.

Although the whole or the greater part of the surface of an organism, in one of the simple animals to which we are referring, may be more or less impressible to shocks or impacts from contact with surrounding bodies, it often happens that such impressions more frequently fall upon, and are more readily received by, certain appendages situated at the anterior extremity of the animal, in close proximity to the mouth. These specialized parts, or 'tactile appendages', are known as papillæ, setæ, tentacles, antennæ, or palpi, according to the forms which they assume in different animals.

Why such organs should be developed so frequently at the anterior extremity of the animal, and in the neighbourhood of the mouth rather than on other parts of the body, is not difficult to explain. Whatever the mode by which they are called into being (and the most opposite views are entertained upon this subject), it seems obvious that, if organs of this nature are to be present at all, they should be found in situations where they may be put to most use. In an animal accustomed to active locomotions, the mouth is, with only a very few exceptions, situated on the part of the body which is habitually directed forward. And of the diverse objects coming into contact with it, some are of a nature to serve as food, and some are not. A high degree of impressibility naturally becomes developed, therefore, in this situation, where the parts are exercised so largely with impressions connected with the discrimination and capture of food. These organs are, in fact, not unfrequently both tactile and prehensile—this combination being more especially met with in sedentary forms of life, like the Hydra, the Sea-anemone, or some of the tentaculated Worms.

Taste.—But it often happens that the solid bodies serving as food are more or less readily soluble, so that in animal organisms comparatively low in the scale of complexity, some of the tactile structures within or around the mouth *may* undergo a further specialization, by which they and their related nerve centres become fitted to discriminate between impressions of a slightly different nature. Such 'organs of taste' would become sensitive to the more refined kind of contact yielded by certain dissolved elements of the food, whose local action is perhaps attended by some slight chemical change in the tissues of the part. Impressions are thus produced whereby the 'sapidity' or flavour of bodies is appreciated; and such impressions gradually become associated with definite related movements, partly of internal and partly of external organs.

Although this mode of impressibility doubtless exists in many of the lower forms of life, still no distinct organ of Taste, or specialized gustatory surface, is as yet actually known to occur among invertebrate animals, except in Insects and in such higher mollusca as Snails and Cuttle-fishes.

Impressions of the two orders already referred to—more or less distinct from one another—are those by which alone multitudes of the lower forms of animal life, such as Polyps and various kinds of Worms, appear to hold converse with the outside world. Seeing, however, that tactile and gustatory impressions can only be made by actual contact of external bodies with the specialized parts of an organism, such impressions are not of a kind to excite movements in 'quest' of food; although they may lead to correlated motions of parts adjacent to those touched, as in the acts of prehension and swallowing.

Sight.—Movements in actual quest of food may, however, be excited in other animal organisms by impressions bringing them into relation with more or less distant bodies. The way is paved for this result when some portion of the anterior and upper surface of the animal, in which aggregations of pigment occur, becomes more than usually sensitive to light. A dark body passing in front of such a region alters or gives rise to certain molecular changes therein, and these molecular changes (produced by large or small, near or remote, bodies) differing among themselves, become capable of exciting dissimilar impressions which the organism is gradually attuned to discriminate. The existence of such a power of discrimination in this, as in all other like cases, is indicated by the creature's capability of responding to impressions of this order by definite muscular movements —as when the Oyster, having the valves of its shell apart, instantly closes them as soon as a shadow falls upon certain pigment-specks, or so-called 'eyes,' at the edge of its mantle.*

This beginning of visual impressions truly enough shows itself as a very exalted appreciation of tactile impressions; and, inasmuch as such an appreciation of the presence of near bodies would in so many instances be quickly followed by a more gross mechanical contact, the rudimentary visual impression is, as H. Spencer happily puts it, a kind of "anticipatory touch." From a simple beginning of this kind, in which bodies only slightly separated from the impressible foci excite certain general or only vaguely specialized impressions corresponding to light and shade, organs of Sight at once more elaborate and more impressible gradually appear. To rudimentary aggregations of pigment, in some animals transparent media are added,

* Owen says ("Comp. Anat. of the Invert. Animals," p. 512):— "Carlisle first showed that oysters were sensible of light; having observed that they closed their valves when the shadow of an approaching boat was thrown forwards so as to cover them, before any undulation of the water could have reached them."

serving to condense the light thereon; and these media in still other organisms are sufficiently like a lens to be adequate to form a definite image of an external body on the layer of pigment, which (on its other side) is in contact with a nerve-expansion directly communicating with a contiguous ganglion. Numerous simple structures of this kind may exist apart from one another, as in many Bivalve Mollusks; or they may be far more numerous and closely aggregated, so as to form such compound-eyes as are met with in Crustacea and in Insects. Or individual ocelli may be perfected, as in Spiders or lower Crustacea, and most notably of all among the Cuttlefish tribe, in the representatives of which two moveable eyes are met with whose organization is just as perfect as those of Fishes.

The difference in degree and range of sensitiveness between the simple 'eye-specks' of some of the lower Worms, and the elaborate visual organs of the highest Mollusks and Insects is enormous. The range and keenness of sight also become progressively extended, so that creatures with the more perfect eyes are capable of appreciating impressions from objects more and more distant, and the various actions which become established in response to impressions habitually made upon such sensitive surfaces also increase enormously in number, variety, and complexity. The relation between the keenness of the sense of sight and the great powers of locomotion possessed by Insects has long been recognized by naturalists. Prof. Owen thus alludes to it: "The high degree in which the power of discerning distant objects is enjoyed by the flying insects corresponds with their great power of traversing space. The few exceptional cases of blind insects are all apterous, and often peculiar to the female sex, as in the Glow-worm, Cochineal-insect, and parasitic Stylops."

As already pointed out, there are obvious reasons why the principal specialized Tactile Organs that may present themselves in lower animals, should be found in the neighbourhood of the mouth; and, for similar reasons, if for no other, the anterior extremity of the body, or the upper surface near this anterior extremity, is the most advantageous site for Visual Organs. To an active animal, eyes would not only be more useful at the anterior extremity of the body than elsewhere, in relation to its food-taking movements, but also in reference to all other uses to which such organs may be applied during active locomotions from place to place. And to this situation of the eyes only two or three exceptions are met with among animals endowed with powers of locomotion: whilst the few cases of deviation are mostly explicable by reference to some peculiarity in the habits and modes of life of the organisms in question.

Smell.—In vision, as above stated, we have to do with a refinement of the sense of touch, whereby the animal, becoming sensible of impressions produced by 'waves' of light emanating from a distance, is brought into mediate contact with certain distant objects. But a sort of refinement of the organs of taste also occurs, whereby bodies possessing sapid and other qualities are also capable of impressing organisms still at a distance. Just as vision is, in its most elementary phases, a sort of anticipatory touch, so is smell a kind of anticipatory taste. Yet the two cases are not altogether similar. In vision, the contact—if it may be so termed—with the distant body is mediate, through the intervention of ethereal undulations; whilst in smell we have to do with a case of immediate contact, not, of course, with the distant body itself, but with extremely minute particles which it gives off. An 'emission' theory serves to explain the diffusion of odours, though it will not hold for the diffusion of light.

From what I have said, it may be inferred that, as regards the delicacy of their respective physical causes, the sense of Smell occupies a strictly intermediate position between those of Taste and Sight.

Although a rudimentary sense of Smell seems unquestionably to be possessed by such aquatic forms of the invertebrata as Crustacea and the higher Mollusks, it is, perhaps, a sense-endowment which generally exists to a more developed and varied extent amongst air-breathing animals. But in whatever forms of life it may be met with, this sense-endowment seems to be always very largely related to the detection and capture of food. In this direction it comes to the aid of the already existing senses of Sight, Touch, and Taste. It has, however, the peculiarity of being scarcely otherwise called into activity amongst invertebrate animals.

Although we have so little positive knowledge concerning the situations of Organs of Smell in invertebrates, there is good reason for believing that they will (when present) always exist in close proximity to the mouth. It seems possible that in Crustacea they are to be found at the base of the antennules; that in Cephalopods they are represented by two little fossæ in the neighbourhood of the eyes; and that in Insects a power of appreciating odours may be possessed either by the antennæ themselves, or by a pair of fossæ near their bases. Another cephalic organ has also been referred to as possibly endowed with a power of being impressed by odours. Owen says:* "The application by the common house-fly of the sheath of its proboscis to particles of solid or liquid food before it imbibes them, is an action closely analogous to

* "Comp. Anat. of Invertebrate Animals," p. 368.

the scenting of food by the nose in higher animals; and, as it is by the odorous qualities, much more than by the form of the surface, that we judge of the fitness of substances for food, it is more reasonable to conclude that, in this well-known action of our commonest insect, it is scenting, not feeling, the drop of milk or grain of sugar."

The part of the body bearing the mouth and the various sensory organs already named, is familiar to all as the 'head' of the animal; and it is owing to the fact of the clustering of sense-organs on this part that the head contains internally a number of related nerve ganglia. This aggregate mass of ganglia constitutes the 'Brain' of invertebrate animals. It forms a congeries of nerve centres, differing much in different classes, as we shall find, not only in regard to the disposition and size, but also in respect to the relative proportions of its component parts. The size of the respective ganglia, indeed, necessarily varies in accordance with the relative importance and complexity of the several sense organs already mentioned—those of Touch, Taste, Smell, and Sight.

The ganglia thus constituting the Brain of invertebrate animals are not only in relation each with its own particular sensory organs, but, in addition, we find the several ganglia brought into relation among themselves and with their fellows of the opposite side by means of connecting or commissural fibres. They are, moreover, often connected, by means of much longer commissural threads, with other nerve ganglia in different parts of the body.

Hearing.—Another special sense endowment remains to be referred to. This has to do with the organism's power of appreciating the vibrations causing 'auditory' impressions —a power which is, however, probably possessed in only a low degree by most invertebrate animals. Even the most perfect form of the organ of hearing among these animals is but a very rudimentary structure. In this respect a great difference exists between the sense of Sight and that of Hearing. Whilst the eye of the Cuttle-fish attains a degree of elaboration not falling so very far short of the most perfect form which the organ displays among vertebrate animals, the organ of hearing throughout the Invertebrata is remarkable for its simplicity, and remains in all of them notably inferior to the very high type attained by this sensorial apparatus in many Mammals and in Man.

Like the sense of Sight and the sense of Smell, that of Hearing, even in its simplest grades, serves to bring the organism into relation with more or less distant bodies. It is only necessary that these latter should be capable of transmitting sonorous vibrations through water or air to the auditory organs which become attuned to receive them.

It seems just possible, however, that the so-called 'auditory saccules' of the Invertebrata, may have more to do with the 'sense of Direction,' or of the organism's relations with space, than with the sense of Hearing.* In Vertebrate Animals, it would appear, that both these functions are associated with the auditory apparatus, and it is by no means certain that the 'sense of Direction,' or of the organism's space-relations, may not be an endowment more primordial than that of Hearing.

No auditory perception seems to be present at all—certainly none has as yet been detected or inferred to exist—in many of the lower forms of life; while in other animals, though possibly existing, its organs remain as yet unrecognized. The latter condition obtains, for instance, with the majority of Crustacea, Spiders, and Insects.

* See p. 218.

Judging from the instances in which 'auditory saccules' have been detected in Mollusks, and in some few representatives of the classes above named, it seems (and the information may be novel to many readers) that the endowment in question is not habitually, or even usually, found in the head, or in direct relation with one of the ganglia composing the brain of Invertebrates. In some Heteropida, and their allies, however, the 'saccules,' whatever may be the function to which they are subservient, seem to be in immediate relation with the brain ganglia.* Further remarks on this subject must, however, be deferred until a brief description has been given in future chapters, of the nature and distribution of the nervous system in some of the principal groups of the Invertebrata.

The foregoing are the commonly received modes by which organisms are impressed from without, and by which they attune themselves to the conditions and actions occurring in their medium. It was recognized by Democritus and other ancient writers, that they are all of them derivatives, or more specialized modes of a primordial common sensibility, such as is possessed by the entire outer surface of the organism. Touch, taste, smell, vision, and probably hearing, are sense endowments, having their origin in organs formed by a gradual differentiation of certain portions of the external or surface layer of the body—that is, of the part in which common sensibility is most frequently called into play. And just as this common sensibility is a crude or general sense of touch, so are the several special senses to be regarded as more or less highly refined modes of the same sense endowment.

The distribution and arrangement of nerves in the various impressible surfaces have certain characteristics

* Siebold, "Manuel d'Anat. Comp.," p. 309, Note 1.

which have been clearly pointed out by Herbert Spencer. "At the surface of the body," he says,* "where the extremities of nerve fibres are so placed as to be most easily disturbed, we generally find what may be called multipliers of disturbances. Sundry appliances, which appearing to have nothing in common, have the common function of concentrating, on the ends of nerves, the actions of external agents." This effect is produced by lenses in the eyes, otoliths and other bodies in the organs of hearing, vibrissæ and *corpuscula tactûs* in the skin; all of which serve to exaggerate the effects of incident forces upon especially sensitive peripheral expansions of the nervous system. "The ultimate nerve fibrillæ, ramifying where they are most exposed to disturbances, consist of nerve protoplasm, unprotected by medullary sheaths, and not even covered by membranous sheaths. In fact they appear to consist of matter like that contained in nerve vesicles, ... and may be regarded as, like it, more unstable than the matter composing the central fibres of the fully differentiated nerve tubes. . . . This peripheral expansion of the nerve on which visual images fall contains numerous small portions of the highly unstable nerve matter, ready to change, and ready to give out molecular motion in changing. It is thus, too [in higher animals], with those terminal ramifications of the auditory nerve on which sonorous vibrations are concentrated. And there is an analogous peculiarity in the immensely expanded extremity of the olfactory nerve. Here, over a large tract covered by mucous membrane, is a thick plexus of the grey unsheathed fibres; and among them are distributed both nerve vesicles and granular grey substance, such as that out of which the vesicles arise in the nervous centres."

* "Principles of Psychology," vol. i. p. 35.

The movements of locomotion, or of limited parts of the body, which become established in correspondence with various kinds of external impressions, tend with time to increase in number, definiteness, and complexity. They are, for the most part, to be classified as actions subservient to the pursuit and capture of prey, to the avoidance of enemies, to the union of the sexes, or to the care of young.

All such movements are found, as a general rule, to have the effect of prolonging the action of any influences which previous individual or race experiences have proved to be favourable to the life and well-being of the organism; and, on the other hand, of cutting short or avoiding influences which past individual or race experiences have proved to be contrary to its general well-being. The capture and swallowing of food are ends to which a very large proportion indeed of the definite motions of most of the lower organisms are directed; and this direction of their energies is only a special case to be included under the rule above indicated—just as efforts to escape from predatory neighbours, are other opposite instances of the same rule.

Visceral Sensations and the 'Muscular Sense.'—In addition to the various modes of impressibility by external influence which we have hitherto been considering, there are also certain other modes due to changes in the condition of internal parts of the organism. These are divisible into two categories: (1) impressions emanating from one or other of the various sets of viscera—such as the alimentary canal and its appendages, the respiratory organs, the genital organs, or other internal parts; and (2) impressions derivable from, or in some way attendant upon, the contractions of muscles.

The first category of internal impressions—those emanating from the viscera—are undoubtedly very important in relation to animal life generally. In part, they have the effect of causing contractions of related muscular portions of the viscera—as when the presence and pressure of food in certain portions of the alimentary canal excites —it may be through local ganglia—contractions by which the food is propelled farther on. In part, however, they act upon the principal nerve ganglia—those constituting the brain—in such a way as to excite the external sense-organs with which they are connected to a higher order of activity. Visceral impressions of one kind may cause an animal more eagerly to pursue prey, whilst those of another sort may tend to an increased alacrity in discovering a mate. In these, and in many other instances, internal impressions, reaching the cerebral ganglia, would seem to excite a higher receptivity for certain kinds of external impressions and a corresponding increased readiness to respond on the part of the moving organs whose activity is related to such conjoined impressions and promptings.

With the second set of impressions, those of the so-called 'muscular sense,' we have at present nothing to do. They differ altogether from others, whether of external or of internal origin, by the fact that they follow or accompany movements whose intensity they are supposed to measure, and do not of themselves incite movements. Granting that such impressions have a real existence, it is obvious we can know nothing about them among Invertebrate Animals, since they have only a subjective existence and do not of themselves alone lead to movements. Our only knowledge of such impressions, as subjective states, must be derived from our own sensations together with what other fellow-men are able to describe.

CHAPTER IV.

THE NERVOUS SYSTEM OF MOLLUSKS.

For several reasons it will be advantageous to depart from the usual zoological order, and consider first the disposition of the nervous system in some of the principal types of the sub-kingdom Mollusca.

These are animals mostly aquatic and wholly devoid of hollow, articulated, locomotor appendages. Their organs of vegetative life attain a disproportionate development, as may be imagined from the fact that some of the simplest representatives of the class consist of mere motionless sacs or bags, containing organs of digestion, respiration, circulation, and generation. The most complex Mollusks, however, are active predatory creatures, endowed with remarkable and varied powers of locomotion, and with sense organs which are both keen and highly developed. The simpler forms are represented by the motionless Ascidian, and the higher by the active and highly endowed Cuttle-fish.

It should be mentioned, however, that the tendency of several recent investigations has been to separate the class to which the Ascidians belong altogether from the Mollusca, and to place them as an independent group, having affinities to the lowest Vertebrates.

The solitary Ascidians may be taken as the type of the **Tunicata**. Their life of relation with the external world is of the simplest description. They are stationary creatures, having even no prehensile organs—their food being brought to the commencement of the alimentary canal by ciliary action.

In correspondence with such a simple mode of life, we might expect to find a very rudimentary nervous system, and this expectation is fully realized. The Tunicata possess a single small nervous ganglion lying between the bases of the two funnels through which water is taken in and discharged (fig. 21, *c*). This ganglion receives branches from the tentacula guarding the orifice of the oral funnel, and possibly from the branchial chamber; whilst it gives off outgoing filaments to the various parts of the muscular sac, and perhaps to the alimentary canal and some of the other internal organs. In some of the solitary Tunicata a rudimentary visual function is presumed to exist. At all events, pigment-spots are situated on, or in very close relation with, the solitary ganglion.

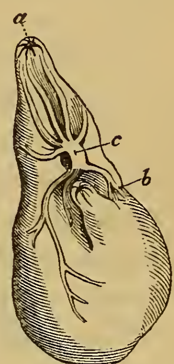


FIG. 21. — An Ascidian, with rough diagrammatic sketch of its Nervous System. (Solly after Cuvier.) *a*, Branchial orifice; *b*, excretory orifice; *c*, nerve ganglion with its afferent and efferent nerves.

The recent investigations of Kupffer tend to show that this extremely simple nervous system, nevertheless, represents a decidedly higher type of organization than had been previously supposed. Further details cannot, however, here be given.*

The **Brachiopods** are among the oldest and most widespread of the forms of life in the fossil state, and the geographical distribution of their living representatives at

* See Gegenbauer's "Comp. Anatomy," English Translation, p. 395.

the present day is also very wide. Like the Tunicata, they are also headless organisms, and lead a sedentary existence, attached to rock or stone either by a pedicle or by one division of their bivalve shells. The mouth is unprovided with any appendages for grasping food—nutritive particles being again brought to it by means of ciliary currents. Numerous muscles exist which connect the valves of the shell to one another, and with the enclosed animal.

Though the visceral organization of the Brachiopods is somewhat complex, no definite Sense Organs have yet been detected in any of them. The nervous system of these sedentary animals, moreover, comprises nothing answering to a 'brain' as it is ordinarily constituted—though ganglia exist around the œsophagus which must receive afferent impressions of some kind, and from which branches proceed to the various muscles and viscera of the body.

Such low sensory endowments would be wholly incompatible with that degree of visceral complexity of organization which the Brachiopods possess, had it not been for the fact that these animals lead a passive existence in respect to quest of food. The absence of sense-organs and of a brain is, indeed, only compatible with such a semi-vegetative existence.

The **Lamellibranchs**, or ordinary headless bivalve Mollusks, also include some representatives—such as the Oyster and its allies—which lead a sedentary life. The valves of the shell in Lamellibranchs generally are lateral, instead of being dorsal and ventral as amongst the curious Brachiopods above referred to.

The mouth of the Oyster is surrounded by four labial processes whose functions are not very definitely known. It presents no other appendages of any kind in the neighbourhood of the mouth, and, as in the two types of

Mollusca already described, the food which it swallows is brought to the entrance of its œsophagus by means of ciliary currents. It has two small anterior or 'labial' ganglia (fig. 22, *a*, *a*,) one being situated on each side of the mouth. They are connected by a commissure arching over it, and also by a more slender thread beneath the mouth. From this lower commissure, filaments (*e*) are given off to the stomach. The anterior ganglia receive nerves (*f*) from the labial processes which are probably for the most part afferent in function —at all events, these processes have no distinct muscular structure. Two long parallel commissures (*d*, *d*) connect the anterior ganglia with a single large compound 'branchial' ganglion (*b*), situated posteriorly, and close to the great adductor muscle. It gives off branches to this muscle, to each half of the mantle, and to the gills (*c*, *c*).

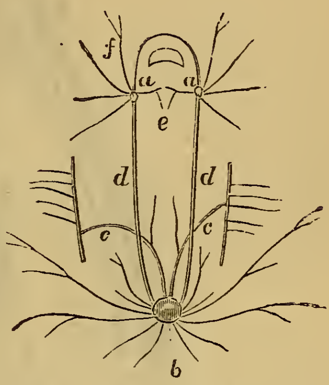


FIG. 22.—Nervous System of an Oyster. (Todd after Garner.) *a*, *a*, Anterior or labial ganglia; *b*, posterior or branchial ganglion (double); *f*, labial nerves *c*, *c*, branchial nerves; *d*, *d*, commissures between labial and branchial ganglia.

Other more active Lamellibranchs possess a muscular appendage known as the 'foot', which is in relation with an additional single or double nervous ganglion ('pedal'), and is used in various ways as an organ of locomotion. Speaking of the diverse uses of the foot among bivalves, Prof. Owen says:* "To some which rise to the surface of the water it acts, by its expansion, as a float; to others it serves by its bent form as an instrument to drag them along the sands; to a third family it is a

* "Lect. on Comp. Anat. of Invert. Animals," p. 505.

burrowing organ; to many it aids in the execution of short leaps."

The bivalves possessing a foot, therefore, present three pairs of ganglia instead of two—the anterior or 'labial',

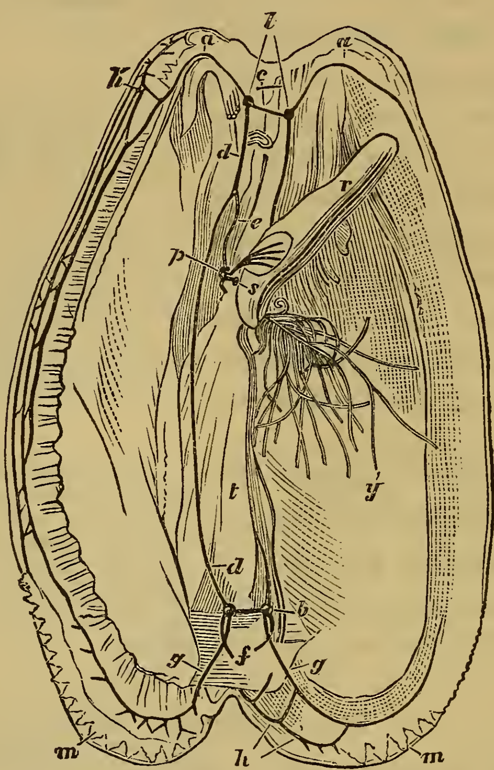


FIG. 23.—Nervous System of the Common Mussel. (After Owen.) *l*, Labial ganglia connected by a short commissure above or in front of the mouth; *b*, *b*, branchial ganglia similarly connected, and also united by very long cords (*d*, *d*) with the labial ganglia; *p*, bilobed pedal ganglion sending branches to the muscular foot (*r*), and closely connected with the 'auditory saccules' (*s*); *h*, *h'*, circum-pallial plexus; *y*, byssus, by which the animal attaches itself to external substances.

the posterior or 'branchial', and the inferior or 'pedal'. It occasionally happens that the ganglia of the posterior or even of the inferior pair may become approximated and fused into one.

The fusion of the posterior ganglia takes place, as in the Oyster (fig. 22, *b*), when the branchiæ from which they receive nerves (*c*, *c*) come close together posteriorly. On the other hand, in those Mollusks in which the branchiæ are farther apart, the two ganglia remain separate and are connected by a short commissure, as in the Common Mussel (fig. 23, *b*).

The separateness or fusion of the inferior or 'pedal' ganglia depends upon the size and shape of the foot, since the nerves in relation with them are distributed almost wholly to this organ and its retractor muscles. Where the foot is broad the ganglia remain separate, and are merely connected by a commissure. But where the foot is small and narrow, as in the Mussel, the two ganglia become fused into one (fig. 23, *p*).

Some of the special senses are unquestionably represented amongst these headless Mollusks, though the distribution of the different organs is very peculiar. Thus in Pecten, Pinna, Spondylus, Ostræa, and many other genera, very distinct and often pedunculated ocelli are distributed over both margins of the 'pallium' or mantle. These vary in number from forty to two hundred or more, and are in connection with distinct branches of the circumpallial nerves. In the Razor-fish, Cockle, Venus, and other bivalves possessing prolongations of the mantle known as 'siphon-tubes', the ocelli are situated either at the base or on the tips of the numerous small tentacles arranged round the orifices of these organs. And these parts, in such bivalves as live in the sand, are often the only portions of the body which appear above the surface. The margins of the mantle are also garnished by a number of short though, apparently, very sensitive tentacles, in which the creature's most specialized sense of touch seems to reside.

Some of these tactile appendages, as well as some of the ocelli, send their nerves to the branchial ganglia, while others, situated on the anterior borders of the mantle, send filaments to the labial ganglia. The latter also receive filaments from the so-called labial appendages, whose function is uncertain, though it has been suggested that they may be organs of taste or smell. Lastly, in close relation with the pedal ganglia or ganglion, there are two minute saccules (fig. 23, *s*), to which an auditory function is usually ascribed.

Thus we find amongst these headless Mollusks a distribution of specially impressible parts or sensory organs, such as cannot be paralleled among any other animals. The functions which we shall find pertaining to the 'brain' in other creatures are in them distributed in a very remarkable manner—so that such organisms may be said to be brainless as well as headless.

The **Pteropods** constitute another interesting class of Mollusks, which lead us on from the comparatively sluggish Lamellibranchs to the Gasteropods and the Cephalopods—organisms which possess definite and wide-reaching powers of locomotion, as well as a distinct head carrying sense-organs and a more or less developed brain.

The possession, by many members of this class, of two fin-like muscular expansions attached to the side of the head induced Cuvier to give them the above class name. According to Owen, "All the species of Pteropoda are of small size; they float in the open sea, often at great distances from any shore, and serve, with the Acalephæ, to people the remote tracts of the ocean. In the latitudes suitable to their well-being, the little Pteropoda swarm in incredible numbers, so as to discolour the surface of the sea for leagues; and the Clio and the Limacina constitute, in the northern seas, the principal article of food of the great whales."

Some of the least highly organized members of this class, such as the Hyalleidæ, possess a bivalve shell, and no distinct head; but in other Pteropods devoid of a shell, we meet with a higher organization. Thus in Clio there is a distinct head bearing sensory appendages, in the form of two tentacula and two eyes, and containing 'a brain' within. The brain is represented by two connected ganglia above the œsophagus, which are in relation, by means of ingoing nerves, with the above mentioned sensory organs. In connection with another commissure uniting these two cerebral ganglia and which passes under the first part of the alimentary canal, are two 'pedal' and two 'branchial' ganglia pretty close together. These two pairs of ganglia exist separately in Clio and its allies, though they are combined into one quadrate mass in Hyalea. In Clio two 'auditory saccules' are in connection with the anterior sub-œsophageal ganglia—that is, with the pair which corresponds with the 'pedal' ganglia of the common bivalve Mollusks.

Gasteropods constitute a class of organisms which, in point of numbers, can only be compared with the still more numerously represented class of Insects. Their name is derived from the fact that they crawl by means of a large muscular expansion or 'foot' stretched out beneath the viscera. The locomotion of members of this class may be said to be, in the main, dependent upon their own individual efforts, so that, in this respect, they differ widely from Pteropods, whose movements from place to place are brought about chiefly by winds driving them along the surface of the water on which they float.

Some Gasteropods are terrestrial, air-breathing animals, though by far the greater number are aquatic and breathe by means of gills. But being all of them, as Prof. Owen says, "endowed with power to attain, subdue, and devour organic matter, dead and living," we find their Nervous System not only better developed, more complex and concentrated, but also in relation with more highly evolved organs of special sense and exploration. This system offers considerable variations in general arrangement, and as regards the relative positions of its ganglia, though these modifications are, to a great extent, referable to differences in the outward configuration of the body.

The wide differences in external form which are to be met with among Gasteropods may be well illustrated by comparing the Limpet or the Chiton with the Snail. Here differences in habit are also marked, so that we almost necessarily meet with very notable variations in the disposition of the principal parts of the nervous system.

In the Limpet two small cerebral ganglia (fig. 24 A) exist, which are widely separated from one another, and lie at the side of the œsophagus. Each receives a rather large nerve from one of the tentacles, and a smaller optic nerve. A commissure above the œsophagus connects these cerebral ganglia with one another, while each of them is also in relation by means of two descending commissures with a series of four connected ganglia forming a transversely arranged row beneath the œsophagus. Of these the two median ganglia (B) correspond with the pedal, while the two external (C) correspond with the branchial ganglia, though they are here separated from one another by an unusually wide interval.

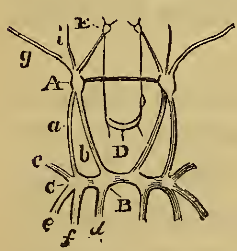


FIG. 24. — Nervous System of Common Limpet. (Todd after Garner.) A, Cerebral ganglia; C, branchial and B, pedal ganglia: D, pharyngeal and E labial ganglia. *a* and *b*, Commissures; *g*, tentacular nerve; *i*, optic nerve.

However small and undeveloped the duplex brain of the Limpet may be, this organ exists in an even more rudimentary state in its close ally, the Chiton, which is about the most simply organized of all the Gasteropods. It has neither tentacles nor eyes, and, as a consequence, no distinct supra-œsophageal ganglia are found (fig. 25). There is, in fact, nothing to which the term 'brain' can be appropriately applied.

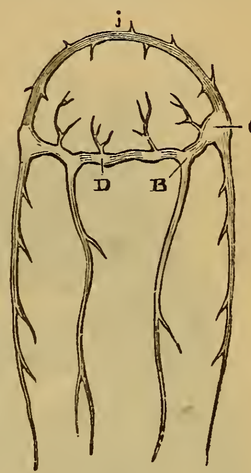


FIG. 25.—Nervous System of *Chiton marmoratus*. (Garner.) D, Pharyngea ganglion (left); B, pedal ganglion (right); C, branchial ganglion; *i*, upper portion of œsophageal ring devoid of any distinct cerebral ganglia.

If we turn, however, to the very active Snail, we find the nervous system existing in a much more developed and concentrated form. There is a large ganglionic mass (fig. 26, *l*) situated over the œsophagus, each half of which receives a considerable bundle of nerve-fibres (*f*) from the eye (*b*) of the same side, which is situated at the tip of the larger tentacle. It also receives another bundle of nerves (*k*) from the small tentacle on each side, which has in all probability a tactile function. The 'auditory saccules' are here in their exceptional position—that is in immediate relation with the posterior aspect of the ganglia constituting the brain, though in most other Gasteropods they are, as in bivalve Mollusks, found in connection with the pedal ganglia. There is one group, however—the Heteropoda—in which the 'auditory saccules' seem to be always in direct relation with the cerebral ganglia, as in Carinaria and Pterotrachea.*

* See Fig. 187, p. 354, Gegenbauer's "Comp. Anat." (Engl. Transl.)

Naturalists now generally admit that Snails and their allies are endowed with a rudimentary sense of smell, though hitherto they have been unable to locate the endowment in any particular organ or surface-region.

The brain of the Snail is connected, by means of a thick cord or commissure on each side of the œsophagus, with a long and curved double ganglionic mass (*m*). This latter body, situated beneath the œsophagus, represents the pair of pedal and the pair of branchial ganglia of the bivalve Mollusks. Here nerves are received from the integument and given off to the muscles of the foot; while they are also received and given off from the respiratory and other organs.

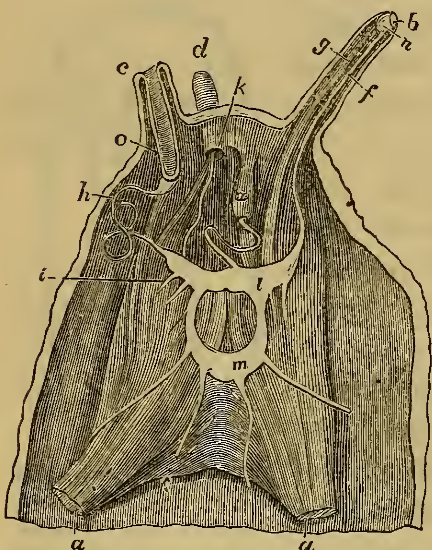


FIG. 26.—Head and Nervous System of the Common Garden Snail. (Owen.) *l*, Cerebral ganglia receiving nerves from smaller (*a*) and from larger tentacles bearing ocelli (*b*); *m*, sub-œsophageal ganglionic mass, representing a pair of pedal and a pair of branchial ganglia. Two of the tentacles are represented in different states of retraction.

The nervous system of one of the Nudibranch Mollusks has been represented in fig. 17. It is also highly developed and concentrated, whilst its sensory and motor ganglia are unusually distinct and separate from one another. A somewhat analogous arrangement of the principal nerve centres exists in the Common Slug (fig. 27), only here the motor ganglia of the two sides are fused together, as in the Snail, instead of being widely separated as in Eolis and its allies. They consequently occupy an inferior rather than a superior and lateral position in regard to the œsophagus. The branchial ganglia are, moreover, fused with them, instead of with the cerebral as they are in Eolis.

The nervous system in the **Cephalopods** presents many peculiarities, which can, however, be only very briefly referred to here. Owing to an extreme amount of shortening of their commissures, the principal ganglia are closely aggregated in the head. The nervous system is, indeed, more concentrated and complex than in other Mollusks, and the animals themselves are notable for the high degree of development of some of their sensory organs as well as for their great powers of locomotion.

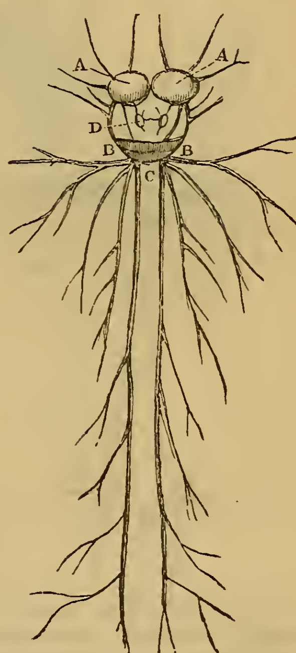


FIG. 27.—Nervous System of the Common Slug (Solly after Baly.) A A, Cerebral ganglia; B B, branchial ganglia and C, pedal ganglia fused into one mass; D, pharyngeal ganglia.

The body of the Pearly Nautilus, contained within the last chamber of its coiled and loculated shell, is enveloped by a muscular mantle open anteriorly, round the head and its numerous sensory appendages. According to Owen,* "the number of tentacles with which the Pearly Nautilus is provided amounts to no less than ninety, of which thirty-eight may be termed digital, four ophthalmic, and forty-eight labial." The eyes, not so well developed as in the Cuttle-fish, are also in relation with smaller optic ganglia (fig. 28, *o o*). Near them are two hollow bodies, regarded by Valenciennes as olfactory organs, the nerves from which join the same ganglia. The situation and

* "Lectures on Comp. Anat. and Physiol of Invert.," p. 581.

relations of auditory organs in this animal have not been definitely settled.

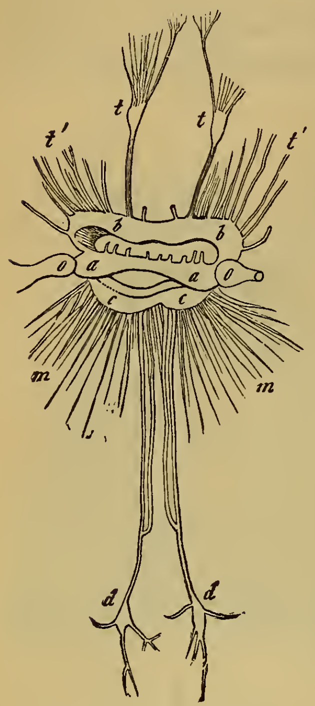


Fig. 28.—Nervous System of Pearly Nautilus. (Gegenbauer after Owen.) *a a*, Cerebral ganglia, constituting the brain ; *o o*, optic ganglia in communication with cerebral ganglia, which are also connected with a lower ganglionic mass (*b b*), receiving nerves (*t t'*) from the tentacles and other parts about the mouth, partly sensory and partly motor. The cerebral ganglia are in addition united to a posterior sub-œsophageal mass (*c c*), supposed to represent a pair of pedal and a pair of branchial ganglia. *m m*, Motor nerves; *d d*, branchial nerves and ganglia.

In regard to organs of taste and touch, Owen writes as follows,—"The complex and well developed tongue of the Pearly Nautilus exhibits in the papillæ of its anterior lobes and in the soft ridges of its root the requisite structure for the exercise of some degree of taste : . . . the sense of touch must be specially exercised by the numerous cephalic tentacles, which, from their softness of texture, and especially their laminated inner surface, are to be regarded as organs of exploration not less than as organs of prehension." The nerves of these tentacles, must be both sensory and motor ; they are in connection with a large double ganglionic mass (*b b*) situated beneath the œsophagus but in front of the other sub-œsophageal ganglion (*c c*), which is thought by Owen to represent "the homologues of both the branchial and pedal ganglions in the inferior Mollusca." The latter pairs of ganglia are clearly combined in function, since the locomotions of the Nautilus, like the much more rapid locomotions of other Cephalopods, seem to be principally effected "in a succession of jerks, occasioned by the reaction of the respiratory currents upon the surrounding water"—these currents

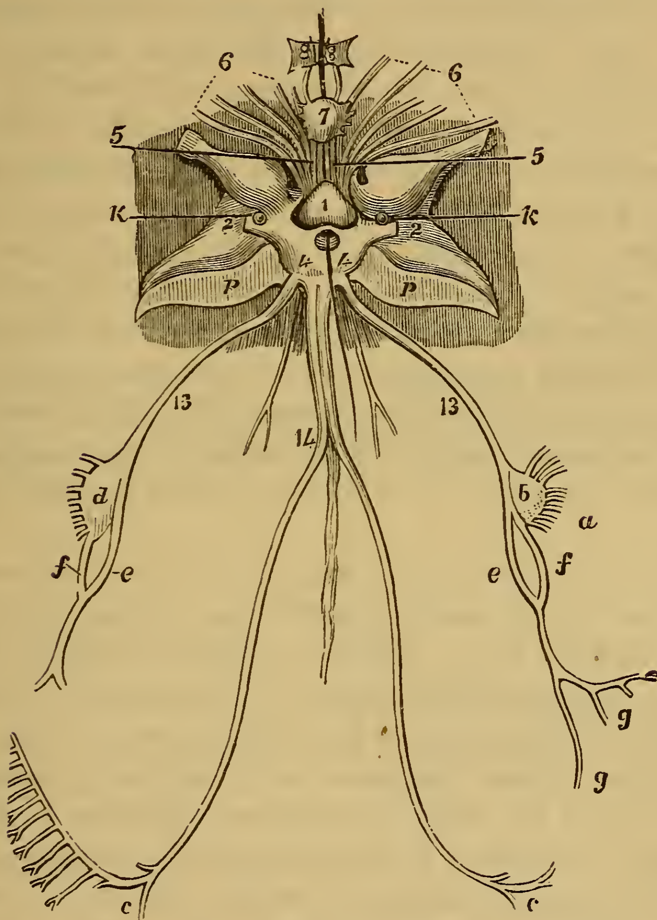


FIG. 29.—Nervous System of the Common Cuttle-Fish (*Sepia officinalis*). (Owen.) 1, Double supra-œsophageal ganglion developed from upper commissure; *p p*, cut surfaces of the cartilaginous cranium; 2 2, optic ganglia; 4 4, posterior sub-œsophageal ganglia (anterior sub-œsophageal ganglia in connection with nerves of feet and tentacles, 6 6, not seen in this view); 7 and 8, ganglia in connection with the pharynx and mouth, connected by nerves (5 5) with the cerebral lobes; 13 13, great motor nerves, of the mantle and other parts, with (*d*) their ganglia; 14, *c c*, respiratory nerves; *k k*, small tubercles in connection with optic ganglia.

being produced by the expulsive contractions of a powerful muscular funnel continuous with a portion of the mantle.

In the Cuttle-fish one of the most striking characteristics of the principal nerve-centres is the fact of the existence of a very large optic ganglion (fig. 29, 2) on each side, in connection with an extremely well-developed eye. Each optic lobe, according to Lockhart Clarke, is "as large as the rest of the cephalic ganglia on both sides taken together." From each of these lobes an optic peduncle passes inward to join a supra-œsophageal ganglionic mass, which bears on its surface a large bilobed ganglion (1), thought by Clarke to be homologous with the cerebral lobes of fishes. It is connected, by means of two short cords, with a much smaller bilobed ganglion, known as the pharyngeal (7). This latter ganglion receives nerves from what are presumed to be the organs of taste and smell, and gives off nerves to the tongue and powerful parrot-like jaws with which the creature is provided.

The supra-œsophageal mass is connected by cords, at the sides of the œsophagus, with a very large ganglion lying beneath it (4), which is partially divided into an anterior and a posterior division. The anterior division—regarded by Huxley as in part homologous with the pedal ganglia of lower Mollusks—is in relation by means of large nerves (6) with the feet and tentacles. A commissure also unites it with the pharyngeal ganglion, so that the tentacles and arms are thus able to be brought into correlated action with the jaws. The posterior portion of the sub-œsophageal mass receives nerves from, and also gives off nerves (14) to, the branchiæ and other viscera, as well as to the muscular mantle (13, 13).

The 'auditory saccules' and their nerves are connected with this great branchio-pallial ganglion. These organs are lodged in the substance of the cartilaginous framework (*p p*) investing the nerve-ganglia—a structure which seems to answer to a rudimentary skull or cranium.

The locomotions of Cuttle-fishes are largely brought about by contractions of the pallial chamber, though these same contractions of the pallium are also subservient, as in the Nautilus, to the respiratory function.

The large share, therefore, which the branchio-pallial ganglia take in bringing about and regulating the movements of these animals, would seem in part to explain the connection of the 'auditory saccules' with them, since in the great majority of other Mollusks in which these organs are known to occur, they are found to be in primary relation with the principal motor centres. Whatever may be the full explanation of these remarkable relations, the fact remains that, even in the Cuttle-fish tribe, the superficial connections of the so-called 'auditory saccules,' are still away from the brain.

CHAPTER V.

THE NERVOUS SYSTEM OF VERMES.

Nothing distinctly answering to a Brain is to be found in some other of the lowest animals in which a nervous system exists. It is thus, for instance, with Star-fishes and the larger Nematoid Entozoa. What most nearly resembles such an organ in Star-fishes, consists of a mere band of nerve fibres, surrounding the commencement of the œsophagus, and containing a few nerve-cells partly between its fibres and partly in groups slightly removed therefrom. The absence of any distinct ganglia in the neighbourhood of the mouth is doubtless due, in the main, to the form of these animals, and their low type of organization. Each arm or ray contains its own nervous system, so that the ring or band round the mouth seems to be little more than a commissure connecting such otherwise distinct parts of the common system. These Echinoderms are, however, here only incidentally referred to.

In the larger parasitic Nematoids the nervous system is more concentrated. The œsophageal ring and immediately adjacent parts constitute almost all that is as yet known of their nervous system, but it contains, or is in relation with, a larger number of ganglion-cells than the similar part in Star-fishes. Thus, in addition to the cells intermixed with the fibres of the ring itself, there are five or six groups adjacent to and in connection with it, which receive fibres from certain large papillæ surrounding the mouth. These papillæ would seem to be the principal sensory organs of the Nematoid. By means of the connecting nerve-fibres and ganglion-cells they are brought into relation with the nervous ring, and from this latter outgoing fibres are, doubtless, given off to the four great longitudinal muscular bands by which the movements of the organism are effected. The distribution of such motor nerve-fibres, however, has not been distinctly traced.

The absence of ganglionic swellings on, or in connection with, the œsophageal ring of Nematoids is probably dependent upon the comparative simplicity and limited number of the impressions capable of being received through their cephalic papillæ.

Among other representatives of the sub-kingdom VERMES, the nervous system varies a good deal in minor details, in accordance with the degree of organization, and with the diversity of the sensory and locomotor endowments of the several organisms. The broad features of the nervous system, however, are comparatively similar in all—especially in the most typical representatives of this sub-kingdom, which contains so many aberrant types. Only a very few forms will be here referred to.

The Nemerteans, a class of marine worms, possess a very simple nervous system. They have soft, unsegmented, and highly contractile bodies, covered with cilia, but are otherwise wholly devoid of all external appendages. On the anterior extremity of the body, a little posterior to the mouth, two, four, or more specks of pigment are met with (fig. 30, *e*, *e*), which are conjectured to serve the purpose of rudimentary ocelli; and whilst the animal is moving from place to place this anterior part of its body doubtless acts also as its principal tactile surface. Nerve-fibres proceed from these regions, and converge so as to form three or four nerve-trunks on each side, which enter a comparatively large compound ganglionic mass (*a*, *a*) lying on the lateral aspects of the sheath of the proboscis. Each of these masses is pyriform in shape, and composed of a sensory and a motor ganglion fused into one. It is connected with its fellow by means of two commissures, one of which passes over, and the other beneath, the proboscis.

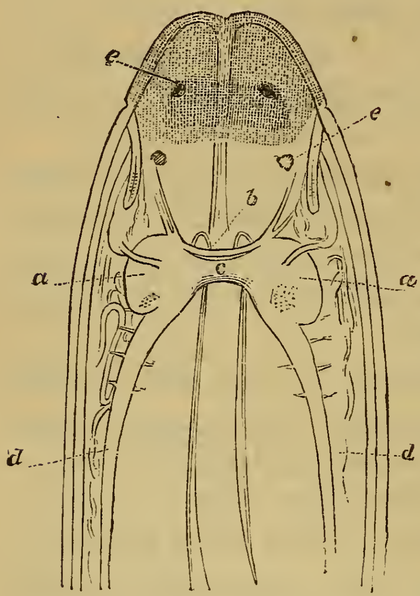
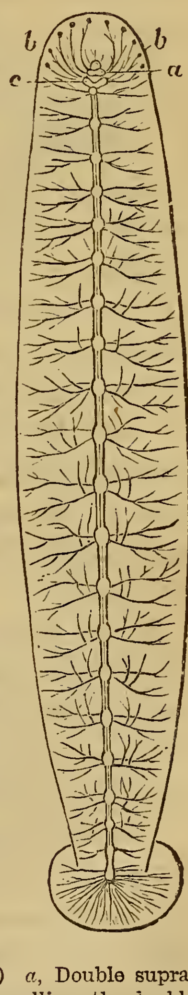


Fig. 30.—Head and Brain of a Nemertean. (*Tetrastemma melanocephala.*) *a*, *a*, Compound lateral ganglia; *b*, narrow upper commissure between which and the much thicker inferior commissure, *c*, the œsophagus passes; *d*, *d*, the great lateral nerve cords; *e*, *e*, pigment spots, or rudimentary ocelli. (After McIntosh.)

It is difficult to trace the ultimate distribution of the nerve-fibres in these creatures; so that, although fibres can be followed nearly up to the pigment-spots, none have been detected in immediate continuity therewith. The inferior commissure (*c*) between the two ganglionic masses is shorter and much thicker than the upper. The two great lateral nerve-trunks (*d*, *d*) start from the ganglia, and, proceeding along the sides of the body, give off numerous branches to the longitudinal and circular muscles between which they are situated.

Tactile and possibly gustatory impressions, together with impressions produced by light or darkness, doubtless come from the anterior extremity of the organism to the anterior part of the pyriform ganglia on either side; and are thence reflected from the posterior parts of these bodies along related channels in the great efferent bundles, the fibres of which proceed to the contractile proboscis and also to the muscles on one or both sides of the body. Other departments of the nervous system may exist in these animals, though as yet none have been detected.

In the common Medicinal Leech the nervous system is somewhat differently developed. The lateral ganglia of the Nemertidæ are replaced by two small upper ganglia (fig. 31, *a*), connected by lateral commissures with a single lower ganglion (*c*) ; and, as a consequence of this coalescence of the two sub-œsophageal ganglia, we have, instead of the two lateral cords of the Nemertidæ, a double ventral nervous cord traversing the whole length of the body. The two cords approximate so closely as to be almost fused into one, and they bear a series of ganglia—one for every three or four of the segments into which the body of the animal is obscurely divided.



The bilobed ganglion above the œsophagus, which is mainly sensory, receives fibres from the tactile lips, together with ten distinct filaments from as many pigment-spots or ocelli (*b b*), situated round the margin of the upper lip. From this bilobed ganglion, corresponding with the brain proper of higher animals, a cord descends on each side of the œsophagus, and the two join the heart-shaped sub-œsophageal ganglion (*c*), from which efferent nerves are given off to

FIG. 31.—Nervous System of the Medicinal Leech. (Owen.) *a*, Double supra-œsophageal ganglion connected by nerves with *b*, *b*, rudimentary ocelli ; *c*, the double infra-œsophageal ganglionic mass, which is continuous with the double ventral cord, bearing distinct compound ganglia at intervals.

the muscles whose business it is to move its three saw-like jaws, as well as to the muscles of the oral sucker. This lower ganglion is in part analogous to the 'medulla oblongata' of vertebrate animals. It is continuous with the double ventral cord, on which twenty equidistant rhomboidal ganglia are developed. Each of these ganglia gives off two nerves on either side, whose branches are distributed to the parietes and the muscles of adjacent segments.

In this animal a simple filament is also given off from the posterior part of the supra-œsophageal ganglion, which is distributed along the dorsal aspect of the alimentary canal. It foreshadows an important system of fibres in higher animals, corresponding partly with the pneumogastric nerves, and partly with the 'sympathetic system.' As it exists amongst the Invertebrates it is known as the 'stomato-gastric system' of nerves. In other members of the invertebrate series it frequently takes origin from the commissures connecting the upper and lower œsophageal ganglia, rather than from the upper ganglia themselves. In some of the worms, in which such an arrangement exists, the stomato-gastric system is also more complicated.

In the Earthworm the body is composed of a multitude of ring-like segments, provided with lateral setæ which the animal calls into play during its subterranean locomotions. It possesses no distinct ocelli, and, having regard to its mode of life, this is not surprising.

The supra-œsophageal ganglia, which together represent the brain of the Earthworm, receive a nerve trunk on each side, composed of fibres coming from the tactile upper lip; and, as no sensory filaments of a different order are known to be immediately connected therewith, the functions of the brain in this animal must be comparatively simple.

The lip is regarded as an organ of touch, but it is equally probable that it is capable of receiving more special impressions representing rudimentary tastes. The separation between these modes of sensibility in such low organisms is probably somewhat indefinite.

The double ventral cord has a fibrous structure along its upper surface, whilst below there is an irregular stratum of ganglion cells. These cells are more abundant about the centre of each body-segment, so that their aggregation gives rise to a series of rudimentary ganglia in these situations. From every one of the ganglionic swellings two nerves are given off on each side; whilst a third pair issues from the cord itself, just anterior to the swelling, and is distributed along the anterior boundaries of the segment. In Serpula, one of the small tube-dwelling marine worms, the ventral ganglia are also very minute, and those of the two sides, together with the ventral cords, lie some distance apart, and are connected by a series of commissures (fig. 32, *b*). In this disposition of the great nervous cords we have something intermediate between their lateral position in the Nemerteans, and their contiguous mid-ventral position in the Leech and the Earthworm. As in the latter, so in Serpula, the afferent nerves entering the brain (*t*) seem to be in the main tactile.

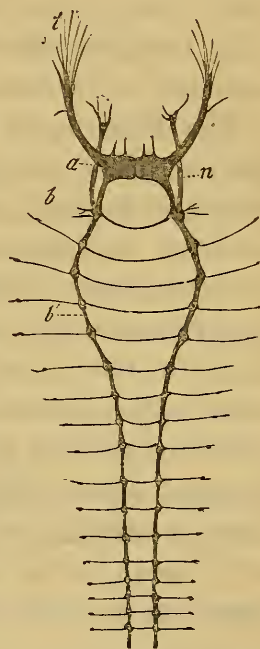


FIG. 32.—Nervous System of *Serpula contortuplicata*. (Gegenbauer, after Quatrefages.) *a*, Supra-œsophageal ganglia; *b*, sub-œsophageal ganglia; *b′* one of ganglionated cords; *n*, motor buccal nerves; *t*, tactile nerves.

The œsophageal ganglia in the Earthworm are, proportionately to the rest of the nervous system, much smaller than in the Nemerteans ; and this is perhaps due in great part to the existence in it of the numerous segmental ganglia,—structures which are absent in the above-mentioned marine worms. The movements of the Nemerteans, like those of the Nematoids, are probably much more exclusively under the control of the œsophageal ganglia than are those of the segmented Earthworm—in which each of the body ganglia, doubtless, has much to do with bringing about the contraction of its contiguous muscles in the same segment.

The Earthworm has a more complex visceral structure than is to be met with among the Nemerteans; and it presents distinct evidences of a nervous interconnection between its internal organs and some of the principal nerve-centres. Lockhart Clarke has described a complicated ganglionic network on each side of the œsophagus, starting from the lateral commissures and sending prolongations to the intestine and other parts. By means of this principal visceral system of nerves, the internal organs are brought into relation with one another, and with the nervous system of animal life—that is, with those parts of it having to do more especially with the relation of the organism to its medium.

CHAPTER VI.

THE NERVOUS SYSTEM OF ARTHROPODS.

THE next sub-kingdom, ARTHROPODA, comprises the Myriapods, Crustacea, Spiders, and Insects. They are all characterized by the possession of hollow and jointed organs of locomotion provided with distinct muscles, instead of the mere lateral setæ or bristles often met with amongst Vermes. The lowest types of these various classes possess a nervous system closely analogous to that of the various kinds of Worms; but in the higher kinds of Crabs, Spiders, and Insects, we meet with a great increase in the complexity of animal organization, and this further complexity, as might have been expected, extends to the nervous system.

Among Insects, for example, the respiratory organs assume a marvellous degree of elaboration, and the development of this system, together with a correlated organization of their nervous and muscular systems, contributes greatly to confer upon these denizens of the air those enormous powers of locomotion for which they are remarkable. But the acuteness, discriminative power, and structural elaboration of sense-organs, is almost sure to be greatly increased in creatures endowed with such activity; and, looking to the constitution of the Brain as well as to the nature of the 'intelligence' of these lower animals, it may easily be conceived that increased sensorial activity is likely to be associated with greater brain development and with higher or more complex brain functions.

Among the lower **Myriapods**, such as Iulus and Geophilus, in which the limbs, though very numerous, are feeble and ill-developed, the nervous system exhibits only a slight advance over the forms which it presents among the higher Annelida. In Iulus (fig. 33) the single abdominal cord shows almost no traces of ganglionic swellings, owing to the great number of the small nerves given off on each side, along its entire length, which are distributed to the hundreds of small segments entering into the composition of the body.

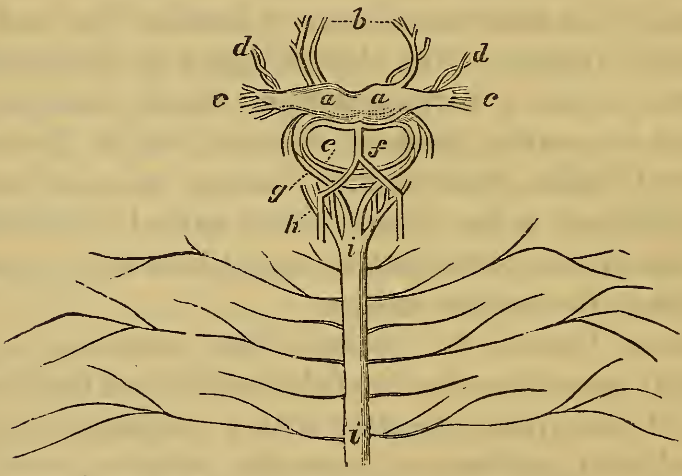


FIG. 33.—Anterior part of the Nervous System of Iulus (Owen). *a*, *a*, Cerebral ganglia; *c*, *c*, optic nerves; *d*, *d*, antennal nerves; *b*, nerves of the palpless mandibles; *g*, œsophageal cords; *e*, *f*, stomato-gastric nerves; *h*, motor nerves to the maxillæ, proceeding from the part which corresponds with the sub-œsophageal ganglia, here fused with *i*, *i*, the ventral cord.

The brain (*a*, *a*), elongated transversely, is divided by a slight median furrow, and is continuous with the short and thick optic nerves (*c*, *c*). Two separate nerves are received from the antennæ on each side (*d*, *d*), below and in front of the optic nerves; whilst nearer the middle line two other nerves on each side (*b*) are in relation with the palpless mandibles. The thick œsophageal cords (*g*) are continued from the posterior and inferior angles of the brain; and, as they descend to enter the medullary or sub-œsophageal ganglion at the commencement of the abdominal cord (*i*, *i*), they are united by a cross branch, as in many Crustacea (fig. 36). From this sub-œsophageal ganglion large nerves are given off on each side (*h*) to supply the maxillæ and other parts about the mouth.

"The stomato-gastric nerves, which arise from the posterior part of the brain immediately, form a third slender ring (*e*) about the œsophagus, from the middle of the upper part of which the trunk of the stomato-gastric system (*f*) is continued a short way back upon the stomach," when it divides into two branches which "bend abruptly backwards, and run parallel with each other along the dorso-lateral parts of the wide and straight alimentary canal." (Owen.)

In the more powerful predatory Myriapods, of which the common Centipede may be taken as a type, a distinct advance is met with. This carnivorous creature has a smaller number of better-developed limbs, and its nervous system closely resembles that found amongst the larvæ or Caterpillars of higher Insects (fig. 39). The supra-œsophageal ganglia, or brain, receive nerves from the two pairs of antennæ, and from the groups of ocelli on each side of the head. They are connected by œsophageal cords with a bilobed infra-œsophageal ganglion, which distributes nerves to the jaws and other parts about the mouth. This bilobed infra-œsophageal ganglion is the first and largest of a series of ventral ganglia, numbering about twenty, which are connected together by a double ventral cord. Every ganglion sends off lateral nerves to a pair of limbs. The stomato-gastric nerves are connected with the posterior part of the brain or with the œsophageal cords, and they distribute themselves over the alimentary canal in the usual manner.

FIG. 34. FIG. 35.

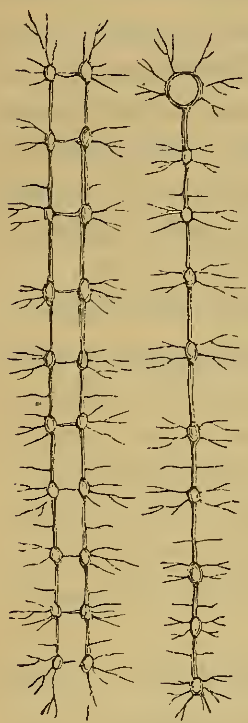


FIG. 34.—Nervous System of Common Sandhopper (*Talitrus locusta*). (Grant.) Showing separate cerebral ganglia, each about the same size as other ganglia situated on the separate ventral cords.

FIG. 35.—Nervous System of Cymothoa. (Grant.) Cerebral ganglia almost wholly absent from œsophageal ring. Œsophageal cords distinct, and uniting below into a single ventral cord, with compound ganglia at intervals.

Among **Crustacea** great differences are met with in the degree of concentration of the nervous system, the variations being, in the main, dependent upon differences of external form and in the arrangement of locomotor appendages, in the different representatives of the class. In some of the lower terms of the series, such as the Sandhopper and its allies, in which the body is elongated and composed of many almost similar segments, the nervous system is not very different from that of many Worms. In the Sandhopper, indeed, the ventral cords and ganglia (fig. 34) of the two sides of the body are separate from one another as they are in Serpula (fig. 32), although the ganglia are here fewer in number and much more distinct.

In slightly higher forms of Crustacea, however, the two divisions of the originally double ventral cord always become fused together, whilst, at the same time, the equality of the several ganglia diminishes. Thus, in such forms as the

Lobster and the Crayfish, the ganglia of the thorax, which supply nerves to the limbs, are distinctly larger than those of the abdominal segments, though these are also of good size, since the tail-segments are actively called into play during locomotion.

In the Prawn a further development and concentration of the nervous system is seen. The thoracic ganglia are fused into a single elliptical mass, whilst those of the abdominal segments still remain separate.

Fig. 36.—Nervous System of a Crab (*Palinurus vulgaris*). *a*, Fused cerebral ganglia receiving optic, tactile, and olfactory (?) nerves; *b*, *b*, long œsophageal cords; *c*, *c*, great ventral ganglionic mass. (Milne-Edwards.)

But in the ordinary edible Crab (fig. 36) and its allies, an even more remarkable concentration of the nervous system is met with. All the thoracic and all the abdominal ganglia are here fused into one large perforated mass of nervous matter (*c*, *c*), situated near the middle of the ventral region of the body.* From this large and compound ganglionic mass nerves are received from, and given off to, the limbs, to the abortive tail, and to other adjacent parts. The brain (*a*) of the Crab is represented by a rather small bilobed ganglion. It receives nerves from the pedunculated compound eyes, from the two pairs of antennæ, and from the palpi-bearing mandibles. The posterior antennæ (or antennules, as they are sometimes termed) contain in their basal joint a body which is supposed to represent an olfactory organ, though others have regarded it (on very insufficient grounds) as an organ of hearing. This small bilobed brain is, indeed, thought by

* A large artery passes through the aperture in this ganglion.

many naturalists really to embody three pairs of ganglia, in relation with three pairs of sensory organs, viz., eyes, tactile antennæ, and the supposed olfactory antennules.

The brain is connected, by means of a long cord on each side (*b*, *b*) of the œsophagus, with the anterior extremity of the great ventral ganglion. Nerves in relation with the organs of mastication join the cords about midway between the brain and the great abdominal ganglion, and small ganglia are to be found in this situation. Just behind these small ganglia a transverse commissure connects the cords with one another. The unusual length of the œsophageal cords is one of the most notable characteristics of the nervous system of the higher Crustacea, and this seems due in part to the fact that the sub-œsophageal ganglia remain separate instead of uniting with one another, as they do in fig. 18.

The 'stomato-gastric' system of Crustacea is very similar to that which exists in Centipedes. One part of it is given off from the œsophageal cord on each side, while another median branch proceeds from the posterior part of the united cephalic ganglia, as in Iulus (fig. 33, *f*). Where the main nerve lies on the upper surface of the stomach, in the higher Crustacea, it is connected with one or two ganglia from which branches pass to the walls of this organ. They send filaments also to the right and left, into the liver. This principal visceral nerve is brought into communication with the above-mentioned nerves, going to the organs of mastication, by means of two filaments which join the ganglionic swellings on the œsophageal cord at the part whence they issue.

Among **Arachnida** forms of the nervous system exist which agree in many respects with those belonging to members of the class last described—especially where there are general similarities in the external configuration of the body. Thus in Scorpions the arrangement of the nervous system is not very dissimilar from that met with in the Prawn and its allies. The thoracic ganglia have coalesced with one another and with the anterior abdominal ganglia; thereby forming a large stellate nervous mass which supplies the limbs and the anterior part of the abdomen. The ventral cord throughout the remainder of the abdomen, and its caudal prolongation, is marked at intervals by a series of small ganglionic swellings.

In Spiders proper, the nervous system attains its maximum amount of concentration. The bilobed brain (fig. 37, *c*) receives nerves on each side (*o*), corresponding in number with the ocelli which the animal may happen to possess.

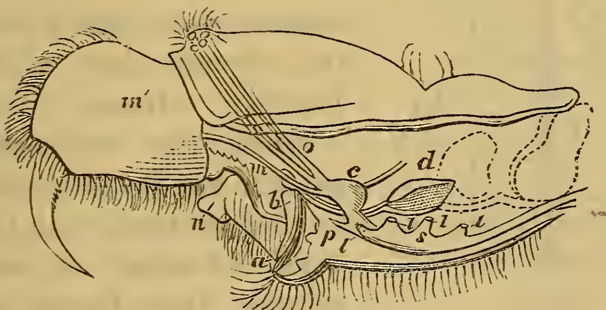


FIG. 37.—Head and Nervous System of a Spider (*Mygale*). (Owen after Dugès.) *c*, Cerebral ganglia (side view), receiving (*o*) optic nerves, and (*m*) nerves (sensory and motor) from the powerful mandibles, *m′*. The cerebral ganglia are connected by very short œsophageal cords with a large stellate ventral ganglion (*s*), from which five large nerves issue on each side (*p*, *l*, *l*); *a*, mouth; *b*, œsophagus; *d*, stomach.

It also receives two large nerves (*m*), which probably contain outgoing as well as ingoing fibres, from the so-called mandibles (*m′*).

Owing to the suctorial habits of these fierce and predatory creatures, the œsophagus is very narrow; and as a consequence, the œsophageal cords are very short, so that the brain is—unlike the arrangement which obtains in the common Crab and its allies (fig. 36)—quite close to the great stellate systemic ganglion (*s*), into which are fused the representatives of the sub-œsophageal, the thoracic, and the abdominal ganglia.

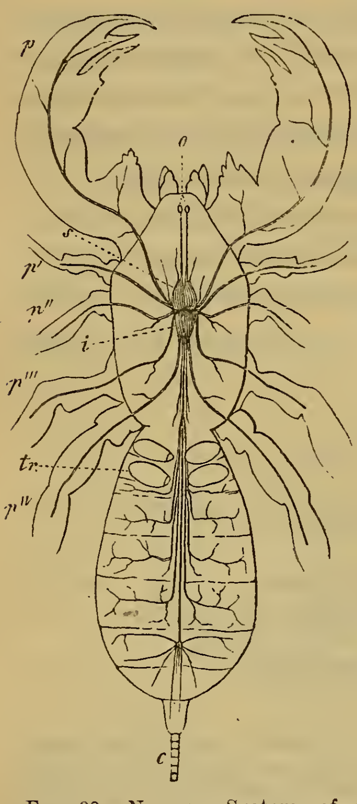


Fig. 38.—Nervous System of a great scorpion-like Spider (*Thelyphonus caudatus*). (Gegenbauer, after Blanchard.) *s*, Cerebral ganglia; *i*, great ventral ganglion, communicating with five large nerves on each side; *o*, eyes; *p*, palpi; *p'*-*p*^iv, feet; *c*, tail-like prolongation.

From this ganglion (fig. 38, *i*) five principal nerves are sent off on each side, "the first to the pediform maxillary palpi; the second to the more pediform labial palpi, which are usually longer than the rest of the legs, and used by many Spiders rather as instruments of exploration than of locomotion; the three posterior nerves supply the remaining legs, which answer to the thoracic legs of hexapod Insects." (Owen.)

Since the sub-œsophageal ganglia are in part analogous, as already stated, with the 'medulla oblongata' of vertebrate animals, their fusion with the thoracic ganglia in Arachnida, as well as in Myriapoda, tends, in a measure, to confirm the view held by some anatomists, that it is better to regard the 'medulla' as a prolongation of the spinal cord, than as an integral part of the brain. The artificial line, that is, which for convenience is drawn between the brain and the cord in Vertebrates, should be placed at the upper rather than the lower or posterior boundary of the 'medulla,' so that the latter part may be regarded as the more highly developed portion of the spinal cord by which fusion with the brain is effected.

The visceral nerves are well developed in the higher Arachnida. They consist of one or two filaments, on which a ganglion may exist, in connection with the posterior part of the brain, and thence proceeding to the stomach and other internal organs. There are, moreover, two or three branches given off from the great ventral ganglion which, after passing through smaller ganglia, distribute numerous filaments to the intestines, the respiratory and genital organs, as well as other viscera. The former set may be in the main afferent, and the latter perhaps principally efferent visceral nerves.

Organs of vision are much more elaborate in Crustacea, Spiders and Insects, than among Worms or Centipedes. And, whilst organs of touch and taste are further perfected, two sensory endowments, found among higher Mollusks, seem also to manifest themselves. These higher Arthropods are capable of being impressed by, and of discriminating, the different odours of some substances anterior to their contact with the mouth. This power must materially aid them in their 'search' for or recognition of food. Some Arthropods seem to be also capable of appreciating those vibrations of the medium they inhabit which induce impressions recognizable by us as sounds or noises. Still, in some of the most highly organized forms of Insects a sense of hearing appears to have no existence. Much uncertainty, in fact, exists in regard to this sense-endowment.* Extreme sensibility of the tactile order may cause the organism to display an apparent sensitiveness to sounds. A delicate general ability to appreciate aerial vibrations, therefore, must not be confounded with the

* *See* pp. 65 and 205.

more special auditory perception. On the other hand, it is quite possible that sounds not appreciable by our

Fig. 39.

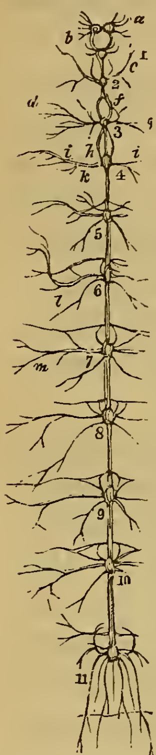


Fig. 40.

Fig. 41.

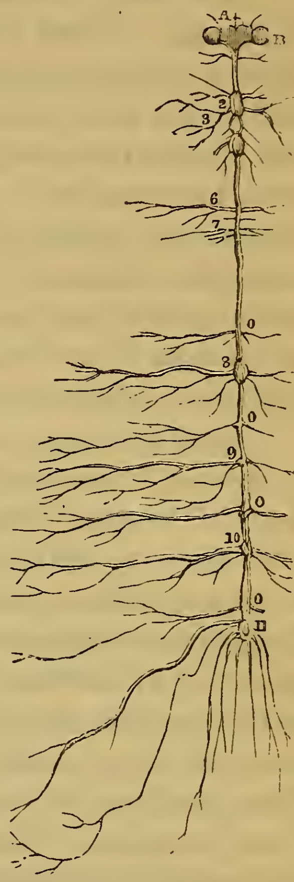


Fig. 39.—Nervous System of full-grown Caterpillar of Privet Hawk-Moth (*Sphinx igustri*), about two days previous to its change to the chrysalis state.

Fig. 40.—Nervous System of the Privet Hawk-Moth thirty days after changing to the chrysalis state. The abdominal cords are now seen to be much shortened, and bearing five instead of seven ganglia.

Fig. 41.—Nervous System of the perfect Insect. A, Greatly enlarged cerebral, and B, optic ganglia. The numerals refer to the numbers of the ganglia. *o, o, o, o,* respiratory nerves, 'nervi transversi.' (Solly after Newport.)

organization may be perceptible by the sensory organs and centres of some of the lower organisms.

Additional sensory endowments like Smell and Hearing would, of course, be of importance to any organisms, but more especially to those possessing active powers of locomotion. They would serve, on the one hand, to assist in bringing their possessors into relation with food, or with sexual mates, and, on the other, to warn them of the approach of enemies.

The nervous system of **Insects** varies not only among different classes and orders, but even in the same individual in different stages of its development. The caterpillar of a Moth (fig. 39) or Butterfly presents a nervous system not very different from that met with in the Centipede; while in the imago or perfected Insect, the same system has undergone some remarkable changes—there is, for instance, an increased size of the cerebral ganglia, and also a notable development of some of the ganglia pertaining to the ventral cord, while concentration or even suppression of others is met with.

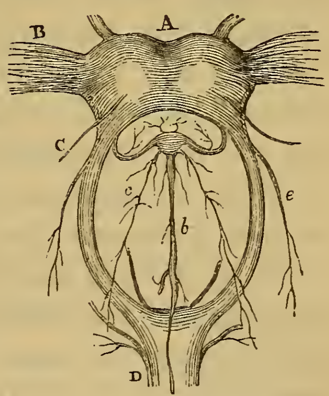


FIG. 42.—Brain and Adjacent Parts of Nervous System of a rather sluggish, apterous Beetle, *Timarcha tenebricosa*. (Newport.) A, Brain receiving the antennal nerves, and also B, the optic nerves; C, origin of the sympathetic from and near the commencement of the œsophageal cords; D, the sub-œsophageal ganglia; *b*, the vagus, or visceral nerve before reaching its ganglion; *c*, lateral visceral nerves.

In such insects as Butterflies, Bees, Dragon-flies, and others where the visual organs are enormously developed, and in which the power of vigorous and sustained flight is correspondingly increased, the nervous system as a whole attains its maximum of development among the Arthropoda. The brain of these creatures differs from that existing in all other members of the class by reason of the great development of those portions of it in relation with the visual organs, as may be seen by fig. 45, representing the nervous system of the Common Fly, and by fig. 42, representing the brain of a Beetle. A ganglionic swelling is frequently found where the optic nerve joins the brain, and in some Insects there are also small ganglionic swellings at the corresponding parts of the antennal nerves.

It is in Ants, Bees, and Flies, however, that the brain of Insects seems to attain its greatest development. Speaking of the brain of the Blow-fly, B. T. Lowne says*:— "Next to bees and ants that of the blow-fly is the largest known in any insect proportionally to its size, being about thirty times larger than the cephalic ganglia of the larger beetles." The same writer adds:—"But a more positive indication of a higher type of organization than even the relative bulk of the sensory ganglia is found in the fact that two very remarkable convoluted nerve centres, connected by a commissure, each about 1-30th of an inch in diameter, surmount the cephalic ganglion, and are connected to it by a pair of distinct peduncles;† these are extremely like the pedunculated convoluted nerve centres which occupy the same position in bees and ants, first described by M. Felix Dujardin ("Ann. des Sc. Nat." (Ser. iii.), t. xiv. p. 195), and considered by him as analogous to the cerebral lobes of the higher animals. That naturalist failed to distinguish these organs in the fly, probably owing to their being imbedded in the substance of the cephalic ganglion." In the Bee, according to Dujardin, these peculiar bodies are attached to the sensory ganglia by a single peduncle, and their united bulk is said by him to equal $\frac{1}{5}$th of the whole brain. Further details concerning these interesting structures are much needed.

The double cerebral ganglion is connected in nearly

* "Anat. of the Blow-fly," p. 14. † Loc. cit., Pl. vii. fig. 4.

all Insects with a separate sub-œsophageal ganglion, from which nerves are given off to the mandibles, the maxillæ, and the labium. But, as in Spiders, the œsophageal ring is often very narrow, owing to the greatly diminished size of the œsophagus in the imago forms of higher Insects. In Spiders and Myriapods, as before stated, the sub-œso-

Fig. 43.

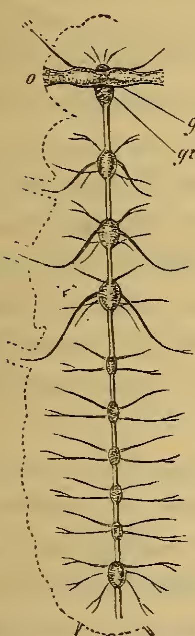


Fig. 44.

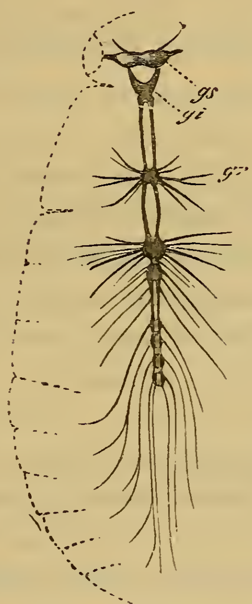


Fig. 45

Fig. 43.—Nervous System of a White Ant (*Termes*). (Gegenbauer after Lespès.)
Fig. 44.—Nervous System of a Water Beetle (*Dytiscus*). (Gegenbauer.)
Fig. 45.—Nervous System of a Fly (*Musca*). (Gegenbauer after Blanchard.) o, Eyes; *gs*, supra-œsophageal ganglia (brain); *gi*, sub-œsophageal ganglion; *gr*, g^2, g^3 fused ganglia of the thorax.

phageal ganglion has no separate existence apart from the thoracic ganglia.

In many Insects the three thoracic ganglia preserve a separate existence (fig. 43), though in others of the higher types above referred to these ganglia are more frequently fused into a single lobed mass (fig. 45). The eight abdominal ganglia, which are always much smaller than the thoracic, also continue to have a separate existence among some of the less developed types of Insects (fig. 43) though it is more frequent for some, or even all, of them to disappear (figs. 44, 45).

The 'stomato-gastric' system of nerves attains a considerable degree of complexity in these animals. In front there is a median ganglion (fig. 42) lying below and often anterior to the brain. This oral ganglion is a swelling situated on the great median (afferent) visceral nerve, at the spot where it bifurcates in order to proceed to each half of the brain. It receives branches from the mouth and adjacent parts. The main nerve, or else the ganglion, is also connected with other branches (c), proceeding from one or two pairs of lateral ganglia situated close to the œsophageal cords, and often in structural relation with them. This visceral system of nerves receives branches from the stomach, the intestines, and other internal organs.

In Insects, moreover, we meet with another semi-independent set of visceral nerves, connected with a chain of minute ganglia lying upon the great ventral ganglionated cord, and united thereto by means of minute nerve filaments. The nerves (fig. 41, o, o, o) in connection with this chain of minute ganglia are received from and distributed to the all-pervading respiratory organs (air tubes) of the Insect. They are known to anatomists, on account of the disposition of their main branches, as 'nervi transversi,' and are much more highly developed in these animals than are anything corresponding to them amongst other Arthropods.

CHAPTER VII.

DATA CONCERNING THE BRAIN DERIVED FROM THE STUDY OF THE NERVOUS SYSTEM OF INVERTEBRATES.

This survey of some of the principal varieties of the Nervous System among the Invertebrata, brief though it has been, should have sufficed to call attention to many important facts and to show the warrant for certain related inferences, many of which are embodied in the following propositions:

1. Sedentary animals, though they may possess a Nervous System, are often headless, and they then have no distinct morphological section of this system answering to what is known as a Brain.

2. Where a Brain exists, it is invariably a double organ. Its two halves may be separated from one another; though at other times they are fused into what appears to be a single mass.

3. The component or elementary parts of the Brain in these lower animals are Ganglia in connection with nerves proceeding from special impressible parts or Sense Organs; and it is through the intervention of these united Sensory Ganglia that the animal's actions are brought into harmony with its environment or medium.

4. That the Sensory Ganglia, which in the aggregate constitute the Brain of invertebrate animals, are connected

with one another on the same side and also with their fellows on opposite sides of the body. They are related to one another either by what appears to be continuous growth or by means of 'commissures.'

5. The size of the Brain as a whole, or of its several parts, is therefore always fairly proportionate to the development of the animal's special Sense Organs. The more any one of these impressible surfaces or organs becomes elaborated and attuned to take part in discriminating between varied external impressions, the greater will be the proportionate size of the ganglionic mass concerned.

6. Of the several sense-organs and Sensory Ganglia whose activity lies at the root of the Instinctive and Intelligent life (such as it is) of Invertebrate Animals, some are much more important than others. Two of them especially are notable for their greater proportional development: viz., those concerned with Touch and Vision. The organs of the former sense are, however, soon outstripped in importance by the latter. The visual sense, and its related nerve-ganglia, attain an altogether exceptional development in the higher Insects and in the highest Mollusks.

7. The sense of Taste and that of Smell seem, as a rule, to be developed to a much lower extent. In the great majority of Invertebrate Animals it is even difficult to point to distinct organs or impressible surfaces as certainly devoted to the reception of either of such impressions. Nevertheless, as we shall subsequently find, there is reason to believe that in some Insects the sense of Smell is marvellously keen, and so much called into play as to make it for such creatures quite the dominant sense endowment. It is pretty acute also in some Crustacea.

8. The sense of Hearing seems to be developed to a very slight extent. Organs supposed to represent it have been

discovered, principally in Mollusks and in a few Insects. It is, however, of no small interest to find that where these organs exist, the nerves issuing from them are most frequently not in direct relation with the Brain, but immediately connected with one of the principal motor nerve-centres of the body. It is conjectured that these so-called 'auditory saccules' may, in reality, have more to do with what Cyon terms the sense of Space than with that of Hearing (p. 218). The nature of the organs met with supports this view, and their close relations with the motor ganglia also become a trifle more explicable in accordance with such a notion.

9. Thus the associated ganglia representing the double Brain are, in animals possessing a head, the centres in which all impressions from sense-organs, save those last referred to, are directly received, and whence they are reflected on to different groups of muscles—the reflection occurring not at once but after the stimulus has passed through certain 'motor' ganglia. It may be easily understood, therefore, that in all Invertebrate Animals perfection of sense-organs, size of brain, and power of executing manifold muscular movements, are variables intimately related to one another.

10. But a fairly parallel correlation also becomes established between these various developments and that of the Internal Organs. An increasing visceral complexity is gradually attained; and this carries with it the necessity for a further development of nervous communications. The several internal organs with their varying states are gradually brought into more perfect relation with the principal nerve centres as well as with one another.

11. These relations are brought about by important visceral nerves in Vermes and Arthropods—those of the 'Stomato-Gastric System'—conveying their impressions

either direct to the posterior part of the Brain or to its peduncles. They thus contribute internal impressions which impinge upon the Brain side by side with those coming through external sense organs.

12. This Visceral System of Nerves in invertebrate animals has, when compared with the rest of the Nervous System, a greater proportional development than among vertebrate animals. Its importance among the former is not dwarfed, in fact, by that enormous development of the Brain and Spinal Cord which gradually declares itself in the latter.

13. Thus impressions emanating from the Viscera and stimulating the organism to movements of various kinds, whether in pursuit of food or of a mate, would seem to have a proportionally greater importance as constituting part of the ordinary mental life of Invertebrate Animals. The combination of such impressions with the sense-guided movements by which they are followed, in complex groups, will be found to afford a basis for the development of many of the Instinctive Acts which animals so frequently display.

CHAPTER VIII.

THE BRAIN OF FISHES AND OF AMPHIBIA.

In all Vertebrates the relation of the principal nervous ganglia to the commencement of the alimentary canal is different from that existing among the Invertebrates. We no longer find, as in the Mollusk, the Worm, or the Insect a ring of nerve matter encircling the œsophagus. The parts which in Fishes answer to the supra- and sub-œsophageal ganglia lie altogether above the œsophagus, and they are, moreover, directly continuous with one another, instead of being connected by long or short commissures.

In Fishes, as well as in other Vertebrates, all the parts constituting the Brain, as well as the Medulla Oblongata, are enclosed within a distinct 'skull' or 'cranium,' while within this they are again surrounded by two membranes —one of which, and the thicker of the two, lines the inner surface of the cranium; while the other, which is delicate and transparent, immediately envelops the great nerve centres. The Spinal Cord, which is directly continuous with the Medulla, is also lodged in a bony case known as the 'spinal canal'; and this is formed by the contiguous posterior arches of the several vertebræ composing the spine or vertebral column.

Among the Invertebrata, it is the nervous system of Insects and other Arthropods which approaches most closely to that of Fishes, inasmuch as they possess a single or double ganglionated nervous cord running through the body, which is fairly comparable with the spinal cord. In Insects and their allies, however, this cord is situated in the ventral region; while the spinal cord of Vertebrates lies above the alimentary canal in the dorsal region of the body. No such structure exists or is needed among Mollusks, because these organisms have no articulated locomotor appendages, and are otherwise notably different in form and organization; yet it is true that among the highest representatives of this latter class (viz., the Cephalopods), we get the first approach to the formation of a distinct brain case or 'cranium.'

All the nerve-centres situated within the cranium have been regarded as parts of the Brain in Vertebrates, whilst those lying beyond it, and within the spinal canal, constitute the Spinal Cord: the two together are sometimes spoken of as the 'Cerebro-Spinal Axis.'

But in addition to the Sensory Ganglia, and the Medulla Oblongata, there are certain highly important supplementary parts entering into the composition of the Brain of the Fish. There is, for instance, a pair of bodies known as the **Cerebral Lobes**; whilst further back, in connection with the Medulla, we have another new nervous ganglion, single, but having equal parts on each side of the middle line, which is known as the **Cerebellum.** That representatives of these parts (seemingly superadded to the brain of Fishes and other Vertebrates) are really non-existent in the highest Mollusks and Insects it would not be safe to affirm; especially as ganglia, which have been compared to Cerebral Lobes, exist in the Cuttlefish, and even more distinctly in Ants, Bees and some Flies. On the other hand, both the Cerebral Lobes and the

Cerebellum tend to increase in size and become more and more complex as we pass from Fishes to Reptiles, from Reptiles to Birds, and from Birds to Mammals.

The relative size of these parts, however, as well as of other divisions of the Brain, will be found to vary greatly in different kinds of Fishes.

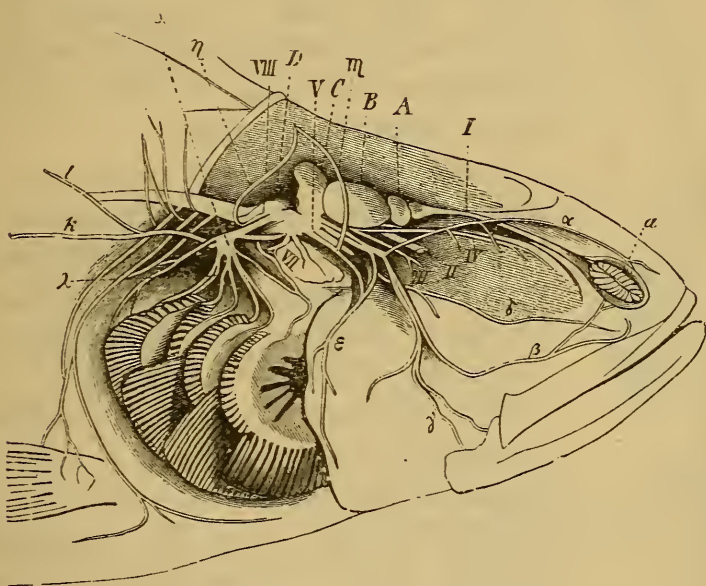


FIG. 46.—Brain and Cranial Nerves of the Perch, side view. (Gegenbauer, after Cuvier.) *A*, Cerebral lobe with olfactory ganglion in front; *B*, optic lobe; *C*, cerebellum; *D*, medulla oblongata; *I*, olfactory nerve coming from *a*, the nasal sac; *II*, optic nerve cut across; *III*, oculo-motor; *IV*, trochlear nerve; *V*, trigeminal; *VII*, auditory; *VIII*, vagus, with its ganglion; *k*, lateral branch of the vagus; *l*, upper twig of the same; *m*, dorsal branch of the trigeminus, which is joined by *n*, the dorsal branch of the vagus; α, β, γ, three branches of the trigeminus; δε, facial nerve; λ, bronchial branches of the vagus.

The **Spinal Cord** of Fishes is more or less cylindrical in shape (fig. 47, H) and almost uniform in thickness throughout, except that it tapers to a point posteriorly. It occurs only rarely that there is, as in the Ray, a slight swelling in the region where the nerves from the great pectoral fins are received, and sent forth. From the whole length of the spinal cord a series of nerves is given off on each side, and each of them is connected therewith by an anterior (or motor) and a posterior (or sensory) root, the latter swelling into a more or less distinct ganglion just where its fibres begin to mingle with those of the anterior root. This mode of connection of the spinal nerves with the spinal cord exists throughout the class of Fishes and also in all other Vertebrates.

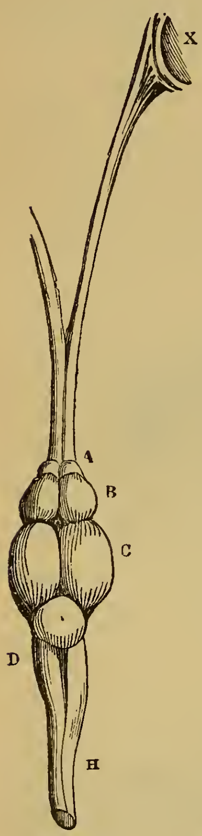


FIG. 47.—Brain of the Pike. A, Olfactory ganglia; B, cerebral lobes; C, optic lobes; E, cerebellum; H, spinal cord; X, olfactory nerve, dividing and penetrating the plate of the ethmoid bone (Solly.)

Anteriorly the cord is continuous with a slightly more swollen prolongation—the before-mentioned **Medulla Oblongata** (fig. 47, D). Many very important nerves, to which reference will subsequently be made, are attached to this part.

Growing from the back of the anterior extremity of the medulla is a semi-ovoid or tongue-like projection, which has been already referred to as the **Cerebellum.** Though single in appearance, it is really double and composed of two symmetrical halves. No distinct connection of nerves with this body can be detected by the naked eye.

The cerebellum exists in its simplest form in the parasitic Cyclostomes, in the Sturgeon, and also in Polypterus and Lepidosiren, where it appears merely as a simple bridge or commissure, crossing the anterior and upper part of the medulla. In most osseous Fishes it is larger, and projects backwards over the medulla in the form of a smooth, convex, semi-ovoid, or tongue-like body (fig. 49, *d*). According to Professor Owen, the cerebellum is "very small in the lazy Lump-fish, and extremely large in the active and warm-blooded Tunny." It attains its highest development, however, in Sharks (fig. 48, c). In these most active and predaceous fishes the cerebellum not only covers much of the medulla, but advances forwards over the optic lobes, and the extent of its surface is further increased by the existence of numerous superficial folds or indentations.

In front of the cerebellum are two rounded ganglia known

FIG. 48.

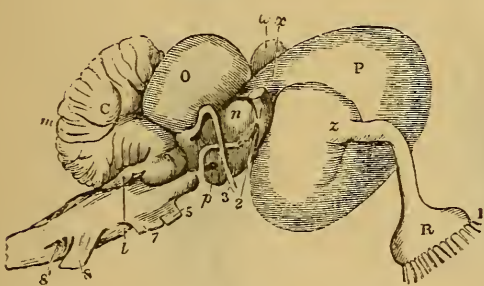


FIG. 49

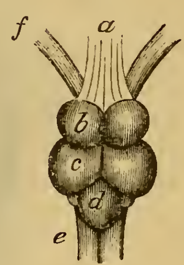


FIG. 48.—Brain of the Shark (*Carcharias*), side view. (Owen.) P, Cerebral hemisphere; O, optic lobe; C, cerebellum with surface folds (*m*); R, olfactory ganglion, giving off (1) olfactory nerves; *z*, junction of olfactory peduncle with cerebral lobe; *x*, Crus cerebri; *w*, pineal body; *n*, hypoaria; *p*, pituitary body; 2, optic nerve; 3, oculo-motor nerve; 5, trigeminus; 7, auditory; 8, vagus.

FIG. 49.—Brain of Roach. *a*, Olfactory peduncles; *b*, cerebral lobes; *c*, optic lobes; *d*, cerebellum; *e*, medulla; *f*, optic nerves. (After Spurzheim.)

as the **Optic Lobes** (fig. 49, *c*), which correspond with the principal part of the Insect's brain. The optic nerves are connected with their under surface; and they decussate (figs. 51, 57), so that the one proceeding from the right eye passes to the left optic lobe, and that from the left eye to the right optic lobe. This new kind of cross arrangement will, in a later chapter, be referred to in detail, since, with slight differences, it also exists in other Vertebrates, and, moreover, seems gradually to extend to other parts of the nervous system.

In many of the lower Fishes the eyes are very rudimentary. In the young Lamprey two pigment spots replace the single 'eye spot' of the Lancelot. In the genus Myxine the eyes are represented by small bodies, which, though in connection with slender optic nerves, are covered over by muscle as well as by skin. The ocular muscles for moving the eyeball are absent in many Fishes; this is the case even in the Gar-Pike, in which, though

FIG. 50.

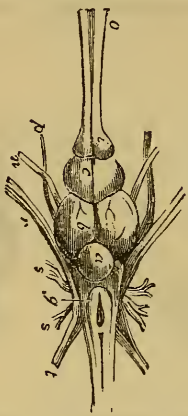


FIG. 51.

FIG. 50.—Brain of Perch, upper surface. (Owen after Cuvier.) *a*, Cerebellum; *b*, optic lobes; *c*, cerebral lobes; *i*, olfactory ganglia; *g*, medulla; *p*, *n*, *r*, *s*, *t*, cranial nerves.

FIG. 51.—Brain of Perch, under surface. (Owen after Cuvier.) *a*, Medulla; *e*, hypoaria; *f*, pituitary body; *n*, optic nerves, decussating; *c*, cerebral lobes; *i*, olfactory ganglia; *p*, *q*, *r*, *s*, *t*, cranial nerves.

small, the eyes are at the surface. In the great majority of Fishes, however, these organs are large and attain a remarkable development.

The optic lobes are usually the largest divisions of the brain in osseous fishes, as in the Perch (fig. 50), and they are commonly united by one or more transverse commissures. Each of them generally contains a distinct cavity or 'ventricle,' and they often bear on their under surface two smaller ganglionic projections, known as 'hypoaria.' These bodies are well developed in the Perch, and in the Cod (figs. 51, 57). Their use is unknown, and it is remarkable that they are structures peculiar to the brain of Fishes.

In connection with the optic lobes there are also two peculiar structures, one above and the other below, known as the 'Pineal' and 'Pituitary' Bodies (figs. 53, 3; 60, 3, 6).

In front of the optic lobes are the already men-

FIG. 52.

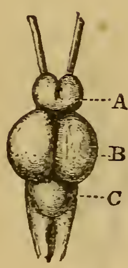


FIG. 53.

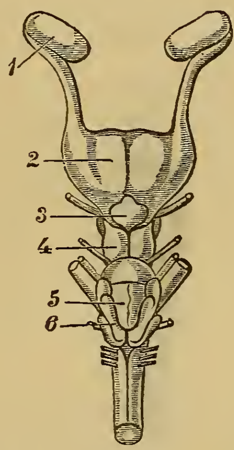


FIG. 52.—Brain of Carp. (Ferrier.) A, Cerebral lobes; B, optic lobes; C, cerebellum and medulla.

FIG. 53.—Upper aspect of the Brain of a Ray, or Skate (*Raia batis*). 1, Olfactory lobes; 2, the conjoined cerebral lobes; 3, the pineal gland; 4, optic lobes; 5, cerebellum; 6, medulla, with ganglionic projections. (Mivart.)

tioned **Cerebral Lobes.** They, like the cerebellum, have no obvious connection with nerves, and vary much in size in different Fishes, though they are mostly, as in the Carp (fig. 52) and the Perch (fig. 50), smaller than the optic lobes.

The Cerebral Lobes are smallest in the Lamprey and its allies, in the Herring, and in the Cod; while they are most developed in the Skate, the Shark, Polypterus, and Lepidosiren. In the Skate (fig. 53), they coalesce into a somewhat flattened, transversely elongated mass, showing only slight indications of a median fissure. In the Shark (fig. 48) they also unite to form a large almost globular mass with little trace of a median furrow. A similar fusion of the two lobes occurs in some other Fishes, though in the majority they exist as spheroids united only by a transverse commissure. In Lepidosiren the cerebral hemispheres are larger than all the rest of the brain; each of them also contains a cavity or ventricle, which is

FIG. 54.

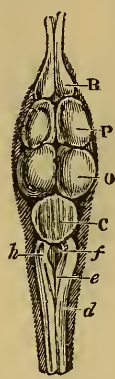


FIG. 55.

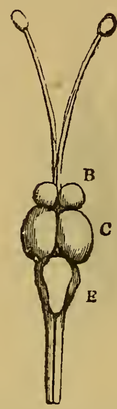


FIG. 54.—Brain of Lepidosteus or Gar-Pike. (Owen.) *n*, Olfactory ganglia; *p*, cerebral lobes; *o*, optic lobes; *c*, cerebellum; *h*, medulla; *f*, fourth ventricle; *d*, lower boundary of medulla.

FIG. 55.—Brain of the Whiting. (Solly.) A, Olfactory ganglia; B, cerebral lobes; C, optic lobes; E, cerebellum and medulla.

prolonged into the olfactory lobe. In these respects they closely agree with the cerebral lobes of Reptiles.

In the Gar-Pike (fig. 54), the Perch, the Mackerel, and many other Fishes, two additional ganglia known as the **Olfactory Lobes** lie immediately in front of the cerebral lobes, and each of them receives a long olfactory nerve.*

* The Lancelot has a single olfactory sac and a single nerve; in all other fishes, except in the Lamprey and its allies, there are two nerves (see Huxley, "Journ. of Linn. Soc." (Zool.), vol. xii. p. 224).

But in such Fishes as the Whiting (fig. 55), the Carp (fig. 52), the Skate (fig. 53), the Shark (fig. 48), and others, the olfactory ganglia are situated at a distance from the cerebral lobes, with which they are connected only by means of two long and narrow outgrowths or peduncles. In these latter Fish the ganglia are to be found close to the olfactory organs, from which they receive numerous short nerves.

Such are the essential parts in the brain of the Fish. Their relative size or development is, however, subject to almost countless diversities in different genera.

From the foregoing description, it will be seen that one of the principal characteristics of the Brain of Fishes is to be found in the serial arrangement of its parts, in a line with one another and with the spinal cord; whilst another is the small mass of the Brain as compared with that of the Spinal Cord, and still more in comparison with the mass and weight of the entire body.

In the former respect, at least, the Brain of AMPHIBIA (fig. 56) agrees closely with that of Fishes. The principal

FIG. 56.—Brain and Spinal Cord of the Frog A, Olfactory lobes; B, cerebral lobes; R, pineal body; C and D, optic lobes; E, cerebellum; H, spinal cord.

divisions of the brain also in these animals are identically the same. The Brain of the Frog is notable principally for the smaller size of its Cerebellum, and also for the diminished bulk of its Optic Lobes and Olfactory Ganglia. The Cerebral Lobes, are, therefore, proportionately large. The Spinal Cord is shorter than usual, and does not occupy the whole length of the 'spinal canal.'

Though the Cerebellum itself does not appear to be immediately connected with any nerves, the Medulla Oblongata, from which this part is an outgrowth, is remarkable in Fishes, as well as in other vertebrates, for the number and importance of the nerves with which it is connected. Indeed, if the limits of the Medulla are taken to be those originally defined by Willis and most anatomists anterior to Haller (1762), they will include the 'crura cerebri'; and in that case all the **Cranial Nerves** (that is, the nerves which pass inwards or outwards through holes in the cranium), except the olfactory and the optic, would have to be described as in direct connection with the medulla oblongata.

The Cranial Nerves of Fishes and of Amphibia are, with few exceptions, similar in number and nature to those existing throughout the vertebrate series, so that they may with advantage be here enumerated. According to the classification of Willis (1664), which is generally followed, they are said to consist of nine pairs, counting from before backwards. (*See* figs. 46, 57, 58.)

CRANIAL NERVES.

- 1st Pair. *Olfactory.*
- 2nd „ *Optic.*
- 3rd „ *Motor oculi communis;* supplying all but two of the muscles of the eyeball and the circular fibres of the iris.
- 4th „ *Trochlearis;* supplying the superior oblique muscle of the eye.
- 5th „ *Trigeminus*
  - Large root: the nerve of general sensibility for the side of the head, face, &c.
  - Small root: supplying muscles connected with the jaw (muscles of mastication).
- 6th „ *Motor oculi externus;* supplying the external rectus muscle of the eyeball.

CRANIAL NERVES.	7th „	*Auditory.* *Facial;* supplying the superficial muscles of the face, &c.
	8th „	*Glosso-pharyngeal* (gustatory nerve and nerve of common sensibility for the pharynx). *Vagus,* or *Pneumogastric* (sensory nerve of respiratory organs, heart, alimentary canal, liver, kidneys, &c. *Spinal accessory;* supplying the muscles of the larynx, &c.
	9th „	*Sublingual,* or *Hypoglossal;* motor nerve of tongue and of muscles which move it.

From this table it will be seen that three of the 'pairs' of cranial nerves (5th, 7th, and 8th) are compound in their nature. Their parts have, moreover, little in common, except for the fact that the components of each so-called 'pair' in man and many of the lower animals pass side by side through the same hole in the skull. This, indeed, seems to have been the principal reason actuating the earlier anatomists when they grouped them together.* No cranial nerves answering to the 9th pair exist in Fishes: their functions being discharged by branches from the first spinal nerve. The motor root of the 8th, the 'spinal accessory,' is also less distinct as a separate nerve in Fishes and some Reptiles, than it is in higher vertebrates.

Looked at from the point of view of the functions which

* Except in the case of the two divisions of the 5th nerve, this grouping was not respected in the classification of Sœmmering (1778). According to him, the cranial nerves were to be regarded as twelve pairs, the first six agreeing with those of Willis, whilst the facial is called the 7th, the auditory the 8th, the glosso-pharyngeal the 9th, the vagus the 10th, the spinal accessory the 11th, and the sublingual the 12th.

they subserve, these Cranial Nerves fall into the following groups:

I. *Nerves of Special Sense.*	Olfactory. Optic. Auditory. Gustatory.
II. *Nerves of General Sensibility.*	Large root of 5th. Part of Glosso-pharyngeal. Vagus (the visceral nerve).
III. *Motor Nerves.*	Motores oculi (3rd, 4th, and 6th pairs). Small root of 5th. Facial nerve. Spinal accessory. Sublingual or Hypoglossal.

Taking the larger view held by Willis and others, as to the limits of the Medulla Oblongata, and including under this name all those parts of the Brain, with the exception of the cerebellum, posterior to the optic lobes, we find the several pairs of true cranial nerves (from 3rd to 9th inclusive) attached to it on each side, and for the most part in the order of their numeration (the 3rd issuing from it close to the optic lobes, and the 9th close to the junction of the medulla with the spinal cord), with the reservation that in Fishes the nerves of the 8th pair are the last which pertain to the medulla.

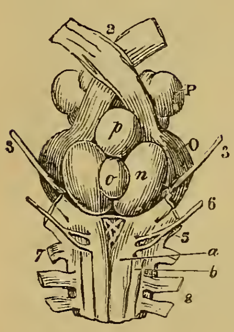


FIG. 57.—Brain of the Cod, under surface. (Owen.) P, Cerebral lobes; C, optic lobes; *n*, hypoaria; *p*, pituitary body; *a*, anterior pyramids; 2, optic nerves, crossing; 3, oculo-motor; 5, trigeminus; 6, external ocular; 7, auditory; 8, vagus and glosso-pharyngeal.

The 'sensory' nerves attached to the Medulla, are, like those of the spinal cord marked by **ganglionic swellings** near or at the points of attachment of such nerves (p. 44).

Thus the roots of the Vagus or Pneumogastric in a large number of fishes become swollen into distinct ganglia at their point of junction with the Medulla, and in some—such as the Carp, the Torpedo, the Electric Eel, and the Skate—these lateral ganglia, situated at the side of the cerebellum, are exceptionally large. The Glosso-pharyngeal is in reality only a large separate branch of the vagus. In some fishes it joins one of the roots of the vagus; and, even where this external junction does not exist, an internal union is effected by the smaller nerve entering the nucleus of the larger one.

A little anterior to the ganglia of the Vagi, large swellings are also frequently met with in connection with the roots of the Trigeminal nerves (fig. 10), which in fishes are mostly very large, and have an extensive distribution even beyond the region of the head. The remaining sensory nerves of the medulla—the Auditory—are attached to it by two or three roots, between the vagi and the 5th nerves. These nerves are large, though it is only rarely that a distinct ganglionic swelling is found at their point of junction with the medulla (fig. 11). The ganglia are usually embedded in the Medulla itself, and some of its roots soon join another large ganglion: viz., the Cerebellum. This apparent connection of the auditory nerves with the great motor ganglion in Vertebrates, whatever its explanation may be, is quite in harmony with the close relation of the 'auditory saccules' and nerves to the pedal ganglia in Mollusks, and with their relation to the most active motorial centres of the ventral cord in those Insects (such as Locusts and Grasshoppers) in which the so-called 'auditory saccules' have been positively detected.*

* The Organs of Hearing in Fishes are always double, as in invertebrate animals. They are, moreover, situated within the body, and mostly have no connection with its surface. Sometimes

The ganglia at the roots of the Olfactory and Optic nerves are sufficiently obvious and remarkable, so that no further reference need here be made to them, except to point out that they, together with the ganglia at the roots of the Trigeminus and Vagus, undergo a proportionate diminution in size as the Cerebral Lobes become better developed, among Reptiles and Birds—changes which seem to imply that functions previously discharged by lower sensory ganglia are gradually passed on and merged as products of a higher order of cerebral activity, when such higher co-ordinating centres arise and come into fuller action.

The ganglia at the roots of the Auditory nerves, however, do not seem to attain their maximum size till we come to Reptiles, a fact which may be accounted for by the probably rudimentary state of this sense endowment among Fishes.

It will be found, therefore, to be a peculiarity of all Sensory Nerves in vertebrate animals that their fibres pass through such Ganglia before they impinge upon the great nerve centres—a fact originally noticed by Sir Charles Bell. No corresponding ganglia exist in connection with motor nerves, outside the anterior cornua of the spinal cord.

they are lodged outside the cranial cavity, sometimes in the walls of the cranium, and sometimes half within and half outside this cavity. Their structure is extremely simple, and in some fishes they are only a very little more complex than the 'auditory saccules' met with in the Cuttle-fish. In the fact that in Fishes, as in other vertebrates, the auditory organs are always situated in the head, we have a departure from the rule so commonly obtaining among Invertebrates. Perhaps, in its simplest forms, this apparatus may have as much to do with the organism's Space relations as with Hearing (see p. 218).

CHAPTER IX.

THE BRAIN OF REPTILES AND OF BIRDS.

The nervous system of Reptiles generally exists in a slightly more developed form than that which is common amongst Fishes.

The **Spinal Cord** occupies the whole length of the spinal canal. It is slender and almost uniform in thickness in Serpents, though it is relatively stouter in Crocodiles and their allies. In the latter it also presents decided swellings in those regions whence the nerves are given off, on each side, for the fore and hind limbs.

The principal divisions of the Brain are the same in all kinds of Reptiles, though, as might have been expected from the varied form and nature of the different representatives of this great class, the respective development of the several divisions of the organ varies much in different orders.

The **Medulla Oblongata**, directly continuous with the spinal cord, slightly widens at its upper part, where it is surmounted by the **Cerebellum**. This latter structure, in the Lizard (fig. 59) and its allies, is very small, consisting only of a thin lamella. The cerebellum is larger, however, among Serpents (fig. 58), and it becomes still more developed in Turtles (fig. 61) and Crocodiles.

The **Optic Lobes** are relatively smaller in most Reptiles than they are among Fishes; and in the Boa Constrictor they show a transverse fissure which divides the two bodies into four parts, corresponding to the 'corpora quadrigemina'

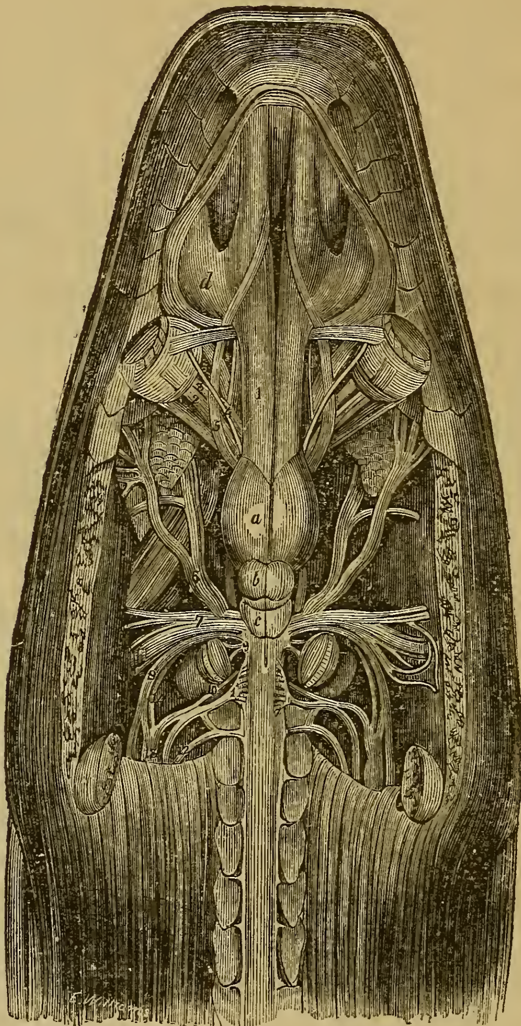


Fig. 58.—Brain and Cranial Nerves of Boa Constrictor. (Rymer Jones, after Swan.) *a*, Cerebral lobes; *b*, optic lobes with transverse depression; *c*, cerebellum; *d*, membrane of the nose; 1, olfactory nerve; 2, optic nerve; 3, third, or common oculomuscular nerve; 4, fourth, or trochlear nerve to the superior oblique muscle of the eye; 5, first trunk of the fifth; 6, second trunk of the fifth; 7, third trunk of the fifth; 8, hard portion of the seventh nerve; 9, auditory nerve; 10, glosso-pharyngeal nerve; 11, trunk of the vagus nerve; 12, ninth nerve. The last three nerves are intimately connected with one another, and with 13, a sympathetic ganglion

of higher Vertebrates (fig. 58, *b*). Between the optic lobes and the next great division of the brain, the cerebral lobes, we find the so-called 'pineal body' (fig. 61, J), projecting upwards, and in a more developed form than that which is met with in Fishes. The nature and uses of this body are wholly unknown. It is chiefly notorious from the fact that Descartes pointed to the corresponding structure in the human brain as the "seat of the Soul."

The **Cerebral Lobes** in the Lizard (fig. 59) and its allies, as well as in Amphibia, are, in comparison with other parts of the brain, much larger than in Fishes. This is due only in part to an absolute increase in their development, as there seems to be some diminution in the size of the olfactory and optic lobes and the cerebellum. In Serpents, Crocodiles, Turtles (fig. 61), and their allies, however, we meet with a decided absolute increase in the size of the cerebral lobes. In Crocodiles, for instance, they are much larger and broader than other parts of the brain, though their surface is still quite smooth. Each lobe contains a cavity or 'ventricle' in its interior, as in some of the higher Fishes. But in Reptiles the ventricle is larger, and, projecting from its anterior and inner surface there is a rounded eminence, supposed by some anatomists to represent a body of considerable importance—which is known amongst higher vertebrates as the 'Corpus Striatum' or striate body.

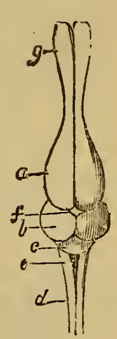


FIG. 59.—Brain of Lizard (*Lacerta viridis*). *a*, Cerebral hemispheres; *b*, optic lobes; *c*, cerebellum; *d*, spinal cord; *e*, fourth ventricle; *f*, pineal body; *g*, olfactory ganglia. (Owen.)

Each Cerebral Lobe is connected with its corresponding optic lobe and with the same half of the medulla oblongata, by means of a thick and composite prolongation called the 'cerebral peduncle.' On the upper and inner part of each of these composite peduncles, just anterior to the optic lobes, there is a small projection, supposed to answer to another very important ganglionic body, which, in higher vertebrates, is known as the 'Thalamus.' As to the identity of these bodies, however, some difference of opinion exists. They, together with the inner faces of the peduncles on which they are situated, constitute the lateral boundaries of another brain cavity, known as the 'third ventricle,' which is mostly covered over above, by the backward extension of the cerebral lobes.

A band of fibres, termed the 'anterior commissure,' which connects certain regions of the two cerebral lobes—hereafter to be specified—arches across the anterior part

FIG. 60.—Vertical Longitudinal Section of the Brain of Perch. (Mivart.) 1, Olfactory lobe; 2, cerebral lobe; 3, pineal body; 4, optic lobe, with large cavity within; 5, cerebellum; 6, pituitary body; 7, hypoarium.

of this Third Ventricle; whilst the upper strata of the two cerebral peduncles are connected by means of a smaller 'posterior commissure,' crossing the posterior boundary of this ventricle, just in front of the optic lobes. The peduncles or attachments of the before-mentioned 'pineal body' are structural relation with the posterior commissure.

The Third Ventricle is continuous below with a funnel-like prolongation, at the extremity of which is a structure named the 'pituitary body,' not altogether unlike the 'pineal body,' and whose use is similarly unknown. Though present in Fishes and higher Vertebrata, the pituitary body is especially large in many Reptiles.

The **Olfactory Lobes** have, throughout the class of Reptiles, a smaller proportionate size than in Fishes. In Serpents (fig. 58) and Crocodiles they are situated, as in some of the last-named creatures, at a distance from the cerebral lobes—being connected with them by long peduncles. In Lizards and their allies the olfactory lobes are more or less continuous with the cerebral lobes (fig. 59); while in the Turtle and other Chelonians, they are marked off from the anterior extremities of the cerebral hemispheres only by a slight constriction (fig. 61, A), and each olfactory lobe is penetrated by a prolongation from the corresponding cerebral 'ventricle.'

With regard to the **Cranial Nerves** of Reptiles, it may be remarked that the Trigeminus and the Vagus (or visceral nerve) are still very large, but neither of them swell at their roots into such distinct ganglia as in Fishes. The Glosso-pharyngeal, or nerve of taste, joins the internal nucleus of the Vagus in Amphibia, though in Serpents and higher Reptiles it has a nucleus of its own, distinct from that of the latter. The Auditory nerves are large, and in Turtles, Crocodiles, and their allies, they swell into distinct ganglionic enlargements at the back of the medulla, on each side of the floor of the 'fourth ventricle.'

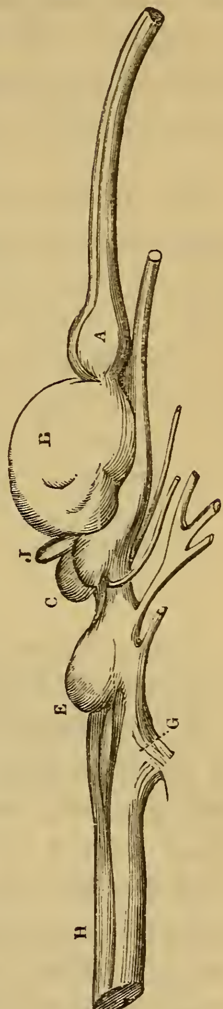


FIG. 61.—Brain of Turtle, side view. (Solly.) A, Olfactory ganglion; B, cerebral hemisphere; C, optic ganglion; E, cerebellum; G, ganglion at root of vagus nerve; J, pineal body.

The brain of Reptiles, like that of Fishes, is still characterized by the arrangement of its several parts and the spinal cord in the same horizontal plane, and by the small size of the Brain as compared with the latter structure. Still, the brain is more nearly equal in weight to the cord than it is in Fishes, and it also bears, in the majority of Reptiles, a greater proportion to the total body-weight.

But in BIRDS we find the Brain attaining a notably greater size in proportion to the bulk of the Spinal Cord than it has among Reptiles, and also presenting other signs of increased development.

According to Leuret, the average proportional weight of the brain to the body in the four undermentioned classes, as deduced from numerous observations on different representatives of each, may be stated to be as follows:

In FISHES	as 1 to 5,668	In BIRDS.........	as 1 to 212
In REPTILES	as 1 to 1,321	In MAMMALIA...	as 1 to 186

These figures must, of course, be regarded merely as approximate averages.

No peculiarity worthy of note exists in the **Spinal Cord** of Birds, except that in the situation of its posterior enlargement, corresponding with the attachment of the great nerves of the legs, the posterior columns of the cord diverge from one another, and shortly again approximate so as to form a space, known as the 'rhomboidal sinus.' This, however, is an anatomical peculiarity to which no physiological significance is attached.

The **Medulla Oblongata**, from the back of which the cerebellum is developed, is, in Birds, decidedly broader than the spinal cord. As in lower vertebrates, the divergence of the upper or posterior columns of the cord leaves at the corresponding surface of the medulla the space known as the 'fourth ventricle,' which becomes much more completely roofed over than it is in Fishes or Reptiles, by the under surface of the now larger cerebellum (fig. 64). The Auditory nerves arise from about the middle of the floor of the fourth ventricle, where, as in some Reptiles, they are connected with a distinct ganglionic eminence on each side of the middle line. The Trigeminus is always large, and exceeds all the other cranial nerves in size, with the exception of the Optic.

The **Cerebellum** is much larger than we have hitherto met with it—with the single exception of that of the

Fig. 62.

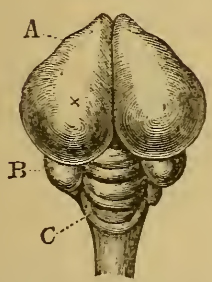


Fig. 63.

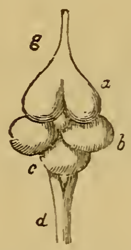


Fig. 64.

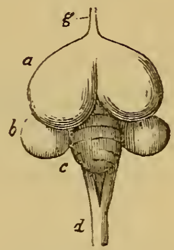


Fig. 62.—Brain of Pigeon. (Ferrier.) A, Cerebral hemispheres; B, optic lobe; C, cerebellum with transverse furrows and very small lateral lobes.

Fig. 63.—Brain and part of Spinal Cord of Chick 16 days old, showing the optic lobes (*b*) still in contact—at their inner borders. (Owen, after Anderson.)

Fig. 64.—Brain and part of Spinal Cord of Chick, 20 days old, showing the optic lobes (*b*) now widely separated, and cerebellum (*c*) greatly developed. (Owen, after Anderson.)

Shark. It now consists of a more or less ovoid median lobe (deeply scored by transverse furrows), and of two much smaller lateral portions, which project slightly behind the optic lobes (fig. 62, c).

These **Optic Lobes** are pushed aside and depressed so that they are partly covered by the large cerebral hemispheres (figs. 63, 64). In form they are rounded bodies, showing no trace of a transverse division. Each contains a cavity, opening below and internally into a subjacent passage or canal, which serves to connect the fourth with the third ventricle. The two optic lobes are connected with one another by a wide commissure, which constitutes the roof of the above-mentioned passage. The optic nerves arise from the under surface of these lobes. They are lamellated structures; and at the place where the two nerves cross one another, their lamellæ interlock; instead of the one nerve, as a whole, passing over the other, as is the case in Fishes.

In front of the optic lobes are the cerebral peduncles or '**Crura Cerebri**,' between which the 'third ventricle' is situated. Stretching across this space, immediately in front of the optic lobes, is the 'posterior commissure' of the brain, with which (as in Reptiles) the peduncles of the 'pineal body' are connected—a structure sometimes seen to project in the brain of Birds between the cerebral hemispheres and the cerebellum. A little in front of this 'posterior commissure' a rounded prominence may be seen on the upper and inner aspect of each cerebral peduncle—that is, on the portion which constitutes part of the lateral boundary of the third ventricle. A similar projection has been previously alluded to as occurring in some Reptiles, and it is supposed to correspond with the important structures termed the '**Thalamus**' of a Mammal's brain. The anterior part of the floor of the third ventricle still communicates, by a short hollow peduncle, with the peculiar 'pituitary body'—a structure which, in Birds (fig. 66, 6) is proportionately less developed than in Reptiles and Fishes (fig. 60, 6).

The **Cerebral Lobes** are large and more or less rounded, though they are flattened at their inner faces, where they come into contact with one another (fig. 65). These all-important divisions of the brain are smooth and still devoid of convolutions; yet in some birds there are traces of a depression, answering to a well-marked fissure (the 'sylvian') always recognizable in the brain of higher Mammals. The cavity within each of the cerebral lobes—answering to the 'lateral ventricles' of the human brain*—is comparatively large, and projecting from the anterior and external part of the floor of each of them, there is an eminence generally admitted to correspond to the '**Corpus Striatum**' in the brain of Man and Mammals generally. The inner walls of the lateral ventricles are thin, and almost in contact with one another. They constitute the inner boundaries of the cerebral lobes.

Fig. 65.

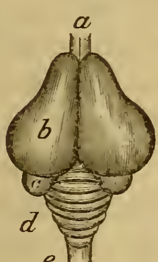


Fig. 66.

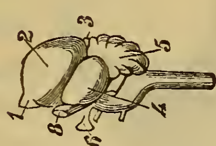


Fig. 65.—Brain of Common Fowl in adult condition. (Spurzheim.) *c*, Optic lobes in part hidden by (*b*) cerebral hemispheres.

Fig. 66.—Brain of Pigeon, side view. (Mivart.) 1, Olfactory lobe; 2, cerebral hemisphere; 3, pineal body; 4, optic lobe; 5, cerebellum; 6, pituitary body; 8, optic nerve.

These lobes are structurally connected, as in Reptiles and Fishes, by a well-marked 'anterior commissure,' while above and behind it there exists another set of connecting fibres, deemed by some anatomists to represent the commencement of the '**Corpus Callosum**.' This latter is the great transverse commissure which unites the two halves of the brain, and whose size increases as we pass from lower to higher orders of the Mammalian series.

* These are the first and second ventricles. The third is situated between the cerebral peduncles, the fourth at the back of the medulla, and the fifth ventricle will be subsequently referred to in the description of the brain of Quadrupeds.

The **Olfactory Lobes**, comparatively small in size, are found in front of, and partly beneath, the cerebral lobes (fig. 66, 1). They are true outgrowths from the cerebral lobes, and the cavity within each of them is continuous through its peduncle with that of the corresponding ventricle. Each 'lateral ventricle' is, in fact, prolonged into the olfactory ganglion of the same side.

Looking to the general characteristics of the Brain in Birds, we find that the Cerebral Lobes and the Cerebellum have attained a much greater development than is to be met with among Fishes and Reptiles; while the relatively smaller Optic Lobes are displaced downwards and outwards, as though from the pushing forwards of the cerebellum. The several parts of the Brain are no longer in serial order, and in the same horizontal plane with the Spinal Cord. The greatly increased weight of the organ as a whole, in comparison with that of the cord and of the entire body, are also seen to be marked features, distinguishing the Brain in Birds from that of lower Vertebrates.

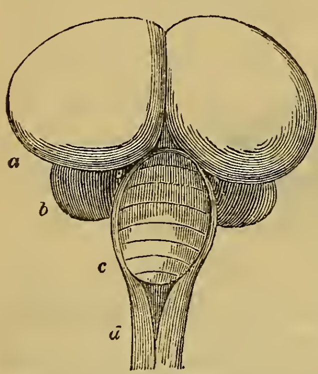


FIG. 67.—Brain of Sea Gull (Owen, after Anderson.) *a*, Cerebral hemispheres; *b*, optic lobes; *c*, cerebellum; *d*, spinal cord.

The Visceral Nervous System in Lower Vertebrates.—As an addition to this account of the Cerebro-Spinal Axis in Fishes, Amphibia, Reptiles, and Birds, a word or two may here be appropriately said in regard to the Visceral System of Nerves met with in these animals.

We saw reason to believe (p. 110) that impressions emanating from the Viscera constitute an important part of the general stock of afferent impressions which arouse the brain activity and mental life, such as it is, of Invertebrate animals; and that such impressions furnish the internal promptings or stimuli inciting these animals to not a few of the acts and movements they are accustomed to perform.

No excuse, therefore, is needed for what might at first sight seem a departure from our proper subject, in taking account of this visceral portion of the Nervous System. All the avenues whence impressions come to the supreme centres, must, in fact, be considered by any one who would properly understand the real share of the work which the Brain takes as an Organ of Mind.

The Visceral System of Nerves in Fishes, as in other Vertebrates, is divisible into two main parts, which, nevertheless, are, to a great extent, distributed together and to the same organs. There is, in the first place, a set of Cerebral Systemic Nerves, represented by the Glosso-pharyngeal and the Vagus or Pneumogastric—and these seem to be almost wholly afferent nerves conveying impressions from the Viscera to the Medulla. Secondly, there is the 'Sympathetic System' of Nerves, which, though to a certain extent an independent system, is also closely related to the Cerebro-Spinal Axis, by means of free intercommunications passing between the 'sympathetic' ganglia, and the anterior spinal nerves as well as most of those which are attached to the medulla.

In this latter system there are afferent and efferent fibres passing between the Viscera and the several 'sympathetic ganglia' with which they are in relation; while these ganglia are, in their turn, connected by afferent and efferent fibres with the cerebro-spinal axis, in the manner above indicated. Though there may be, and probably is, a considerable amount of independent activity on the part of the 'Sympathetic System,' the action of its several parts is also subject to the controlling and regulating influence of certain cerebro-spinal centres, with which they are connected in the manner above referred to.

In the Suctorial Fishes and the Lepidosiren, the 'Sympathetic System' is said not to exist, though the Cerebral Systemic Nerves are large and widely distributed over the viscera. In the Sharks and Rays, also, this system is ill-developed, but in the majority of osseous Fishes it consists of a cord on each side of the spine, forming connections with the cerebral and spinal nerves, and in some of these situations developing small ganglia and sending off branches towards the viscera, which unite with others from the Vagus nerve, so as to form large median 'plexuses,' or 'plexuses' and ganglia, whence multitudes of fibres are distributed to the different internal organs. Many differences of detail occur in different Fishes.

In Reptiles, also, there are various minor modifications; but, on the whole, the connections of the 'Sympathetic System' with spinal nerves are more developed in these animals, and the Ganglia at such points of junction are more numerous and distinct. In Birds the distribution of the Visceral System of Nerves also, in the main, tends to approximate pretty closely to the general plan above indicated, which will be described in further detail when we come to speak of its more complex development among higher Vertebrates.

By means, therefore, of this double set of Visceral Nerves, the internal organs are brought into close relation with one another, as well as with the Spinal Cord and with the Brain.

We are not fairly entitled to measure the intensity of the systemic impressions of a Fish, a Reptile, or a

Bird, by that of those with which we are ourselves familiar. In such animals many visceral impressions may be decidedly attended by more of conscious accompaniment than those which we experience, and they may enter in a much larger proportion into the web of sensory impressions constituting the basis of the conscious life of such creatures. Professor Owen truly says of Fishes that, "the appetite for food appears to be their predominant desire, and providing for its gratification to form their chief occupation."

Certain it is, that when prompted by different visceral states, animals may show an extraordinary amount of sensorial activity and power of executing related muscular movements. The sensorial endowments of the Shark, of the Python, or of the Vulture, are, when these creatures are under the influence of hunger, exalted to the highest degree; so that at such times either of them may become keenly sensitive to odours, sounds or sights which, had they been in a state of satiety, might have passed wholly unheeded. Similar differences also exist between the degree of sensorial activity of animals swayed by sexual desires, and those in whom such feelings are quiescent. These two classes of visceral promptings largely instigate and dominate the brain activity of all lower animals, and when the related needs or desires no longer exist, and no longer rouse the creature's sensorial activity, sleep is apt to come, as with a veil, and sever for a time the correspondence between the organism and the outer world.

CHAPTER X.

THE SCOPE OF MIND.

MUCH needless confusion is often thrown over the study of mental phenomena by the mode in which the subject is regarded, and by the phraseology in common use. It is customary to speak of 'the Mind,' as though it were a something having an actual independent existence—an entity, that is, of 'spiritual' or uncorporeal nature. Consequently we find, spread abroad in all directions, definitions of Mind and descriptions of the powers of Mind which, to say the least, carry with them implications of a decidedly misleading character.

It is the common and almost inevitable practice of substituting some abstract word for a more cumbersome phrase or statement, which tends to keep up the notion of a distinct psychical entity. Thus the word 'Mind' is generally used as a collective designation for the subjective states which reveal themselves to each one of us in consciousness, and which we infer to exist in other beings like ourselves. But the genesis and real legitimate meaning of such a term is only too frequently forgotten by some writers, whilst, by others, it has never been clearly apprehended; as a consequence, the word 'Mind' comes to be used most frequently, not as a general abstract name answering to no independent reality, but as though it corresponded to a real and positive something, existing of and by itself. A similar popular fallacy attaches to the common acceptation of the word 'Life.' To many this also is the name of an entity, though, in reality, it is only a more general abstraction, including under it the one with which we are now concerned.

The term 'Mind,' indeed, no more corresponds to a definite self-existing principle than the word 'Magnetism.' This conclusion, if not a direct revelation of Consciousness, is one of those "legitimate inferences" to which John Stuart Mill alludes, in the following passage, as constituting so large a part of human knowledge.

He says*:—"All theories of the human Mind profess to be interpretations of Consciousness. The conclusions of all of them are supposed to rest on that ultimate evidence either immediately, or remotely. *What Consciousness directly reveals, together with what can be legitimately inferred from its revelations, compose by universal admission all that we know of the Mind or, indeed, of any other thing.*"

The various conscious or subjective states known to each one of us are often classified under three principal categories, corresponding to what are commonly spoken of as (1) Sensation and Emotion; (2) Intellect, and (3) Will or Volition.

All that we know of Mind is derived (*a*), directly or by inference, from our own subjective states (*Subjective Psychology*), supplemented by (*b*), what we are able to infer from the words or other actions of our fellow-men and lower animals, as to the possession by them of similar states (*Objective Psychology*), and (*c*) by what we are able to learn as to the dependence of these subjective states upon the activity of certain parts of our bodies and of the bodies of other animals (*Neurology*,

* "Examination of Sir William Hamilton's Philosophy," p. 107.

or the Anatomy, Physiology, and Pathology of Nervous Systems).

Our knowledge of Mind (that is of mental phenomena) differs, therefore, altogether from our knowledge of all other phenomena. The very existence of this mysterious and inexplicable class (*a*), so dissimilar as it seems from everything else in the universe, would have sufficed to separate this branch of knowledge from all others, were it not the fact that, strictly speaking, all knowledge whatsoever of any *other* natural phenomena is still but the expression and summation of our own conscious states—were it not the fact that all *other* phenomena can only be known in terms of Mind.

The customary ideal or imaginative embodiment of these subjective states into a non-corporeal or spiritual *Ego* is, from this point of view, not altogether surprising.

But if we were to lean implicitly and exclusively upon these direct revelations of Consciousness, we must, as the history of philosophy has shown, inevitably commit ourselves to a system of universal scepticism, needing, as Hume proclaimed, a rejection of all grounds of certainty for our belief in an external world, in body, and, indeed, in Mind as an entity—leaving to each one of us a mere fleeting series of Conscious States as representatives of the totality of existence.

The absurdity of resting content with such a conclusion has been commonly recognized both by philosophers and mankind in general. In fact, we use our Consciousness to enable us, in imagination at least, to transcend these direct revelations of Consciousness. They are by each one of us invariably supplemented and modified, where necessary, by what we deem to be 'legitimate inferences'—not only in regard to Mind, apart from the narrow yet all-embracing region of our own subjective states (that is, in the spheres of Objective Psychology and Neurology), but also in regard to the whole system of Natural Knowledge. Thus, as regards vital, mental, magnetic, electric, thermal, chemical, mechanical, and all other phenomena, our actual present 'knowledge' is made up of a closely-interwoven potential but intelligible fabric derived from actually existent, from remembered, described, or inferred Conscious States or relations between them, together with inextricably intermixed and more or less 'legitimate inferences' therefrom.

Our knowledge of what is called Objective Psychology, as well as our knowledge of the relation of subjective states generally to the activity of the Nervous System, as deduced from its Anatomy, Physiology, and Pathology (the knowledge, that is, which contributes so largely to make up what we know concerning Mind, or mental phenomena) stands, therefore, on precisely the same foundation as our knowledge of Magnetism—that is of the magnetic phenomena presented by different forms of iron. The word 'Magnetism' is one which has come into use in much the same way as the word 'Mind,' although it is true that the connotation of the latter is wider in kind and degree, since under it we include not only what are considered 'legitimate inferences' from conscious states (our only sources of knowledge concerning Magnetism), but also these very conscious states themselves. It is on this latter ground only—though of course it is one of fundamental importance—that our knowledge of 'Mind' differs from what we know generally in regard to all other natural phenomena.

From a basis of agreement, therefore, as to the acknowledged insufficiency of the direct revelations of Consciousness in any branch of natural knowledge, it seems to the writer incontestible that the same kind of evidence as that which assures us of the existence of our own bodies and of the properties of external things (viz., inferences from conscious states), should guide us in the study, and as to the conclusions deducible from our own mental phenomena and those of other living beings. An attentive consideration, however, of such evidence altogether fails to assure us of the existence of 'the Mind' as a self-existent entity. It is, indeed, quite the reverse. Very many of those who are most entitled to form a judgment upon this subject, regard it as a 'legitimate inference' from existing knowledge that Conscious States, and, indeed, 'mental phenomena' generally, are dependent upon the properties and molecular activities of nerve-tissues, just as 'magnetic phenomena' are dependent upon the properties and molecular actions of certain kinds or states of iron. Regarded as ultimate facts, we are just as impotent to 'explain' the relation or nexus of causation existing between Magnetic Phenomena and the one set of molecular activities, as we are to explain the causation, direct or indirect, of Conscious States by other molecular activities. The mere fact that we are each of us conscious of the existence of mental or subjective states, inscrutable and ultimate as these must always be, certainly cannot be supposed to give any knowledge of 'Mind' as a self-existent entity.

Some of those who seek to expound mental phenomena from a scientific stand-point, have not always been sufficiently careful to suit their language to their views. This should, however, be done somewhere; and, if not elsewhere, certainly in a preliminary disquisition, in order that there may be no room for doubt as to an author's meaning when he uses the term 'Mind.' With this end in view some further remarks and explanations will now be given.

One of the principal errors, which the metaphysical conception of Mind as an entity entails, is that 'mental phenomena' are supposed to be limited or bounded by the sphere of Consciousness. That this has been the view of the great majority of philosophers any student of their writings will easily discover. Thus Consciousness is said by one of them, to be "the fundamental condition of all intelligence," whilst another holds that, "of all the present operations of the mind, consciousness is an inseparable concomitant." Such doctrines are, indeed, legitimate deductions from the metaphysical view concerning Mind, though its inadequacy is now fully recognized not only by physiologists, but also by some modern psychologists. Thus Professor Bain, after speaking of Mind in its three fundamental capacities, Feeling, Action (Volition), and Thought, says*: "Consciousness is inseparable from the first of these capacities, but not as it appears to me, from the second or the third. True, our actions and thoughts are usually conscious, that is, are known to us by an inward perception; but the consciousness of an act is manifestly not the act, and, although the assertion is less obvious, I believe that the consciousness of a thought is distinct from the thought."

The sphere of 'mental phenomena' cannot, indeed, be circumscribed by the sphere of Consciousness, and the recognition of this fact necessitates the absolute rejection of the word 'Mind' in its old signification, and compels us to include under this collective abstract term multitudes of processes or nerve actions, which now, so far as we are aware, have no correlative subjective aspects, though they

* "The Senses and the Intellect," p. 1. The language of the three statements there given by way of definition of Mind, seems to imply a belief in a self-existent something, able to Feel and Think, and capable of Acting.

may intervene as indubitable links or constituents of 'mental phenomena.' There need be the less hesitation in admitting this latter conclusion from the fact that it is one which each of us can so easily verify for himself.

We are frequently conscious of the first term of some process of thought, and we become aware of the last, whilst those which intervene, numerous though they may be, do not in the least reveal themselves to our consciousness. We seek, for instance, to recall some name or word at the time forgotten. We are conscious only of a sense of 'effort' which may, at the time, be fruitless, and yet, after a period, in which we have been thinking of other things, the desired word or name suddenly declares itself in our consciousness. We may say with Dr. Carpenter: "Now it is difficult, if not impossible, to account for this fact upon any other supposition than that a certain train of action has been set going in the cerebrum by the voluntary exertion which we at first made; and that this train continues in movement after our attention has been fixed upon some other object of thought, so that it goes on to the evolution of its result, not only without any continued exertion on our parts but also without our consciousness of any continued activity." And that some such view as this has commended itself to so distinguished a philosophical thinker as the late J. S. Mill may be gathered from the following quotation in reference to parallel phenomena. He says*: "If we admit (what physiology is rendering more and more probable) that our mental feelings as well as our sensations have for their physical antecedents particular states of the nerves, it may well be believed that the apparently suppressed links in a chain of association, those which Sir William Hamilton considers as latent, really are so,

* "Examination of Sir Wm. Hamilton's Philosophy," p. 285.

that they are not even momentarily felt; *the chain of causation being continued only physically, by one organic state of the nerves succeeding another so rapidly that the state of mental consciousness appropriate to each is not produced.*"

It is, indeed, certain that multitudes of nerve actions having no subjective side (that is, which are unaccompanied by phases of consciousness), form links or integral parts of our momentarily occurring mental states, and that such mere objective phenomena powerfully assist in determining our so-called mental acts. Nay, more, it seems almost certain that the greater part of our Intellectual Action proper (that is Cognition and Thought as opposed to Sensation) consists of mere nerve actions with which no conscious states are associated. And, lastly, each one of us may have had frequent occasion to notice that states of Feeling which at first accompany unfamiliar Muscular Movements, after a time no longer reveal themselves in Consciousness, that is, when such movements have by dint of frequent repetition become easy of performance. Thus, rapid and unconscious Automatic Actions are constantly tending, in our own experience, to take the place of slower and more consciously executed Volitional Movements.

From this, as well as much more which might be said, it would appear that those nerve actions attended by conscious states (to which latter correlatives philosophers have been accustomed to restrict the words 'Mind' and 'mental phenomena') constitute, in reality, only a very small fraction of the sum total of nervous states or actions which are now known to be comprised among (*a*) the initial nervous phenomena leading to Sensation and Emotion, among (*b*) the intermediate links of Thought and Imagination, among (*c*) the beginnings of

Desire, and which exist (*d*) as the incitations to, or accompaniments of, Volitional Action. But, if this be true, what becomes of the metaphysical entity called 'Mind'?

Thus, it would appear that, if we are, as so many philosophers tell us, to regard the sphere of Mind as co-extensive with the sphere of Consciousness, we should find 'Mind' reduced to a mere imperfect, disjointed, serial agglomeration of feelings and conscious states of various kinds—while the multitudes of initial or intermediate nerve actions (which serve to bind those other nerve actions commonly associated with conscious correlatives into a complex, continuous and coherent series) would have no claim to be included under this category.

For these and other reasons, we feel ourselves driven to the conclusion that the common notion as to what should be included under the term Mind, is one which is altogether erroneous, and such notion ought clearly enough to be given up, unless some warrantable extension of the meaning of the narrower term Consciousness should permit the rectification to be made in this direction.

It would seem to most persons impossible so to widen the signification of the word Consciousness, as to make it co-extensive with unconscious nerve actions, though some such proposition seems suggested by Professor Bain when he says:* "We assume as a fundamental fact, that with nervous action feeling begins." This is certainly a large assumption, and one which it is difficult to admit, though a notion of the same kind was, several years ago, advocated by G. H. Lewes,† who holds steadfastly to the notion that sensibility is the property of ganglionic nerve tissue in general, even though the action of such ganglionic tissue

* "Mind and Body," p. 53. † "Physiology of Common Life."

may not reveal itself by any phases of Consciousness whatsoever.* To have a feeling of which we are not conscious will seem to most of us a contradiction in terms. J. S. Mill was evidently of this opinion, since he says:† "To feel, and not to know that we feel, is an impossibility."

What, it may be asked, is the nature of an unconscious 'sensation'? Language employed in this way seems to become meaningless, and, in the writer's opinion, cannot be justified. If an impression receives none of our Attention, that is only saying in other words, that we are not conscious of it or do not feel it. In such a case we have no reasonable warrant for calling such an impression a 'sensation.' No excuse for such language appears to be found in the mere fact that there are different degrees or intensities of Consciousness, and that nerve actions without feeling cannot be sharply separated from nerve actions which are accompanied by feeling. It should be clearly recognized that this kind of reasoning tends to give us no definite resting point: from such a basis we might (and in fact ought logically) to go on to postulate the existence of Consciousness in plants, and even in inanimate things—since the demarcation between Consciousness and the absence of it, is more radical than that which separates nerve tissues from other living tissues, and living from not living matter.‡ Although, however, as we may freely concede, the phrase 'unconscious sensation' is far from being meaningless or unjustifiable from the point of view of a purely speculative philosophy,§ its

* Since the above was written, G. H. Lewes has published his "Physical Basis of Mind," 1877, in which his views are more elaborately developed and supported.

† "Examination of Sir Wm. Hamilton's Philosophy," p. 132.

‡ "Beginnings of Life," vol. i. p. 79; vol. ii. p. 77.

§ See A. Barratt's "Physical Ethics," 1869, p. 112.

use tends to introduce confusion into a subject the natural complexity of which already makes it sufficiently baffling. There may be nascent, ill-defined, or abortive subjective sides to many nerve actions, but, if these do not answer in ourselves to what we know as Consciousness, it should not be said, that 'sensibility' is an appanage of such nerve actions.

If, however, we are compelled to believe that Consciousness is not co-extensive with the sphere of 'Mind,' in the ordinary acceptation of these terms, and that no expedient modification of the meaning of the word Consciousness could make it so, then in face of the now admitted fact concerning the frequent interpolation of what J. S. Mill called mere "organic states of the nerves," or unconscious nerve actions, as integral parts of mental processes—only one other course lies open to us. We must widen the signification of the term 'Mind' itself.

This is no question of choice, but one of absolute necessity. The meaning of the word 'Mind' must be very considerably enlarged, so as to enable us to comprise under its new and more ample signification the results of all nerve actions, other than those of outgoing currents. We should thus include as 'mental phenomena,' the functional results of all nerve actions on the side of ingoing currents and in the nerve centres—whether these nerve actions are accompanied by a recognizable conscious phasis, or whether they form what appear to be mere physical links (or "organic states of the nerves") between other nerve actions which are unquestionably in relation with definite Conscious States.

We thus include under the word 'Mind' all those well-known results of nerve action which are comprised under the general categories of (1) Feeling, Sensation or Emotion, (2) Intelligence, Instinct or Thought, and (3)

Attention, Volition or Will; and we do not exclude the multitudinous results of mere unconscious nerve actions, which constitute so many integral parts of our mental life—interpolating themselves from moment to moment, and having their origin in various parts of our nervous system. The functional results of outgoing currents, however, lie wholly beyond the sphere of mind: they terminate in such physico-vital phenomena, as the contraction or the arrest of contraction in Muscles, and the stimulation or the reverse of Glandular Activity—events which are in no sense mental, though brought about by nervous influence. They are purely physical phenomena, and are taken cognizance of by means of special impressions made upon and conducted to the Cerebrum by such ingoing or sensory nerves as are in relation with the moving parts or secretory organs.*

Here a difficulty at once presents itself. It will doubtless be said on all sides that we cannot rightly group the various Conscious States which accompany certain nerve actions (subjective phenomena) with mere unconscious nerve actions (objective phenomena). These two groups of phenomena, it is always said, are separated from one another by what appears to be utter dissimilarity of nature, as typified by the fundamental contrast of Subject and Object (the *Ego* and the *Non-Ego*).

This is an objection based upon our ignorance as to the exact genetic relation existing between subjective states and the bodily conditions (or nervous actions) on which they seem to be dependent. It is probably due to an equal extent to a temporary forgetfulness on the part of those who advance it, that we are as much in the dark as to the real nature of Motion as we are about the real mode

* These questions as to the relation of 'outgoing currents' to Mind will be fully discussed in Chap. xxvi.

of origin of Feeling. Motions, whether molecular or other, we know only by their effects upon us, that is, in terms of Feeling. Who, therefore, is to declare that there *can* be no kinship between that which is the cause of Feeling and the molecular movements of certain nerve tissues, when, as to the cause of Feeling, knowledge other than that which comes from inference, is, from the very nature of the problem, for us impossible, and when we confessedly know nothing concerning molecular movements other than what we can learn through Feeling.

There seems, therefore, no real room or occasion, from a scientific point of view, for the protests which some will assuredly make against this necessary grouping of (*a*) the conscious states and certain parent nerve actions, with (*b*) other mere unconscious nerve actions, which are contributory to, rather than directly associated with, conscious states—as the constituent phenomena Mind in its new and altogether broader acceptation. That the two classes of nerve actions referred to are in reality separated by no arbitrary line, and that the more simple (*b*) are connected by innumerable gradations with the more complex (*a*) is an assumption favoured by all who believe in the philosophy of Evolution.* Such persons will, therefore, more easily see that 'mental phenomena,' as above defined, correspond to a coherent rather than, as of old, to an incoherent and non-consecutive assemblage of processes.

Some such change is inevitable, and we of the present generation must bear the discomfort and inconvenience naturally arising from an altered meaning of the term Mind, in order that those who follow may reap the benefit which will after a time result from the rectification. Knowledge is progressive, and, if old terms are to be

* See Prof. Nägeli's Address at Munich on "The Limits of Natural Knowledge," as translated in "Nature," Oct. 25, 1877, p. 561.

retained, their implications must from time to time be amended, in order that further progress may be made more easy or even possible.

Those who take the step above indicated, will recognize another truth which has been already implied. They will find themselves logically compelled to depart still further from commonly recognized views. On strict enquiry, it will be seen that the notion that the Brain is the exclusive 'organ' of Mind can no longer be entertained. This view was, indeed, too broad to be justified by the old philosophy, since only a very small part of the nerve actions taking place in the different ganglia entering into the composition of the human brain are attended by Conscious States. But, if the seat assigned to Mind was formerly much wider than physiology could warrant, it now, on the other hand, becomes much too narrow.

This will be seen to be a necessary consequence of including under the term 'Mind' a multitude of the unconscious nerve actions occurring in the Brain. For it is impossible to draw any valid line of demarcation between many unconscious nerve actions taking place in the brain of man or any lower animal, and others (with which they are continuously or genetically related) in the spinal cord, or in any of the ganglionic masses in different parts of the body. The division of the Nervous System into Brain, Spinal Cord, and Sympathetic System is one which, though justifiable enough on anatomical grounds, is much less so from a physiological point of view. The Nervous System is really one and indivisible, so that, if, with certain reservations, unconscious nerve actions occurring in the Brain are to be regarded as 'mental phenomena,' we can find no halting point short of including under the same category any unconscious nerve actions of a similar order, wheresoever they may occur. In this sense, therefore, almost the whole Nervous System would have to be regarded as the 'organ' of Mind, while the Brain should be regarded as merely its principal component part.

Views closely similar to those above set forth were advanced by the writer in 1870, when he said:* "Let us openly profess what has been tacitly implied by many. Instead of supposing that Mind and Consciousness (in its ordinary acceptation) are co-extensive, let us make Mind include all unconscious nerve actions as well as those which are attended by Consciousness . . . . We must inevitably come to this, and the doctrine of 'unconscious cerebration' has served to pave the way for it. . . . . Seeing that Mind, even in its ordinary acceptation, is the product of all 'potential' as well as of all realized, knowledge, the word cannot without the intervention of a fundamental error be considered as a convertible term for realized or realizable knowledge only. That which is realizable now, or capable of being recalled to consciousness, may, and often does, after a time cease to be so, and yet the essential nerve actions themselves may still go on, and none the less surely work their influence upon our fleeting succession of conscious states. Thus has it been with the race, and thus is it with the individual. And shall we cease to call a given nerve action mental, when by frequent repetition it has become so habitual that it no longer arouses Consciousness?" Transitions from conscious nerve actions to unconscious nerve actions are habitually taking place during the education of the individual, and the development of the nervous system in each one of us, and "the more fully such phenomena are recognized as parts of an orderly succession by which alone,

* "Journal of Mental Science," Jan., p. 522.

greater and greater complexities of thought and feeling are rendered possible, the moré will it become evident that the sphere of mind cannot at any time be circumscribed by the then present or possible states of Consciousness, the more it is obvious that in our conception of mind we should also include all past stages of Consciousness, which now in the form of unconscious nerve actions are, from moment to moment, manifesting themselves potentially, if not actually, in all our present Thoughts, Feelings, and Volitions."

Certain qualifications of this doctrine are now introduced, since, for reasons which will be more fully considered in later chapters, those tracts of the Nervous System exclusively concerned with the passage of 'outgoing currents' are now deemed to have no more claim to be regarded as parts of the 'organ' of Mind than has the Muscular System itself, with which they are in immediate relation.

The views above sketched, are different from those commonly entertained by physiologists, and they also differ, in one or other respect, from those of modern British philosophers such as Spencer, Lewes and Bain. They differ, however, still more widely from the views of other philosophical writers who, not having emancipated themselves from the mere metaphysical doctrines concerning Mind, habitually regard it as an entity, and speak of 'the Mind' using the Brain as its instrument.

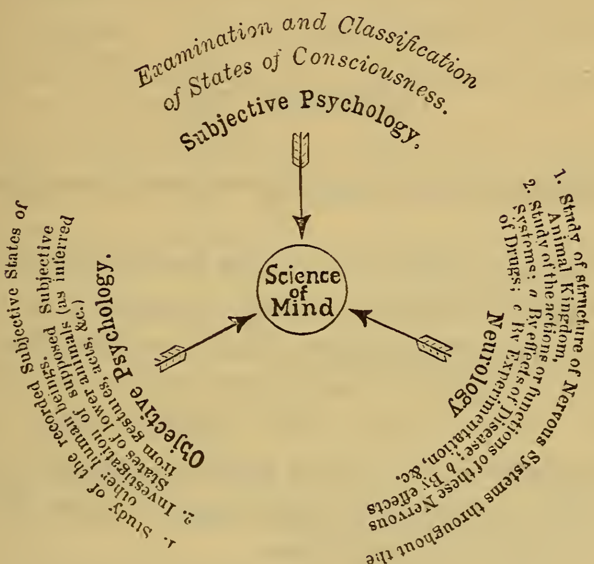
This latter doctrine, which still counts a wide circle of adherents, and is likely, perhaps, to do so for some time, has been aptly met by Professor Bain. He says:* "In the first place it assumes that we are entitled to speak of Mind apart from body, and to affirm its powers

* "Mind and Body," p. 130.

and properties in that separate capacity. But of mind apart from body we have no direct experience, and absolutely no knowledge. . . . . In the second place we have every reason for believing that there is, in company with all our mental processes, *an unbroken material succession.* From the ingress of a sensation to the outgoing responses in action, the mental succession is not for an instant dissevered from a physical succession . . . . . It would be incompatible with everything we know of cerebral action, to suppose that the physical chain ends abruptly in a physical void, occupied by an immaterial substance; which immaterial substance, after working alone, imparts its results to the other edge of the physical break, and determines the active response—two shores of the material with an intervening ocean of the immaterial." The difficulties in working such a hypothesis are in fact extreme, even if it had not been negatived by the many other considerations referred to in previous pages.

In treating of 'the Brain as an organ of Mind,' therefore, it will be understood that we use the word 'organ' merely in the sense that it is a part whose molecular changes and activities, constitute the essential correlatives of those phases of Consciousness known as Sensations, Emotions, Thoughts, and Volitions, as well as of a considerable part of the sum total of those other related nerve actions which are unattended by Consciousness, and whose results form, in accordance with the views above stated, so large a proportion of the phenomena comprehended under the general abstract word 'Mind.'

From what has been already said, it will be seen that the study of 'mental phenomena' has to be carried on in many different directions, and that it is one which is beset with peculiar difficulties. The following table or diagram indicates the principal kinds of data which require to be combined, and more or less fused, in order to give birth to a legitimate Psychology or true science of Mind.



These three departments supply data almost equally important. To neglect the facts supplied by Neurology would be about as unreasonable as to dismiss the legitimate study of Subjective Psychology, and certainly is on no grounds to be defended by those who do not refuse to include the study of Objective Psychology—and are thus willing to take account of the data obtainable as to the conscious states of animals and of human beings other than themselves. For, if a departure is once made from the sphere of the subjective, the data of Neurology must be admitted to constitute as important a division of the science of Mind as those derived from Objective Psychology—from which they differ more in degree than in kind.

CHAPTER XI.

REFLEX ACTION AND UNCONSCIOUS COGNITION.

THE nature of a Reflex Action has been already indicated, and the tissue elements usually concerned in such an elementary nervous operation have been described. They consist of ingoing fibres continuous in a Nerve Centre with so-called 'sensory' nerve cells, which in their turn are in communication with some group or groups of 'motor' nerve cells, whence issue outgoing fibres for the transmission of stimuli to muscles.

Such groups of tissue elements variously connected together are continually increasing in definiteness and number during the course of structural development, as well as during the whole time in which the 'education' of animal organisms progresses. The cellular elements are aggregated into Ganglia of different sizes, and, by reason of their close approximation in these bodies, the establishment of structural connections between those cells which are functionally related, either on the side of 'impression' or on that of 'reaction,' is doubtless facilitated.

Thus it seems to result from the very nature of nerve tissues and their mode of development, that variations in the kind and combination of impressions acting upon any particular organism, as part of its life phenomena, become by slow degrees organically linked to different and severally appropriate motor results. The organism 'learns' to discriminate one impression from another, either unconsciously or consciously—as we are compelled to infer, from the different nature of its motor responses and the suitability of each as an answer to the impression which it follows. Thus 'discrimination' comes to be an essential result or concomitant of the action of even the simplest nerve tissues.*

And as 'discrimination' is generally recognized by philosophers to be the root faculty or most fundamental manifestation of Intelligence, we shall find in the phenomena of Reflex Action, now about to be illustrated, a further strong support for the view that the nervous system generally is to be regarded as the Organ of Mind.

In most lower animals, as we have seen, several separate Nerve Centres, or Ganglia, constitute the main subdivisions of the nervous system. In animals like the Centipede, these ganglia are very numerous, and distinct from one another; in others, such as the Grasshopper, several become fused at intervals, so that separate ganglia are less numerous; while in Vertebrate animals, as we have seen, the fusion is carried still further. In the Fish, the

* Something very like organic discrimination may occur in Plants. A writer in "Nature" (June 26, 1873, p. 164) cites what may be regarded as an instance of this. He says: "The Ivy Linaria grows on an old wall; its flowers and the flower-stalks stand out for the sun and Insects to visit the little 'snap-dragon.' But no sooner does the corolla fall than the peduncle begins to curve inwards to the wall, and usually contrives to tuck its seed-vessel well into the brickwork again." An action like this may perhaps be the result of an organic impulse or tendency fostered, if not engendered, by 'natural selection.' And as the observer intimates, there are certain obvious relations between such a process and some of the instinctive actions of animals in connection with ovi-position.

Reptile, and other Vertebrates, the separate ventral ganglia of the Centipede are represented functionally by a continuous cord-like aggregation of fused centres, which occupy the median line in the dorsal aspect of the body.

The lower the organism, the more independent is the functional activity of its several nerve ganglia, while the higher the animal in type and scale of organization, the more closely knit together are the activities of these several parts of the nervous system. Even in Man himself, however, we have frequent evidence of the independent action of more or less limited regions of the nervous system. This is the case, for instance, in winking, sneezing, coughing, swallowing, which are all of them reflex or 'automatic' actions. The latter name has been given on account of the machine-like regularity with which such acts are performed—independently of all conscious guidance.

The existence and mechanism of 'reflex actions' were first distinctly referred to by David Hartley in 1748; they were more definitely described by Prochaska in 1784; though it was Marshall Hall who, some fifty years later, first clearly recognized and elucidated their real importance. Since his time our knowledge of these actions has been widened in all directions by the labours of many physiologists.

The fact that each Ganglion in one of the lower animals constitutes an independent centre for reflex actions, and that the movements to which it gives rise are always co-ordinated and adaptive in their characters, was experimentally established by Dugès.

This naturalist made some interesting observations on the 'Mantis,' a large insect having some resemblance to a Cricket which is very common in the south of France and in Italy. The creature is notable for a long, narrow, first thoracic segment, to which are attached a pair of large and powerful arms terminating with hooks, with which it is accustomed to seize and pierce its prey. When the head together with this first thoracic segment was excised, the body of the Insect, supported on its four remaining legs, resisted attempts made to overturn it, and at the same time agitated its wings and wing-cases. When, after this, the head was detached from the first thoracic segment, the latter single and isolated body segment afterwards showed signs of life by the continuance of 'reflex actions' of a purposive character for more than an hour. When touched, it moved its arms, turning them towards the finger of the experimenter, and even nipping it strongly.

These were actions of much the same kind as would have been exhibited towards a Fly or other prey, if the segment had formed part of an entire Mantis. In such a case, the movements would, doubtless, have been, to some extent, consciously instigated through the Brain of the animal. The above-mentioned experiment, however, shows conclusively that the movements of the arms and claws which were seen when the thoracic segment was severed from the head, must have been executed through the intervention of the single bilobed ganglion, together with the afferent and efferent nerves which the segment contains.

Dr. Carpenter says:* "If the head of a Centipede be cut off whilst it is in motion, the body will continue to move onwards by the action of its legs; and the same will take place in the separate parts, if the body be divided into several distinct portions. After these actions have come to an end, they may be excited again by irritating any part of the nerve centres, or the cut extremity of the nervous cord. The body is moved forwards by the regular and successive action of the legs, as in the natural state; but its movements are always forwards, never

* "Mental Physiology," 3rd Edition, p. 53.

backwards, and are only directed to one side when the forward movement is checked by an interposed obstacle."

If we look now to such reflex movements as are commonly manifested by one of the higher animals—a Frog, for instance—we shall meet with the same machine-like regularity in the execution of motor responses to ordinary stimuli, the same semblance of an intentional effort to accomplish a certain end—even when the animal has been deprived of its Brain, and when the movements are therefore as involuntary and unconscious as those of the thoracic segment of the Mantis above referred to.

After the head and neck of a narcotized Frog had been removed, Vulpian* slightly pinched a toe of one of the stretched-out hind limbs, and observed, as others have done, that this stimulus was quickly followed by a flexion of all the segments of the limb upon one another. The same result constantly followed the application of such a stimulus, and as Vulpian points out:—"It is not an indefinite reaction. All the muscles do not contract; for if it were so, there would be forcible extension of the limb, as in strychnia poisoning, since the extensor muscles in the frog are together much stronger than the flexors. . . . . . Here, on the contrary, a certain number of muscles only contract, while the others remain more or less inert. There is a contraction of muscles combined in such a manner as to produce a particular result, and the result of these harmonized contractions is to withdraw the limb from the exciting cause."

A much stronger excitation applied to one of the hinder paws of this headless Frog will lead to a different reaction, but still to one which is always the same under similar conditions. We no longer witness a movement of flexion in the limb that has been touched, but both it and the

* "La Physiolgie du Système Nerveux," p. 415.

corresponding limb are suddenly extended; and "this movement of the two legs is," as Vulpian says, "that which is most appropriate, either to repel the cause of irritation or to shoot the animal forward, and so remove it from the influence of the irritating agent."

Again, if the skin of the side of the body is slightly pinched in a headless frog, the foot of the hind limb on the same side is brought up so as to endeavour to rub away the irritating agent. Here also we have a complex movement brought about by many muscles definitely combined and adapted to obtain a certain result. But the particular movements executed always vary in accordance with the site of irritation. Thus, a pinch at the posterior extremity of the trunk, evokes wholly different movements from those just described. In this case, according to the same authority, "There is a new combination of muscular contractions, by means of which the feet are first brought towards the point irritated and there pressed together, and then the limbs are suddenly extended, thus giving rise to the movement most suitable for repelling the cause of irritation."

In addition to the instances already cited there is the celebrated experiment of Pflüger still to be mentioned, in which the reflex act evoked was so definite and purposive as to lead him to claim for the Spinal Cord a kind of conscious perceptive power, similar to that which physiologists generally restrict to the Brain. He placed a drop of acetic acid on the upper part of the thigh of a decapitated Frog, and the segments of the corresponding limb were quickly flexed, so that the foot was made to rub the seat of irritation. He then amputated this foot of the headless animal before reapplying the acetic acid. The result was most remarkable. The maimed animal began to make fresh efforts to rub the irritated spot, but was unable to reach it now that the foot was removed. After some moments of agitation, as if the brainless creature were seeking a new means of accomplishing its end, the motor stimulus flowed out in a different direction, causing the animal to bend the limb of the other side till with its foot it succeeded in rubbing the irritated region.

Thus, as Vulpian says,—"Each spot irritated acts as a kind of spring for calling into play a mechanism which varies according to the point excited, and according to the intensity of the excitation. But each mechanism that is called into play always determines a tendency to remove the region irritated from the irritating cause. The efforts differ, the mechanism differs also, but both are always appropriate, and, as it were, chosen."

Multitudes of reflex acts having the same general characteristics are quite familiar to us from their occurrence in the higher animals and in man. Of these it may suffice to mention the closure of the eyelid before an approaching body, the rapid drawing away of the paw or hand from injury, the throwing out of the arms in the act of falling, the movements of suction and deglutition following impressions on mouth and throat, together with the acts of vomiting, coughing, and sneezing.

It will have been seen that there are two distinct sides to the process which we have hitherto been considering. We have to take into account what occurs on the side of 'ingoing currents,' in the nervous centre; and also what occurs on the side of 'outgoing currents.' The latter processes are the distinct sequences of the former; and if we have inverted the proper order of description, and have referred more especially, in the first place, to the gradual growth of the power of performing adaptive movements, it is only because such an inversion of the natural order has commended itself from the peculiarities of the facts to be explained.

As to the existence or nature of the phenomena which take place on the side of the ingoing current in lower animals we can know nothing directly. We can only infer that processes of great importance occur on this side, because of the increasingly complex and purposive character of the movements which higher or older animals become capable of manifesting.

The characters of the movements, therefore, are the objective facts, and it is only by an attentive study of them, and of the conditions under which they are manifested, that we are entitled to come to an opinion as to the occurrence of organic discriminations on the side of the ingoing current—as to the existence, in fact, of what we can only term 'unconscious cognitions.'

The increase in the number and variety of the nervous impressions, both simultaneous and successive, to which Animal Organisms become attuned to react, takes place at a comparatively slow rate. The addition to the receptive powers of any one individual are only slight, and it is during the period in which it is acquiring these powers that the corresponding structural changes will become more and more perfected, partly in the form of new or altered nerve cells, and partly by the formation of intercellular processes and connecting fibres. And owing to the fact that the germ or egg produced by an organism always tends to develop into a form similar to that of its parent (similar that is not only in external shape but in the intimate texture and arrangement of its organs and tissues), the successive lineal descendants of any one kind of organism may in effect be regarded as portions of the same organism, gradually developing through successive generations or stages of one life history.*

The doctrine of 'Inherited Acquisition,' to the enunciation and development of which we are so largely indebted to Herbert Spencer, explains, therefore, how it is that young organisms, only just arrived at maturity, are often better adapted, in some respects, to their surroundings than were their predecessors, near or remote, at a corresponding age. Consequently, if during their lifetime again, or during that of their descendants, some further modes of impressibility (with corresponding powers of discrimination) become possible either in old or in new directions; and if simultaneously there arises some new or altered capacity for acting in response to these new impressions, it will not be difficult for the reader to understand that this would constitute one important mode in which the nervous system slowly develops and becomes more complex.

Thus it is that habitual or often recurring stimuli of new kinds are presumed to be constantly leaving their traces in the plastic tissues of lower organisms, and inducing such structural modifications in them as tend not only to make the recurrence of similar impressions more easy, but also to render the reception and recognition of new impressions more possible.

Most of us must be familiar with the fact that by the concentration of Attention in certain directions, aided by voluntary efforts, we are capable of increasing our powers of Discrimination in the range of either of the senses, and

* The many influences capable of accelerating or retarding this kind of race development cannot here be even enumerated. Suffice it to say that some of the principal of them have been described and copiously illustrated by Mr. Darwin in his works on "The Origin of Species," and on "Sexual Selection."

that each new acquirement renders possible other and more refined discriminations. But there is reason to believe that, even without conscious voluntary efforts, the same kind of progress (though more slowly) is capable of being brought about by the action upon the organism of all the varying influences by which it is surrounded.

The mode by which mere 'organic discriminations' are rendered possible may be, in part, illustrated by reference to the building up of the links between conscious discriminations and actions in higher organisms—such as Cephalopods and Fishes.

Particular attention must be called to the fact that each new impression which becomes registered is not something wholly different from what has gone before. It is rather some slight modification or refinement upon impressions which have preceded it, and just as it takes its origin in similar parts of the body, so would it naturally proceed to those same regions in the central nervous system to which preceding impressions of like kind had been transmitted. The determining conditions and route by which the impression travels could scarcely be different in the case of some new visual impressions, for instance, from what they had been in regard to all previous visual impressions. Thus the physical counterparts of like kinds of old and new impressions are almost necessarily brought into close relation with one another, and with the same sets of outgoing nerve fibres, however these latter may from time to time be supplemented and modified in their combinations. An organic continuity, in fact, is supposed to lie at the root of impressions new and old, whereby they are classed at the same time that they become organized. Intelligence would thus be subject to actual 'growth' in more senses than one. The process is of course notably more complex than it is here represented. Some of the essential complications of the process are, however, of an obvious nature.

It is not only that impressions of touch become organically related to other impressions of the same kind, that visual impressions become classed with visual impressions, and so on. Unions also would seem to spring up in some less explicable way between central nerve units of different orders—that is, between contiguous sensory ganglia. Thus if in the experience of any organism, such as a Cuttle-fish, visual impressions are usually quickly followed by tactile impressions, it would seem for various reasons to be almost certain that communicating fibres would become developed between corresponding portions of the visual and tactile ganglia, and any motor response that might follow would thus be either directly or indirectly related to foci of excitement in both these sense centres. In the same manner the odour from some Cod-fish, or other object of prey, may reach the voracious Shark either before the object is seen or simultaneously, and these two impressions will, in a very large number of cases, be followed by certain tactile and by certain gustatory impressions. The first impressions become related to and may find an outcome in the production of movements of pursuit; while those engendered during the process of capture (viz., of touch and taste combined) immediately call into play the complicated simultaneous and successive movements of jaws, throat, œsophagus, and stomach, which form part of, or are accustomed to succeed, the act of swallowing.

From what has been said in this chapter, it may be safely concluded that as, by the frequent repetition of like stimuli, the structural connections of nerve currents (or the precise paths of ingoing impressions through nerve centres and along outgoing nerve fibres) are developed and rendered definite, so certain appropriate actions will follow certain impressions with unfailing regularity and precision. There goes on, as it were, an organization of 'Intelligence' primarily of the organic or unconscious kind, which is the hidden cause of the purposive character displayed by so many movements.

We say that the process is primarily of the organic or unconscious type, because one may witness even in Medusæ and in organisms only a little above them actions of a purposive type in response to stimuli acting upon different parts of their bodies. And it is difficult to believe that the Neural Developments in such creatures, by means of which the several motions follow in response to the several stimuli, can have been brought about under the influence of any distinct 'conscious' guidance. We have here, doubtless, to do with 'organic processes' only a few degrees more complex than those which may take place in a Sun-dew or other 'Sensitive Plant.'

Organic processes of the same kind possibly constitute the basis or starting point for all subsequent neural developments and Mental Acquisitions, even when in higher animals such processes become quickened, in some further unknown manner, under the directive influence of Conscious Efforts of gradually increasing distinctness.

CHAPTER XII.

SENSATION, IDEATION, AND PERCEPTION.

Neurology may be advantageously studied by beginning with the investigation of the simplest and earliest forms of the Nervous System, and thence proceeding to examine its more and more complex types. A wholly different order is, however, compulsory, in regard to Psychology. Its 'subjective' division constitutes for each of us the sphere of positive knowledge in regard to this subject; while that portion of 'objective' Psychology having reference to the mental states or processes of our fellow-men has the next greatest amount of certainty for us—since the human faculty of Articulate Speech enables us to compare, to some extent, the subjective experiences of other men with our own.

Objective Psychology, so far as it relates to inferior forms of life, is merely a field for more or less probable conjecture, in which the basis of certainty diminishes the further we depart from the human type. Knowledge garnered from our own experiences and those of our fellow-creatures affords, as it were, the lamp wherewith we seek to illuminate the dark places of animal Psychology. Hence it is necessary for us in the first place, before attempting to consider the mental processes of lower animals, to look to some of the fundamental facts pertaining to human Psychology. The previous consideration of 'Reflex Action and Unconscious Cognition,' will be found to be a fully justifiable procedure, and it was equally desirable that its consideration should have been prefaced by an enquiry as to the scope of 'Mind' and the nature of mental phenomena.

Descartes, Leibnitz, Spinosa, and other philosophers have, as Sir William Hamilton reminds us, been led to regard "the faculty of Cognition as the fundamental power of mind from which all others are derivative;" while Condillac and his school attributed this rank to Sensation rather than to Cognition, and similarly derived all other mental faculties from this as a base or starting point.

It would not be in accordance with the point of view of Evolutionists to say that either of these faculties could generate all the others. If we grant it to be true, that one or other of them—either Cognition or Sensation—does, in fact, constitute the primary manifestation of mental activity, we should rather say, that as the nervous actions upon which the mental process is dependent grow more complex, so may other so-called 'faculties' of mind be gradually engendered as related phases of the same neurological activity, and marked by a growing tendency to become more and more distinct from one another.

As to which of the mental modes or manifestations is to be regarded as primary, there seems to us to be little room for doubt. Hamilton truly observes*:—"The faculty of knowledge is certainly the first in order, inasmuch as it is the *conditio sine quâ non* of the others; and we are able to conceive a being possessed of the power of recognizing existence, and yet wholly void of all feeling of pain and pleasure, and of all powers of desire and volition. On the other hand, we are wholly unable to con-

* "Lectures on Metaphysics." Fifth Edition, vol. i., p. 188.

ceive a being possessed of feeling and desire, and, at the same time, without a knowledge of any object upon which his affections may be employed, and without a consciousness of these affections themselves."

Some highly significant facts have, indeed, already been mentioned, tending to show that mere organic discriminations or Cognitions may be manifested by plants, lower animals, or even parts of animals under conditions in which it is not warrantable to assume the co-existence of anything like that which we know as Consciousness or Feeling. We have seen some and shall find more reason for believing that Feeling, in its ordinary acceptation, is gradually superadded, in higher forms of animal life, as a newly-begotten accompaniment of nerve actions which hitherto, in lower forms, have been unendowed with any distinct subjective phasis. At first we may have the existence of unconscious impressions and mere organic discriminations; while afterwards, during the evolution of the animal series, and consequently of nerve centres, we suppose the superaddition to some nervous actions of a more and more definite subjective phasis, answering to lower grades of what each of us knows in himself only—during processes of Sensation or Perception more especially.

We must now look, from our human point of view, to what is included under these latter terms. James Mill says,*—"What we commonly mean when we use the terms SENSATION or phenomena of Sensation, are the feelings which we have by the five senses—*Smell, Taste, Hearing, Touch*, and *Sight*. These are the feelings from which we derive our notions of what we denominate the external world—the things by which we are surrounded. . . . . . When we smell a rose there is a particular feeling, a particular consciousness, distinct from all others,

* "Analysis of the Human Mind," 1829, vol. i. pp. 3 and 7.

which we mean to denote when we call it the smell of the rose. In like manner we speak of the smell of hay, the smell of turpentine, and the smell of a fox. . . . . . We can distinguish this feeling, this consciousness, the sensation of smell, from every other sensation. Smell and Sound are two very different things; so are Smell and Sight. The smell of a rose is different from the colour of the rose; it is also different from the smoothness of the rose, or the sensation we have by touching the rose. . . . . . In all these cases what we speak of is a point of consciousness, a thing which we can describe no otherwise than by calling it a feeling; a part of that series, that succession, that flow of something, on account of which we call ourselves living or sensitive creatures. . . . . . The feelings, however, which belong to the five external Senses are not a full enumeration of the feelings which it seems proper to rank under the head of Sensations, and which must be considered as bearing an important part in those complicated phenomena which it is our principal business in this inquiry to separate into their principal elements and explain. Of these unnamed and generally unregarded sensations, two principal classes may be distinguished:—first, Those which accompany the action of the several Muscles of the body; and secondly, those which have their place in the Alimentary Canal [and other internal Viscera]."

This explanation of the word Sensation is clear and leaves room for no uncertainty. The term is seen to be interchangeable with the word Feeling, although the latter has a wider signification and is applicable to every modification of Consciousness whatsoever. For instance, we are said to feel excited or depressed, we feel fearful or confident, we feel joy and sorrow, we feel love and hatred —though these various emotional or moral states are sometimes distinguished from our more primary and simpler feelings by calling them 'Sentiments.'

In addition, however, to the 'simple' Sensations experienced through the activity of the organs of any one sense, we are capable of experiencing clusters of simultaneous sensations from some external object. It is in part by the differences existing between such clusters of sensations that we are able to distinguish 'external objects' from one another. Each cluster may be said for the present to answer to a kind of 'complex' Sensation, and this we are accustomed to denote by the name of the corresponding object. A qualification of this statement will, however, subsequently be needed.

James Mill says,—"The name rose is the mark of a sensation of colour, a sensation of shape, a sensation of touch, a sensation of smell, all in conjunction. The name water is the mark of a sensation of colour, a sensation of touch, a sensation of taste, and other sensations, regarded not separately but as a compound." But as the same writer adds:—"We not only give names to clusters of sensations, but to clusters of clusters; that is, to a number of minor clusters, united into a greater cluster. Thus we give the name 'wood' to a particular cluster of sensations, the name 'canvas' to another, the name 'rope' to another. To these clusters, and many others, joined together in one great cluster, we give the name 'ship.' To a number of these great clusters united into one we give the name 'fleet' and so on. How great a number of clusters are united in the term 'house'? And how many more in the term 'city'?"

But another term must now be defined. A Sensation, whether 'simple' or 'complex,' which has once been experienced is, as we all know, apt to persist or to be revived in memory. On this subject, again, James Mill writes:—

"It is a known part of our constitution that when our sensations cease, by the absence of their objects, something remains. After I have seen the sun, and by shutting my eyes see him no longer, I can still think of him. I have still a feeling, the consequence of the sensation which—though I can distinguish it from the sensation and treat of it as not the sensation, but something different from the sensation—is yet more like the sensation than anything else can be; so like that I call it a copy, an image, of the sensation. . . . . . Another name by which we denote this trace, this copy of the sensation, which remains after the sensation ceases, is IDEA. . . . . The word IDEA in this sense will express no theory whatsoever; nothing but the bare fact, which is indisputable. We have two classes of feelings: one, that which exists when the object of sense is present; another, that which exists after the object of sense has ceased to exist. The one class of feelings I call SENSATIONS, the other class of feelings I call IDEAS. . . . . . As each of our senses has its separate class of sensations, so each has its separate class of ideas. We have ideas of sight, ideas of touch, ideas of hearing, ideas of taste, and ideas of smell." These copies of sensations may recur singly or in clusters, so that they, like Sensations, are and have been long classified as 'simple' and 'complex.' For the process of recurrence itself, which of course varies much in complexity, James Mill proposed the term IDEATION.

But in referring to the sensations derived from, and the realization of the nature of, an 'external object,' we have passed beyond the range of 'Sensation proper,' and have encroached upon what is commonly considered as 'Perception proper.' The full meaning and explanation of this statement will become plain if we briefly consider the order in which our Sensations and Ideas occur, and the modes in which they combine with one another.

With respect to the order of our Sensations, it is obvious enough that, to a considerable extent, they occur according to the order established among what we call the objects and phenomena of nature; and that these are divisible into two categories:—(1) the synchronous order, and (2) the successive order. As James Mill says:—"The synchronous order, or order of simultaneous existence, is the order in space; the successive order, or order of antecedent and consequent existence, is the order in time. Thus the various objects in my room, the chairs, the tables, the books, have the synchronous order, or order in space. The falling of the spark and the explosion of gunpowder have the successive order, or order in time."

We habitually receive, therefore, synchronous Sensations from external objects co-existing in space, and we as habitually receive trains of successive Sensations following one another in time. And as Ideas are merely weak copies or revivals of Sensations, it is only natural to expect that they would, as they do, derive their order in the main from that of our sensations. On this head Herbert Spencer * remarks,—"the *persistence* of the connection between states of consciousness is proportionate to the *persistence* of the connection between the agencies to which they answer. The relations between external objects, attributes, acts, are of all grades from the necessary to the fortuitous. The relations between the answering states of consciousness must similarly be of all grades from the necessary to the fortuitous."

Now it so happens that "of the objects from which we derive the greatest part of our sensations, most of those which are observed synchronically are frequently observed

* "Principles of Psychology," vol. i. p. 448.

synchronically; most of those which are observed successively are frequently observed successively." * But the effects of such repetitions of Sensations, 'associated' by their occurrence either "precisely at the same instant of time or in the contiguous successive instants," and whether referring to the same object or to different objects, were clearly enunciated nearly a century and a half ago by Hartley in his celebrated 'Doctrine of Association.' † He then laid down the following important law of Mind:—"*Any Sensations, A, B, C, &c., by being associated with one another a sufficient Number of Times, get such a Power over the corresponding Ideas, a, b, c, &c., that any one of the Sensations A, when impressed alone, shall be able to excite in the Mind b, c, &c., the Ideas of the rest.*" Muscular Motions were also shown by Hartley ‡ to exhibit a similar tendency to cohere with Sensations and Ideas, and "the whole doctrine of association" was comprised by him in a 'theorem' to that effect, almost precisely similar to what has been re-affirmed and fully illustrated in our own time, by Alexander Bain, as 'The Law of Contiguity.'

Hartley, moreover, showed that "Simple Ideas will run into complex ones, by means of Association;" and on this head James Mill says:—"Ideas, also, which have been so often conjoined that whenever one exists in the mind the other exists along with it, seem to run into one another, to coalesce, as it were, and out of many to form one idea, which idea, however, in reality complex, appears to be no less simple than any one of those of which it is compounded. . . . The word 'gold,' for example, or the word 'iron,' appears to express as simple an idea as the word

* James Mill, loc. cit., p. 55.

† "Observations on Man." Sixth Edition, 1834, p. 41.

‡ Loc. cit., p. 65.

'colour' or the word 'sound.' Yet it is immediately seen that the idea of each of those metals is made up of the separate ideas of several sensations: colour, hardness, extension, weight. Those ideas, however, present themselves in such intimate union, that they are constantly spoken of as one, not many. We say, our idea of iron, our idea of gold; and it is only with an effort that reflecting men perform the decomposition."

Ideas fuse themselves in this manner into clusters, or complex ideas, because, being only repetitions or weak copies of sensations, they are reproduced in the same order as the sensations. And the Sensations in question habitually occur in clusters because the 'external objects' to which they correspond usually impress the organism simultaneously through different senses. Thus it happens, according to the law above cited from Hartley, that when any one constituent of a natural cluster of sensations comes within the range of the corresponding sense organs of an animal, the other possible impressions composing the cluster (and representing the organism's knowledge of the external object) become simultaneously nascent in memory, so that the object is perceived or recognized. If in a dark room my hand comes upon an orange or upon a book, either of these sensations of touch will immediately fuse with nascent ideas of other possible sensations from the same object (whichever it may be) so that this object is perceived as a present external reality. This, then, is the nature of the process known as PERCEPTION: in which we have a present sensation linking itself indissolubly by 'association' with a complex idea derived from our past experiences with similar objects. It is not, as James Mill implies, the appreciation of a mere 'cluster of sensations.'

Thus it happens that an object is recognized immediately or intuitively, not so much by the mere single or double present impression, as by the blending of this with more or less fully revived memories of other impressions which have at various times been associated with the same object. Truly enough, as Bain says:—"When we see, hear, touch, or move, what comes before us is really contributed more by the mind itself than by the present object."

Different Perceptions, as the reader will easily understand, vary immensely in the complexity of their contents. This quality is always strictly dependent upon the wealth of antecedent experiences in relation to any object present to sense, both in the individual itself and in the race from which it has been derived. The natural simplicity or complexity of the object perceived is also, of course, of great importance. The possible impressions comprised in the perception of a bar of 'iron' are naturally few in comparison with those which may be included under the perception of a 'house.' Still, the same object may in different men excite perceptions of quite a different nature. A savage who has never seen gunpowder before would, for instance, have a set of notions called up by the sight of it, which would not at all correspond with those of an educated European who well knew its composition and properties. To the one it would appear as a black powder, and he would perceive it more or less simply as such. The perception of the same substance by the European, however, would be much more complex, containing more or less fully revived ideas as to its nature, together with half-nascent memories of the various kinds of effects which it is capable of producing by explosion.

A neuro-physiological interpretation of Perception will here serve more fully to elucidate this important process, and show its harmony with what has previously been said in regard to the functional activity of the Nervous System.

It is only in comparatively low organisms, or in *some* of the nerve actions of higher organisms, that ingoing impressions would impinge upon a more or less isolated group of nerve-cells, and be thence transmitted to other cells and along outgoing fibres to groups of muscles. This is what occurs in the simplest kinds of 'reflex action.' But just as complications seem almost inevitably to spring up on the outgoing side, in the form of new nervous connections between groups of motor cells (serving to render possible those complex simultaneous and successive movements seen in the more elaborate 'reflex actions' of the Frog and other animals), so in the manner briefly indicated in the last chapter, will analogous structural complications spring up in the highest nerve centres on the side of ingoing currents. Here connections become established between the organic mechanisms concerned with the passage of simultaneous or successive impressions, excited by objects in the outside world.

Thus, in relation with the most familiar 'external objects,' a connected internal symbolic register of their attributes and relations is gradually established in the Brain. There is an opening up, in some habitual but imperfectly understood manner, of a series of interconnecting channels or fibres between particular cells in each of the impressed Sensory Centres and all the others. This would always occur in accordance with a fixed plan (p. 166).

When, therefore, an external object is 'perceived' by any animal having developed sense-organs, an impression upon one or more of its sense-centres suffices to rouse into simultaneous conjoint activity not only these but also other centres in parts of the brain which have previously been called into action when an object of the same kind had been presented. It is, therefore, by the simultaneous consciousness and fusion, as it were, of the subjective sides of various new and old impressions that a present object is 'perceived,' or recognized. It could only be by the previous establishment of structural communications between the several related sensory cells, that the excitation of those of any one order would suffice to revive more or less strongly in other groups just such molecular changes as like objects had on previous occasions excited. And it may be easily understood that the molecular movements initiated by any one or two ingoing sense impressions, may start from such groups of cells and thence flow over into all communicating channels between them and the cells of other related groups—just as outpoured water from some overfull lake or reservoir would flow easily through any set of connected channels which might have become established around it. The more definite the nervous paths, and the more frequently they have been traversed by stimuli, the easier will it be for molecular movements (as it would be for water, in the illustration given) to flow along such channels when the next occasion arises.

Some such process as is above indicated would seem to correspond physically with what is known as an act of Perception. As the writer has elsewhere* pointed out, one of the principal features of such an act is that it tends to associate, as it were, into one state of consciousness much of the knowledge which has been derived at different times and in different ways concerning any particular external object. When impressions from such an object are made upon any sensory nuclei, they strike first upon the corresponding 'perceptive centres' in the cerebral hemi-

* "The Physiology of Thinking."—"Brit. Med. Journ.," May, 1869.

spheres and thence immediately radiate to other perceptive centres, there to rouse the activities of functionally related cells. This process takes place with such rapidity that the several excitations are practically simultaneous, and the combined effects are fused into one single act of Perception. Thus, I see an orange at a distance; this, as an object of visual sense, is simply a rounded yellow area; but past experience has led me to know what are the tactile and muscular sensations usually associated with the sight impressions—how it is really a spherical body, with a somewhat rough surface. Then I have learned, also, that these impressions are usually associated with a certain odour, with a certain taste, a degree of succulence, and certain internal visual characters, including a divisibility into segments and the possible presence of seeds within. A combination of any of these, or of a host of other revivable impressions, may go to constitute my 'perception' of an orange, and may flash into consciousness more or less simultaneously, on the presentation of the object to the visual sense.

If we now turn our attention to another aspect of the question, and look to the notable differences existing between different kinds of Sensations, it will gradually be made plain that these are marked off from simple and complex Perceptions by differences of degree rather than of kind, and also that Emotion and Intellect are, in their rudimentary phases, alike inseparable even from simple Sensations.

Professor Bain says,—"Some sensations are mere pleasures or pains, and little else; such are the feelings of organic life, and the sweet and bitter tastes and odours. Others stretch away into the regions of pure intellect, and are nothing as regards enjoyment or suffering, as, for example, a great number of those of the three higher senses." This difference is more fully explained when he says, "If we examine the sensations of organic life, Taste, and Smell, we shall find that, as regards pleasure and pain, or in the emotional point of view, they are of great consequence; but that they contribute very little of the permanent forms and imagery employed in our intellectual processes. This last function is mainly served by Touch, Hearing, and Sight, which may therefore be called the Intellectual Senses by pre-eminence. They are not, however, thereby prevented from serving the other function also, or from entering into the pleasures or pains of our emotional life."

In what is above said the important fact is implied that to every Sensation there are two sides, an 'emotional' and an 'intellectual,' and that in some sense-impressions the one, and in some the other, predominates. This, in slightly different terms (viz., the inverse proportion of Sensation and Perception), has been strongly insisted upon by Sir William Hamilton. In illustration the following passage may be placed before the reader. He says:—"If we take a survey of the Senses, we shall find, that exactly in proportion as each affords an idiopathic sensation more or less capable of being carried to an extreme either of pleasure or of pain, does it afford, but in an inverse ratio, the condition of an objective perception more or less distinct. In the senses of Sight and Hearing, as contrasted with those of Taste and Smell, the counter-propositions are precise and manifest; and precisely as in animals these latter senses gain in their objective character as means of knowledge, do they lose in their subjective character as sources of pleasurable or painful sensations. To a Dog, for instance, in whom the sense of Smell is so acute, all odours seem, in themselves, to be indifferent. In Touch or Feeling the same analogy holds good, and within itself; for in this case, where the sense is diffused throughout the body, the subjective and the objective vary in their proportions at different parts. The parts most subjectively sensible, those chiefly susceptible of pain and pleasure, furnish precisely the obtusest organs of touch; and the acutest organs of touch do not possess, if ever even that, more than an average amount of subjective sensibility."

Sensation is, in fact, a complex rather than a simple mental process. It is invariably compounded of Cognition and Feeling.

That there is a discriminative or 'intellectual' side to even the most subjective of our Sensations is fully admitted by Hamilton and others. Any Sensation, however simple, can only be recognized as such—can only become an element of our Consciousness, (*a*) by the simultaneous memory or revival of some past impressions, (*b*) by the intuitive recognition of their likeness or unlikeness to the present impression, and (*c*) by the similar recognition that this is felt as in a certain place. This holds good even for Touches and Tastes which are habitually referred to some part of that inner circle of the Non-Ego, represented by the organism's own body. And in reference to such Odours, Sounds, and Sights as are referred to the outside world beyond the organism, it becomes plainly impossible to attempt to preserve any real distinction between Sensations and Perceptions—since precisely the same mental processes are involved in both. Thus, according to Sir William Hamilton, Perception also is "an *Assertory Judgment*, that within the sphere of sense an object *exists*, and exists *thus or thus conditioned*." The number of the 'conditions' may, of course, vary greatly, but without altering the real nature of the process. Indeed he subsequently says, "It is manifestly impossible to discriminate, with any rigour, Sense from Intellect;" and after calling attention to the similar opinion held by Aristotle, adds these words, "Sensitive apprehension is, in truth, only the recognition by Intelligence of the phenomena presented in or through its organs."

It seems plain, therefore, that a gradual transition may be traced between simple Sensations and the most elaborate Perceptions; that there is a difference in degree, rather than in kind, between these two processes; and that James Mill, in his "Analysis of the Human Mind," was not without justification in making no use of the latter term, and in speaking merely of 'simple' and of 'complex' Sensations. Moreover, it must be steadfastly borne in mind, that in every complex Sensation (or Perception) of an external object, there occurs an embodied cluster of judgments and inferences, similar in kind to those which compose the basis of all Intellectual Action. Thus the notion that an intellectual element enters into the very groundwork of all Sensations is so well founded as to make it not at all surprising that such an opinion should have been held alike by ancient and by more modern philosophers.

It will be probably far less difficult for the general reader to acknowledge the fact of the close genetic relations existing between Sensations and those complex states of feeling known as Emotions, than for him to recognize the relationship, above pointed out, between Sense and Intellect. This is natural enough, because those who have not reflected or read much on these subjects, are apt not adequately to appreciate the importance of the Intellectual element in all Sensations, though they may have little difficulty in recognizing that Sensation and Emotion are merely different kinds of Feeling. It will not, therefore, at present, be necessary to dwell long upon this latter aspect of the problem as to the genesis of Mind.

We may safely assume it to be admitted, as a general truth, that Emotions of various kinds gradually manifest themselves and gain in strength, as the sensorial endowments of animals, and their relational correspondence with their environment, increase in definiteness and complexity. 'Pleasures' and 'pains' soon begin to be realized as direct results of their various movements and sensorial activities, and from the traces of these which survive in the form of nascent and clustered memories of many related sensations, those numerous, vague, but all-powerful modes of Feeling, commonly known as Emotions, take their origin, and often seem to increase in strength as the wealth of associations from which they are derived becomes organized and widened in successive generations of animals. The revival of such vague clustered memories of 'pleasures' or 'pains' usually follows as a direct result of some Perception. An impression made upon some organ of sense may thence reverberate through the brain so as to produce a Perception of the corresponding object, and may simultaneously evoke some distinctly related Emotion.*

This double or two-sided nature of Sensation, and the necessary development from it of the germs of Intellect on the one side, and of Emotion on the other, as from a common root, is a fact of the greatest interest from a physiological as well as from a philosophical point of view. We must perforce admit that every kind of Sensation has two distinct though closely related sides, the one of which, as mere Feeling, reveals the mode of affection of the *Ego*; while the other, as Discrimination or Cognition, reveals the relations and qualities of what we call the *Non-Ego*.

* On the subject of the genesis of Emotion, the reader may consult a chapter in Herbert Spencer's "Principles of Psychology," vol. i. pp. 481–494.

These two components exist in every Sensation, though, as Sir William Hamilton contends, in an inverse ratio. The formula of the one is *I feel*, the formula of the other *I know*. The one is represented by what has been termed 'Sensation proper,' and, in its higher developments, by Emotions, and Moral Sentiments; the other by 'Perception proper,' and, in its higher developments, by Judgment, Imagination, Conception, Reasoning, or the more purely Intellectual Processes.

There is, indeed, a third aspect of Sensation or Perception, which has not yet been mentioned, though it seems to be one of great importance in helping to determine the Development of Nervous Structures, and the correlative increasing complexity of Mental Phenomena. This is to be found in that exercise of Volition or Will which enters into every Perception under the form of Attention. Nor must it be here forgotten that in still another way are Sensations related to Volitions. The pleasures and pains of Sense, either actually present or represented in Idea, seem unquestionably to constitute the subjective sides of those neural processes which most frequently issue in the so-called Volitional Movements. But this subject will be more fully considered in a later chapter.

It is of great importance, however, here to note that Intelligence, Sensation, Emotion, and Volition are mental processes, the primary stages of which are dependent upon, and inseparably connected with, different modes or aspects of the functional activity of the Perceptive Centres; and that this conclusion at which we have arrived is one which will be found to be quite harmonious with the dicta of philosophers in regard to human Psychology. Thus Sir William Hamilton says*:—"In every, the simplest, modifications of Mind, Knowledge, Feeling, and Desire or

* "Lectures on Metaphysics," vol. i. p. 188.

Will go to constitute the mental state; and it is only by scientific abstraction that we are able to analyze the state into elements which are never really existent but in mutual combination. These elements are found, indeed, in very various proportions in different states—sometimes one preponderates and sometimes another; but there is no state in which they are not all co-existent." Similar views have been even more prominently urged by Herbert Spencer, and they are, moreover, fully in accordance with his general notion that "the highest forms of psychical activity arise little by little out of the lowest, and cannot be definitely separated from them." *

But why, it may be asked, should progress be observed in the development of the Perceptive Powers and all that this includes, as we pass from lower to higher animals? and what evidence have we that the acquirements and susceptibilities of one generation of animals are handed down to the next, to be by them improved upon and transmitted in turn? These all-important questions now need our brief but earnest attention.

Life is aptly described in general terms by Herbert Spencer, as "*the continuous adaptation of internal to external conditions*." Nerve tissues and organs are, as we have seen reason to believe, at once the result of this correspondence, and the means whereby it becomes organically registered. And as mental phenomena are held to result from the actions of this registering mechanism, they must necessarily show something of that continuity which exists in the mechanism itself. As the degree of correspondence between the organism and its surroundings increases, the sum total of mental phenomena must be

* See "Principles of Physiology," vol. ii. pp. 512–516.

increased and modified in a manner related to the new developments and modifications taking place in the registering mechanism itself.

There must, therefore, from the very nature of things, always exist an organized continuity in the mental phenomena possible to organisms, quite independent of the nature of the phenomena themselves—that is, whether they be high or low, complex or simple. The mental processes, moreover, whose nervous substrata are fully organized, would, in accordance with this view and with the doctrine of hereditary transmission, always represent what is most permanent or habitual in the experiences of the race. Mind thus truly becomes, and cannot be other than, a faithful reflex of the vital relations and activities of the organism.

The doctrine of 'Inherited Acquisition' is not only widely applicable in explanation of the genesis of Mind in the animal series; it suffices, moreover, to reconcile the adverse doctrines of the 'Transcendental' and the 'Empirical' schools of Philosophy. It shows that the former were right in a certain sense, in contending for the existence of 'innate ideas'; though, looked at from a larger point of view, it strongly tends to confirm the views of the experiential school of philosophy. All knowledge comes from 'experience'—not from that of the individual, except to a comparatively small extent, but rather from that of the race. This in the main is transmitted, by the inheritance of the ancestral type of nervous mechanism, which, in preceding countless generations, has been slowly attuned to certain modes of action, and needs only the incidence of certain impressions to set it going. This is now no mere theory. In so far as it concerns Perceptions and Instinctive Acts, the doctrine may be regarded as substantially proved—the highly interesting observations and experiments of

Douglas A. Spalding* in relation to the untaught Perceptions, Emotions, and Motor Powers of Birds, having supplied a final confirmation which was needed.

Many of Spalding's observations were made upon young Chickens, some of which were carefully hooded as they emerged from the egg, and for two or three days thereafter, so as not to permit the incidence of any Sight impressions. The young Birds being then placed on a smooth white surface, sprinkled with some seeds and insects, the hoods were removed, and the creatures' acts were carefully timed and duly recorded in a note-book.

"Often at the end of two minutes," Spalding says, "they followed with their eyes the movements of crawling insects, turning their head with all the precision of an old fowl. In from two to fifteen minutes they pecked at some speck or insect, showing not merely an instinctive perception of distance, but an original ability to judge, to measure distance, with something like infallible accuracy. . . . . They never missed by more than a hair's breadth, and that too, when the specks at which they aimed were no bigger, and less visible, than the small dot of an *i*."

Here, in some detail, is an account of the doings of one of these chicks immediately after it was unhooded:

"For six minutes it sat chirping and looking about it; at the end of that time it followed with its head and eyes the movements of a fly twelve inches distant; at ten minutes it made a peck at its own toes, and the next instant it made a vigorous dart at the fly, which had come within reach of its neck, and seized and swallowed it at the first stroke; for seven minutes more it sat calling and looking about it, when a hive-bee coming sufficiently near, was seized at a dart and thrown some distance, much disabled. For twenty minutes it sat on the spot where its eyes had been unveiled, without attempting to walk a step. It was then placed on rough ground, within sight and call of a hen with a brood of its own age. After standing chirping for about a minute, it started off towards the hen, displaying as keen a perception of the qualities of the outer world,

* "Macmillan's Magazine," February, 1873.

as it was ever likely to possess in afterlife. . . . It leaped over the smaller obstacles that lay in its path, and ran round the larger, reaching the mother in as nearly a straight line as the nature of the ground would permit."

Experiments were also made with regard to the sense of Hearing. Chicks before they had fully escaped from the shell were rendered more or less deaf by sealing their ears with several folds of gummed paper. Three of them were found, when thus treated, to be so deaf, that they remained perfectly indifferent to the voice of the mother, separated from them by only an inch board. After having been kept in a bag in a dark room till they were between two and three days old, the ears of these three chicks were uncovered, and, Spalding says, "on being placed within call of the mother, hidden in a box, they, after turning round a few times, ran straight to the spot whence came what must have been very nearly, if not actually, the first sound they had ever heard." These facts are, as he adds, "conclusive against the theory that, in the history of each life, sounds are at first but meaningless sensations; that the direction of the sounding object, together with all other facts concerning it, must be learned entirely from experience."

But just as young Chicks follow the call of their mother before they have had any opportunity of associating that sound with pleasurable feelings, so do they, and other young birds, appear to be inspired, independently of all education on their part, with an immediate Emotion of dread, or sense of danger, at the sight, or on first hearing the cry, of birds of prey, whose predecessors have been the natural enemies of their predecessors. Thus, a young Hawk, able to take only short flights, was made to hover over a hen with her first brood, then about a week old.

"In the twinkling of an eye," says Spalding, "most of the chickens were hid among grass and bushes. The hen pursued it, and scarcely had the hawk touched the ground, about twelve yards from where she had been sitting, when she fell upon it with such fury that it was with difficulty that I could rescue it from immediate death. Equally striking was the effect of the hawk's voice when heard for the first time. A young turkey which I had adopted when chirping within the uncracked shell, was, on the morning of the tenth day of its life, eating a comfortable breakfast from my hand, when the young hawk, in a cupboard just beside us, gave a shrill chip, chip, chip. Like an arrow the poor turkey shot to the other side of the room, and stood there motionless and dumb with fear, until the hawk gave a second cry, when it darted out at the open door, right to the extreme end of the passage, and there, silent and crouched in a corner, remained for ten minutes. Several times during the course of that day it again heard these alarming sounds, and, in every instance, with similar manifestations of fear."

Other most interesting observations are cited concerning the Instinctive Acts of chickens, ducklings, and young turkeys, more especially in reference to their mode of seizure and disposal of food.* Facts are not wanting, moreover, to show that the same kind of inheritance of mental and bodily capacities, and of likes and dislikes, obtains among higher animals. Instances of this will be given in a subsequent chapter.† One, however, may here be cited.

"So old is the feud," says Spalding,‡ "between the cat and the dog, that the kitten knows its enemy before it is able to see him, and when its fear can in no way serve it. One day last month, after fondling my dog, I put my hand into a basket containing four blind kittens, three days old. The smell my hand had carried with it set them puffing and spitting in a most comical fashion."

Facts of the kind above cited enabled Douglas Spalding to deduce the following all-important conclusions:—(1) That young chickens can display an intuitive Perception

* "Macmillan's Magazine," pp. 287 and 288. † See pp. 211, 229.
‡ "Nature," Oct. 7, 1875, p. 507.

by the Eye of the primary qualities of the external world, as well as an appreciation of the distance and direction of sounds on the occasion of the first exercise of the Ear; (2) That chickens instinctively bring into action Muscles that were never so exercised before, and perform a series of delicately Adjusted Movements ending in the accomplishment of a definite act—independent of any antecedent experience, and, therefore, of any 'conception' of such act; (3) That "in the more important concerns of their lives animals are guided by Knowledge which they individually have not gathered from experience."

Other facts illustrative of these truths will be found recorded in the chapter on 'Instinct.'

General Statement of Results. Our brief survey of the structure of Nervous Systems, in passing from their simplest forms to those possessed by Birds, has shown that they tend to become more and more complex as animals rise in the scale of organization. We have also seen reason for believing that the Mental and Motor phenomena, of which such organisms are capable, show a similar tendency to increase in complexity.

The increase in structural complexity is brought about by the growth and development of nerve-tissues in the individual under the stimulus of sensory 'experience'; aided by the continuation, through the principle of heredity, of such new developments in succeeding individuals. By the more or less universal repetition of such processes along different lines of development, slow structural progressions have been achieved; and with them have arisen corresponding developments of function in the direction of Mental and Motor Phenomena. Just as, in the individual, the appearance of new structure and the occasional manifestations of new function have been coeval; so the 'inheritance' of any particular nervous structures carries with it the possibility of manifesting (on fit occasions) the functional activities with which such structures have previously been in relation in ancestral forms—whether these activities have been concerned with more or less complex Mental Phenomena, or in evoking complex Muscular Movements.

We have seen that the Nervous Systems in Invertebrates generally, are composed of Ganglia variously connected together, some of which are in relation, by means of 'ingoing' nerves, with impressible surfaces or special Sense Organs; while others are in relation with Muscles and Glands through the intervention of 'outgoing' nerve fibres. Such surfaces and organs are, therefore, the inlets of all impressions by which the Organism attains a Knowledge of, or, in other words, is brought into relation with, the External World. The celebrated phrase of the schoolmen, '*nihil est in intellectu quod non fuerit prius in sensu*,' would seem, therefore,—so far as it is applicable at all—to be a mere truism for all lower animals, whose Brain is represented by a mere congeries of Ganglia in connection with impressible surfaces and more special Sense Organs.

But we have seen how these Sensory Ganglia increase in size and tend to grow into closer relations with one another in higher Mollusks and in Insects; how in Fishes, Reptiles, and Birds they undergo a still further development in each class—nay, more, how in these lower Vertebrates certain new co-ordinating ganglia known as Cerebral Lobes appear, in intimate structural relation with the several sensory ganglia, and which notably increase in their proportional size as we pass from Fishes to Reptiles, and from Reptiles to Birds.

But let the reader also bear in mind what has been set forth in the present chapter—How philosophers in all times have recognized that no Impressions or Sensations can be realized without an accompanying Intellectual Activity, and that though such activity is simple and rudimentary, in the case of simple Sensations, it becomes more definite and complex with the increasing many-sidedness of the multiplying Perceptions of higher animals. He will then dimly see how an increase of Sensorial Activity in successive generations of animals necessarily involves a corresponding increase in Instinctive and Intellectual Activity, associated, as we shall find, with a growing wealth of Emotion and more than the germs of Volition. He will then, too, be able better to realize the full significance of the increasing development and the knitting together of the sensory ganglia which at first compose the Brain, and the subsequent appearance of separate organs, the **Cerebral Lobes**, in connection with each and all of them, in which the various substrata for Sensory Impressions may come into relation with one another, and in which, more especially, there may develop the structural correlatives whose activity is associated with such Perceptions, Intellectual Acts, Emotions, and Volitions, as the several creatures are accustomed to experience or manifest.

If we look, therefore, to the principles of 'heredity' generally, and to such facts as have been disclosed by the observations of D. A. Spalding, it becomes manifest that the dogma of the schoolmen, already quoted, supported as it was by Gassendi, Hobbes, and later still by Condillac, is no more true for individual animals above the lower grades than it is for man himself. Each organism does not acquire all its Knowledge by 'experience' through the avenues of Sense—each inherits a complex mechanism, already attuned during the lives of a long line of progenitors to be affected in certain ways and to act in certain modes. When, therefore, the phrase or dogma '*nihil est* *in intellectu quod non prius fuerit in sensu'* was being repeated some two centuries ago as an embodiment of the reigning philosophical creed concerning the 'Origin of Ideas,' it was with justice that Leibnitz added—'*nisi intellectus ipse,*' if we take this latter phrase, as we may, in accordance with Spencer's luminous view, to represent the possibilities of intellectual affection and action bequeathed to an organism in the already elaborated nervous system which it inherits. Within this nervous system lie latent the creature's 'forms of Intuition,' or 'forms of Thought,' which need only the coming of appropriate stimuli to rouse them into harmonious action. It is the fact of the previous orderly organization of the structural correlatives of mental processes, which causes some degree of those modes of mental affection, known to us as Feeling, Intellectual Action, Emotion, or Volition, to be engendered even in the young untaught organism in response to suitable stimuli.

Thus the several mental 'faculties' may be said to have been making their appearance, and gradually becoming more distinct, during the whole period in which a building-up and organization of Nervous Systems has been in progress.

CHAPTER XIII.

CONSCIOUSNESS IN LOWER ANIMALS.

Some of the common but elementary Conscious States of Men having been principally considered in the last chapter, we have now to turn our attention more particularly to such states in lower organisms and in members of the so-called 'brute creation.'

At some stage in the complication of the nervous actions of lower organisms, as well as of brutes generally, there is good ground for inferring that the in-going molecular movements, which traverse nerve fibres and thence diffuse themselves among related groups of nerve cells, give rise (in a way which is inexplicable) to what we know and have just been considering as Feeling or Sensation. The mere molecular movements and changes in the nerve tissues—representing 'impressions' in their purely physical aspects—are supposed to acquire, engender, or, at all events, become associated with certain subjective phases, answering to what we call 'States of Consciousness.' Though nothing can be known as to the precise manner in which these supposed Conscious States arise, it seems to many to be a 'legitimate inference' that a bond of kinship must exist between them and the molecular movements of the fibres and cells with which, as commonly admitted, they are in some manner intimately related.

But the very existence in lower animals of any conscious states analogous to those which we ourselves experience, is a matter only of warranted inference. A word or two in explanation, and by way of comment, will make the truth of this statement more obvious.

All States of Consciousness whatsoever, whether they occur under the guise of Sensations, Thoughts, or Emotions, are phenomena which each of us knows only for himself, and as existing in himself. I see around me fellow-beings who behave in many respects like myself, and from the fact of this similarity of behaviour, as well as from what they can tell me (by articulate speech), I am able, legitimately, to infer that these other beings are possessed of Feelings very similar to my own. This inference (with or without a full realization of its grounds) we each of us make, and though it has been long recognized by a few,* it should be more generally known that such an inference is based partly (*a*) upon our observations of the gestures or movements of our fellow-men, under circumstances with which we are ourselves familiar; and partly (*b*) on our appreciation of the *results* of special classes of movements, by which Emotional Cries, Articulate Speech, or Written Characters are produced. These latter, vocal or graphic, results of special movements, are only interpretable after prolonged efforts, during which we learn to recognize the several Auditory and Visual Symbols, and associate them with corresponding objects, acts, states, ideas, and their relations.

Though the conclusion that our fellow-beings are sentient creatures like ourselves, capable of Feeling, Thinking, Desiring and Willing, comes to most of us as a kind of intuition or self-evident truth, not requiring any proof, it is well that readers should know on what grounds the

* See Dr. W. Alison, art. "Instinct," "Cyclop. of Anat. and Physiol.," vol. iii. p. 27, 1839.

intuition really rests, in order that they may the more clearly recognize the only means by which it is possible for us to form an opinion as to the existence and nature of Conscious States in the various classes and tribes of lower animals.

Of course the information obtained by us through Language (whether spoken, written, or printed) as to the Feelings and Thoughts of our fellow-men, is overwhelmingly greater and more certain than that derivable in other ways. But it is precisely this most definite source of knowledge of which we are deprived in the case of the lower animals. In some of them we find only a more or less vague emotional or gesture language, of which we have examples in the cries, chirpings, or songs of Birds, and in the sounds, facial movements, and more general actions of Dogs, Apes, and other of the higher animals. But we have not even so much as this to reveal the nature of the subjective states of the great majority of animals.*

What means have we then of forming an opinion as to

* Though we are not able to understand very much of their language, it does not at all follow that animals of the same kind may not be able to make their emotional language understood by one another. Swainson says (" Habits and Instincts of Animals," p. 62):—"No attentive observer can have watched them without having perceived the mutual recognition of each other's wants and feelings, which is implied both by voice, look, and action. In many cases, however, this communication is doubtless carried on in a way which we cannot comprehend, and by tones which we are at a loss to interpret. But those intonations in the voice, which we may not be able to catch, are perfectly understood by the animals themselves. It is well known that the ewe and her lamb can distinguish each other even in the most numerous flock, and that when separated for a time and again turned loose into the field, the latter instantly recognizes the well-known voice of its dam, and skips joyfully up to her the instant it hears her bleat."

the Feelings and degrees of Intelligence of the various representatives of the brute creation? Our own experience, and what we believe to be that of other human beings, has to be taken as our guide and standard throughout. We must watch the movements of animals under particular but varying circumstances, in order to judge of their different emotional states, and of the degree of reason or instinct guiding their actions. But in the case of multitudes and multitudes of the lower organisms, their actions give us no occasion for inferring the existence of anything so complex as Emotion, Reason, or even Instinct—it becomes a question rather as to whether there does, or does not, exist in them a mere vague 'sentience,' such as might be included under the word Consciousness, in the ordinary acceptation of the term.

The fact, therefore, that this method of inferential interpretation is the only one by which we can in any way form an opinion as to the Mental States of the Lower Animals, necessarily leaves us either altogether, or very much in the dark, as regards certain important questions to which reference must now be made.

(1.) We are wholly unable to determine what degree of complexity the Nervous System must attain, before even the dimmest and most obscure subjective manifestations analogous to what we know in ourselves as Consciousness may result from the actions taking place in the principal nerve centre of an organism. We cannot, to take an example, at all definitely decide whether any of the nerve actions of the Oyster, or of the Earth-worm, are, or are not, attended by subjective states or phases, akin even to our dimmest Sensations. Nor can we say whether any such subjective states accompany the nerve actions of many other organisms presenting Nervous Systems of greater complexity.

The highest ganglion of an animal, or that in which the most varied impressions are brought into relation with one another, is the part in connection with which the phenomena of Consciousness will be likely first to become nascent—as in higher animals it will be the part with the action of which the most vivid Conscious states are likely to be associated. On this subject, Herbert Spencer says:*—"There cannot be co-ordination of many stimuli without some ganglion through which they are all brought into relation, this ganglion must be subject to the influence of each—must undergo many changes. And the quick succession of changes in a ganglion, implying as it does perpetual experiences of differences and likenesses, constitutes the raw material of Consciousness."

The above-mentioned difficulty in ascertaining when Consciousness begins to manifest itself, of course implies a belief that Conscious States do not necessarily, as some have suggested, accompany all nerve actions. This, indeed, is a truth revealed to us every day, since multitudes of nerve actions occur in ourselves and in our fellow-men without any appreciable subjective accompaniment—and it would be absurd to say we are 'conscious' of what we do not appreciate. There is, as previously indicated, an habitual absence of sensation or feeling of any kind in conjunction with many reflex and other nerve actions.

This inference as to the absence of a subjective side with many nerve actions, is allowed by nearly all physiologists to be strengthened by the occurrence of 'reflex movements,' following unfelt impressions, in persons with disease of the spinal cord—*i.e.*, when this is of such a kind as to prevent the passage of nerve currents to or from the brain. A similar conclusion has also been arrived at by many from a study of the results of experiments with

* "Principles of Psychology," vol. i. p. 435.

Frogs and other lower animals, in which the spinal cord has been completely cut across so as to prevent impressions reaching the brain. The adverse reasoning of G. H. Lewes and others would prove too much. It would warrant the belief that all nerve centres are seats of Conscious Sensibility; and the acceptance of this view would easily lead to its extension, and soon make it almost impossible to deny a similar attribute to the leaves of the Sun-dew and other 'sensitive' plants—or, indeed, to stop even here. Endless confusion might thus be produced, without commensurate gain.

A fairly legitimate conclusion has, therefore, been drawn, to the effect that not only do many nerve actions exist which are unaccompanied by Conscious States in the ordinary acceptation of the term, but that such nerve actions may evoke movements which are just as suitable and appropriate, as responses to the several antecedent impressions, as if the movements in question had actually been evoked under conscious guidance. The fact that there is an apparent 'fitness' in the movement which is made in consequence of, and as a response to, a stimulus, does not by any means alone entitle us to infer that the corresponding impression had a conscious side, or was a real Sensation. It may have been the case or may not. At all events, it should be recollected that the quality of fitness decidedly characterizes the motor responses to many nerve actions belonging to the 'reflex' category, as occurring in ourselves, and in which the antecedent impression has certainly not been attended by any phase of Consciousness. Fitness of response seems, indeed, as was pointed out in a preceding chapter, to be almost a matter of necessity for all nerve actions which have been sufficiently often repeated—even where they occur in simple organisms possessing only the most rudimentary nervous systems, and where, therefore, conscious guidance may have been absent even at the time when the structural correlatives of the movements were originally organized.

Yet, in spite of the acknowledged source of uncertainty in regard to this criterion, it must be confessed that we are, to a great extent (for want of any better guide), driven to look to this very quality of 'fitness,' in reference to the nature of actions and the impressions which instigate them, as our chief though very uncertain means of forming an opinion concerning the probable presence, amount, or kind of Conscious Intelligence in animals generally. We have to look especially to the range, complexity, and degree of adaptation of the movements to varying circumstances and to unfamiliar conditions; and we are accustomed, in addition, to look to the degree of development of the Nervous System in the animals under observation.

(2.) The same kind of difficulty presents itself in another form, with regard to such animals as Insects, Cephalopods, Fishes, Reptiles, and Birds. These organisms are so high in the scale of organization, as to leave almost no room for doubt that some of their nerve actions are attended by Conscious States, but it is impossible for us definitely to decide, which are, and which are not, so endowed.

Two principal difficulties stare us in the face. First there is the necessity for the caution on which we have last dwelt, in respect to drawing conclusions from the degree of 'fitness' noticeable in the nature of the response; and second, there is the further difficulty that our own experience can only be taken as a very uncertain guide. Impressions of certain kinds, which, in ourselves, are no longer attended by Conscious States, may, nevertheless, be commonly accompanied by some such states in Cephalopods and Insects, or even in lower Vertebrate forms. This, indeed, seems highly probable, judging from facts furnished by our own experience. Each one of us, after a little reflection, will recall the fact that many novel impressions or muscular movements, at first associated with a distinct consciousness of their performance, may, when they have been often repeated and rendered facile by habit, after a time occur without arousing any kind of Consciousness. What has taken place, therefore, during our own individual development, probably has been occurring also to a much wider extent during the gradual development of the Nervous System, through the countless generations of animals, which, in past ages of the earth, have gradually been perfecting their relations with the sum total of their surroundings.

It may thus well happen that impressions which in lower animals are commonly attended by Consciousness, gradually become in other higher animals (connected with them by descent and the bond of kinship) so habitual that they no longer arouse Consciousness. It seems not unlikely that something of the kind may, in the course of long ages and with untold generations of animal forms, have occurred with certain of the most habitual and least varied of Visceral Impressions, and (though to a less extent) with other impressions emanating from contracting Muscles of all kinds.

For in organisms of greater Sensorial and correspondingly increased Mental Activity, whose higher nerve centres, by reason of these activities, become more engrossingly occupied with vivid extrinsic impressions, those of an habitual character which emanate from muscles or other internal parts would probably less and less engage the animal's Attention or Consciousness. The customary incitative or guiding impressions will still impinge upon higher nerve centres, and they may procure the continuance of definite muscular movements in response to mere unconscious nerve actions; although, originally, the occurrence of similar responses could only have been ensured by the directive and constructive influence appertaining to an undivided Attention or Consciousness.

For such reasons as these we are robbed of all definite grounds for anything like correct inference, as to the degrees of 'sentience' accompanying the different nerve actions of the countless hosts of lower animals. We have a fair warrant for inferring that, in the higher Mammals, Feeling is an appanage of the action of the same kinds of nerve centres as suffice to evoke it in ourselves—however different the Feelings of such creatures may be in their wealth of emotional and intellectual accompaniments. But concerning the seats, so to speak, of the subjective states of animals lower than these, we must necessarily remain very much in the dark. We should, indeed, find it difficult to disprove, even though we did not believe, the doctrine of Descartes, that they in common with others were mere unconscious automata.

(3.) We are not entitled to conclude that the Sensations experienced by lower animals, through the intervention of their various sense-organs, have more than a general resemblance to the Sensations which we experience, through the medium of what appear to be corresponding organs.

In some cases, indeed, we cannot decide as to the precise kind of sense endowment which pertains to an organ legitimately regarded as in some way sensitive. The impressions which the Nudibranch Mollusk receives through its large tentacles, or that the Insect receives through its antennæ in addition to those of touch, may be principally those of smell—or they may be something wholly different. Kirby and Spence, for instance, believe it to be through the medium of their antennæ that many Insects are enabled to perceive approaching alterations in the weather. Bees, they say, seem in some way to become aware of the approach of a shower, and hastily return to their hives in time to escape from it, when we may be able to perceive no indications of any atmospheric change.

But, even apart from this possible existence of unknown modes of sentiency in some of the lower animals, enormous differences must exist in regard to the Perceptions derived through those channels of sense which are more or less analogous to our own.

The actual nature and complexity of the Conscious and Cognitive States roused in animals by external objects will, necessarily, be influenced by two principal causes. First, their qualitative nature (within the sphere of each sense) will depend upon the structural elaboration of the several sense-organs and of their related nerve-ganglia, in different animals. While, secondly, their complexity will also be largely dependent upon the degree of development of the higher nerve-centres as a whole, because, on the occasion of any impression upon an organ of sense, what is actually perceived (*i.e.* the completeness of the Perception) depends principally upon the degree of rapid irradiation of the impression to other parts of the brain. The Perceptions of similar objects by different kinds of animals will vary extremely, as pointed out in a previous chapter, in regard to the number and complexity of their components. And these variations, as the reader will easily understand, must in the main depend upon the average race-experiences and sensorial endowments generally of the different kinds of animals, in their associations with the particular objects perceived.

The mere keenness, or discriminative refinement of the several sensory endowments in different animals, is subject to great variation—the extremes being both far below and far above the human standard.

Thus the **Sight** impressions of certain Worms and Mollusks, obtained even at their best through simple ocelli, can only be regarded as of the most vague and general description, and probably more or less wanting in any such accompaniment as constitutes the conscious side of our own visual impressions. But how different is this from the same mode of sensorial activity in Birds. In a large majority of them, their power of vision seems far to transcend that of man or other animals, both in regard to range and keenness of discrimination. Sight is unquestionably the dominating sense of Birds.

"A hawk," observes Buffon, "during its aerial soaring, will discern a lark upon a clod of earth, coloured almost exactly like itself, at twenty times the distance at which a man or a dog can perceive it. A kite, having soared to an elevation beyond our ordinary vision, can distinguish lizards, field mice, and small birds, and select those upon which he chooses to pounce."

Again, the majority of invertebrate animals seem to have extremely little power of **Hearing** or discriminating different kinds of sounds.* Thus Sir John Lubbock says,†—

"Approaching an Ant which was standing quietly, I have over and over again made the most shrill noises I could—using a penny pipe, a dog-whistle, a violin, as well as the most piercing and startling sounds I could produce with my own voice, but without effect. At the same time I would by no means infer from this that they are really deaf, though it certainly seems that their range of sounds is very different from ours. We know that certain

* See "Nature," 1878, pp. 540 and 568.

† "Journal of Linn. Soc." (Zool.), vol. xiii. p. 244.

allied insects produce a noise by rubbing one of their abdominal rings against another. Landois is of opinion that ants also make sounds in the same way, though these sounds are inaudible to us. Our range is, however, after all very limited, and the universe is probably full of sounds which we cannot perceive. There are, moreover, in the antennæ of ants certain curious organs which may be of an auditory character."

Hearing is, however, developed in some respects to a degree far beyond our own in birds like the Owl, as well as in other night-flyers. According to Swainson also, the "sense of hearing in many quadrupeds is particularly keen, and seems to be given more especially to the herbivorous tribes: thus the Elk, although not remarkably swift, is enabled to avoid its enemies by an unusual keenness in its perception of sounds. The same delicacy of hearing is well known to be possessed by the Stag." The acuteness of this sense in the Horse, the Seal, and the Porpoise, is also said to be very remarkable.

The sense of **Touch** in different animals presents a wide range of variation in regard to its delicacy and discriminative accompaniments. Though always, to some extent, a possible mode of sentiency, it does not rise in many of the lower organisms very much beyond the level of that possessed by simple protoplasm. In higher animals, however, it is far different, and in them the sense becomes localized in some particular part or parts of the body which are to be regarded as the special tactile organs.

The sense of Touch is not distinctly localized, and probably not very keen or discriminative, in Fishes or Reptiles, though in Birds it becomes at once more developed and more localized.

Swainson says,—"In birds it is probably confined to the feet and bill. This is particularly apparent in rapacious birds, which use their feet in seizing and retaining their prey; while in those—

such as ducks, snipes, and woodcocks—which push their long bills into the mud, the point of the mandible is not only comparatively soft, but is often covered with a very thin membranous skin, which evidently implies considerable sensibility."

In the majority of Quadrupeds this sense is perhaps not very highly developed, though as in birds it seems to be principally localized in the paws and lips. There are, however, two remarkable exceptions. The trunk of the Elephant is evidently endowed with a very keen and discriminative sense of touch, and is to some extent put to the same kind of use as the four hands of Quadrumana, or the two of human beings. The tactile endowments of all these parts, however, in regard to mere sensitiveness, are altogether thrown into the shade by the second exception above referred to—viz., that presented by the inter-digital membranes, or so-called wings of Bats, and by the skin over their large ears. The sensitiveness of these parts is so marvellous that it can take the place of sight, and enables Bats to avoid even the most delicate obstacles in their tortuous and rapid flight. As Spallanzani first observed, these animals will, even when they have been blinded, "guide themselves through the most winding and complicated passages without once hitting the walls, or striking against any impediment which may seem to obstruct their progress." When in this condition they can even avoid coming into collision, during their rapid gyrations, with threads of silk which have been purposely stretched across a gallery or passage.

The three senses already referred to constitute the special intellectual senses of man—those upon which most of his knowledge of the external world is based. There is, however, another sensorial endowment—the sense of Smell—which, though it plays a very inconsiderable part in ministering to the guidance of civilized human beings, is of the very greatest importance as an intellectual sense to many different kinds of lower animals, and is frequently, like other sensorial endowments, very keen in some of the less civilized human races.*

In such creatures as Worms, and in the majority of Mollusks, it seems probable that the sense of Smell is either absent or else extremely vague and indefinite. There is reason to believe that it exists in Gasteropods, in the various kinds of Cuttle-fish, and in many Crustacea. In some Insects a keenly developed sense of Smell appears to be the dominating sense endowment. Sir John Lubbock has shown that the most intelligent of Insects, namely the social Ants, seem incapable of appreciating sounds, and that they make comparatively little use of their small eyes. Their leading sense is, unquestionably, that of Smell.† It seems to be by aid of this faculty that they find their way about, and follow their multifarious daily avocations. A recent writer, speaking of the mode in which Ants follow an established trail, says‡—

> "I have experimented with this, frequently obliterating the scent for a space of but a few inches, and watching the puzzled wanderers, each going an inch or less beyond his predecessors, hunting the lost clue until the blank was finally bridged over. After that, if the new route, as re-opened, differed from the old, it was nevertheless rigidly followed, even if longer and less direct."

Again, as evidence that Bees and Butterflies select the

* In regard to this latter subject, many very interesting facts will be found recorded in Houzeau's work "Les Facultés Mentales des Animaux," 1872, vol. i. pp. 90–94.

† "Journal of Linn. Soc.," vol. xiii. (Zool.), pp. 239, 244; and "Nature," April 10, 1873, p. 444.

‡ "Nature," February 7, 1878, p. 282.

flowers, which they visit by means of Smell rather than Sight, a writer says,*—

"Bees particularly, and also butterflies, visit a distinct variety, and for the time confine their attention to it, settling on and sucking the honey of that variety only; *e.g.*, a bee settling on a scarlet geranium will not go from it to another species or variety, but gives its attention to the particular variety only . . . . . . never going from a scarlet geranium to another scarlet flower, even if in contact. . . . . . I never remarked a bee go from a lily to an amaryllis, or the reverse."

W. M. Gabb, writing from St. Domingo, with regard to the Butterfly, says,†—

"My Indian servants always carried with them a fermented paste of maize flower, which they mixed with water to the consistency of gruel, as a beverage. On our arriving at the side of a stream in a narrow gorge, invariably, within a few minutes after they opened a package of this paste, although there might not have been a butterfly in sight before, those most brilliant of their kind would come sailing up, always from leeward, and I have made some of my best catches in this manner. I have also caught them by baiting with a piece of over-ripe or even rotten banana. At other times they were almost unapproachable."

Again, another remarkable fact points to a similar keenness of the sense of Smell in Moths,‡—"Collectors of Lepidoptera are well aware that if a virgin female moth of a certain species is enclosed in a box, males of the same species will make their appearance from distances which may be relatively pronounced prodigious."

There seems, therefore, good reason for believing that the actions of many Insects are largely determined by a subtle and highly discriminative sense of Smell, which in

* "Nature," October 18, 1877.

† "Nature," February 7, 1878, p. 282.

‡ "Quarterly Review of Science," Oct., 1877. Art. "Our Six-footed Rivals." See also "Nature," July 18, 1878, pp. 302 and 311.

acuteness may perhaps rival, if it does not exceed, that of any other animal whatsoever. In certain Insects with enormously developed eyes, however, such as Dragonflies, Sight also seems to be an all-important sense: so that Smell and Sight may be said specially to guide the actions of Insects, though not equally in the same species.

The sense of Smell in Fishes, moreover, seems, according to Kirby,* to be the most acute of all their senses.

Lacepede says:—"It may be called their real eye, since by it they can discover their prey or their enemies at an immense distance; they are directed by it in the thickest darkness, and the most agitated waves. The organs of this sense are between the eyes. The extent of the membrane on which the olfactory nerves expand in a shark twenty-five feet long, is calculated to be twelve or thirteen square feet."

In a few Birds, such as Vultures and their allies, a marvellously keen sense of Smell was for a long time supposed to exist, though the observations of Darwin and others make it probable that this supposition is erroneous, and that the facts on which it was based may be better explained by the great keenness of their sense of Sight. Certainly in the majority of Birds, the olfactory sense seems to be very slightly developed.

An extremely acute sense of Smell seems, however, to exist with many wild and domestic Quadrupeds. A well-known instance, belonging to the former category, is that of the Deer.

Again Swainson writes,†—"The scent of the American Bison is said to be so keen that it is difficult for either men or dogs to get near him, excepting on his leeward side; while the Camel, by the perfection of the same sense, is enabled, while wandering over

* Kirby's "History, Habits, and Instincts of Animals," vol. ii. p. 278.

† "Habits and Instincts of Animals," p. 49.

the sandy and parching deserts in which he so often ranges, to discover the vicinity of water at the distance of a mile."*

The keen scent of the Dog in detecting and tracking various kinds of game, and also in following his master's footsteps, even in the midst of a public thoroughfare, is familiar to all. There is reason to believe, moreover, that the Dog habitually puts its sense of Smell to uses that we can only faintly realize. A good instance of this sort is cited by Dr. Huggins,† who possesses a son of a celebrated English Mastiff, named Turk, and in whom he speedily discovered a strange antipathy to all butchers, and dislike of butchers' shops. On making enquiry of the original owner of Turk, Dr. Huggins found that a similar antipathy existed in the father, and in the grandfather of his dog, as well as in other sons of Turk, by different mothers. Concerning one of these latter dogs, named Paris, this gentleman communicated some most interesting facts.

He says,—"Paris has the greatest antipathy, as he would hardly go into a street where a butcher's shop is, and would run away after passing it. When a cart with a butcher's man came into the place where the dogs were kept, although they could not see him, they all were ready to break their chains. A master-butcher, dressed privately, called one evening on Paris's master to see the dog. He had hardly entered the house before the dog (though shut in) was so much excited that he had to be put into a shed, and the butcher was forced to leave without seeing the dog.

* R. C. Norman writes,—"That frogs are enabled to know when water is near, and that they are instinctively attracted towards it, I have had abundant means of certifying in localities where there was a pond on the other side of a paling or a wall. I have found frogs, during the spawning season, in numbers, close against the impeding fence, with their heads towards it; and when I threw them over, they immediately proceeded in the direction of the water."—WHITE's "Natural History of Selborne" (Bohn's edition), p. 407.

† "Nature," February 13, 1878, p. 281.

The same dog, at Hastings, made a spring at a gentleman who came into the hotel. The owner caught the dog and apologized, and said he never knew him to do so before, except when a butcher came to his house. The gentleman at once said that was his business."

This detection of butchers at a distance and out of sight, as well as when disguised, could only have been brought about through the dog's highly developed sense of Smell, enabling it to detect odours which might well be regarded as altogether inappreciable.

In reference to a suggestion made by Mr. Wallace,* to the effect that animals which have been taken to a distance shut up in a basket, or along a route which they have not seen, may, in some instances, find their way home principally through the intervention of their highly developed sense of Smell (a suggestion which gave rise to a long and very interesting discussion), Prof. G. Croom Robertson writes:†—"Our external world (whether as actually perceived or imaginatively represented) may be called a world of sights and touches, blended with and modifying each other in the most intimate way. . . . . . All other sensations, as of hearing, smell, and taste, come before us only discontinuously and intermittently, not being had from all things, nor always from the same things. But, in a dog's experience, touch cannot possibly co-operate with sight, as it regularly does in ours. The organ of effective touch in man—touch that gets associated with vision—is, in the last resort, the hand, combining mobility and sensitiveness in the highest degree; and the dog has no hand. Its mobile limbs are not sensitive at the extremities, and, though it has sensitive lips, these, having no such active mobility as the human hand has, are

* "Nature," February 20, 1873, p. 303.
† "Nature," February 27, 1873, p. 323.

extremely limited in the scope of their apprehension. Its touch being thus defective, what is there then in the dog to play second to sight—which as leader needs support, were it only because there is not always light to see with? Smell, I cannot but think, seeing that, whilst the organ is incontestably acute, it has the great advantage over the tactile surface of the lips, of receiving impressions from things already at a distance. If we only suppose—what the facts make very likely—that the dog's smell is acute enough to have some sensation from all bodies without exception, nothing more is wanting to enable a psychologist to understand that the dog's world may be, in the main, a world of sights and smells continuous in space."

Horses, also, would seem to have a similarly acute sense of Smell, and an interesting fact is cited by Mr. Darwin which apparently illustrates this point. He says,*—

"Many years ago I was on a mail-coach, and as soon as we came to a public-house, the coachman pulled up for a fraction of a second. He did so when he came to a second public-house, and I then asked him the reason. He pointed to the off-hand wheeler, and said that she had been long completely blind, and she would stop at every place in the road at which she had before stopped. He had found by experience that less time was wasted by pulling up his team than by trying to drive her past the place, for she was contented with a momentary stop. After this I watched her, and it was evident she knew exactly, before the coachman began to pull up the other horses, every public-house on the road, for she had, at some time, stopped at all. I think there can be little doubt that this mare recognized all these houses by her sense of smell."

It seems pretty certain, however, that many of the actions of lower animals, in finding their way to distant places, cannot be explained by reference to any of the senses, either singly or in combination, which we have as yet considered. How, for instance, is the Dog, the Cat,

* "Nature," March 13, 1873, p. 360.

or the Horse, enabled to find its way home in a short space of time, through a previously unknown tract of country, and along a route never previously traversed in any way? How, again, is the migratory Bird able to steer its way across the sea, and for thousands of miles back to the same chimney, house-top, or bush, where in the previous spring it had built its nest and reared its young? We are compelled to assume that a '**Sense of Direction**' exists in many animals, which enables them wholly to transcend the range of other senses.

This endowment occurs in such a rudimentary state in the majority of human beings, as to make the corresponding highly developed faculty of some animals appear almost in the light of a wholly new and mysterious sense endowment.

The degree to which the rudiments of such an endowment exist amongst ourselves, varies much in different individuals. Some dwellers in cities, otherwise highly intelligent, are almost incapable of finding their way through intersecting streets to a not very distant place, whose direction was known at the time of starting; whilst others, setting out with a correct notion of the relative position of the place they wish to reach, are easily able to find it, even though they may have to pass through a previously unknown maze of turnings. This power of keeping a 'known direction' in mind, during many shiftings of direction, exists, however, in a much higher degree in some savage or semi-savage races of men. Thus, according to Darwin, Von Wrangel has recorded the truly wonderful manner in which the natives of Northern Siberia are able to keep "a true course towards a particular spot, whilst passing for a long distance through hummocky ice, with incessant changes of direction, and with no guide in the heavens, or on the frozen sea." North American Indians show a similar facility in finding their way through immense mountainous tracks, so thickly wooded, that vision can only penetrate for a few yards ahead; or over pathless wastes of prairie land, where a dreary sameness reigns supreme. On this subject, G. C. Merrill, writing from Kansas, says:*—

"I have learned from the hunters and guides who spend their lives on the plains and mountains west of us, that no matter how far, or with what turns, they may have been led, in chasing the bison or other game, they, on their return to camp, always take a straight line. In explanation, they say that, unconsciously to themselves, they have kept all the turns in their mind."†

The excellence of this faculty in Siberians, Indians, and others, whose daily mode of life of itself furnishes strong motives for cultivating it, seems to show that practice may

* "Nature," May 22, 1873, p. 77.

† Referring to his travels in the State of Western Virginia, Mr. Henry Forde ("Nature," April 17, 1873, p. 463) writes as follows:—"It is said that even the most experienced hunters of the forest-covered mountains in that unsettled region are liable to a kind of seizure—that they 'lose their heads' all at once, and become convinced that they are going in quite the contrary direction to what they had intended, and that no reasoning nor pointing out of landmarks by their companions, nor observations of the position of the sun, can overcome their feeling; it is accompanied by great nervousness and a general sense of dismay and 'upset.' The nervousness comes after the seizure, and is not the cause of it. This is spoken of by the natives as 'getting turned round.' The feeling sometimes ceases suddenly, or it may wear away gradually." Colonel Lodge, in his "Hunting Grounds of the Far West," 1876, speaks of the same kind of feelings seizing upon, and occasionally demoralizing, old and experienced prairie travellers. Indian chiefs all concurred in assuring G. Catlin ("Life amongst the Indians," p. 96) that "whenever a man is lost on the prairies, he travels in a circle, and also that he invariably turns to the left; of which singular fact," the author adds, "I have become doubly convinced by subsequent proofs."

make perfect in this as in other respects; while the common want, or the existence of the mere germs of such a faculty, among dwellers in cities, leading, as they do, an artificial and wholly different kind of life, would seem to suggest that with them it is a faculty which has lapsed through mere disuse.

But the peculiarity in regard to many animals is, that they seem able to preserve, in some marvellous manner, this initial knowledge of direction, under circumstances in which such powers as Siberians or North American Indians possess, would seem likely to be of little avail. A very suggestive story in reference to this kind of potency in the Horse, has been narrated by Mr. Darwin. He says:*—

"I sent a riding-horse, by railway, from Kent, *viâ* Yarmouth, to Freshwater Bay, in the Isle of Wight. On the first day that I rode eastward, my horse, when I turned to go home, was very unwilling to return towards his stable, and he several times turned round. This led me to make repeated trials, and every time that I slackened the reins, he turned sharply round and began to trot to the eastward, by a little north, which was nearly in the direction of his house in Kent. I had ridden this horse daily for several years, and he had never before behaved in this manner. *My impression was that he somehow knew the direction whence he had been brought.* I should state that the last stage from Yarmouth [Isle of Wight] to Freshwater is almost due South, and along this road he had been ridden by my groom; but he never once showed any wish to return in this direction. I had purchased this horse, several years before, from a gentleman in my own neighbourhood, who had possessed him for a considerable time."

This story is valuable and instructive, but as a more complete instance of a power there only indicated, one of the many examples recorded by A. W. Howitt of Gippsland may be quoted. He says:†—

* "Nature," March 13, 1873, p. 360.
† "Nature," August 21, 1873, p. 323.

"Mr. Mackintosh, of Dargo, informs me that about two years ago, when gathering wild cattle on the Avon River, he got away from his men down that river for many miles before he ascertained that he was astray. Finding then that his horse persisted in going in a certain direction, he gave him his head, and the horse went in a straight line to the place where the camp was fixed, a distance of some ten miles, through a scrubby country, and without a track."

As another typical instance of this kind of power in a Dog, exercised, moreover, after a long interval, the following occurrence may be cited :*—

"A hound was sent by Charles Cobbe, Esq., from Newbridge, county Dublin, to Moynalty, county Meath, and thence, long afterwards, conveyed to Dublin. The hound broke loose in Dublin, and the same morning made his way back to his old kennel at Newbridge, thus completing the third side of a triangle by a road he had never travelled in his life."

Powers akin to this displayed by the Horse and the Dog seem possessed in considerable perfection by many other kinds of animals, among which, in ascending order, may be mentioned Insects, Crabs, Migratory Fishes and Birds, some Reptiles as well as such Quadrupeds as the Cat, the Sheep, the Ass, and probably many others.†

A very remarkable and well-attested example of such an endowment in this latter animal has been cited by Kirby and Spence‡—

"In March, 1816, an ass, the property of Captain Dundas, R.N., then at Malta, was shipped on board the *Ister* frigate, Captain Forest, bound from Gibraltar for that island. The vessel having struck on some sands off the Point de Gal, at some distance from the shore, the ass was thrown overboard to give it a chance of swimming to land—a poor one, for the sea was running so high

* "Quarterly Review," October, 1872.

† For recorded instances, see "Nature," vol. vii.

‡ "Introd. to Entomology," seventh ed. 1860, p. 552.

that a boat which left the ship was lost. A few days afterwards, however, when the gates of Gibraltar were opened in the morning, the ass presented himself for admittance, and proceeded to the stable of Mr. Weekes, a merchant, which he had formerly occupied, to the no small surprise of this gentleman, who imagined that from some accident the animal had never been shipped on board the *Ister*. On the return of this vessel to repair, the mystery was explained; and it turned out that Valiante (so the ass was called) had not only swum safely to shore, but, without guide, compass, or travelling map, had found his way from Point de Gal to Gibraltar, a distance of more than two hundred miles, which he had never traversed before, through a mountainous and intricate country, intersected by streams, and in so short a period that he could not have made one false turn. His not having been stopped on the road was attributed to the circumstance of his having been formerly used to whip criminals upon, which was indicated to the peasants, who have a superstitious horror of such asses, by the holes in his ears, to which the persons flogged were tied."

In consideration of the existence of facts of this kind, it is contended that we cannot possibly account for them by any conceivable extension of the senses of Smell and Sight; and that we must suppose animals generally, though unequally, to be endowed with a peculiar sense whereby they are enabled to retain, in the midst of all their wanderings, a constant perception or 'sense of direction' of places from which they have been removed and with which they have become intimately associated.

Quite recently, too, an announcement has been made by M. E. Cyon,* which will doubtless, sooner or later, throw much light upon the question of the Organ and Nerve Centres, having to do with this assumed 'sense of Direction' which seems to exist, though very unequally, in Man and so many of the lower animals.

M. Cyon's researches have led him to announce the existence of a more or less independent Organ of Sense

* "Comp. Rend.," 31st December, 1877.

(previously regarded as one of the parts of the organ of Hearing, of great physiological importance, which he designates the 'sense of Space.' Some of his conclusions on this subject are as follows :—

"The Semi-circular Canals are the peripheral organs of the sense of Space, that is to say, the impressions produced by the excitation of the nerve expansions in the ampullæ of these canals seem to form our notions of the three dimensions of space. The impressions from each canal correspond to one of these dimensions."

"The physiological excitation of the peripheric terminations belonging to the organ of the sense of Space occurs probably in a mechanical manner, by means of the otoliths which exist in the ampullæ. These otoliths will be thrown into vibration by every active or passive movement of the head, and, perhaps, also by the atmospheric waves whose movements the tympanic membrane transmits to the liquid which fills the system of semi-circular canals."

"The eighth pair of cerebral nerves thus contains two nerves of sense altogether distinct—the Auditory Nerve and the Space Nerve (Raumnerv)." *

* All that pertains to this difficult subject is still in its infancy. Since the above was in type two articles have been published on the question in this country, which, in addition to exposition and criticism, contain references to the literature of the subject. The one, by Dr. Crum Brown, is in "Nature" for October, 1878; and the other, by Prof. Croom Robertson, in "Mind," October, 1878, p. 559.

CHAPTER XIV.

INSTINCT: ITS NATURE AND ORIGIN.

We may, without much difficulty, convince ourselves that certain muscular actions are habitually going on within our bodies in a more or less continuous fashion, independently of Will, and even without arousing our Consciousness. To this class belong the movements of the Heart. Again, we may learn that other internal muscular actions, equally independent of Will and free from conscious accompaniment, take place in a distinctly intermittent fashion. To this class belong those contractions of the Stomach and Intestines which occur during the digestion and assimilation of food. Again, we may learn that still other internal contractions—such as those concerned in oviposition or in the birth of young—recur at much longer intervals, though they are similarly independent of Will and uninstigated by conscious impressions.

Other and wider muscular actions, partly internal and partly external, also take place in a rhythmical manner in relation with systemic conditions. The motions of the diaphragm and of the thoracic and abdominal walls, in connection with Respiration, belong to this category. These movements, though in the main independent of Will, are capable of being very considerably modified thereby; and while they are most frequently unheeded, they have a very recognizable accompaniment of feeling when attention is distinctly turned to them.

Actions which take place independently of Will as an instigator and with machine-like regularity, are, as the reader is now aware, known to physiologists as 'reflex' or 'automatic' actions. All the acts above mentioned belong to this category, and these particular examples are further characterized by the fact that the impressions which incite them are altogether unfelt. They are results, that is, of unconscious impressions. Many other automatic actions, however, exist—sneezing and coughing being examples—in which this latter peculiarity is wanting.

But why, it may be asked, are the actions above specified performed with such undeviating regularity, and at the instigation of mere unconscious impressions?

During the untold ages, in which organisms have existed with food-taking propensities and alimentary canals, contractions of the Intestine have been ensuing at short intervals, in response to the stimulus supplied by food. Since contractile Hearts were first evolved, they have never ceased to beat in the lineal descendants of inconceivably numerous generations of slowly modifying animal types. The contractions of Oviducts or of the Womb, as well as the movements concerned in Respiration, also had their beginnings in forms of life whose advent is now buried in the immeasurable past.

Let us, however, place side by side with these considerations, the well-known fact that one of the essential peculiarities of nervous action is, that movements which are at first executed slowly and irregularly, may, after numerous repetitions, become rapid and regular—more especially if on successive occasions the stimuli are similar, and nothing intervenes to alter the manner in which the recurring acts are performed. It need not, therefore, surprise us—especially after what we have learned as to the genesis of 'reflex' actions—to find that the contractions of viscera take place automatically, and even in response to unfelt impressions.

But now let us glance at other incidents in association with these visceral impressions and actions.

No 'needs' or 'appetites' exist in connection with the action of the Heart, for the very simple reason that its stimulus is always at hand, and, in the form of arterial or venous blood, actually flows into the several cardiac chambers, after each contraction. It is a little different with regard to the Respiratory Organs. Aerated water or pure air does not always surround the organism; and, as a consequence of this occasional absence of the proper stimulus, it is found that under such unnatural conditions a 'respiratory need,' or want, is felt. Owing, however, to this being a want of accidental, rather than of regular, occurrence, it never attains the more definite and more regularly-recurrent character of an 'appetite.'

How different is it with the Alimentary Canal. Its particular stimulus is not ever present like that of the heart, or only occasionally absent, as with that of the respiratory organs; it mostly has to be sought. Hence it is that the habitually recurring need reveals itself as a definitely returning appetite for food. Much the same kind of origin is to be ascribed to the sexual appetite, except that it is one which, in organisms generally, recurs at more or less distant intervals. Just as hunger, however, depends, almost wholly, upon impressions coming from the alimentary canal, so does the sexual appetite depend, in the main, upon particular states of certain Generative Organs.

Any one, who carefully studies the acts of lower animals, will readily recognize how very large a proportion of them are, either immediately or remotely, instigated by one or other of these visceral needs or 'appetites.'

The mode in which states of viscera operate in determining an organism's activities is not difficult to understand. It has been previously pointed out that the Stomach is always in direct communication with the Brain, and that the Generative Organs are also, either directly or indirectly, in close connection therewith. Impressions, therefore, may emanate from either of these organs, which habitually pass on to the principal nervous centres, and there come into some kind of relation with one or more of the special sense-centres, whose activity they serve to heighten. That there is an intimate correlation between visceral needs and sensorial activity cannot be denied. An appetite for food, or a desire to find a mate, commonly suffices to call certain sense-centres into a state of keen receptivity to impressions, and thus affords conscious intelligence an opportunity to come into play for the immediate guidance of the animal in its search for what it needs, and in its execution of all those acts to which it is prompted for the gratification of this or that appetite.

From what has been previously said, it will be seen to be almost an inevitable necessity that all acts which are immediately responsive to visceral needs, as well as all which daily and habitually suceeed some recurring impression, should be the most deeply automatic in nature. The mode in which the representatives of each kind of organism seize and swallow their food, should, for instance, like the action of the viscera, be more or less common to the whole of them, and performed with machine-like regularity. And so with other actions which have, during succeeding ages, been taking place in response to particular sensorial impressions throughout the lives of untold generations of animals.

It would follow, therefore, for the same reason, that if, with any organisms, the acts more *remotely* prompted by visceral needs are performed amidst practically uniform conditions, that these acts would also tend to exhibit some degree of the same uniformity—whether they are connected with search after or storing of food, with capture of prey, with sexual dalliance, or with the deposition or care of eggs or young. The nerve tissues having to do with any mixed series of habitually recurring impressions and actions, would, in the course of ages, come to be so organically knit together as to permit of the manifestation of a machine-like regularity of habit, approximating to that which is observed in the performance of the simpler acts more immediately dependent upon visceral stimuli.

The possibility of executing any simple Instinctive Acts, and still more those which constitute a complex series, can only have been built up and definitely organized after successive generations of animals have been habitually subjected to the impressions to which the acts are related, and after such impressions have, at last, invariably led to the particular motor results in question. We owe the first distinct enunciation of this light-giving notion to Herbert Spencer. He says :*—" Let it be granted that the more frequently psychical states occur in a certain order, the stronger becomes their tendency to cohere in that order, until they at last become inseparable; let it be granted that this tendency is, in however slight a degree, inherited, so that if the experiences remain the same, each successive generation bequeaths a somewhat increased tendency; and it follows that, in cases like the one described, there must eventually result an automatic connection of nervous actions, corresponding to the external relations perpetually experienced. Similarly, if from some change in the environment of any species, its members are frequently brought in contact with a relation having terms a little

* "Principles of Psychology," vol. i. p. 439.

more involved: if the organization of the species is so far developed as to be impressible by these terms in close succession; then, an inner relation corresponding to this new outer relation will gradually be formed, and will, in the end, become organic. And so on in subsequent stages of progress."

This clustering together and mutual dependence of the organic representatives of certain impressions and acts, might be expected to take place more especially in connection with an animal's search after, capture and disposal of, food; with the construction of their habitations, or the seeking out of places of shelter; also, in reference to the successive incidents of their amours, to the best disposal of their eggs (with possible migrations to effect this object), or to the proper care of their young till they are capable of looking after themselves. This, however, covers the ground of most of the so-called Instincts, which, as H. Spencer says, are to be regarded as "organized and inherited habits" of a more or less intricate character.

In all the more complex Instinctive Acts, we have in fact to do with a more or less prolonged series of impressions and interpolated muscular movements associated very closely, and following one another with a regularity only a little less marked than that which characterizes the sequence of impressions and movements in those 'reflex acts' described in a previous chapter. Instincts are therefore very correctly regarded as serial aggregations of such reflex acts, and accordingly they have also been named by Herbert Spencer 'compound reflex actions.'

Although each of the component acts may (like reflex acts in general) present purposive characters, and, though they may be all combined so as to lead to a definite end, there is no reason for believing that such 'ends' are, of necessity, previously realized or imagined by the creature performing the acts, any more than the headless frog realizes the 'end' of movements which seem to us to be distinctly purposive. It may, however, be otherwise.

Thus in many Instincts an abiding visceral state (begetting, as it does, a corresponding appetite or desire) exercises its powerful influence upon the higher nerve centres generally, and so supplies a stimulus more or less definitely realized prompting to a series of sensorially-guided acts, which, owing to the similarities of the environments of individuals of each species, are subject to comparatively little variation in their successive steps.

Broussais, following in the wake of Cabanis, was one of the first to point out the great importance of visceral states and impressions in reference to Instinctive Acts. Citing a well-known, but important, illustration, he says:* "If, when a hen is impelled to incubation, we dip her belly several times in cold water, the excitement disappears, and the kind of clucking which accompanies this desire ceases, together with all the other acts related to the same end." And, that there are visceral causes or states lying at the root of the sexual instincts generally, may be inferred, among other things, from the fact that in animals which have undergone certain mutilations such instincts remain in abeyance. These states are only periodically aroused in many animals, and in Birds, more especially, we find sexual changes forming part of the seasonal rhythm of bodily states. "The pairing of animals usually begins to take place in the spring; when the winter is passed, the earth is covered by verdure and adorned by the various flowers that now expand their blossoms. . . . The birds sing their love songs; the nightingale is now 'most musical most melancholy'; the cuckoo repeats his

* "Traité de Physiologie," Pt. I., chap. vii.

monotonous note; and every other animal seems to partake of the universal joy."*

The principal Instincts of animals have been grouped by naturalists under three heads:—

1. Those dependent, immediately or remotely, upon incitations from the Alimentary Canal (*e.g.*, mode of seeking, capture, seizing, storing, or swallowing of food; and some cases of migration).
2. Those dependent upon incitations from the Generative Organs (*e.g.*, pairing, nidification, oviposition, care of young; and some cases of migration).
3. Those dependent upon more general impressions, perhaps partly internal and partly external in origin (hybernation and migration).

These are the classes considered by Kirby and other writers. Those of the first set are often spoken of as Instincts of "self-preservation," and the second as Instincts "devoted to the perpetuation of the species." But language of this kind is apt to be misleading. Animals under the influence of these instincts cannot rightly be supposed to act as a result of reflection, but rather to be at each step (though more or less guided by memory and present sensorial impressions) urged on by a 'blind impulse.' Although the successive components of Instinctive Acts for the most part lead to very definite ends, apparent enough to the onlooker, no definite conception of the ultimate end to be obtained can be commonly supposed to actuate the animal.

It is this negative characteristic, indeed, which goes far to explain the essential peculiarity of Instinctive, as opposed to Rational, Acts. Three leading peculiarities of these Acts were given long ago by Dr. W. Alison,† which are as

* Kirby's "Habits and Instincts of Animals," vol. ii. p. 188.
† "Cyclop. of Anat. and Physiol.," vol. iii. p. 4.

follows:—(1) They are always performed by individuals of the same species in nearly, if not in exactly, the same manner. (2) No experience or education is required in order that the different voluntary efforts requisite for these actions may follow one another with unerring precision. (3) They are occasionally seen to be performed under circumstances which the onlooker (having regard to the ends usually accomplished by the acts) recognizes as rendering them nugatory.

In illustration of the first and second peculiarities, the following quotation from Bichat may be cited. He said: "If we examine different animals at the moment of birth, we shall see that the special instinct of each directs the execution of peculiar movements. Young quadrupeds seek the mammæ of their mothers, birds of the order Gallinaceæ seize immediately the grain which is their appropriate nourishment, while the young of the carnivorous birds merely open their mouths to receive the food which their parents bring to their nests."

The third peculiarity exemplifies the 'blindness of Instinct,' and may be illustrated by the fact that Blow-flies often deposit their eggs on a plant (*Chenopodium fœtida*) whose odour resembles decaying meat, though it is quite unsuitable as a nidus for such eggs; or by the fact that the Bee gathers and stores up honey even in a climate where there is no winter; by the fact that a Hen will continue to sit on a pebble which has been put in the place of an egg, and that she shows the same kind of solicitude for ducklings that have been hatched under her as she would for chickens produced from her own eggs.

Some powers and instincts (*a*) are connate: that is, the animals are capable of manifesting them almost immediately after birth, and without the occurrence of previous abortive attempts and failures. D. A. Spalding says:*

"The pig is an animal that has its wits about it quite as soon after birth as the chicken. I, therefore, selected it as a subject of observation. The following are some of my observations: That vigorous young pigs get up and search for the teat at once, and within one minute after their entrance into the world; that if removed several feet from their mother, when aged only a few minutes, they soon find their way back to her, guided apparently by the grunting she makes in answer to their squeaking. . . . . . One pig I put in a bag the moment it was born, and kept it in the dark till it was seven hours old, when I placed it outside the sty, a distance of ten feet from where the sow lay concealed inside the house. The pig soon recognized the low grunting of its mother, went along outside the sty, struggling to get under or over the lower bar. At the end of five minutes, it succeeded in forcing itself through, under the bar, at one of the few places where that was possible. No sooner in, than it went without a pause into the pig-house to its mother, and was at once like the others in its behaviour."

In other cases, however, powers or instincts (*b*) which cannot be manifested at birth become developed after days or weeks; apparently because, in these cases, the Nervous Systems of the young animals have to go through certain stages of development beyond those which have been attained at the time when the young leave the oviducts or womb of the mother.

On this subject, D. A. Spalding remarks: "The human infant cannot masticate; it can move its limbs, but cannot walk, or direct its hands so as to grasp an object held before it. The kitten just born cannot catch mice. The newly-hatched swallow or tomtit can neither walk, nor fly, nor feed itself. They are helpless as the human infant. Is it as the result of painful learning that

* "Macmillan's Magazine," February, 1873.

the child subsequently seizes an apple and eats it? that the cat lies in wait for the mouse? that the bird finds its proper food, and wings its way through the air? We think not. With the development of the physical parts, comes, according to our view, the power to use them in the ways that have preserved the race through past ages. This is in harmony with all we know. Not so the contrary view."

In regard to some of those powers which only become possible several days after birth, it can be clearly shown that they are no more 'learned' by the individual than are those which are capable of being manifested immediately after birth. Some organisms are born in a state of greater maturity than others, and in those in which immaturity is most marked (as in the human infant), as well as in those in which it is less marked, the necessary time must elapse for the several parts of the body, and especially of the Nervous System, to develop, before certain truly instinctive desires and acts are capable of showing themselves. Thus only can we explain the late appearance of many Instinctive Acts in animals generally, as, for instance, the powers of flight shown by young, but only recently-fledged, Birds who have made no previous attempts to fly. The manifestation of this latter power, independently of learning, has also been experimentally verified by Spalding.

He placed some young unfledged Swallows "in a small box not much longer than the nest from which they were taken. The little box, which had a wire front, was hung on the wall near the nest, and the young swallows were fed by their parents through the wires. In this confinement, where they could not even extend their wings, they were kept until after they were fully fledged." The birds were then liberated, and their actions carefully watched. Of two young swallows which had been confined in this manner till their wings had grown, Spalding says, "One, on being set free, flew a yard or two too close to the ground, rose again in the direction of a beech-tree, which it gracefully avoided; it was seen for a considerable time sweeping round the beeches, and performing magnificent evolutions in the air high above them. The other, which was observed to beat the air with its wings more than usual, was soon lost to sight behind some trees." He adds, "Titmice, tomtits, and wrens I have made the subjects of a similar study, and with similar results."

The Plasticity of Instinct.

The same careful observer says:* "Though the instincts of animals appear and disappear in such seasonable correspondence with their own wants and the wants of their offspring as to be a standing subject of wonder, they have by no means the fixed and unalterable character by which some would distinguish them from the higher faculties of the human race. They vary in the individuals as does their physical structure. Animals can learn what they did not know by instinct, and forget the instinctive knowledge which they never learned, while their instincts will often accommodate themselves to considerable changes in the order of external events." He then records the following experiment:—

"Everybody knows it to be a common practice to hatch ducks' eggs under the common hen, though in such cases the hen has to sit a week longer than on her own eggs. I tried an experiment to ascertain how far the time of sitting could be interfered with in the opposite direction. Two hens became broody on the same day, and I set them on dummies. On the third day I put two chicks a day old to one of the two hens. She pecked at them once or twice; seemed rather fidgety, then took to them, called them to her, and entered on all the cares of a mother. The other hen was similarly tried, but with a very different result. She pecked at the chickens viciously, and both that day and the next stubbornly refused to have anything to do with them."

* "Nature," October 7, 1875, p. 507.

Another excellent example of the plasticity of Instinct; that is, of the way in which an instinct will vary under new conditions, has been recorded by G. J. Romanes. This ingenious observer writes* :—

"Three years ago I gave a pea-fowl's egg to a Brahma hen to hatch. The hen was an old one, and had previously reared many broods of ordinary chickens with unusual success, even for one of her breed. In order to hatch the pea-chick, she had to sit one week longer than is requisite to hatch an ordinary chick. . . . . . The object with which I made this experiment, however, was that of ascertaining whether the period of maternal care subsequent to incubation admits, under peculiar conditions, of being prolonged; for a pea-chick requires such care for a very much longer time than does an ordinary chick. As the separation between a hen and her chickens always appears to be due to the former driving away the latter when they are old enough to shift for themselves, I scarcely expected the hen in this case to prolong her period of maternal care, and, indeed, only tried the experiment because I thought that if she did so, the fact would be the best one imaginable to show *in what a high degree hereditary instinct may be modified by peculiar individual experience.* The result was very surprising. For the enormous period of eighteen months this old Brahma hen remained with her ever-growing chicken, and throughout the whole of that time she continued to pay it unremitting attention. She never laid any eggs during this lengthened period of maternal supervision, and if at any time she became accidentally separated from her charge, the distress of both mother and chicken was very great. Eventually the separation seemed to take place on the side of the peacock. . . . . . In conclusion, I may observe that the peacock reared by this Brahma hen, turned out a finer bird in every way than did any of his brothers of the same brood which were reared by their own mother; but that, on repeating the experiment next year with another Brahma hen and several pea-chickens, the result was different, for the hen deserted her family at the time when it is natural for ordinary hens to do so, and, in consequence, all the pea-chickens miserably perished."

Another observation proving the modifiability of In-

* "Nature," October 25, 1875, p. 553.

stincts in Birds has been recorded by the same observer, and is of great interest. He says*:—

"A bitch ferret strangled herself by trying to squeeze through too narrow an opening. She left a very young family of three orphans. These I gave, in the middle of the day, to a Brahma hen, which had been sitting on dummies for about a month. She took to them almost immediately, and remained with them for rather more than a fortnight, at the end of which time I had to cause a separation, in consequence of the hen having suffocated one of the ferrets by standing on its neck. During the whole of the time that the ferrets were left with the hen, the latter had to sit upon the nest, for the young ferrets, of course, were not able to follow the hen about as chickens would have done. The hen, as might be expected, was very much puzzled at the lethargy of her offspring. Two or three times a day she used to fly off the nest, calling upon her brood to follow; but upon hearing their cries of distress from cold, she always returned immediately, and sat with patience for six or seven hours more. I should have said that it only took the hen one day to learn the meaning of these cries of distress; for after the first day she would always run in an agitated manner to any place where I concealed the ferrets, provided that this place was not too far away from the nest to prevent her from hearing the cries of distress. Yet I do not think it would be possible to conceive of a greater contrast than that between the shrill piping note of a young chicken and the hoarse growling noise of a young ferret. On the other hand, I cannot say that the young ferrets ever seemed to learn the meaning of the hen's clucking.

"During the whole of the time that the hen was allowed to sit upon the ferrets, she used to comb out their hair with her bill, in the same way as hens in general comb out the feathers of their chickens. While engaged in this process, however, she used frequently to stop and look with one eye at the wriggling nestful, with an enquiring gaze expressive of astonishment. At other times, also, her family gave her good reason to be surprised, for she used often to fly off the nest suddenly with a loud scream, an action which was doubtless due to the unaccustomed sensation of being nipped by the young ferrets in their search for the teats. It is further worth while to remark that the hen showed so much uneasiness of

* Loc. cit., p. 554.

mind when the ferrets were taken from her to be fed, that at one time I thought she was going to desert them altogether. After this, therefore, the ferrets were always fed in the nest, and with this arrangement the hen was perfectly satisfied, apparently because she thought that she then had some share in the feeding process. At any rate, she used to cluck when she saw the milk coming, and surveyed the feeding with evident satisfaction. . . . . Altogether, I consider this a very remarkable instance of the plasticity of instinct. The hen, it should be said, was a young one, and had never reared a brood of chickens. A few months before she reared the young ferrets she had been attacked and nearly killed by an old ferret, which had escaped from his hutch. The young ferrets were taken from her several days before their eyes were open."

This variability of instincts under varying conditions is a matter of considerable importance in enabling us better to understand the enormous variety of Animal Instincts and the mode in which some of the most complex and extraordinary of them may have originated. On this subject Mr. Darwin says:* "Under domestication instincts have been acquired, and natural instincts have been lost, partly by habit, and partly by man selecting and accumulating during successive generations peculiar mental habits and actions, which at first appeared from what we must in our ignorance call an accident. In some cases compulsory habit alone was sufficient to produce inherited mental changes; in other cases compulsory habit has done nothing, and all has been the result of selection pursued both methodically and unconsciously." Again, among wild animals "changes of instinct may sometimes be facilitated by the same species having different instincts at different periods of life, or at different seasons of the year, or when placed under different circumstances, &c.; in which case either the one or the other instinct might be preserved by natural selection. And such instances of diversity of instinct in the same species can be shown to

* "Origin of Species," 6th edition, 1872, pp. 206, 207, 211, 233.

occur in nature. . . . Under changed conditions of life it is at least possible that slight modifications of instinct might be profitable to a species; and if it can be shown that instincts do vary ever so little, then I can see no difficulty in natural selection preserving and continually accumulating variations of instinct to any extent that was profitable. It is thus, as I believe, that all the most complex and wonderful instincts have originated. As modifications of corporeal structure arise from, and are increased by, use or habit, and are diminished or lost by disuse, so I do not doubt it has been with instincts. But I believe that the effects of habit are in many cases of subordinate importance to the effects of natural selection, of what may be called spontaneous variations of instincts: that is of variations produced by the same unknown causes which produce slight deviations of bodily structure. . . . . For peculiar habits confined to the workers or sterile females, however long they might be followed, could not possibly affect the males and fertile females which alone leave descendants."

As typical instances of the more complex Instinctive Acts may be cited the web-weaving and nest-building habits of Spiders; the gathering and storing of honey, together with all the social acts of Bees; the slave-making and other habits of Ants; the migrations of Fishes at spawning-time; the selection of site and mode of oviposition among Amphibia; the nest-building acts and migrations of Birds; the house-building and food-storing acts of Beavers. There can be little doubt, that if our means of knowledge were greater than it is, we should be able to explain these and all other Instincts by reference to the doctrines of 'inherited acquisition' and 'natural selection,' either singly or in combination.

CHAPTER XV.

NASCENT REASON, EMOTION, IMAGINATION AND VOLITION.

The views set forth in preceding chapters in regard to Reflex and Instinctive Actions permit certain important corollaries to be deduced therefrom. And should these be found to harmonize with many known facts, such correspondence of facts with theoretical deductions will probably be held to afford additional evidence in favour of the views in question.

In this chapter we shall refer to three such corollaries, and see what evidence can be adduced in support of them.

(1.) It would seem likely that,—All the definite acts of very low organisms would partake either of the nature of Reflex Actions or of the Simple Instinctive Acts into which these latter merge by almost insensible gradations.

This proposition might be expected to hold good for all the actions of Medusæ, Worms, and Mollusks—with the exception, perhaps, among the latter, of some of those manifested by the active and highly endowed Cephalopods.

A rude unfamiliar touch of any kind evokes in a Snail, on its travels, only one set of actions: its body and horns contract, and the former is drawn by its retractor muscle within the shell. No other actions are ever seen to follow such a stimulus. In its daily walk, also, the various movements of the Snail are of the simplest kind, largely instigated, it would seem, by the visceral and general condition known to us as 'hunger,' and only more rarely diversified by other promptings. Influenced by an 'impulse,' or 'desire' for food, impressions of Smell and Sight doubtless guide the animal to the plants on which it is accustomed to feed, and whose leaves it devours with that accompaniment of Feeling, definite or indefinite, which may pertain to its rudimentary nervous actions.

(2.) We might expect to find that,—The lower the development of the Brain in those organisms which perform any of the more Complex Instinctive Actions, the less frequently would anything like Reason appear to intervene in their accidental relations with unfamiliar phenomena outside the range of their ordinary instinctive experiences.

In order to test the correctness of this inference, it seems desirable to study pretty closely some of the recorded acts of those Social Insects of which we know most, and whose instincts are so remarkable—such as Bees, Wasps, and Ants. We may thus be able to arrive at some conclusion as to the extent to which, what is ordinarily termed 'Reason,' seems to influence their actions. Fortunately, we have available the records of numerous experimental observations recently made by Sir John Lubbock,* and conducted with all the care that could be desired, in regard to the reputed high intelligence of these very animals. They, or, at all events, Bees and Ants, have long been the special favourites of naturalists, many of whom have not hesitated to put the most liberal constructions upon the acts and demeanour of their insect friends. There has been, unquestionably, a tendency to look at these acts from a much too exclusively human point of view.

This being so, it was all the more necessary that some

* "Journ. of Linn Soc. (Zool.)," vols. xii., xiii., and xiv.

skilled observer should, as Sir John Lubbock has done, make new and special observations on the subject.

A few illustrations will enable the reader to form his own judgment, as to the extent of the power possessed by the Social Insects of adapting themselves to unfamiliar conditions.

The first instance shows forcibly the comparative inability of Bees to accommodate themselves to changes in their environment, and, incidentally, their lack of any real loyalty or 'sympathy' for their queen when she is away from her customary surroundings.

Wishing to exchange his queen Bee for one of another breed, she was placed, Sir John Lubbock says, "with some workers in a box containing some comb." Under these new and unaccustomed conditions the workers took no notice of their queen, so that three days afterwards she was found "weak, helpless, and miserable." The next day some bees were coming to a store of honey at the observer's window, and he placed the helpless queen close to them. "In alighting, several of them even touched her; yet not one of her subjects took the slightest notice of her. *The same queen, when afterwards placed in a hive, immediately attracted a number of bees.*"

Another experiment also tends to confirm the machine-like or undeviating regularity of the intelligence of Bees, by showing their difficulty in recognizing food when it is placed under conditions slightly different from those to which they are accustomed.

A number of these insects were noticed to be very busy with some berberries, and Sir John Lubbock says: "I put a saucer with some honey between two bunches of flowers; these were repeatedly visited, and were so close that there was hardly room for the saucer between them, yet from 9.30 to 3.30 not a single bee took any notice of the honey. At 3.30 I put some honey on one of the bunches of flowers, and it was eagerly sucked by the bees; two kept continually returning till past five in the evening."

Again, not to be able to supplement one mode of sensorial guidance by another, as in the following simple case, recorded by the same able observer, reveals what seems to be a strange lack of adaptive intelligence on the part of the Bee.

"At 10.15 I put a bee into a bell-glass, 18 inches long, and with a mouth 6½ inches wide, turning the closed end to the window; she buzzed about till 11.15, when, as there seemed no chance of her getting out, I put her back into the hive. Two flies, on the contrary, which I put in with her, got out at once. At 11.30 I put another bee and a fly into the same glass; the latter flew out at once. For half an hour the bee tried to get out at the closed end; I then turned the glass with the open end to the light, when she flew out at once. To make sure, I repeated the experiment once more, with the same result."

"Both bees and wasps," Sir John Lubbock thinks, "find their way about by a 'sense of Direction' rather than that of Sight, though the wasp does not so helplessly ignore the latter source of knowledge as the bee seems to do." The Ant, on the contrary, appears to have scarcely any 'sense of Direction.' It seems to guide itself almost wholly by its sense of Smell, and, when baffled on such a track, wanders about vainly, making little or no use of its sense of Sight. This has been most clearly shown.*

Ants often take little, or, mostly, no notice of friends in distress, or of dead ants lying in their path, yet if one or two are crushed to death, in some portion of a frequented track, all those arriving just afterwards at the spot appear to become frightened and bewildered. They run hither and thither in an excited manner, and soon either wander away or return. This is, perhaps, due in the main to a very strong odour emanating from the crushed Ants, rather than to any violent emotion produced by the

* "Journ. of Linn. Soc.," vol. xiii. pp. 239-244.

sight of dead comrades, whom they generally disregard. This notion is borne out by the fact that they behave in almost the same way if the tip of the finger is drawn across their line of route on a wall; or if a mark is made with a stick or a stone across their route when they are travelling on the ground. These Insects appear, indeed, to become excited and bewildered in the face of any unusual impressions coming through their dominating sense-organs, and this to a degree proportionate to the strength and novelty of such impressions.*

The common Ants of this country will not, even under strong temptation, drop or jump downwards from some slight elevation. Sir John Lubbock frequently made experiments of this kind. He introduced some ants (*Lasius niger*) to a store of larvæ, and after they had been engaged for some time in removing them, he elevated one portion of the bridge over which they were compelled to pass in going back to the larvæ, so that this elevated end of the bridge was three-tenths of an inch above the remaining portion. The result, frequently repeated, was that, after a while, and much coursing backwards and forwards, they all "went away, losing their prize, in spite of most earnest efforts, because it did not occur to them to drop $\frac{3}{10}$ of an inch."† The same observer adds:—"At the moment when the separation was made there were fifteen ants on the larvæ. These could, of course, have returned if one had stood still and allowed the others to get on its back. This, however, did not occur to them." They wandered about for a long time in the most aimless manner.

This apparent lack of ingenuity and reluctance to drop from small heights, as shown by our English ants, is very

* "Nature," vol. vii. p. 443; vol. viii. pp. 244, 303.

† "Journ. of Linn. Soc." (Zool.), vol. xiii. p. 217.

remarkable, but certainly not common to such creatures generally. This is shown by facts communicated to Kirby* by Colonel Sykes, from his own observation, concerning certain "large black ants" common in India.

"When resident at Poona," he says:—"the dessert, consisting of fruits, cakes, and various preserves, always remained upon a small side table, in a verandah of the dining-room. To guard against inroads, the legs of the table were immersed in four basins filled with water; it was removed an inch from the wall, and, to keep off dust from open windows, was covered with a tablecloth. At first the ants did not attempt to cross the water, but as the strait was very narrow, from an inch to an inch and a half, and the sweets very tempting, they appear, at length, to have braved all risks, to have committed themselves to the deep, to have scrambled across the channel, and to have reached the objects of their desires, for hundreds were found every morning revelling in enjoyment: daily vengeance was executed upon them without lessening their numbers; at last the legs of the table were painted, just above the water, with a circle of turpentine. This at first seemed to prove an effectual barrier, and for some days the sweets were unmolested, after which they were again attacked by these resolute plunderers; but how they got at them seemed totally unaccountable, till Colonel Sykes, who often passed the table, was surprised to see an ant drop from the wall, about a foot above the table, upon the cloth that covered it; another and another succeeded. So that though the turpentine and the distance from the wall appeared effectual barriers, still the resources of the animal, when determined to carry its point, were not exhausted, and by ascending the wall to a certain height, with a slight effort against it, in falling it managed to land in safety upon the table."

These seem to have been acts prompted by 'reason,' but they were probably guided by a far better sense of Sight than is possessed by our English ants, which, as Sir John Lubbock has shown, rely very little upon this sense for guidance. It is only fair to point out, therefore, that the seeming lack of intelligence betrayed by our English ants,

* "Habits and Instincts," vol. ii. p. 251.

from their disinclination to take a small leap, may be due simply to their defective sight. A sense of Smell, however keen, would scarcely afford sufficient guidance to tempt an animal to jump, and the very small laterally-placed eyes of the English ants would probably not be very serviceable in the accomplishment of such an act.

Bees have been commonly reputed to show signs of Compassion for their fellows when injury or misfortune overtakes them. In regard to this, Sir John Lubbock says*:—

"It is, no doubt, true that when they have got any honey on them, they are always licked clean by the others; but I am satisfied that this is for the sake of the honey rather than of the bee. On the 27th of September, for instance, I tried with two bees: one had been drowned, the other was smeared with honey. The latter was soon licked clean, of the former they took no notice whatever. I have, moreover, repeatedly placed dead bees by honey on which live ones were feeding, but the latter never took the slightest notice of the corpses." Further experiments confirmed this opinion, as in his second paper (loc. cit., vol. xii. p. 231) Sir John Lubbock says: "far indeed from having been able to discover any evidence of affection amongst them, they appear to be thoroughly callous and utterly indifferent to one another."

No evidence was forthcoming to show that the behaviour of English Ants to wounded comrades was very different (loc. cit., p. 492), though it is true that those which were marked and then returned to their nests, usually had the paint cleaned off by their fellows.† But Mr. Belt, in his "Naturalist in Nicaragua," cites some very remarkable instances of sympathetic helpfulness, which were displayed by 'foraging Ants' towards unfortunate comrades. He says:—

"One day when watching a small column of these ants (*Eciton*

* Loc. cit., vol. xii. p. 128. † Loc. cit., vol. xiii. p. 230.

hamata) I placed a little stone on one of them to secure it. The next that approached, as soon as it discovered its situation, ran backwards in an agitated manner, and soon communicated the intelligence to the others. They rushed to the rescue: some bit at the stone and tried to move it; others seized the prisoner by the legs, and tugged with such force that I thought the legs would be pulled off—but they persevered till they got the captive free. I next covered one up with a piece of clay, leaving only the ends of the antennæ projecting. It was soon discovered by its fellows, which set to work immediately, and by biting off pieces of the clay, soon liberated it."

It is possible, however, that such acts as are above recorded may have been very commonly performed by 'foraging Ants' on behalf of distressed comrades, though they are not habitual with Ants of other species. It is not at all necessary to believe that any definite communications had, as Mr. Belt suggests, been made to the Ants which came out to help. They may have simply followed their excited companion. Evidence in regard to this latter point, so far as ordinary Ants are concerned, will presently be cited.

Again, the Social Insects have been said to show signs of Joy, by mutual caresses, when old comrades meet after weeks or months of separation. But careful test experiments gave Sir John Lubbock no evidence of this behaviour, either with Bees, Wasps, or Ants. It has been often said that the members of one hive always recognize one another, and that strangers are driven out. This seemed to be true only in part. He found that Bees knew and almost habitually returned to their own hive. Occasionally, however, they entered a strange hive, and this without fear or molestation. Ants seem to remember each other much better than Bees. Sir John Lubbock found* that strange Ants were not permitted to remain in a nest; they were,

* Loc. cit., vol. xiii. pp. 221–237.

in almost all cases, persistently attacked and ultimately killed—one species, however (*Lasius flavus*), presented an exception to this rule. Previous comrades, after a separation of six months or more, are not received with any signs of cordiality, though, at the same time, their presence is not as a rule objected to, and they soon appear quite at home again. This apparent memory of individuals pertaining to the same nest for one another may, perhaps, after all, be rather dependent upon some subtle discrimination by the sense of Smell. An Ant of a strange colony, though belonging to the same species, may present some sensorial attribute leading to its recognition as an intruder; whilst a member of the same colony, even after long absence, presenting no unusual characters, is not so much remembered as passed by in a heedless manner.

What, moreover, are we to infer as to the memory or ability to be taught by their own individual experience on the part of Wasps, in the face of the following facts narrated by Sir John Lubbock?*

A Wasp which had been marked for identification, smeared her wings with syrup, so that she could not fly, and as the experimenter did not know where her nest was, he could not submit her to the before mentioned cleansing operations of her companions. He thought she was doomed, but, as a last resource, resolved to wash her himself, fully expecting "to terrify her so much, that she would not return again." He, therefore, "caught her, put her in a bottle half full of water, and shook her up well till the honey was washed off." She was then transferred to a dry bottle, and put in the sun. When she was dry, Sir John Lubbock says, "I let her out, and she instantly flew to her nest. To my surprise, in thirteen minutes she returned as if nothing had happened, and continued her visits to the honey all the afternoon. . . . . This experiment interested me so much, that I repeated it with another marked wasp, this time, however, keeping the wasp in the water till she was quite motionless and insensible. When taken out of the water she soon

* "Journ. of Linn. Soc.," vol. xii. p. 138.

recovered; I fed her; she went quietly away to her nest as usual, and returned after the usual absence. The next morning this wasp was the first to visit the honey."

After what has been already stated, the reader will not be surprised to learn that the careful enquiries of Sir John Lubbock give no support whatever to the supposition that the Social Insects have a kind of language of their own. He found no evidence of their possessing a power of communicating with one another by means of their antennæ, or otherwise, so as to enable them "to narrate facts or describe localities." His enquiries were carefully directed and often repeated, with the view of throwing decisive light upon this question; and, in opposition to the statements of Hüber and Dujardin, they seem, as he says, "to show that wasps and bees do not convey to one another information as to food which they may have discovered." He adds:—"No doubt when one wasp has discovered and is visiting a supply of syrup, others are apt to come too, but I believe that they merely follow one another. If they communicated the fact considerable numbers would at once make their appearance; but I have never found this to be the case." The experiments and observations made by this skilful investigator with Ants, with the view of throwing light upon this same question, have been even more exhaustive and carefully planned, and have led him to the following conclusion*:—"When an Ant has discovered a store of food and others gradually flock to it, they are guided, in some cases by sight, while in others they track one another by scent."

Bees and Wasps again have been imagined by some to be in the habit of making known their Emotions to one another by means of sounds, which would of course imply that they possess a sense of Hearing. As previously

* Loc. cit., vol. xii. p. 485.

stated (p. 205), however, the same observer found that neither Bees, Wasps, nor Ants, seemed to take the least notice of the most varied sounds produced in their vicinity.

These investigations of Sir John Lubbock are the best that have ever been made to really test, by means of carefully devised experiments, the adaptive intelligence of the Social Insects, whose Instinctive Acts are so complicated and marvellous, and as far as they have yet gone they suffice to show us the very scanty grounds that exist for crediting them with anything like Reason. His experiments have revealed, in the great majority of cases, a very surprising lack of Reason, when even the slightest departure from their customary actions was alone needful, in order that these Insects—the most intelligent of their class—might adapt themselves to certain purposely-altered conditions in their environment.

(3.) The next corollary is the converse of that which has just been illustrated. It is this,—The higher the development of the Brain in those organisms which perform any of the more complex Instinctive Actions, the more frequently will acts of 'Reason' appear to intervene in their accidental relations with unfamiliar phenomena outside the range of their ordinary instinctive experiences.

Next to those of Insects, the instincts of Birds are, perhaps, the most remarkable, and as the Brain and Nervous System generally is so much more highly developed in Birds than it is in Insects, we ought, in accordance with the corollary above mentioned, to find in the former a much greater liberty and choice of action, together with a more decided and more frequent exercise of the lower modes of Reason, Emotion, Imagination, and Volition than is to be met with among the latter.*

* It is not meant for the reader to infer that the distinct manifesta-

It will not, we think, be difficult to find evidence of the existence among Birds of an altogether richer and more varied series of life phenomena. Some few illustrations will now be cited.

An interesting story from the pen of the Scottish naturalist, Thomas Edwards, so much of whose life has been devoted to the study of the habits of the lower animals, may first be quoted. It refers to a little bird called the 'Turnstone,' which feeds on the small Sandhoppers of the sea-shore. The acts cited seem to testify to the existence of a distinct imagination of an end desired, and also

tion of these mental states is not met with till we come to animals of this degree of organization. The signs of Emotion, for instance, are most typical in certain Reptiles. R. M. Middleton says ("Nature," October 31st, 1878, p. 696):—"During the past summer I have kept five Chameleons in captivity, and have repeatedly observed their terror and rage when confronted with snakes. When a large Algerian chameleon, now in my possession, perceives a common snake wriggling in its vicinity, he at once inflates his body and pouch, sways himself backwards and forwards with considerable energy, or walks rapidly away with his body leaning over in the direction farthest from the snake, opening his huge cavernous mouth, and hissing, and even snapping at what he evidently regards as his natural enemy. At the same time his body assumes an almost instantaneous change of colour, and is quickly covered with a large number of small brown spots. It is curious that even similar symptoms of fear and anger are displayed when a lizard or even a tree-frog is exhibited to him. The climax of grotesque nervousness was, however, reached one day when the sight of a child's doll produced the like effect; in this case it is probable that the glass eyes of the doll, giving to it the appearance of life, were what caused this terror in the reptile." The writer has also lately noticed these signs of anger or terror in the chameleon. The swaying of the body backwards and forwards, together with the wide opening of its enormous mouth, were constant features, and when the animal was taken up at this time, a peculiar thrill-like vibration of the body could be distinctly felt.

of a reasoned and volitional adaptation of means to bring about such an end. T. Edwards says :—

"Passing along the sea-shore on the west of Banff, I observed on the sands, at a considerable distance before me, two birds beside a large-looking object. Stooping down with my gun upon my back, prepared for action, I managed to crawl through the bents and across the shingle for a considerable way, when I at length came in sight of the two little workers, who were busily endeavouring to turn over a dead fish which was fully six times their size. I immediately recognized them as turnstones. Not wishing to disturb them, anxious at the same time to witness their operations, and observing that a few paces nearer them there was a deep hollow among the shingle, I contrived to creep into it unobserved. I was now distant from them but about ten yards, and had a distinct and unobserved view of all their movements. . . Having got fairly settled down in my pebbly observatory, I turned my undivided attention to the birds before me. They were boldly pushing at the fish with their bills and then with their breasts; their endeavours, however, were in vain—the object remained immovable. On this they both went round to the opposite side, and began to scrape away the sand from close beneath the fish. After removing a considerable quantity, they again came back to the spot which they had left, and went once more to work with their bills and breasts, but with as little apparent success as formerly. Nothing daunted, however, they ran round a second time to the other side, and recommenced their trenching operations, with a seeming determination not to be baffled in their object, which evidently was to undermine the dead animal before them, in order that it might be the more easily overturned. While they were thus employed, and after they had laboured in this manner, at both sides alternately, for nearly half-an hour, they were joined by another of their own species, which came flying with rapidity from the neighbouring rocks. Its timely arrival was hailed with evident signs of joy. . . . . . Their mutual congratulations being over, they all three fell to work, and after labouring vigorously for a few minutes in removing the sand, they came round to the other side, and, putting their breasts simultaneously to the fish, they succeeded in raising it some inches from the sand, but were unable to turn it over. It went down again to its sandy bed, to the manifest disappointment of the three. Resting, however, for a space, and without moving from their respective positions, which were a little apart the one from the other, they resolved, it appears, to give the matter another trial. Lowering themselves upon their breasts close to the sand, they managed to push their bills underneath the fish, which they made to rise to about the same height as before; afterwards, withdrawing their bills, but without losing the advantage they had gained, they applied their breasts to the object. This they did with such force, and to such purpose, that at length it went over and rolled several yards down a slight declivity. It was followed to some distance by the birds themselves before they could recover their bearing. They returned eagerly to the spot whence they had dislodged the obstacle which had so long opposed them, and they gave unmistakable proof, by their rapid and continued movements, that they were enjoying an ample repast as the reward of their industrious and praiseworthy labour."

Again, a writer in "Nature"* describes an incident witnessed by himself outside an Inn near Richmond, where some 'Pouter' pigeons were feeding. The actions of one of them were of a very unusual character, and had in all probability been learned by the individual bird itself. It would seem, moreover, that they must have been undertaken with a pretty distinct notion of the end to be obtained. The writer says :—

"A number of them were feeding on a few oats that had been accidentally let fall while fixing the nose-bag on a horse standing at bait. Having finished all the grain at hand, a large 'Pouter' rose, and, flapping its wings furiously, flew directly at the horse's eyes, causing that animal to toss his head, and in doing so, of course, shake out more corn. I saw this several times repeated; in fact, whenever the supply on hand had been exhausted." The writer may well ask whether this was not "something more than mere instinct."

The maternal affection of the Bird for its young is well known; but no less remarkable is the Reason which they sometimes display under the promptings of this Emotion. A few examples will illustrate this.

* Aug. 21, 1873, p. 325.

White, in his "Natural History of Selborne," says that some Fly-catchers built every year in the vines that grew on the walls of his house. "A pair of these little birds," he adds, "had one year inadvertently placed their nest on a naked bough,—perhaps in a shady time, not being aware of the inconvenience that would follow: but a hot sunny season coming on before the brood was half fledged, the reflection of the wall became insupportable, and must inevitably have destroyed the tender young, had not affection suggested an expedient, and prompted the parent birds to hover over the nest all the hotter hours, while, with wings expanded, and mouths gaping for breath, they screened off the heat from their suffering offspring."

Another remarkable instance is also cited by the Editor of the above work.* He says:—"During a wet day, a house swallow's nest became saturated, and fell to the ground. It contained five unfledged young ones. A lady who saw the accident, collected the brood, placed the lining of the nest in a small basket inside [? outside] the window of her dressing-room. She soon had the pleasure of seeing the old birds come and feed their offspring. One of them was so weak, that it did not receive the same quantity of food as the others, and, consequently, when they were able to leave the nest, this helpless one remained, only half fledged, and suffering from cold, when it had the whole nest to itself. There was at the time a bitter north-east wind, which penetrated through the openings in the basket work, and which, of course, added to the misery of the poor bird. *All at once the old ones were seen to come with clay in their mouths, and in a short time they built up a wall against the basket, which effectually screened the young one from the cold wind.* It was reared and took its flight."

These seem to be unquestionably reasoned acts, performed with a distinct 'imagination' of the objects which they were to subserve, and this, too, in the face of altogether unfamiliar conditions. We have, therefore, Reason, Imagination, and Volition, combining for the attainment of a novel end. But other notable instances may be cited. The Editor of White's 'Selborne' says†:—

* Bohn's "Illustrated Library" edition, p. 154.

† Bohn's edition, p. 166.

"Several interesting facts have been communicated to me of the revengeful disposition of martins, when their nests have been invaded by sparrows. In one instance, at Hampton Court, a gentleman informed me the morning it took place, that a couple of sparrows had hatched their young in a martin's nest. Two or three days afterwards, a number of martins came, pecked the nest to pieces, and he saw the unfledged young dead on the ground beneath the window. In another instance, the foreman of the carpenters at the palace, Hampton Court, informed me, that while working at his bench close to the window, a pair of swallows built their nest in a corner of it, and where he frequently watched it. When completed some sparrows took possession of it, and deposited their eggs. While the hen was sitting on them, several martins came and closed up the hole. After a few weeks he examined the nest, and found the bird dead on her eggs."

Again, according to Swainson, "Many of the parrot family are well known to evince a strong and lasting affection towards each other;" and he adds:—"Bonnet mentions the mutual affection of a pair of those called love-birds, who were confined in the same cage. At last, the female falling sick, her companion evinced the strongest marks of attachment; he carried all the food from the bottom of the cage, and fed her on her perch; and when she expired, her unhappy mate went round and round her, in the greatest agitation, attempting to open her bill, and give her nourishment. He then gradually languished; and survived her death only a few months."

But the actions of Birds in defence of their young are perhaps the most remarkable, and associated with the greatest strength of Emotion—"self seems no longer to be considered, danger no more dreaded." As Swainson says:—"The most feeble birds, at the season of incubation, assault the strong and fierce; the weakest will assail the most powerful. It is a well-known fact that a pair of ravens, which dwelt in a cavity of the rock of Gibraltar, would never suffer a vulture or eagle to approach their nest, but would drive them away with every appearance of fury." And "the artifices employed by the partridge, the lapwing, the ring plover, the peewit, and numerous other land birds, to blind the vigilance, and divert the attention of those who may come near their little ones, is equally curious."

It may fairly be held that the more varied and complex the Sensorial Impressions capable of being discriminated from one another (the wider the range, that is, of an animal's Cognitive Powers), the more occasion and opportunity is there for elementary modes of Reason to intervene between ingoing impressions and the motor responses which they are destined ultimately to incite.

But it seems clear that, with the single exception of the sense of Smell, the sensorial endowments of Birds are to be regarded as far more developed than those of Insects. Their far-reaching and discriminative Vision, their acute powers of Hearing, together with their highly refined 'sense of Direction,' must of necessity confer upon Birds a power of increasing enormously the range and complexity of their relations with the outside world. To these advantages they add those which accrue from their longer individual lives, and, above all others, from the fact that these superior endowments and opportunities of improvement operate in concert with a vastly more complex Nervous System which they have inherited from a long but indefinite series of simpler ancestors. Need we wonder, then, if the evidence should seem to show, that, while the instincts of Birds are perhaps less elaborate, their adaptive intelligence or Reason, and the strength and definiteness of their Emotions, are unquestionably far superior to those presented by the Social Insects.

We may, perhaps, safely conclude that, while many Instinctive Actions are more or less immediate products or resultants, consequent upon the undeviating regularity in the recurrence of Visceral States and impressions and of the sense-guided movements which they evoke; Reason, Imagination, and Volition, on the other hand, as mere higher developments arising out of previous processes, have their seed-time in all that is unfamiliar among the chance Sensorial Impressions which Animals, whose 'experience' is growing and whose Nervous Systems are developing, are accustomed at intervals to receive from the outer world.

CHAPTER XVI.

THE BRAIN OF QUADRUPEDS AND SOME OTHER MAMMALS.

A GREAT advance is to be met with in the development of the Brain in passing from Birds to Mammals, and from lower to higher forms of the latter. There are obvious differences in external conformation, and also internal differences only to be detected by dissection of the organ.

External Differences.—The *first* and most important of these peculiarities is the increasing size of the **Cerebral Lobes or Hemispheres.** In lower Quadrupeds these parts scarcely extend far enough back to cover the Optic Lobes, whilst in higher terms of the series they not only hide these bodies completely, but also in part hide the more developed Cerebellum. The Cerebral Hemispheres in Quadrupeds also tend to become more and more plainly indented by certain primary depressions or 'fissures,' by which they are divided into what are called 'lobes.' The Hemispheres are also, to an increasing extent, marked by various smaller secondary fissures or 'sulci,' by which, together with the primary fissures, certain foldings of the surface of the brain, known as 'convolutions' or 'gyri,' are produced.

The *second* of the external peculiarities, above referred to, is the gradually increasing size of the lateral lobes of the **Cerebellum**—parts which, like the Cerebral Hemispheres, will be found to attain their maximum development in Man.

The *third* external peculiarity is a consequence of the second. It consists in the gradual increase of the '**pons Varolii**,' a part of the brain which stretches across the inferior surface of the Medulla in a bridge-like fashion. Hence its name—coupled with that of one of the earlier anatomists. This structure, which was formerly believed to be merely a great transverse commissure uniting the lateral lobes of the Cerebellum with one another, becomes well developed in higher Quadrupeds and in Cetacea, though it is represented in Birds only by a few barely perceptible fibres. Its true nature will be more correctly defined in the description of the human brain.

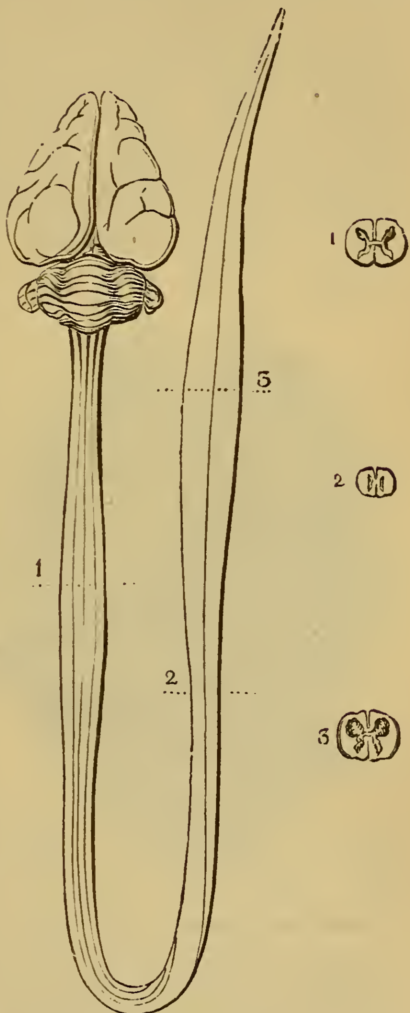


FIG. 68.—Brain and Spinal Cord of Kangaroo (*Macropus*). (Owen.) 1. Section o Spinal Cord in situation from which Nerves to anterior extremities are given off ; 2. Section through lower dorsal region ; 3. Section through lumbar swelling of Cord. Each of these sections shows the double area of 'grey' ganglionic matter within the Spinal Cord.

Internal Differences.—Only a few of the most important and obvious of these can be here referred to.

(1.) The two **Optic Lobes** become relatively smaller in higher Quadrupeds, though in all of them they are more or less deeply indented in the transverse direction, by a depression or groove which thus divides them into four rounded swellings, answering to what, in higher animals and in Man, are known as the 'Corpora Quadrigemina.' The cavity existing within them in lower Vertebrates now becomes reduced to a mere passage between the third and fourth Ventricles.

(2.) A great transverse commissure, connecting the Cerebral Lobes with one another, appears as a rudi-

Fig. 69.—Brain of the Horse, outer surface. (Solly, after Leuret.) *e*, Olfactory lobe; *h*, hippocampal lobe, or 'processus pyriformis. 1, 2, 3, Lobes of the Cerebellum. *o*, Optic nerve; *m*, motor occuli; *p*, fourth nerve; *t*, fifth nerve; *u*, sixth nerve; *f*, facial nerve; *l*, auditory; *g*, glosso-pharyngeal; *v*, vagus; *s*, spinal-accessory; *n*, hypoglossal nerve. x, Pons Varolii

mentary structure in lower Quadrupeds and gradually increases in size in higher representatives of this class. It is known as the **Corpus Callosum.** This commissure principally connects the upper parts of the Cerebral Lobes, and soon comes to form the roof of the two great 'lateral ventricles.'

(3.) A double commissure, known as the **Fornix,** appears and gradually becomes more developed, as another boundary of the 'lateral ventricles.' Long erroneously described as a double longitudinal commissure, its halves, in reality (after a very irregular course, the direction of which varies in different animals), connect in each Cerebral Lobe, parts that are almost situated in the same transverse plane. The nature of these parts and the other relations of the Fornix will be given further on (p. 272), and also in the description of the corresponding structure in the human brain. Its relations are of a complex order, so that its

FIG. 70.

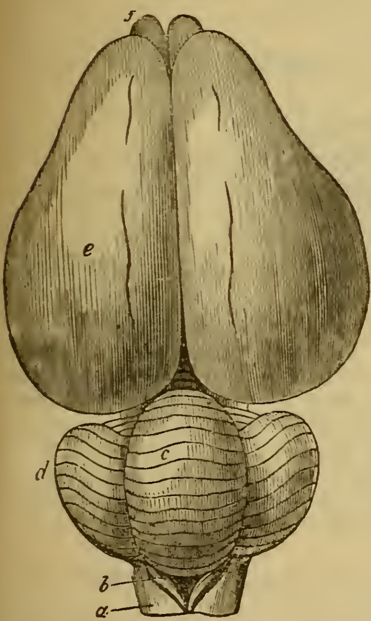


FIG. 71.

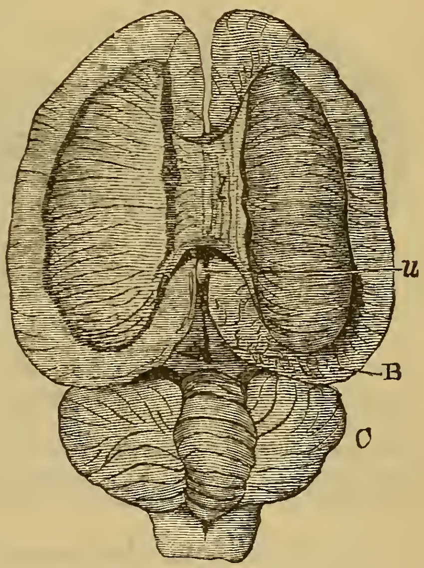


FIG. 70.—Brain of Agouti. (Owen.) *a*, Medulla; *b*, fourth ventricle; *c*, median, and *d*, lateral lobes of Cerebellum; *e*, Cerebral Hemisphere; *f*, olfactory lobes.

FIG. 71.—Brain of Beaver. (Owen.) The upper parts of the Cerebral Hemispheres have been cut away to the level of the 'corpus callosum,' so as to show this great transverse commissure. *u*, Pineal body; B, corpora quadrigemina; C, cerebellum.

fuller description will be better reserved. It is necessary, however, here to state, that it mostly lies beneath the 'Corpus Callosum,' and is closely connected with this great transverse commissure posteriorly, though in passing forwards the two structures diverge from one another.

(4.) In the space left between the Corpus Callosum above (fig. 72, *c*, *c*) and the diverging Fornix below, are two thin vertical and almost parallel septa. These septa represent the inner walls of the 'lateral ventricles' and constitute parts, therefore, of the contiguous inner faces of the two Cerebral Lobes. They, together with the great transverse commissure above and the Fornix below, form the boundaries of a narrow and somewhat triangular cavity known as the **'fifth ventricle.'** This small ventricle is

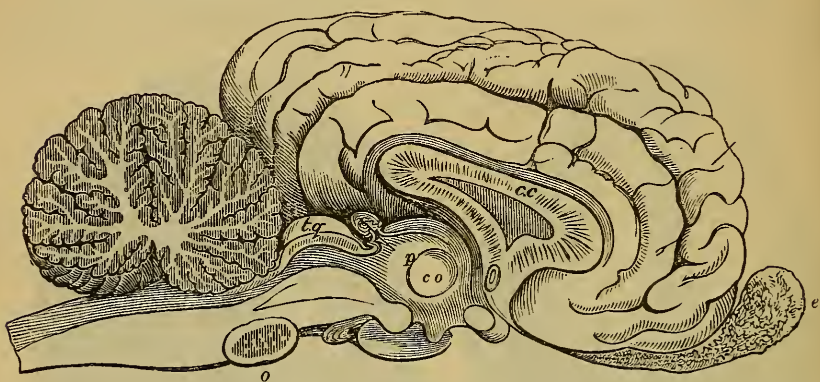


FIG. 72.—Brain of Horse, longitudinal section through its centre, showing internal surface of Cerebral Hemisphere. (Solly, after Leuret.) *c c*, Corpus callosum, between it and the Fornix below and behind, is the 'fifth ventricle.' *p*, Thalamus; *co*, the middle or soft commissure; *tq*, corpora quadrigemina, in front of which is the Pineal body, with one of its 'peduncles' passing forwards along the upper border of the corresponding Thalamus, and behind it the cut surface of the middle lobe of the Cerebellum. *e*, Olfactory lobe; *o*, olivary body.

quite different from, and also quite unconnected with, the other four brain cavities, which are all of them continuous with one another—as are the corresponding antecedent cavities met with in the early developmental phases of the brain. But the 'fifth ventricle' obviously could not come into existence till the Corpus Callosum and Fornix had become developed. Consequently no such cavity exists in Birds, Reptiles, Amphibia, or Fishes.*

* The arrangement of these central parts of the Brain in lower Quadrupeds has been well described and figured by Prof. Flower in the Philosoph. Trans. for 1865.

It must not be supposed that anything like a regular serial order or progression is to be observed in the development of the Brain among Mammals. In the higher types of lower orders it will often be found better developed than among the lower types of higher orders. Still if we compare the extremes of the class—that is, higher with lower Mammals—a great increase in the developmental complexity of the organ, or in type of Brain, as judged by the human standard, will become perfectly obvious.

The ratio of the weight of the Brain to the weight of the body, is subject to great variations, from different causes, so that a table of such ratios does not give any trustworthy information as to the relative development of the organ in different species of animals. We may be able to deduce some kind of rough average, sufficing to indicate its increasing development if we compare class with class—as Fishes with Birds, or Birds with Mammals—but in detail and for estimating the relative development of the Brain in different species, its indications are of little or no value. This may be illustrated by the following table in which some of these ratios are given:—

Greenland Whale	1 : 3000	Ornithorynchus	1 : 130
Ox	1 : 860	Porpoise	1 : 93
Great Kangaroo	1 : 800	Rat	1 : 76
Wombat	1 : 614	Chimpanzee	1 : 50
Elephant	1 : 500	Man	1 : 36
Horse	1 : 400	Field Mouse	1 : 31
Sheep	1 : 350	Goldfinch	1 : 24
Dog	1 : 305	Marmozet	1 : 22
Cat	1 : 156	Canary	1 : 14
Rabbit	1 : 140	Blue-headed Tit	1 : 12

It is, of course, obvious enough that the order indicated in the above series is one which does not correspond with the Intelligence of the respective creatures; neither shall we find that it in the least degree harmonizes with the complexity of development to which the Brain attains.

One of the principal disturbing causes arises from the fact, that in animals of any given order, the bulk or weight of the Brain when passing from its smaller to its larger representatives, does not increase at all in the same proportion as the total body-weight of such animals. Some striking illustrations of this fact have been cited by Professor Owen.* Small and large representatives of the same order of animals are, in the subjoined list, bracketed together, in order to show how much greater is the ratio of brain-weight to body-weight in the diminutive forms.

Very small Marsupial	1 : 25	Rock Coney	1 : 95
Great Kangaroo	1 : 800	Rhinoceros	1 : 764
Small Ant-eater	1 : 60	Weazel	1 : 90
Great Ant-eater	1 : 500	Grisly Bear	1 . 500
Pygmy Chevrotain	1 : 80	Marmozet	1 : 20
Giraffe	1 : 900	Gorilla	1 : 200

In part explanation of these very interesting peculiarities, Prof. Owen advances the following hints. "The Brain," he says, "grows more rapidly than the body, and is larger in proportion thereto at birth than at full growth. . . . . So in the degree in which a species retains the immature character of dwarfishness, the brain is relatively larger than the body." This may be to some extent an explanation of the peculiarity above shown to exist; but there are, doubtless, other vital and mechanical reasons, why the bulk of the Brain should not increase quite proportionately with the bulk of the body.

We may now point out some of the more striking pecu-

* "Anat. of the Vertebrates," iii. p. 143.

liarities of the several parts of the Brain, as met with in different representatives of the great class of Quadrupeds.

The **Medulla**, the **Cerebellum**, and the **pons Varolii**, are so intimately related to one another, both structurally and functionally, that they may here be regarded as constituting one compound division of the Brain.

There is nothing special to be said concerning the **Medulla** in Quadrupeds, except that the lateral projections, known as 'olivary bodies,' gradually become more developed (fig. 72, *o*). In many animals, a layer of fibres on each side, known as the 'corpus trapezoideum' (fig. 73), crosses these structures and partially hides them. In higher Quadrupeds, however, such transverse fibres cross the Medulla at a higher level or appear to be absent (fig. 74). Where this is the case the 'olivary bodies' are uncovered; and as they also become larger, they may form rounded prominences, one on each side of the Medulla.

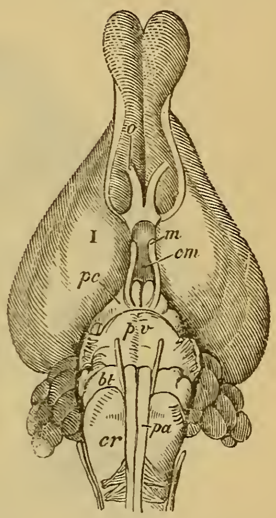


FIG. 73.—Brain of Rabbit, under surface. (Solly, after Leuret.) A, Olfactory lobe; I, Lobe of the Hippocampus, or 'processus pyriformis;' *o*, optic nerve; *m*, motor occuli; *c m*, corpus mammillare; *p c*, crus cerebri; *p v*, pons varolii; *b t*, corpus trapezoideum; *p a*, anterior pyramid; *c r*, olivary body.

The above-mentioned 'corpora trapezoidea,' usually cross the Medulla at the level of the 'origin' of the auditory and facial nerves. They are very distinct in the Lion, the Dog, and the Sheep.*

The upper part of the Medulla is bridged above and closely embraced by a much thicker mass of fibres known as the **pons Varolii**, the development of which in different Mammals, is found to be strictly proportionate to the development of the lateral lobes of the Cerebellum.

* *See* Tiedemann's 'Icones Cerebri Simiarum,' Tab. III. and VII.

Where the Pons is well developed, the 'cerebral peduncles,' being more covered, appear to be curtailed in length (fig. 74, *i, i*).

The **Cerebellum** in Marsupials (fig. 68), still consists principally of the 'median lobe,' the surface of which is marked by deep transverse fissures, giving rise to a series of nearly parallel convolutions. Its 'lateral lobes' exist

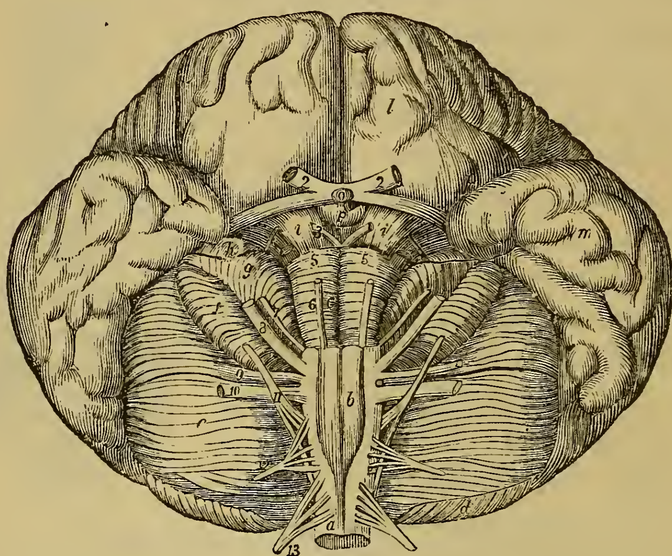


FIG. 74.—Brain of Dolphin, under surface. (Owen, after Tiedemann.) *a*, Spinal cord; *b*, anterior pyramids; *c*, Pons Varolii; *e*, posterior inferior lobe of Cerebellum; *f*, anterior inferior lobe, *g*, amygdaloid lobe, and *h*, flocculus, all lobes of Cerebellum. *i, i*, Cerebral peduncles; *p*, corpus albicans; *o*, pituitary body; *m*, temporal lobe, and *l*, anterior lobe of Cerebrum. Olfactory bulbs absent; 2. optic nerves; 3, motor nerves of eyes (fourth nerve appears from above the Cerebellum, in front of *g*); 5, the trigeminus; 6, the sixth nerve; 7, the facial, and 8, the auditory nerves; 9, glosso-pharyngeal; 10, vagus; 11, spinal accessory; 12, hypoglossal; 13, first cervical nerve.

merely as small appendages, and are thought by some anatomists to correspond in higher forms with certain accessory lobules, named 'flocculi.' Among Rodentia the lateral lobes show a marked increase in size, which is obvious in the Hare (fig. 76), and still more so in the Beaver (fig. 71) where these parts are distinctly larger than the median lobe. In Solipedes, Ruminants, and Carnivores, the lateral lobes also begin to surpass the median in size. This increase is very notable among the latter in the Cat (fig. 79), and also in the Dog (fig. 80); but it is still more marked in many Cetacea, such as the Dolphin (fig. 74), and the Porpoise (fig. 77).

Fig. 75.

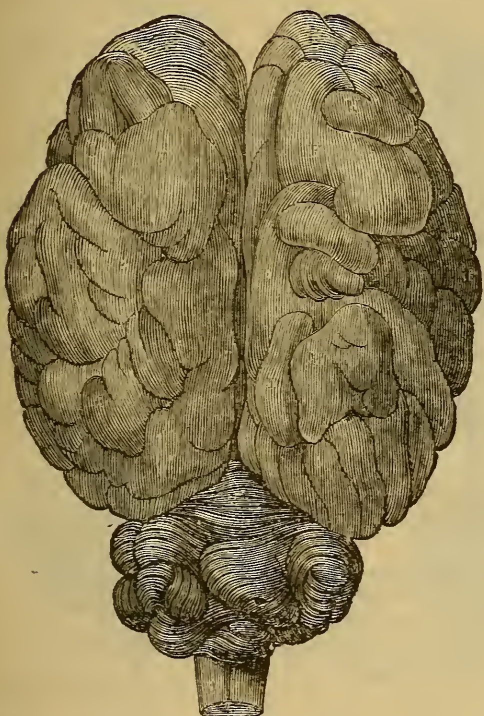


Fig. 76.

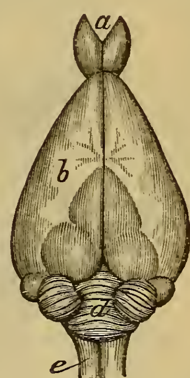


Fig. 75.—Brain of the Horse, upper aspect. (Owen.)
Fig. 76.—Brain of the Hare, upper aspect. (Spurzheim.) *a*, Olfactory lobes; *b*, Cerebral Hemispheres; *d*, Cerebellum; *e*, Medulla.

In some Solipedes and Carnivores, the Cerebellum, instead of consisting of broad and comparatively smooth lateral lobes, together with a narrower and much divided median portion (fig. 77), is, as Marshall says,* "very uneven upon its surface, apparently consisting of a

* "Outlines of Physiology," vol. i. p. 414.

cluster of many irregular and deeply foliated lobules." This kind of conformation is represented in fig. 75. In the marvellously active Bat, the Cerebellum is very large in proportion to the size of the Cerebral Lobes—though in this animal it seems to be the median portion which becomes so highly developed (fig. 78).

Between the under surface of the median lobe of the Cerebellum and the back of the Medulla, there is a small lozenge-shaped space, known as the 'fourth ventricle,' formed by the divergence of what were the posterior columns of the Spinal Cord, and the consequent opening up of its central canal. The lower extremity of this space may be seen in figs. 79, 80.

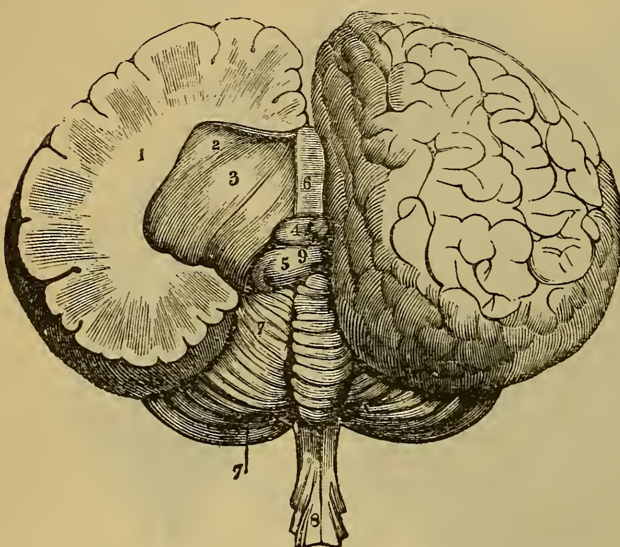


FIG. 77.—Brain of the Porpoise, with the upper half of the left Hemisphere cut away so as to show the contents of the Lateral Ventricle. (Solly.) 1, Outer wall of Ventricle ; 2, Corpus Striatum ; 3, Fornix ; 4, 5, anterior and posterior segments of quadrigeminal bodies ; 6, corpus callosum ; 7, Cerebellum ; 8, Spinal Cord ; 9, Pineal body.

The size of the **Optic Lobes**, in proportion to the rest of the Brain, is very much less in Quadrupeds than it is in Birds, and this ratio goes on diminishing as we pass from lower to higher representatives of the former class. These bodies have a greater proportional size in Marsupials and Rodents, for instance, than in Ruminants and Carnivores. The cavities to be found in their interior in Birds and lower Vertebrates have almost ceased to exist. The transverse depression which divides the two bodies into four (' corpora quadrigemina '), though present in all Quadrupeds, divides them variously. Thus in nearly all the lower classes, as well as in most Ruminants and Solipedes, the anterior segments are larger than the posterior (fig. 81); while in Carnivora and in some of the Cetacea, such as the Porpoise (fig. 77), the posterior segments are usually the larger. In many Quadrupeds, however, the anterior and the posterior segments are nearly equal in size. The degree of development of the posterior segments seems to be often in accordance with that of the Cerebellum with which they are in close structural connection.

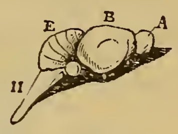


FIG. 78.—Brain of the Bat, side view. (Solly.) A, Olfactory lobe; B, Cerebral Hemisphere; E, Cerebellum; H, Spinal Cord.

FIG. 79.

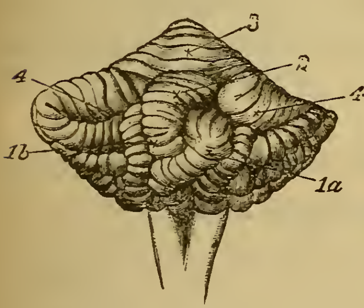


FIG. 80.

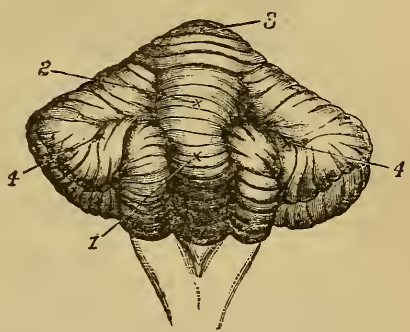


FIG. 79.—Cerebellum of the Cat, upper and posterior aspect. (Ferrier.)
FIG. 80.—Cerebellum of the Dog, upper and posterior aspect. (Ferrier.)

The **Cerebral Hemispheres**, narrowed in front, are more or less elongated and ovoid in form—except in Seals, Porpoises and Dolphins (figs. 77, 101), in which the transverse diameter of these segments may even exceed the longitudinal. They are relatively small in the lower orders of Quadrupeds, as may be seen from the figure of the brain of the Kangaroo (fig. 68), together with those of the Hare and the Squirrel (figs. 76, 82). In these animals they leave the 'olfactory lobes' more or less uncovered in front, and sometimes the 'corpora quadrigemina' in the same condition behind. But in Ruminants, Solipedes and Carnivores (figs. 94, 72, 87) the Cerebral Lobes increase in size, so as not only to cover the before-named bodies in front and behind, but also in part to overlap the Cerebellum.

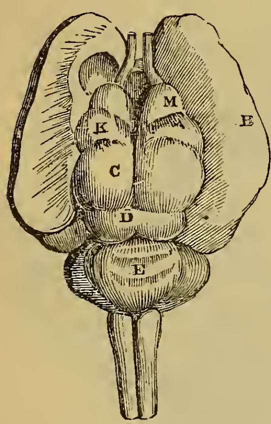


FIG. 81.—Brain of the Squirrel, Hemispheres separated so as to expose the great basal ganglia. (Solly.) B, Cerebral hemisphere; E, Cerebellum; M, Corpus striatum; K, Thalamus; C, D, Corpora quadrigemina.

In the Seal, the Porpoise and the Dolphin (figs. 77, 101), the Cerebral Hemispheres undergo a still more marked increase in size. In these animals, also, as well as in Quadrumana and Man, we no longer find a distinct 'pyriform process,' recognizable as a part of each 'temporal lobe' at its under and inner surface—such as exists in the majority of the lower forms of Quadrupeds.

These bodies, which have also been named 'hippocampal lobes,' are merely the lowest portions of the Temporal Lobes more or less separated from the remainder by a superficial depression. The continuity existing between the Olfactory Peduncles and these parts of the brain is particularly well marked in the Red Coatimondi, the Agouti, the Porcupine and the Water Rat, as may be seen from the figures given by Tiedemann. This connection is also indicated by our figs. 69, 73, 82, 93 and 94.

These 'pyriform processes' are hollowed by spurs of the lateral ventricles. In the animals in which they are well marked, the Olfactory Peduncles and Lobes are likewise well developed hollow structures, as they are in many Reptiles. The size of the 'pyriform processes' in Quadrupeds is, in fact, generally in direct relation with that of the **Olfactory Lobes**, and these are especially well developed in Rodents, Ruminants, and certain Carnivores, while they are absent altogether in some of the Cetacea (fig. 74).

The more minute description of the external surface of the Cerebral Hemispheres, comprising some account of their 'fissures,' 'lobes,' and 'convolutions,' may for the moment be deferred, till we have first given some attention to the Ventricles, Commissures, and other internal parts of the Brain.

FIG. 82.—Head and brain of a Squirrel, side view. (Solly.) A, Olfactory lobe; B, Cerebral hemisphere; E, Cerebellum; H, Spinal Cord.

Internal Topography of the Brain in Quadrupeds and some other Mammals.

Each Cerebral Lobe or Hemisphere contains a **Lateral Ventricle**, the size and shape of which is very variable—these being in great part dependent upon the general form of the Hemispheres, and upon the relative size and shape of the ganglionic prominences which the Ventricles contain. As already mentioned, in Quadrupeds possessing very large Olfactory Lobes, prolongations of the Lateral Ventricles extend into them through their 'peduncles,' from those spurs which stretch downwards into the correspondingly developed 'pyriform processes.'

At the anterior part of the floor of each Lateral Ventricle, is the rounded prominence known as the **Corpus Striatum.** These bodies vary much in size in animals of different orders. They are small in Marsupials, and are in them partly overlapped by another well-developed projection known as the **Hippocampus Major**—a body corresponding with, and produced by, a deep depression

FIG. 83.

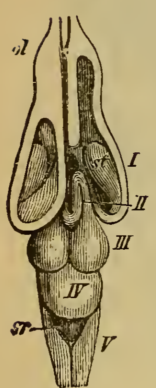


FIG. 84.

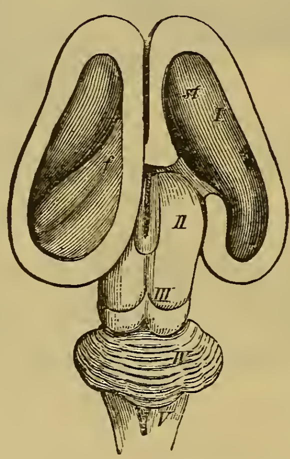


FIG. 85.

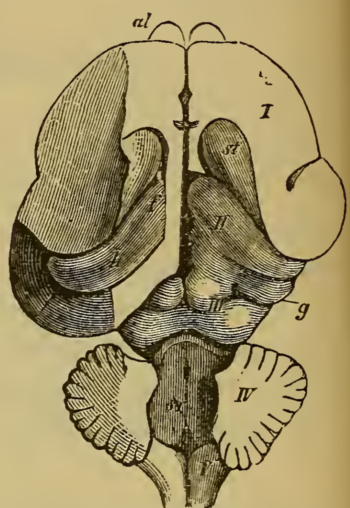


FIG. 83.—Brain of a Chelonian. FIG. 84.—Brain of a Fœtal Calf. FIG. 85.—Brain of a Cat.

These three figures, from Gegenbauer, illustrate the comparative development of the Cerebral Hemispheres and related parts. In Figs. 83, 84, the roof of the Lateral Ventricle is removed on the left, and the Fornix and Hippocampus also on the right. In Fig. 85 the whole lateral and posterior portions of the right Hemisphere are removed, and as much on the left as is necessary to display the upward bend of the Hippocampus. In all the figures I marks the Cerebral Hemisphere; II, the Thalamus; III, the Corpora Quadrigemina; IV, The Cerebellum; V, the Medulla. *o l*, Olfactory lobe (shown in Fig. 83 as communicating with the Lateral Ventricle); *s t*, Corpus Striatum; *f*, Fornix; *h*, Hippocampus; *s r*, fourth ventricle; *g*, geniculate body.

or fissure on the inner surface of the Hemisphere—the ‘fissure of the Hippocampus.’ In Hares also the Corpora Striata are small, while the Hippocampi are large. The latter bodies are remarkable for their great size in the Beaver. The Corpora Striata are said, by Stannius, to be large in Bats, in many Rodents, and also in the Edentata.

Contiguous and posterior to each Corpus Striatum is another rounded eminence, sometimes called the 'Optic Thalamus,' but which it will be far better simply to term the **Thalamus.** These bodies have previously been

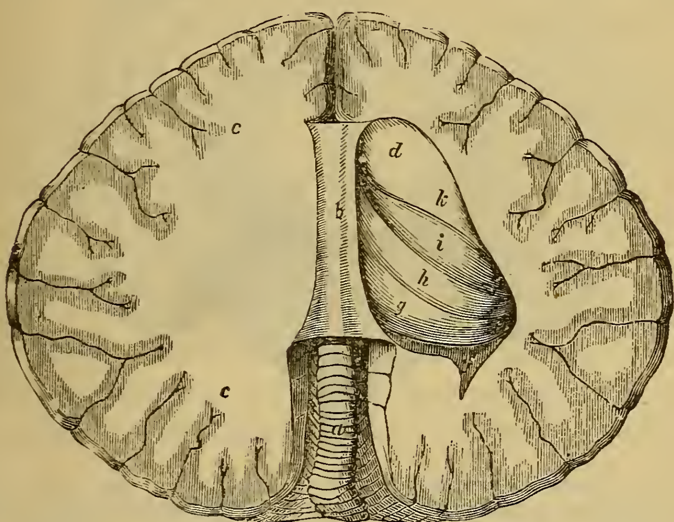


FIG. 86.—The Brain of the Dolphin, with the upper part of the Hemispheres cut off—above the level of the Ventricle on the left, and so as to show this cavity on the right side. (Owen, after Tiedemann.) *b*, Corpus callosum; *c*, *c*, bottom of surface fissures or 'sulci;' *d*, *k*, Corpus Striatum; *h*, Hippocampus, with its unusually broad free border or 'tœnia' (*i*) continued into the Fornix; *g*, Thalamus.

referred to in Reptiles and Birds, where they first show themselves as projections developing from the upper and inner aspects of the Cerebral Peduncles: in Quadrupeds, however, owing to the backward extension of the Cerebral Hemispheres, they seem to become included within these and to project into the inner part of the floor of each Lateral Ventricle. But in reality they lie outside these parts. They are overlapped by the 'velum interpositum,' a membrane constituting the roof of the Third Ventricle.

and also by the 'fornix' and 'lyra,' the description of which will shortly follow.*

Between the contiguous inner surfaces of the Thalami

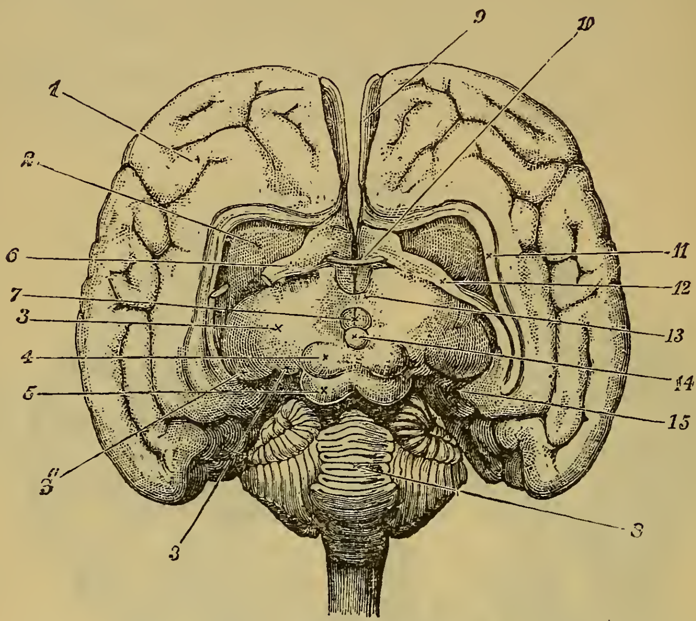


Fig. 87.—The Cerebral Hemispheres of the Dog, separated, after division of the Corpus Callosum, so as to expose the Ventricles and Basal Ganglia. (Ferrier.) 1, Internal surface of left Hemisphere; 2, Corpus Striatum; 3, Thalamus; 4, 5, corpora quadrigemina; 6, anterior pillar of the fornix, divided on the left, undivided on the right side (12); 7, the third ventricle, exposed by drawing the thalami asunder; 8, the upper surface of the Cerebellum; 9, olfactory lobe or bulb; 10, anterior commissure; 11, corpus callosum, divided; 13, middle commissure, extending across the third ventricle; 14, pineal body, lying over and concealing the posterior commissure; 15, descending cornu of the lateral ventricle.

there is a narrow space known as the **Third Ventricle** (figs. 72, *p*; 87, 7). It is situated below the level of the Lateral Ventricles, though each of these opens into it

* By reference to fig. 87, it will be seen that the fornix (12) constitutes the inner and posterior boundary of the Cerebral Hemisphere, and that the Thalamus (3) lies quite outside it and its Ventricle—though the inspection of a horizontal section of the hemisphere, as in fig. 86, might give rise to an entirely opposite impression.

anteriorly through the 'foramen of Monro.' Behind, it is continuous by means of a passage beneath the Corpora Quadrigemina (fig. 72, *t q*) with the Fourth Ventricle. The Third Ventricle is likewise continuous below with the 'infundibulum' of the Pituitary Body. At its posterior and upper boundary is the peculiar pyriform structure known as the **Pineal Body**, which is attached by two long peduncles to the upper and inner borders of the Thalami (fig. 72). This body itself lies against and just in front of the Corpora Quadrigemina; it is, in proportion to other parts, decidedly smaller than the corresponding structures in Reptiles or Birds. It is extremely small in the Rabbit and some other Rodents.

The distinct Commissures seen in or in connection with the Lateral and Third Ventricles are five in number. Of these, three are to be found also (though in a very rudimentary condition) in some of the lower Vertebrates, while the two others appear for the first time in Quadrupeds.

The **Anterior Commissure** is a band of fibres of variable thickness, which stretches across the anterior and upper boundary of the Third Ventricle (fig. 87, 10), and penetrates deeply through each Corpus Striatum to certain surface regions of the Cerebral Hemispheres. It is larger in Marsupials and Monotremes than in any other Mammals, and in higher representatives of the class it is usually thickest in those animals which have well-developed Olfactory Lobes, since it seems to be a commissure serving principally to bring the two cerebral centres of the sense of Smell into relation with one another. In part it connects the Olfactory Peduncles with one another, and in part it serves to bring into relation those regions of the brain in each hemisphere in and about the Hippocampi, to which the majority of the root fibres of such tracts proceed. It is a structure, therefore, much larger in the greater number of Quadrupeds than it is in Man. In some of the Cetacea the 'anterior commissure' is so small as to be almost non-existent.

The **Middle Commissure** is a short and rather thick bridge of soft ganglionic matter, which passes across the middle of the Third Ventricle (figs. 87, 13; 72, *c o*) from one thalamus to the other, and therefore serves to connect these two great ganglia.

The **Posterior Commissure** is small, and composed of white fibres. It passes immediately in front of the base of the Pineal body, and its fibres are prolonged, on each side, into the substance of the posterior part of the Thalamus.

We come now to the commissures met with only in the brain of Mammals.

The **Fornix** is a double commissure, each half of which suffices to connect two regions of the same Hemisphere with one another—viz., the Hippocampal region with the inner part of the corresponding Thalamus. The two halves of this structure come into contact only during a small part of their course—about the middle of it—but they are also brought into some sort of relation posterior to this point by means of a stratum of cross fibres, the nature and connections of which are described below.

Along the inner side of the Hippocampus, as it projects into the descending prolongation of the Lateral Ventricle, a ridge or band of white fibres ('tenia hippocampi') may be traced upwards on each side (fig. 86, *i*), which soon becomes free as the 'posterior pillar' of the Fornix, and bends forwards and inwards over the Thalamus so as to join its fellow on the opposite side, as above stated. Posterior to the point of contact of these 'pillars' with one another, certain transverse fibres (known as 'psalterial fibres') exist, which form a reflected part of the great transverse commissure or Corpus Callosum. This body is, in fact, bent upon itself behind, and it is the portion (thence prolonged forwards to the posterior pillars of the Fornix, somewhat triangular in shape) which, in higher Mammals, is commonly called the 'psalterium' or 'lyra.' Beneath it is a membrane ('velum interpositum') lying on the surface of the Thalami (a great part of which it hides), and forming a kind of roof over the Third Ventricle.

Opposite the anterior extremities of the Thalami, the two halves of the Fornix again separate so as to constitute its 'anterior pillars,' which dip downwards just behind the Anterior Commissure, along the side of the third ventricle to its floor, where each, after twisting upon itself, so as, with its fellow, to cause a single white projection 'Corpus albicans') near the centre of the base of the brain (fig. 74, *p*), again passes upwards and penetrates the inner side of the corresponding Thalamus.

The Fornix exists in all Quadrupeds, and has a much larger relative size in some of the lower forms than in the Quadrumana or Man. It is, for instance, extremely well developed in the Beaver, the Rabbit, and other Rodents.

The **Corpus Callosum** was formerly believed not to exist in the Monotremes and Marsupials; and, in fact, it is present in them only as a very rudimentary structure. In Insectivora it is larger; while in some Rodents it has already attained a considerable development, as may be seen from the brain of the Beaver (fig. 71), where it is thick and comparatively long from before backwards. In this animal it has also attained the more horizontal direction commonly met with in higher forms, though in some other Rodents it is a notably less developed structure—being short, thin, and nearly vertical in direction. The figures show a more developed form of the Corpus Callosum in the Horse (fig. 72), in the Dolphin (fig. 85), and in the Dog (fig. 87).

The Corpus Callosum stretches across from one Cerebral Hemisphere to the other; its fibres constitute the roof of each Lateral Ventricle, and thence diverge to many parts of the surface grey matter of each Hemisphere. Similar cortical areas on the two sides are thus brought into functional relation with one another. It has, therefore, a wider kind of office, though identical in nature to that performed by the Anterior Commissure. It is an error, however, to place these structures in the same category with the Fornix, as many of the older anatomists and even some modern writers have done—since this latter commissure serves to unite different regions of the same Hemisphere, rather than similar regions of the two Hemispheres with one another.

The mode in which the Corpus Callosum and the Fornix are united posteriorly by the 'psalterial fibres,' and the way in which the same two bodies recede from one another anteriorly, and thus contribute to the formation of the Fifth Ventricle, has been previously described (*see* also fig. 72).

Any one wishing to obtain more distinct notions as to the varying developments and relations of these several Commissures, should consult the admirable figures given by Flower,* illustrating the relative size and distribution of these parts in the Sheep, Rabbit, Sloth, and Hedgehog, as compared with what obtains among certain Marsupials and Monotremes.

* Philosoph. Trans. 1865, Pl. xxxvii. and xxxviii.

External Topography of the Brain in Quadrupeds, and some other Mammals.

The thickness of the layer of ganglionic Grey Matter on the surface of the brain undergoes a gradual increase among the Vertebrata. The layer is so thin in Fishes that the surface of the Cerebral Lobes appears almost white to the naked eye. In Mammals, however, we have, even in the lowest of them (and its thickness increases in higher forms) a continuous stratum of such matter covering the whole of the Cerebral Hemispheres. Of course the more the surface of the hemisphere is folded and convoluted, the greater is its proportional amount, since this Grey Matter covers all parts of the surface, whether it be folded inwards or outwards (fig. 85, *c*, *c*).

In Fishes, Amphibia, Reptiles, and Birds, there are no regular 'fissures,' and, consequently, no division of the Cerebrum into 'lobes.' Each Cerebral Hemisphere has, indeed, in these lower forms been supposed by some, though on insufficient grounds, to correspond with the 'anterior lobe' of the brain of the Ape and Man. The 'middle lobes' are believed to make their appearance subsequently, as added parts, in the lower Quadrupeds; while the 'posterior lobes' are, similarly, deemed to make their first appearance among the lower Quadrumana. But, as Prof. Marshall very properly observes, "the lobes may not be distinguishable, and yet homologous parts of the cerebral hemispheres may be present, however slightly developed, throughout all the Vertebrates." The appearance, indeed, of the brain of some of the Cetacea, such as the Porpoise and the Dolphin, makes it rather more probable that it is the middle regions of the brain which are specially developed in them, while both anterior and posterior lobes (and especially the latter) are in a comparatively rudimentary condition.

Speaking generally, it may be said that in Quadrupeds the Brain tends gradually to become more and more convoluted as we proceed from lower to higher orders. It must not be supposed, however, that anything like a serial development is to be detected—in the first place, because certain differences in 'plan of Convolution,' seem to be traceable among them; and secondly, because in all the orders (and therefore, even in cases where the same plan is observable), the degree of complicacy of the convolutions is very largely determined by the mere size of the animal. It has been found, for instance, as a general rule to which there are only few exceptions, that in animals of the same group or order, the number and complexity of the convolutions increase with the size of the animal. This may be recognized, for instance, by a comparison of the brain of the Horse with that of the Elephant; of those of the Sheep and Ox; of the brain of the Cat with that of the Seal; and also, as we shall find, of those of smaller and of larger Quadrumana. In the Elephant, the largest though also the most sagacious of existing Quadrupeds, the complexity of cerebral convolutions is at its maximum. They are also exceedingly complex in the huge Cetacea, and even in some of the smaller representatives of the same class.

It has been previously shown that the weight of the Brain as compared with that of the body is less in different orders of animals, as the size of the representative of any such order increases; yet now it appears that this smaller proportional size of the Brain in large animals is, to a certain extent, compensated by its greater proportional extent of surface ganglionic matter—obtained through increased number and depth of Convolutions.

There cannot therefore be, among animals of the same order, any simple or definite relation between the degree of the Intelligence of the creature and the number or disposition of its Cerebral Convolutions—since this structural feature of the Brain seems to be most powerfully regulated by the mere bulk of the creature to which it belongs. But if, when taken alone, the degree of complicacy of the convolutions affords no safe guidance in regard to the degree of an animal's Intelligence, when comparing different species of the same order (whose convolutional 'pattern' is therefore the same), it will be found to fail even more, as a criterion for estimating the relative Intelligence of representatives of different natural orders—especially if these should happen to be orders characterized by a different convolutional 'pattern.' Thus, the brain of the Beaver is almost smooth, while that of the Sheep presents numerous convolutions which both in number and complexity decidedly surpass even those of the Dog.

The more closely animals are related to one another, however, and the more they are of about the same size, the more should we be entitled to look for some proportional relations between the development of their Cerebral Convolutions and their Intelligence. The comparison of convolutional complexity is therefore of principal interest and value when we are concerned with species of the same or closely allied orders, or, even more, when we compare the Brains of individuals of the same species, or of mere varieties, with one another. This kind of interest, therefore, culminates in the comparison of the degrees of convolutional complexity to be met with among the different races of Man.

In taking account of the mere size of the Brain in different animals, as well as of its degree of convolutional development, in reference to the amount of Intelligence they are accustomed to display, several points have to be borne in mind, which are too apt to be overlooked. Size of Brain, and with it convolutional complexity, must, for instance, be closely related to the number and variety of an animal's Sensorial Impressions—the raw material as it were of Intelligence; but it must be also largely dependent upon the organism's power of evoking simple Movements continuously or with great energy, as well as upon its power of performing very varied or intricate Movements. Herbert Spencer has called special attention to this latter point of view.*

The importance of taking into account the powers of Movement possessed by the animal is fully borne out by the fact that the Brain attains such a remarkable size in the Shark, as well as in the Porpoise and the Dolphin—all of them creatures whose Movements are exceptionally rapid, continuous, and varied. The great increase in the size of the Cerebellum in each of these creatures is, therefore, not so surprising; but it seems very puzzling, at first sight, to understand why this should be accompanied by a co-ordinate increase in the development of the Cerebral Hemispheres. For this, however, there are two causes; the one general and the other more special. It is a fact generally observed, that Sensorial Activity, and therefore Intelligent Discrimination, increases with an animal's powers of Movement; and secondly, there must be special parts of the Cerebral Hemispheres devoted to the mere Sensory Appreciation of Movements executed. The nerve elements lying at the basis of this latter appreciation, however they may be distributed through the Hemispheres, would naturally be the more developed (and, consequently, all the more calculated to help to swell the size of the Cerebrum), in

* "Principles of Psychology," vol. i. p. 192.

proportion to the variety and continuance of the Movements which the animal is accustomed to execute.

Arrangement of Convolutions.—In the lowest Quadrupeds there are no Convolutions at all. This, for instance, is the case with Monotremes, and the lower Marsupials and Rodents. But in other higher forms Convolutions exist, and are arranged in accordance with two distinct types or patterns, which have been named respectively, the 'oblique' and the 'longitudinal.' The following brief references to these two patterns are condensed from Owen's account of them.* It is not intended to give anything like a full description here, but merely to indicate some of their most striking peculiarities.

The 'oblique pattern' is met with among the hoofed Quadrupeds, viz., Ruminants, Solipedes, and Pachyderms. The 'longitudinal pattern' pertains to other Mammals, comprised principally within the orders Carnivora and Cetacea.

A third or 'transverse pattern' is common to the Quadrumana and Man, as will be shown in subsequent chapters, and on this we shall find it worth while to bestow a much larger amount of attention.

Notwithstanding the very numerous differences in detail, certain primary 'fissures' seem to be common to the three types. One of the most constant of these is the 'fissure of Sylvius' on the outer surface of the Hemispheres; while, another, also very constant, is the 'fissure of the Hippocampus.' The latter, situated on the inner aspect of the hemispheres, has already been alluded to as corresponding with the body of the same name which projects, in each hemisphere, into a descending prolongation of the Lateral Ventricle.

* "Anatomy of the Vertebrates," vol. iii.

The 'Oblique Pattern.'—The simple form of this type of convolutional arrangement may be well seen in the small

Fig. 88.

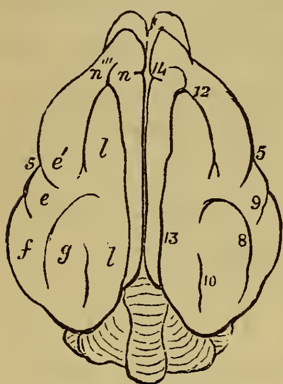


Fig. 89.

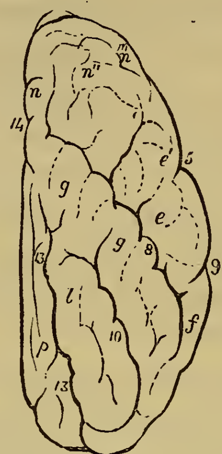


Fig. 90.

Fig. 88.—Brain of the Rock Coney (*Hyrax*).
Fig. 89.—Left Cerebral Hemisphere of the Horse.
Fig. 90.—Left Cerebral Hemisphere of the Rhinoceros.

Rock Coney (figs. 88, 93). More complete forms are to

Fig. 91.

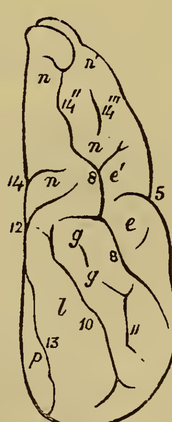


Fig. 91.—Left Cerebral Hemisphere of the Stag (*Cervus*).

Fig. 92.

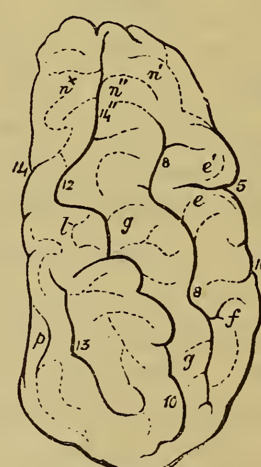


Fig. 92.—Left Cerebral Hemisphere of the Giraffe.

be seen in the Horse (fig. 89) and the Rhinoceros (fig. 90).

In the latter the hinder parts of the Hemispheres are notably expanded, and the anterior lobes are larger in all their dimensions. In this convolutional plan, as the figures borrowed from Owen's 'Anatomy of the Vertebrates' show, the primary convolutions of the two halves of the Cerebrum converge from behind forwards, as far as the anterior third of the Cerebral Hemispheres—and thence diverge in different directions.*

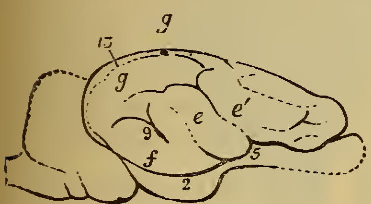


FIG. 93.—Brain of the Rock Coney, side view.

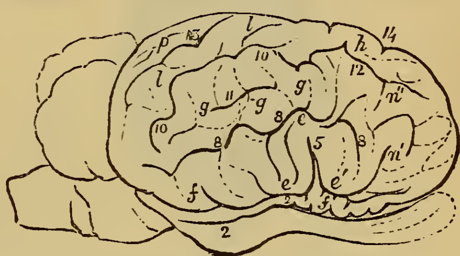


FIG. 94.—Brain of the Giraffe, side view.

Starting from another small form, the Pigmy Chevrotain (Tragulus), we may find a similar convolutional development attaining to higher types of the same general pattern in the Stag (fig. 91), the Sheep, the Ox, the Giraffe (figs. 92, 94), the Camel, the Hippopotamus and the Elephant (fig. 95). The greater convolutional complexity of the brain in these larger forms is represented in detail, as Owen has pointed out, by the fuller development of the 'primary fissures,' by their more sinuous course, and by

* The letters and numerals in the several figures are always the same for corresponding Convolutions and Fissures, and this will materially assist the reader in his comparison of the different forms. The explanations of these references are given by Owen (loc. cit., vol. iii. pp. 136, 137), where the Fissures and Convolutions of Mammalia are enumerated mainly in their order of constancy. Many outline figures of the Cerebral Convolutions of other animals will likewise be found in this work.

the development from them of numerous offshoots in the form of 'secondary fissures.'

The 'Longitudinal Pattern.' This mode of arrangement of some of the principal convolutions is well seen in many of the Carnivora when the brain is looked at from above, as in the Cat (fig. 96). When viewed from the side the surface of the hemisphere may be seen, as Marshall says, to be divided "into four principal antero-posterior convolutions, which seem to bend in simple curves around the upper end of the Sylvian fissure, one above the other, and pass continuously from the anterior or frontal, into the middle or parieto-temporal lobe." This is well shown in figs. 98–100.

Fig. 95.—Right Cerebral Hemisphere of the Elephant, side view, much reduced.

In the larger Feline animals most of the primary fissures present short secondary branches. In the Fox and in the Dog the fissures are more numerous still.* The Cerebrum is also larger and narrower anteriorly, though in the Bear it is again found to be more oblong. In the Seal this part of the Brain attains the greatest relative size and complexity known in the present group.† The Hemispheres are unusually broad, and richly convoluted; but a comparison of the relative depth of the fissures enables the primary

* This is more obvious in the Dog than in the Fox, owing to the greater number, length, and depth of its secondary fissures.

† Excellent figures of the brain of the Seal are given by Tiedemann in his 'Icones Cerebri Simiarum.' Tab. 2, figs. 7, 8.

to be distinguished from those of the secondary order. The mass of the Hemispheres behind the 'fissure of Sylvius' is relatively greater than in other Carnivora, and a larger proportion of the Cerebellum is also covered thereby.

The general parallel arrangement of the convolutions

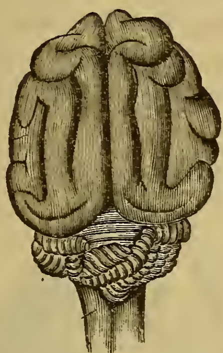


FIG. 96.—Brain of the Cat. (Tiedemann.)

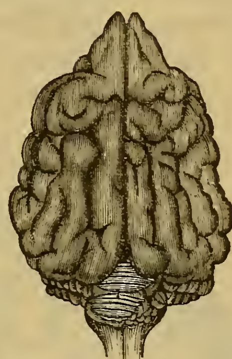


FIG. 97.—Brain of the Dog. (Tiedemann.)

in the Carnivora is, as Owen points out, even more marked in the Cetacea. This may be seen in the Porpoise (fig. 77), and, though less distinctly, in the Dolphin (fig. 101). The breadth of the Cerebral Hemispheres is most striking in both these creatures—but especially in

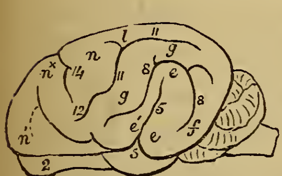


FIG. 98.—Brain of the Coati.

FIG. 99.—Brain of the Cat.

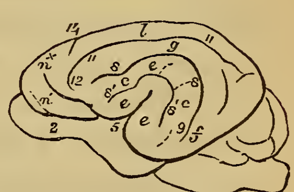


FIG. 100.—Brain of the Fox.

the Dolphin. The convolutions in the latter are also exceedingly complex, so that in this respect its brain stands at present at the head of the well-known representatives of the 'longitudinal pattern,' just as that of the Elephant (fig. 95) does at the head of the representatives of the 'oblique pattern' met with among Herbivora.

It is somewhat puzzling that such a position should be taken by the brain of a creature possessing no greater dimensions than the Dolphin. But we need more information as to the exact characters of the brain in the larger Cetacea, in which, according to the rule previously specified, the complicacy of convolutions ought to be extremely well marked—though their diminished powers

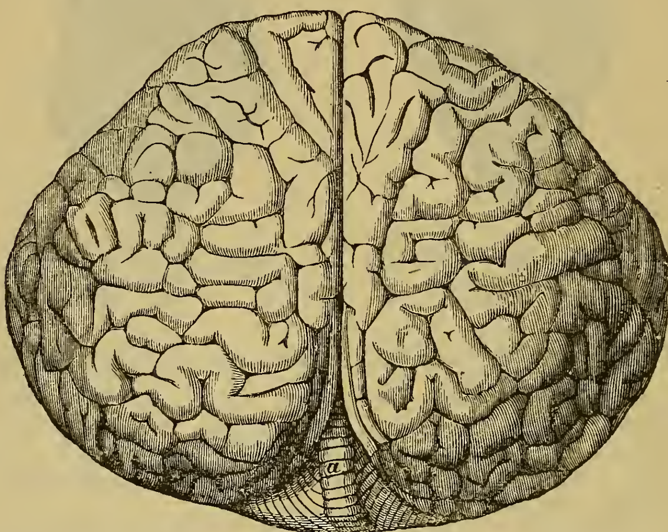


FIG. 101.—Brain of the Dolphin, upper aspect. (Owen, after Tiedemann.)

and diminished customary rate of Movement would afford a set-off in the contrary direction. While one of the great Whales is leisurely moving along at the rate of five miles an hour, a Dolphin may and often does easily cover twenty miles in the same time, and its superiority in regard to variety of Movements would probably be equally well marked.*

* Since this Chapter has been in the printer's hands, a description with figures of the Brain of the White Whale (*Beluga*) has been published in the *Journal of Anatomy and Physiology*, Jan. 1879, by Dr. Major.

According to Owen, the convolutions of the lateral aspect of the Hemispheres, around and above the 'fissure of Sylvius,' are more undulating or interrupted—and therefore less neatly defined—in the larger Herbivora than among the larger Carnivora and Cetacea. This lack of definition is, however, carried to an extreme degree in the most richly convoluted brains of both types.

CHAPTER XVII.

THE BRAIN OF QUADRUMANA.

THE Brains of Lemurs, Monkeys, Baboons and Apes, present many common characters, which testify to the close relationship of these several forms with one another. A sort of gradation, though not that of a single series, is to be met with. Beginning in the Lemurs, with a brain whose structure is only little removed from that of Rodents, we may pass by means of most distinct transition forms to the more highly evolved Cerebral Hemispheres of the great 'man-like' Apes—the Chimpanzee, the Gorilla, and the Orang-utan.

A certain community of structure is perceptible throughout the whole series. The brain of every Quadrumanous animal is distinguished from that of Quadrupeds by certain well-defined characters. Structures previously existing no longer manifest themselves; while, on the other hand, new parts become differentiated from the old, so as to present themselves as more or less independent structures.

The structures existing in many Quadrupeds, but not met with in Quadrumana, are these :—

1. Prolongations from Lateral Ventricles into Olfactory Lobes.
2. Distinct 'pyriform processes' (or 'hippocampal lobes') on the under surface of the Temporal Lobes.
3. The so-called 'trapezoid bodies' of the Medulla Oblongata.*

* Some traces of these structures still exist in the Howler Monkey.

The additional characters or newly-differentiated parts met with among Quadrumana, but absent in lower brutes, may be thus enumerated :—

(1.) The differentiation of a distinct Posterior (or 'Occipital') Lobe in each of the Cerebral Hemispheres, containing in its interior a 'posterior horn' or 'cornu' of the Lateral Ventricle, which is marked by a more or less distinct projection ('Hippocampus Minor') corresponding with a fissure on the inner surface of this lobe.* The development of this Posterior Lobe causes the Cerebral Hemispheres to extend so far backwards as to cover the greater part or the whole of the Cerebellum.

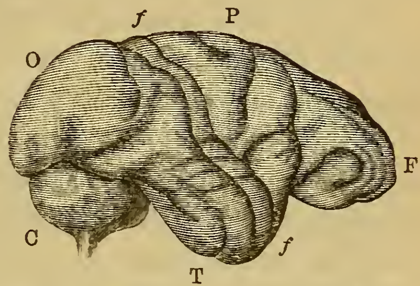


FIG. 102.—The Brain of the Brown Macaque (*Macacus nemestrinus*), side view. F, Frontal Lobe; P, Parietal Lobe; O, Occipital Lobe; C, Cerebellum. *f*, *f*, Greatly prolonged Fissure of Sylvius.

(2.) The appearance of certain 'primary' Cerebral Fissures, similarly disposed in all Quadrumana, and the gradual development of other 'secondary' and 'tertiary' Fissures—the whole series of depressions serving to divide the surfaces of the Hemispheres into Lobes and Convolutions according to a new but constant and definite pattern. This differs notably from the two principal convolutional patterns of Quadrupeds, though it agrees in all essential respects with what we shall find—though in a more developed form—in the Human Brain.

(3.) The existence of a Central Lobe, corresponding with the part known in Man as the 'Island of Reil.'

(4.) Another additional character is of less importance,

* The Seal is the only Quadruped in which a 'posterior cornu' is known to exist, as a prolongation from each Lateral Ventricle.

and does not pertain to the brain in all Quadrumana; it exists only in some of the higher Monkeys and Apes. It consists in the replacement of a single protuberance (the 'mammary') existing at the base of the brain in Quadrupeds by two smaller projections ('Corpora mamillaria' or 'albicantia'), side by side in the same situation, each of which is produced by a bend of one of the 'anterior pillars' of the Fornix (p. 273).

(5.) A fifth character may also here be mentioned; though this is likewise not common to the whole class. Speaking of the Olfactory Lobes, Prof. Flower says:*— "In the large majority of mammals, the base of these lobes extends backwards to the under surface of the temporal lobe, obliterating the lower part of the fissure of Sylvius, whereas in the true Apes and in Man, their connexion with the Cerebral Hemisphere is chiefly with the anterior lobes and the bottom of the fissure itself."

The convolutional arrangement we have now to consider is known as the '**Transverse Pattern.**' No distinct transition forms are known between it and either of the other two patterns, though Flower † seems inclined to think that this may hereafter be found in Bats of larger size than have hitherto been examined. In common Bats the Cerebrum is very short and the Sylvian Fissure almost non-existent. Among them, in fact, no species exists of sufficient size to possess sulci on its surface. But this, as Flower remarks, is not so very surprising "when such markings are almost absent in the brain of a true Primate of even larger size (Hapale)." For, in regard to convolutional development, the same primary rule holds good among Quadrumana as with Quadrupeds, viz., that, taking

* "Trans. of Zoolog. Soc. 1866," vol. v. p. 108.
† Loc. cit., p. 109.

representatives of the same genus or family, small forms commonly have comparatively smooth brains; while larger animals present, in proportion to their size, more and more richly convoluted Cerebral Hemispheres.

In some of the Lemurs the Cerebral Hemispheres are so small as not to cover more than one-half of the Cerebellum. There is, indeed, a kind of gap between the lower and the lowest Simians—that is between the old

FIG. 104.

FIG. 105.

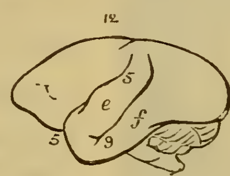
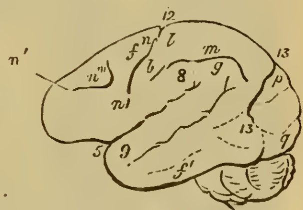


FIG. 107.



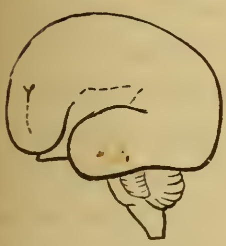


FIG. 108.

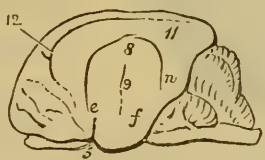


FIG. 103.

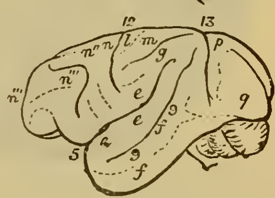


FIG. 106.

FIG. 103.—Brain of an Aye-aye, one of the Lemurs.
FIG. 104.—Brain of the Marmoset (*Midas*).
FIG. 105.—Brain of the Squirrel-Monkey (*Callithrix*).
FIG. 106.—Brain of a Macaque.
FIG. 107.—Brain of a Gibbon.
FIG. 108.—Brain of a 5th month Human Fœtus. (Owen.)

and new world Apes and Monkeys, and the Lemurs. "Every Lemur which has yet been examined," says Prof. Huxley,* "has its cerebellum partially visible from above, and its posterior lobe, with the contained posterior cornu and hippocampus minor, more or less rudimentary. Every Marmoset, American monkey, old world monkey, Baboon, or Man-like ape, on the contrary, has its cerebellum entirely hidden, posteriorly, by the cere-

* "Man's Place in Nature," p. 96.

bral lobes, and possesses a large posterior cornu with a well-developed hippocampus minor."

In the smallest Lemurs, the Hemispheres are quite smooth, or, at most, show traces of one primary fissure—the 'Sylvian' (fig. 103, 5). Even the larger Lemurs possess only a few primary fissures.

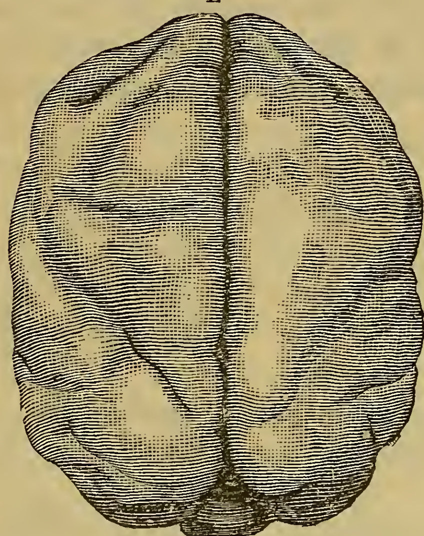


FIG. 109.—Brain of the Howler Monkey (*Mycetes*), seen from above. (Duncan.) L, Longitudinal Fissure; F, Fissure of Sylvius.

In the diminutive but active Marmoset (fig. 104), the Cerebral Hemispheres are relatively larger, so that they completely cover and even slightly overlap the posterior border of the Cerebellum. They are, however, quite smooth and wholly devoid of convolutions. Only one fissure is seen—the 'Sylvian'—forming the boundary line between parts which will subsequently be spoken of as the Parietal and the Temporal Lobes.* In the Squirrel Monkey, another small allied form also notable for its extremely active habits, a fissure below and behind the Sylvian is added—known as the 'parallel fissure' (fig. 105, 9). This runs along the centre of the Temporal Lobe, and backwards towards the upper and inner edge of the Hemisphere. Both these fissures are less vertical and slope backwards more than the corre-

* The names of these lobes of the Brain are derived from those of the bones of the skull against which they lie. The two lobes above named together constitute what was formerly principally spoken of as the 'Middle Lobe.'

sponding fissures in any Lemur (fig. 103) in which they are present.

The Howler, like the Marmoset and the Squirrel Monkey, is a New World form. The former, in fact, is the largest of the series, and is usually supposed to belong to the highest group of these American Monkeys. Its brain, however, is very poorly developed (fig. 109), and, considering its size, possesses very few surface markings. It is remarkable chiefly for the very small size of the Occipital, and the full development of the Temporal Lobes. In connection with the very small Occipital Lobes, Flower * has noted an almost complete absence of the External and Internal Perpendicular Fissures. The brain of the Howler Monkey is also remarkable for the extreme backward extension of the Sylvian Fissures (F, F), each of which almost reaches the upper and inner border of its corresponding hemisphere.

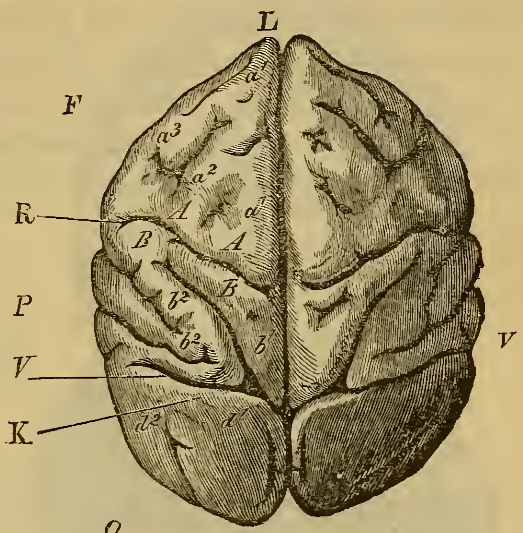


FIG. 110.—Brain of the Mangabey (*Cercopithecus æthiops*), upper aspect. (Vogt.) F, Frontal; P, Parietal; and O, Occipital Lobes. L, Great Longitudinal Fissure; R, Fissure of Rolando; V, External Perpendicular Fissure; K, Operculum. A, A, Ascending Frontal; a^1, a^2, a^3, First, Second, and Third Tiers of Frontal Convolutions. B, B, Ascending Parietal; b^1, b^2, First and Second Tiers of Parietal Convolutions. d^1, d^2, First and Second Tiers of Occipital Convolutions.

(This simple nomenclature for the Convolutions is that of R. Wagner, excepting that A, and B, are named by him Anterior and Posterior Central Convolutions. Though it is a terminology which is by no means without merit, it has not been commonly adopted.)

* "Proceed. of Zoolog. Soc." 1864, p. 335, Pl. xxix.

In the Capuchins, among the new world Monkeys, as well as in the old world 'Dog-like' forms, viz., the Baboons, Macaques, and Monkeys proper, together with the Gibbons (which are usually regarded as the lowest of the 'Man-like' Apes), the Fissures and Convolutions become more numerous, whilst the Cerebral Hemispheres are larger, so that they now uniformly cover the whole of the Cerebellum. A good notion of the mode of distribution of the Fissures on the outer surface of the Hemispheres may be gathered from the outline diagrammatic sketches of these parts in the Macaque and the Gibbon (figs. 106, 107); especially if they are compared with corresponding sketches of the much simpler brains of the Marmoset and the Squirrel Monkey (figs. 104, 105).

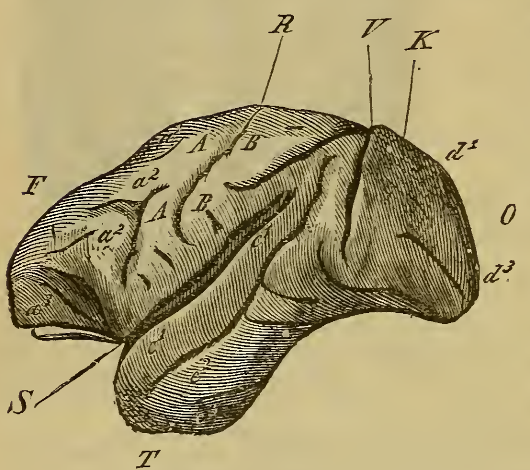


FIG. 111.—Brain of Mangabey, side view. (Vogt.) Some of the references are the same as for fig. 110. S, Sylvian Fissure. T, Temporal Lobe. c^1, c^2, c^3, First, Second, and Third Tiers of Temporal Convolutions.

In the brain of the Mangabey (figs. 110, 111), and also in that of the Wanderoo (figs. 112, 113), which is very similar, the principal primary fissures of the Cerebral Hemispheres, and therefore the included portions or Lobes, are quite distinct. Thus R, represents the 'fissure of Rolando' which separates the Frontal from the Parietal Lobe; S, is the 'fissure of Sylvius,' constituting the upper boundary of the Temporal Lobe, and separating it from the Parietal'; V, is the vertical or 'perpendicular fissure' which is obvious on the inner as well as the outer surface of the hemisphere, and serves to mark off the Occipital Lobe. Another well-marked sulcus, known as the 'parallel fissure,' runs along the outer face of the Temporal Lobe.

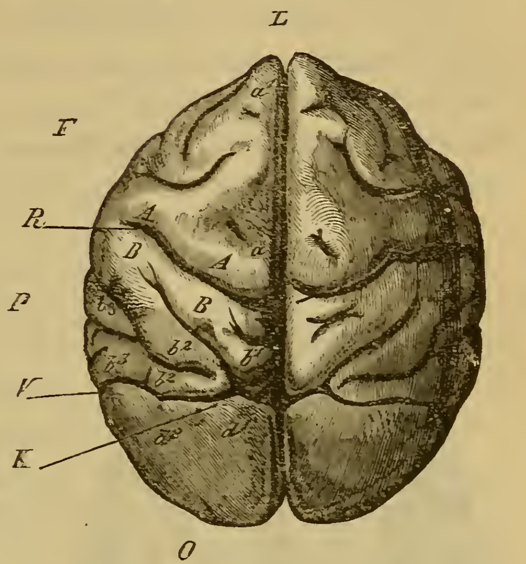


Fig. 112.—Brain of the Wanderoo (*Macacus silenus*), upper aspect. (Vogt.) References as in fig. 110.

Rudimentary Convolutions show themselves on the Frontal Lobe, which is bounded posteriorly by a well-marked 'ascending convolution' (a, a). Another convolution, equally distinct (b, b), forms the anterior boundary of the Parietal Lobe. The Occipital Lobe, though large, is still almost free from any trace of convolutions, and its anterior border (k) is quite distinct. This anterior border—or 'Operculum,' as it has been termed—has been cut away in fig. 113, so as to show a small convolution marked (x), known as one of the 'bridging convolutions.'

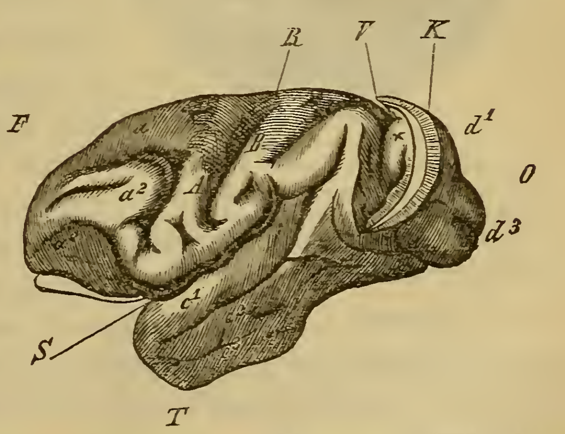


Fig. 113.—Brain of the Wanderoo, side view. (Vogt.) References as in fig. 111.

These latter folds become further developed in the Orang, and still more so in Man.

In the Baboon, the Convolutions, as may be seen from fig. 114, are pretty distinctly defined on the Frontal and Parietal Lobes, and they are also more distinct on the Occipital than they have been in either of the forms previously mentioned. The Frontal Lobes, too, are fuller and less pointed than they are in lower terms of the series.

We may now pass to a brief consideration of the Brain in the highest representatives of the Quadrumana at present existing, viz., the three great 'man-like' Apes—the Chimpanzee, the Gorilla, and the Orang.

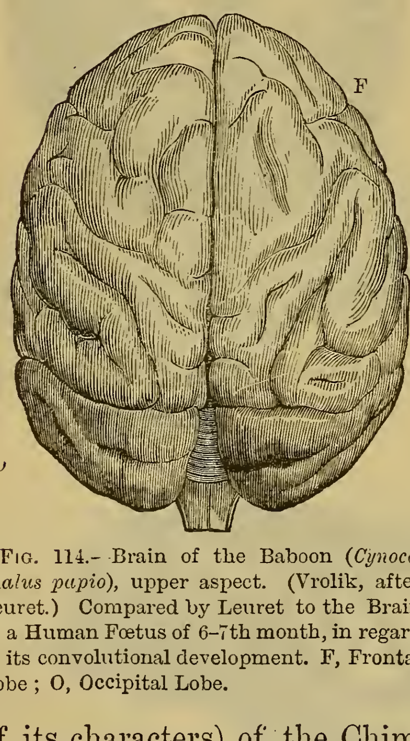


FIG. 114.- Brain of the Baboon (*Cynocephalus papio*), upper aspect. (Vrolik, after Leuret.) Compared by Leuret to the Brain of a Human Fœtus of 6–7th month, in regard to its convolutional development. F, Frontal Lobe ; O, Occipital Lobe.

No differences in the brain characters of these animals have been found sufficiently marked in amount or in nature to enable us to say that one of them is very unmistakably higher than the others. Some distinguished anatomists are disposed to think that the brain (having regard to the sum total of its characters) of the Chimpanzee is the simplest, and that of the Orang the most highly developed. Others, however, give the first place to that of the Gorilla.

The brain of a Chimpanzee was carefully described and figured in 1861 by Prof. Marshall.* The animal was not

* "Nat. Hist. Review," vol. i. p. 296.

an adult. It was both young and small; its height being 2 ft. 4 in., its weight $16\frac{1}{2}$ lbs., whilst the weight of its brain was 14 ozs. The proportion of its brain-weight to its body-weight was therefore 1:19.

The brain of an Orang also has been described with great care and minuteness by Prof. Rolleston.* It was taken from a young male, weighing $16\frac{3}{4}$ lbs., whose height was 2 ft. 7 in. As the weight of the brain was 12 oz., its weight compared with that of the body was 1 : 22·3.

Our knowledge of the brain of the Gorilla is still very imperfect; as of the three specimens which have, as yet, been examined, one was in a very poor condition,† and the two others were taken from very dissimilar animals—the one, examined by Broca, being an adult male,‡ and the other a young specimen, only six months old.§ Broca suspects, moreover, that there may be two species of Gorilla, instead of one as hitherto supposed; and, while admitting that the brain of the Orang presents a slightly higher type than that of the other two, he considers the brain of the Gorilla to be on the whole simpler than that of the Chimpanzee.

The **Cerebral Hemispheres** in the Chimpanzee were much smaller in proportion to the size of the Cerebellum than they are in the human Brain. They, however, slightly overlapped the Cerebellum, and this organ was flatter and wider than it is in Man.

Looked at from above (fig. 115) the Chimpanzee's brain has a short, wide, ovoid form, though in the lower races of Man it has a long, ovoid outline. Seen in profile,

* "Nat. History Review," 1861, p. 201.

† That of an adult female, examined by Gratiolet, in 1860.

‡ "Etude sur le Cerveau du Gorille," *Revue d'Anthropologie*, 1878.

§ This was examined by Drs. Bolau and Pansch, and their account was made the subject of some interesting comments by Prof. G. D. Thane ("Nature," December 14, 1876).

the Frontal Lobes are short and shallow, though as a whole its upper outline is decidedly convex. The lower and hinder boundary of the Cerebral Hemisphere, when compared with the corresponding region in Man, is notable for its concavity and slanting direction from behind forwards. This is due to the marked shallowness of the Occipital

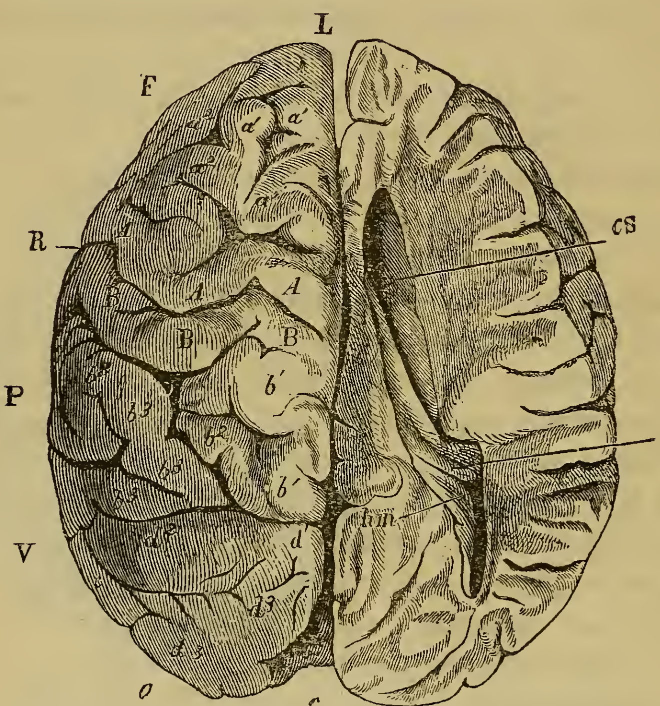


Fig. 115.—Brain of the Chimpanzee, upper aspect, with upper part of Right Hemisphere cut away so as to expose Lateral Ventricle. (Vogt, after Marshall.) Letters of reference for Left Hemisphere similar to those of fig. 110. *c s*, Corpus Striatum, in the anterior cornu of the Ventricle; *c a*, Hippocampus Major, in the descending cornu; *h m*, Hippocampus Minor, in the posterior cornu.

Lobes in the Chimpanzee—these divisions of the Brain being wide but not deep. The same peculiarity is to be seen in the brain of the Orang (fig. 121).

The Frontal Lobes in the Orang have a recurved beak-like termination (seen also in fig. 121); and if we turn the organ over so as to examine its base, the orbital or under surface of these lobes is found to be distinctly concave, as it is in most of the larger Monkeys and Apes. Just behind these parts, the lower terminations of the two Temporal

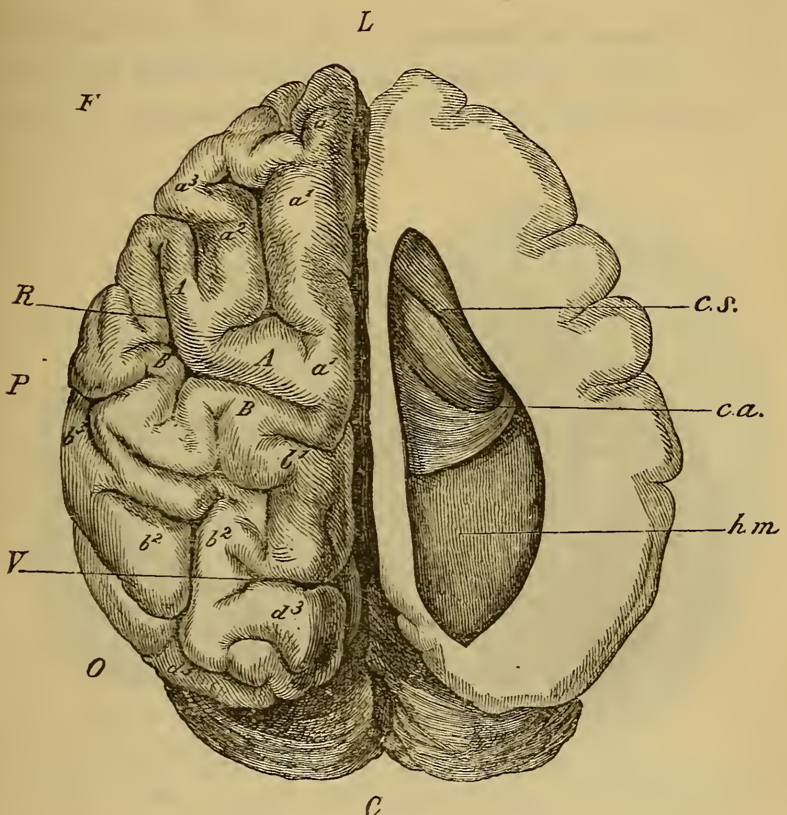


FIG. 116.—Brain of a Human Idiot. (Vogt, after Theile.) This brain, examined by Theile, weighed only 10·6 oz. (300 grammes). With the exception of one, it is the smallest Male Idiot's Brain whose characters have been recorded.

This figure is placed here for comparison with that of the brain of the Chimpanzee; the letters of reference being the same in each of them.

Lobes approach rather close to one another (fig. 118), and between them are two 'Corpora albicantia,' as in Man.

The **Sylvian Fissure** in the Chimpanzee as well as in the Gorilla (fig. 117), and the Orang (fig. 121), is much less horizontal than it is in Man. In this respect it pretty closely resembles the disposition met with in the brain of the Mangabey, the Wanderoo, and other of the 'Dog-like' Apes (figs. 111, 113). Its direction more nearly approaches the horizontal in the Gorilla than in the other two.

The **Fissure of Rolando** is very distinct in the Chimpanzee, though its upper extremity is situated in front of the middle of the brain, instead of being more decidedly

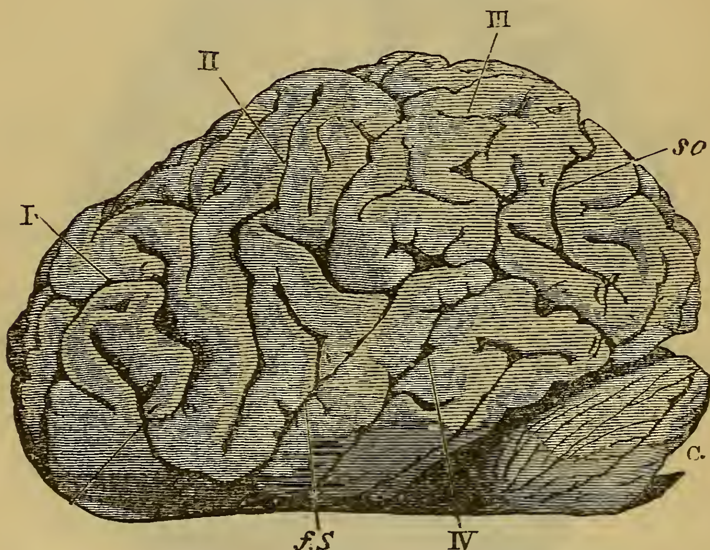


FIG. 117.—Brain of the Gorilla, side view. (After Bolan and Pansch.) I, Frontal lobe; II, Fissure of Rolando; III, Parietal lobe; IV, Temporal lobe. C. Cerebellum; *f s*, Fissure of Sylvius; *s c*, External Perpendicular Fissure separating Parietal from Occipital Lobe.

behind it as in Man. According to Marshall, a little more than one-third of the surface of the Cerebrum lies in front of the Fissures of Sylvius in the Chimpanzee, instead of nearly one-half as in Man. In the Orang the proportionate size of the Frontal Lobes is strictly intermediate.

In the Orang, too, the Fissure of Rolando (fig. 121) is very strongly bent upon itself—almost at right angles—so that its lower extremity, instead of being in advance of the anterior extremity of the Temporal Lobe, as it is in the Gorilla (fig. 117), is more nearly opposite the middle of the Sylvian Fissure. This peculiar disposition of the fissure of Rolando in the Orang coincides with a greater comparative development of the lower (or third) tier of 'frontal convolutions,' and with a notable falling off in the size of the lower half of the 'ascending parietal' convolution. On the other hand, the disposition met with in the Gorilla seems to be due principally to the greater development in it of the lower part of the parietal region of the Hemispheres. Thus, the great size of the 'supra-marginal lobule' and of the lower part of the 'ascending parietal' convolution, seems to cause the lower half of the fissure of Rolando to be pushed decidedly forwards. These peculiarities do not appear to have been previously noticed by anatomists.

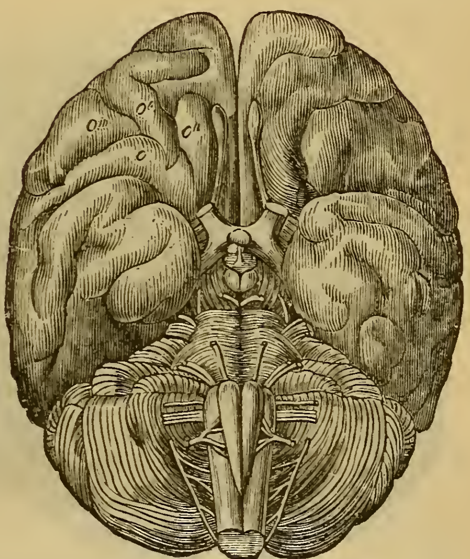


FIG. 118.—Brain of Orang, view of base or under aspect. (Owen, after Tiedemann.) Compare with base of Human Brain Fig. 144.

The **External Perpendicular Fissure** is particularly well marked in the Chimpanzee (fig. 115), though it is seldom distinctly visible in the human brain. In the Chimpanzee it is not crossed by any superficial 'bridging convolutions,' so that its posterior border (or 'Operculum' as it is called in lower forms of Quadrumana) is uninterrupted. This fissure is continued on the inner side of the brain as the 'Internal Perpendicular Fissure' (fig. 120, *fp*).

In the Gorilla also, the External Perpendicular Fissure (fig. 117, *s c*) is very distinct and long, its hinder margin (Operculum) being convex anteriorly, and somewhat more sinuous than it is in the Chimpanzee. The first 'bridging convolution' emerges from beneath it above. But in the Orang this Perpendicular Fissure is sometimes much shorter and less obvious (fig. 119) than it is in either of the other two great Apes, so that in this respect its brain approaches more closely to that of Man. It is sometimes interrupted above by an upper 'bridging convolution' which has a superficial position of this kind in no other of the Quadrumana, except in Ateles.

FIG. 119.—Brain of Orang, upper aspect. (Duncan, from specimen in Museum of Royal College of Surgeons.) F, Frontal Lobe; O, Occipital Lobe.

According to Rolleston this superficial position of the upper or first 'bridging convolution' is not constant in the Orang or even in Man—while in both it may at times be present on one side and absent on the other. He adds:—"In the higher species of the order Apes, as in the higher varieties of the species Man, we find variability the rule, uniformity the exception; in the lower species, as in the lower varieties of Man, the reverse condition obtains."

The second 'bridging convolution' which is always present, superficial and easily recognizable in Man, is said to be as invariably absent in the Chimpanzee and the

Orang, and it was also absent in the young Hamburg Gorilla.

The three principal Fissures already referred to, viz., the Sylvian, that of Rolando, and the External Perpendicular, divide the outer surface of the Hemisphere into four **Lobes**, in the manner already described (p. 292); and though their relative size is very different in the several creatures in which they exist, these Lobes may be considered

FIG. 120.—Brain of Gorilla, longitudinal section, inner aspect. (Bolau and Pansch.) *s. cm*, Calloso-marginal Fissure; *f. p*, Internal Perpendicular Fissure; *f. c*, Calcarine Fissure, being the posterior part of the 'Fissure of the Hippocampus.'

to represent strictly homologous parts in inferior Monkeys, in higher Apes, and also in the Brain of Man.

Concealed by the lips of the Sylvian fissure, and forming part of its floor, we may find the small Central Lobe, commonly known as the 'Island of Reil.' This part becomes well marked and even complex in Man, and, according to Flower,* is traceable, except in the diminutive Marmoset, throughout the Quadrumanous series, though it is absent in all other Mammalia.

* "Trans. of Zoolog. Soc., 1866," vol. v. p. 108.

Three other Fissures of secondary importance are easily recognizable in each of the great man-like Apes, as well as in many of the lower forms, viz., the *Parallel Fissure*, situated parallel with, and posterior to, the fissure of Sylvius, in the long axis of the Temporal Lobe; the *Calloso-marginal Fissure* on the inner side of the Hemisphere (fig. 120), just above the Corpus Callosum; and the *Fissure of the Hippocampus*, situated near the junction of the inner

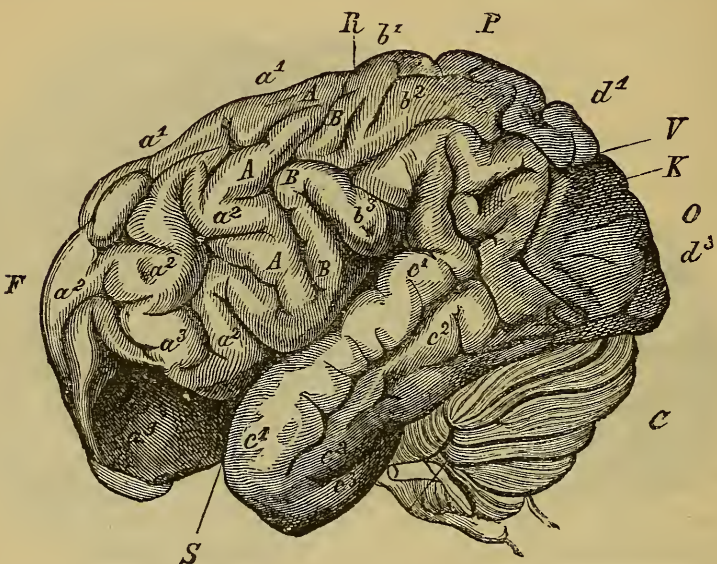


Fig. 121.—Brain of Orang, side view. (Vogt, after Gratiolet.) Letters of reference as in Figs. 111, 133, and 142—with which compare.

with the under surface of the posterior half of the Hemisphere (fig. 120, *f. c*).

Next to the Sylvian, the 'Parallel Fissure' is the most constant of the markings on the outer surface of the Cerebral Hemisphere (fig. 105); though after this, according to Flower, "the most persistent fissure on the outer face appears to be the one bounding the upper border of the angular gyrus" (fig. 107, *m*). The same anatomist adds:—"But it is, perhaps, the sulci of the inner face of the hemisphere that are most characteristic of the Primates, and offer the most striking differential features from other Mammalia." The posterior part of the 'Hippocampal Fissure,' named 'Calcarine' by Huxley (fig. 120, *f. c*), is peculiar to Man and the Quadrumana. It sometimes persists deeply marked in the lowest forms, when every other trace of a fissure except the Sylvian has disappeared. The Sylvian, however, is found in lower Mammals, and the 'Calloso-Marginal,' which is usually very distinct among Quadrumana (fig. 120, *s. cm*), seems also to exist in the great majority of Mammals.

The part of the outer face of the Hemisphere known in Man as the 'Supra-Marginal Lobule' (figs. 133, 142, b^3 b^3), existing above the posterior end of the fissure of Sylvius, was said by Gratiolet to be invariably absent, in the great 'man-like' Apes. But, according to Prof. Rolleston,* "the development of this part is very frequently asymmetrical on the two sides of the same brain, and its development in any two human brains, taken at hap-hazard, is pretty sure to present the greatest differences." It would seem, moreover, that a simple representative of this structure is unquestionably to be found in the Chimpanzee, that it is better developed in the Orang (fig. 121, b^3, and posterior thereto), and that it is larger still in the Gorilla (fig. 117): so that the supposition as to its absence in these creatures was a mistake, and we certainly have not in this direction, as Gratiolet thought, a differentiating mark between the brain of the great Apes and that of Man.

The several Convolutions will not now be further referred to, but the names of many of them may be ascertained by a careful study of figs. 115–121. Although the letters and numbers affixed to corresponding parts in these several representations of the brain of the Chimpanzee,

* Loc. cit., p. 212.

the Gorilla, and the Orang, are not in all cases the same, the reader will have little difficulty in recognizing in each the parts which correspond.

No great difference exists between these three Apes in regard to the **Internal Topography** of their brains, so far as it is known. The following particulars refer in the main to that of the Chimpanzee (fig. 115).

The Corpus Callosum is shorter and thinner than in Man, and Prof. Marshall concludes that, in proportion to the size of the brain, its bulk is twice as great in Man as it is in the Chimpanzee. The Anterior Commissure is proportionally large, and so is the soft or Middle Commissure. The Posterior Commissure, however, is small. The Fornix is thin, and the 'tenia semicircularis' is just discernible as a thin white band lying over the line of junction between the Thalamus and the Corpus Striatum, and joining the pillars of the Fornix anteriorly.

The Lateral Ventricles are rather large, and its three Cornua are quite distinct. The central part, known as the body of the ventricle, corresponds with the parietal lobe externally; its anterior cornu is prolonged into the frontal lobe; its descending cornu traverses the temporal lobe, and its posterior cornu extends into the occipital lobe. On the inner side of the descending cornu is the projection (fig. 115, *c a*), known as the 'Hippocampus major,' from which the posterior pillar of the fornix is derived. On the inner side of the floor of the posterior cornu is the 'Hippocampus minor' or 'calcar avis,' a small eminence (*h m*), produced by a deepening of part of the fissure of the hippocampus (the 'calcarine'), to which it corresponds externally. Between this projection and the upper part of the bend of the larger Hippocampus is another small projection ('eminentia collateralis'), which is also recognizable in Man.

Of the Corpora Quadrigemina the anterior pair are the larger, though they are somewhat less prominent than the other couple. The Pineal Body is rather large and soft.

In its general shape the inferiority of the brain of the Chimpanzee, as compared with that of Man, is most marked in the direction of vertical height; in the relatively small dimensions of its frontal lobes; and in the similarly small relative bulk of its occipital lobes.

The outline of the brain of the Gorilla, as seen from above, is that of a broad ovoid, though it is not so broad as that of the Chimpanzee. Its anterior lobes are wide, rather shallow, but long, more so even than in the Orang—though the latter exhibits a greater complexity of its convolutions. In vertical height, too, its Hemispheres seem decidedly superior to those of the Chimpanzee and the Orang; but its posterior or occipital lobes are distinctly smaller and shorter than they are in either of the other two 'man-like' Apes. The parietal lobes of the Gorilla are notable for their great size both in width and depth, while the convolutions of this region are well defined, and decidedly more developed than in other parts of the brain. Its 'supra-marginal lobule' especially, is larger and better defined than it is in either of the other 'man-like' Apes. The temporal lobes are comparatively smaller, while their convolutions are simple, though not very symmetrical on the two sides.

Owing to the greater narrowness of its anterior lobes, the outline of the brain of the Orang, as seen from above, is not nearly so rounded as it is in the Chimpanzee, and it is also rather narrower than that of the Gorilla. The anterior lobes are somewhat deficient in length and depth, and in consequence of this, as well as of the smaller relative development of the parietal lobes, the Sylvian fissure deviates much more from the horizonal position in the Orang than in either the Gorilla or the Chimpanzee.* The lower and posterior border of the Cerebral Hemispheres is notably more oblique than it is in Man, owing principally to the small size and shallowness of the occipital lobes. In this latter respect, as well as in the generally deficient depth of the Hemispheres as compared with those of Man, the Chimpanzee and the Orang are closely allied.

On the whole, it would appear that the convolutions of the Gorilla's brain are slightly more subdivided and complex than those of the Chimpanzee; though in this respect the brain of the Orang is, to about the same extent, superior to that of the Gorilla. As regards the want of exact symmetry of many of the corresponding convolutions of the two Cerebral Hemispheres, that of the Orang also approaches most closely to the still more marked asymmetrical condition of the brain of Man.

* This direction is very well seen in the figure given by Prof. Rolleston (loc. cit., pl. 3, fig. 1), though it is not so distinct in that of Gratiolet (see fig. 121 in text).

CHAPTER XVIII.

THE MENTAL CAPACITIES AND POWERS OF HIGHER BRUTES.

In a previous chapter some account has been given of the instinctive and occasional actions of the higher Social Insects, with the effect of disclosing the extremely routine nature of their operations; these being carried on under the guidance perhaps of one, and rarely of more than two, really potential Sense Endowments. The power shown by these organisms of adapting their actions to new conditions with which they were brought face to face, was found to be very slight and almost wanting.

Reference has also been made to the instincts of Birds, to the wider range of mental phenomena displayed by these animals, as well as to their greater power of adapting their actions to the exigencies of new conditions. The nervous system of Birds is, however, much more highly developed than that of Insects, as is evidenced more especially by their possession of large Cerebral Lobes for the correlation of sensorial impressions. Birds are, moreover, commonly guided by three highly acute Sense Endowments instead of two, in addition to others of minor importance.

Our consideration of the actions of Birds afforded good warrant for the inference that in them the germs, or sometimes rather more than the germs, of higher mental manifestations may become nascent in the form of rudimentary Thoughts, or more developed Emotions and Volitions.

The survey since taken of some of the principal forms of the Brain in Quadrupeds and Quadrumana reveals a very marked increase in the relative size and complexity of the Cerebral Hemispheres in each of these great classes. And though no distinct serial order is to be traced, it must be obvious from the preceding descriptions and figures, that the brain of the higher Apes presents almost as great an advance in relative size and complexity over that of the higher Quadrupeds, as that which characterizes the brain of these latter animals in comparison with the brain of Birds.

It remains, therefore, briefly to consider the scope of the mental life of Quadrupeds and Quadrumana for comparison with that of Birds. The materials for arriving at a judgment upon this point must still be of the same order as they were in the case of animals lower in the scale of organization. We can only study their actions in the records which have been given of them, striving to interpret them in the manner previously indicated (p. 196) by the reflected light derived from our knowledge of human intelligence and human actions—and yet not too much from the mere human point of view.

It is worth while here to take note of the fact that the most intelligent Quadrupeds—and more especially Elephants—have the advantage of bringing into play a rather highly developed sense of Touch, in aid of their other acute and highly discriminative senses of Sight, Smell, and Hearing; and also that the same four sensorial endowments are commonly in active operation among Quadrumana—although with them Smell seems to diminish in importance, while the more definite and intellectual sense of Touch becomes more and more called into play, as it is with human beings.

In Chapter XII. it has been shown that Intelligence or Reason, as well as Emotion, have their roots in, and cannot be separated from, Sensorial Activity; and it has also been shown (pp. 187–191) that the sensorial endowments and mental attainments, such as they are, of all animals whatsoever tend to be transmitted in a constant and truly marvellous manner to their offspring.

The question of the number and the excellence of the Sense Endowments of particular kinds of animals is, therefore, of considerable importance in relation to the degree of their Intelligence. Each practically new addition or greatly developed activity of this kind, in animals whose intelligence is so far developed as to be obvious and indubitable, cannot fail to give additional breadth and strength to their mental operations—to say nothing of the new special knowledge, resulting from its exercise, as to the qualities of the outer world of things by which such organisms are surrounded.

Gradually altering race experiences, if persistent enough, are certain to leave their marks in the form of minute structural modifications of the Nervous System—and these, if not actually recognizable in themselves, reveal themselves by their effects—that is, by the manifestation on the part of such animals of new or altered susceptibilities to Impressions from external things or occurrences. It is a familiar fact that disuse blunts the sensorial powers of individual animals, while use and exercise tend to sharpen them. We can easily imagine, therefore, what potent modifiers 'use' and 'disuse' may be when they bear respectively upon the same Sense Endowments for generation after generation of some particular kind of animal.

Inasmuch as nothing like a single serial progression is to be traced among animals now extant, or even when these are intercalated with the remains of the very small fraction of extinct forms which have as yet been discovered in the shape of fossil relics, so nothing like a mental serial progression is to be looked for. Whatever the grade of organization of an animal may be, we have, in estimating the nature of its mental processes and powers, to look much to its present sensorial organization and endowments. It is true, however, that the experiences of ancestral forms will have had much to do with the basis and background of the creature's Mental Processes, both in special and in general directions.

If the Mole and its ancestors, owing to their usual conditions of life, have had little need of eyes, and these have consequently, in the course of generations, undergone a process of atrophy from disuse, the basis of the mental processes of these particular animals must have been thereby proportionately altered. Sight impressions being cut off, other Sensorial Endowments would have gradually risen in importance for the daily conduct of their life. The sum total of the neural impressions and responses of such animals would, therefore, come to be very different from those of their near ally, the keen-visioned Rat. How different, again, must be the web of sensorial impressions constituting the basis of the mental life of the Stag, into which Scents enter so largely, when compared with that of the Whale, the Porpoise, or the Dolphin, in whom impressions of this order seem to be almost or wholly wanting.

While there may, therefore, be a general onward progress in the complexity of mental phenomena in different groups of animals, regarded as groups, this general advance may be strangely chequered and interrupted, if we look at its manifestations in individual forms, owing to the peculiar habits of each, and the consequently varying nature of their sense endowments—either in the direction of defect or of hyper-refinement in discriminative power.

The space available in this volume is wholly inadequate to permit of any attempt to do more than call the reader's attention to a few of the more important of the recorded actions of some of the most intelligent of Quadrupeds and Quadrumana. These, however, may be useful for comparison with those recorded in previous chapters concerning animals lower in the scale of development.

The instinctive operations of Beavers are both well-known and remarkable. While they show us a much less machine-like series of actions than are exhibited by Insects, Beavers also display a more distinct power of adaptation to new or unusual conditions than is to be met with among Birds. They live in colonies, and work together in a most skilful manner to bring about, by numerous and complicated means, some common purpose—a purpose, moreover, which has at different times to be executed under by no means identical conditions. As Leuret* points out, so great a variety of labours is needed for the constructions carried on by the Beaver; they include so many instances of a well-made choice; so many accidental difficulties are surmounted by these animals, that it is impossible not to recognize in their acts the characteristics of a rather high intelligence—even though it may be of instinctive origin. The fact of their intelligence having this basis does not, however, detract in the least from its dignity and importance, seeing that instinctive operations constitute almost the necessary starting-point for that freer play of choice and independent

* "Anat. Comp. du Syst. Nerv." t. i. 1839, p. 506.

adaptation of means to ends which characterizes Intelligence in all its grades.

The sagacity of the Horse and of the Dog—and especially of the latter—is well known and appreciated. Much of the high intelligence exhibited by Dogs, however, is perhaps to be regarded as a distinct result of the education of individual animals while they have been acting as Man's associates and helpers. Under his influence the aptitudes and cerebral organization of the race appear to have been slowly improved. Still, notwithstanding the advantages of this association, the Dog could never have profited by it so much as he has done, had he not been endowed with an unusual plasticity of organization, together with faculties of observation and a power of Attention of no ordinary kind.

The faculties of the Wild Dog are not very different from those of the Wolf, and in almost all respects they are notably inferior to those of animals whose ancestors have been educated by association with Man. Even Wolves will, however, hunt their prey in couples with skilfully concerted though varying actions, calculated to make their victims fall an easy prey to stratagem. Dogs have also been known to adopt a very similar *rôle*—and that even when the conspirators have been altogether different in size and breed.

Evidence is not wanting to show that some of the emotions of a Dog may have an altruistic basis—apart from mere instinctive love or affection for their offspring. The Dog's sympathy with its master when in distress, is more marked and more frequently met with than it is for members of its own kind whom it may chance to meet under circumstances of more or less distress. Of the former kind of Sympathy on the part of the Dog numerous stories are on record; and this feeling is to be regarded as the joint product of the animal's intelligence and of its love for its master or mistress. Of the manifestations of sympathy for their own kind the records are comparatively scarce. Swainson, however, quotes a good instance of it. He says*:—

"The Rev. Mr. S——, of M——, Denbighshire, had a favourite Newfoundland dog, who lived at large, partook of the best of everything, and exercised his power with great mildness. He was seen more than once leaping the gate which separated the yard of the house from the farm-yard, and carrying large bones that had been given him to a sporting dog, who was tied up in the stable."

The occasional dislike of the Dog for members of its own species—engendered almost at first sight—is sometimes striking enough in itself, but when we find that a memory of this sort of Emotion is retained, and roused again after a long period by a simple Association of Ideas—roused, too, in such force as to stimulate to immediate action—the fact is one which deserves to be recorded in illustration of the mental and emotional processes of the Dog. Dr. Paladilhe, of Montpelier, has cited an interesting instance of this kind. Being about to spend some days with relatives living in a small village about twenty-two miles distant, he took his greyhound with him, she never having been there before.

"It so happened," he says,† "that not far off there was a hound bitch belonging to one of my cousin's neighbours, and between these two animals (from the beginning of my short stay) there arose the deepest hatred and animosity, and conflicts of the most ferocious kind were matters of daily, almost hourly, occurrence. Time altogether failed in producing any better feeling between them, and to the end of my visit each was ever ready and anxious to try its

* "Habits and Instincts of Animals," p. 72.

† "Nature," August 7, 1873.

strength whenever the opportunity offered. In the course of the following year I paid a second visit to the same place accompanied by my greyhound, and about three-quarters of an hour before I reached the village, the animal, as if struck with a sudden idea, rushed forward at her full speed, and all attempts to call her back proved quite ineffectual. On reaching the village I found that a terrible encounter had already taken place between the two heroines, who were on the point of renewing the attack after a temporary cessation of hostilities."

Some Dogs seem even to entertain an embryo notion of 'justice' and its opposite, the realization of which testifies to the occurrence of mental processes of some complexity for such animals. Leuret cites the following anecdote:—

"Arago, the astronomer, was once overtaken by a storm in a small village in the south of France, and Dureau de Lamalle, who related the story ('Ann. des Sc. Nat.' t. xxii. 1831), says the cottagers with whom he had taken refuge could only offer him a chicken for dinner—and this he at once ordered to be cooked. The spit was provided with a revolving drum, into which a dog was accustomed to enter in order to give it the necessary movement. One of the dogs kept for this purpose ('turnspits' as they were called) was in the kitchen, and on the cottager attempting to take it, the dog showed his teeth, hid himself, and obstinately disobeyed his master's orders. Arago, in surprise, asked the cause, and was told that the dog rebelled because it was his companion's turn. The astronomer directed that the other dog should be fetched, and on its arrival, at the first sign from his master, it went into the drum and turned the spit for about ten minutes. In view of completing the experiment, Arago caused the drum to be stopped and the dog liberated, telling the cottager then to summon the previously restive animal. The order was given, and the animal whose refusal had previously been so obstinate, convinced that his turn of drudgery had come, entered the drum of his own accord, and began to turn it."

Those who have kept intelligent dogs know the surprising extent to which they become capable of understanding language—that is their power of comprehending and of acting upon mere verbal instructions. A good instance of this has lately been cited by Mr. Charles Stewart, of Tighnduin, Perthshire. He says:—*

"A few years ago I kept a collie dog named 'Bodach' at my farm, for herding the milk cows, and who recognized the dairymaid as his mistress. On her directing him to keep the cows on a certain part of a field, he would lay himself down in the centre of a line fixed by him as the proper limit. Patiently and vigilantly he would remain in quietness, until any of the cows passed his limit, when he would swoop down on the trespasser, take her by the heels, and drive her back. It was wonderful in how short a time the cows came to recognize and respect the arrangement. He also came to know some of the cows by name. One of them named 'Aggi' required at certain seasons to be milked oftener than the others, and the dairymaid had only to say in Gaelic, 'Bodach, go and bring home Aggi,' when he would start for the pasture, single out Aggi, and bring her carefully home."

The cunning of the Fox is proverbial, and often characterized by a degree of intelligence which is not a little remarkable, when we consider that it is altogether the result of the creature's unaided converse with Nature—and certainly independent of any encouragement from Man. A good example of this native intelligence is to be found in the following incidents †:—

"A farmer looking out of his window one summer's morning about three o'clock saw a fox crossing a field before it, carrying a large duck that he had captured. On coming to a stone dyke about four feet high, on the side of the field, Reynard made an effort to leap over it with his prey, but failed, and fell back into the field. After making three attempts with the same result he sat down and viewed the dyke for a few minutes; after apparently satisfying himself, he caught the duck by the head, and standing up against the dyke with his fore-paws, as high

* "Nature," May 1, 1879, p. 21; another excellent illustration of the intelligence of a dog is given in "Nature," March 20, 1879, p. 458.

† "Nature," March 27, 1873, p. 410; February 27, 1879, p. 385; and March 6, 1879, p. 409.

as he could reach, he placed the bill of the duck in a crevice in the wall; then springing upon the top, he reached down, and pulling up the duck dropped it upon the other side, leaped down, and, picking it up, went on his way."

The Rev. G. Henslow writes thus :—

"The Arctic fox—too wary to be shot like the first who took a bait tied to a string, which was attached to the trigger of a gun—would dive under the snow and so pull the bait down below the line of fire." Dr. John Ray adds that he has known several cases in which, under such conditions, instead of digging and jumping into a trench in the snow to avoid the shot, an Arctic fox has "cut the line attaching the bait to the trigger of the gun before taking the bait."

The large and highly convoluted brains of the Porpoise and of the Dolphin, as well as those of many marine Carnivores, have long been deemed remarkable peculiarities in these animals; and doubts have been expressed whether their Mental Faculties are in any way equal to what might have been expected if we look merely to the size and development of their Cerebral Hemispheres. Some remarks have already been made on this subject, with the view of showing that the extraordinary activity and varied muscular movements of these creatures may have much to do with the great size even of the Cerebral Hemispheres, as it has unquestionably to do with the great development of the Cerebellum.* Their voracity is enormous; and this, together with the rapidity and variety of their movements, must entail a corresponding activity of all their Sensorial Organs. The diversity of their daily experiences also is probably greatly increased by the fact that they are gregarious animals, accustomed to hunt their prey and live together in small troops. It is quite possible, therefore, that the sagacity and emotional nature of these

* *See* p. 278.

animals may be much more highly developed than is generally imagined.

But we, unfortunately, know very little about the more intimate habits of either Porpoises or Dolphins, as the medium in which they live removes them so much from any minute and continuous examination. Some few interesting observations have, however, been recorded concerning two Porpoises formerly in the large tank of the Brighton Aquarium.

W. Saville Kent says: *—"The first comer so readily accommodated itself to its altered conditions, that on the second day it took its food, smelts and sprats, from its keeper's hand, and has continued to do so ever since. The later arrival was at first less sociably inclined, but both have latterly become equally tame, and frequently, while receiving fish from my hand with the gentleness of pet dogs, have permitted me to pat and stroke their slippery india-rubber-like backs."

Curiosity is a sign of Intelligence of a comparatively high order. It may be said to be almost absent in Birds, but it seems to exist to a very marked degree in the Porpoise.

W. Saville Kent says:—"A new arrival is at once subjected to the most importunate attention, and, advancing from familiarity to contempt, if disapproved of, soon becomes the object of attack and persecution. A few Dog-fish, three or four feet long, placed in the same tank, soon fell victims to the tyranny cf the Porpoises; and a fine Sturgeon, six feet long, was likewise much persecuted and had to be removed. This was also the case with some large Skates. The latter, so long as they maintained their usual habit of lying sluggishly on the floor of the tank, escaped molestation; but no sooner did these fish display any unwonted activity than the Porpoises were upon them, and, making a convenient handle of their characteristic attenuated tails, worried them incessantly." On one occasion, the same observer witnessed "the two Cetacea acting evidently in concert against one of the Skates."

* "Nature," July 17, 1873, p. 229.

Porpoises make a prodigious slaughter among the shoals of Herring, Mackerel, and other fish which periodically visit our coasts.

As to the Dolphin we have no precise knowledge, but many stories have come down to us from ancient times, the general purport of which seems to testify to their rare docility, intelligence, and sympathetic nature. Fact and fable may be here inextricably intermixed, though, as Leuret suggests, it seems probable that there is some basis of truth for these various stories. We stand much in need, however, of some accurate modern observations as to the habits and degree of Intelligence of these highly interesting creatures, whose brain is so large and well developed. Swainson quotes Cuvier, to the effect that the Dolphin "carefully suckles and tends its young, carrying them gently under its pectoral fins, sporting with and continuously exercising them in swimming. The male also attaches himself for life to his female companion, and becomes her most zealous guardian and protector."

The Elephant is, by general consent, regarded as the most sagacious of all four-footed beasts living in a state of nature. It seems pretty certain, however, that this estimate would not be applicable to brutes generally, inclusive of the Quadrumana.

Like the Apes, the Elephant adds to its other sensorial endowments an acute and discriminative sense of Touch. Its prehensile trunk serves all the purposes to which a highly sensitive hand could be applied. The Elephant enjoys the further very considerable advantage resulting from a prolonged length of life. When an animal which already, in its early days, possesses a fair amount of intelligence, has its experiences extended over a period so considerable as 150 years or more, we have a right to expect that individuals, and ultimately the race, should benefit much therefrom in the way of increased sagacity. The importance of this point will be best appreciated by those who know the differences in point of Sagacity between the generality of young dogs and those that have lived on to their full term of active life. For, if so much difference in this respect arises with the Dog in the course of eight or ten years, we may naturally look for notably greater effects of the same kind during a life at least ten times as long as that of the Dog.

On the other hand, it must not be forgotten that the Elephant never breeds in captivity, and therefore never, like the Dog, bequeaths to succeeding generations any of those higher developments of its faculties and powers which may have resulted from its intercourse with, and education by, human associates. The individual Elephant, therefore, can be educated by man, but the race must have its faculties sharpened in the wider school presented by the sum-total of their own natural surroundings.

When once tamed, the Elephant becomes, as Buffon says, the most tractable and submissive of all animals:—

> "He is affectionate to his keeper, caresses him and does whatever he can to please him. In a little time he understands signs, and even the expression of sounds; he distinguishes the tone of command, that of anger or goodnature, and acts accordingly. He never mistakes the words of his master; he receives his orders with attention, and executes them with prudence and eagerness."

The intelligence and sagacity which the Elephant is well known to display, in aid of his keepers, in capturing *sauns* or solitary males in the wild state, as quoted by Swainson,* is so surprising as to be almost incredible, were it not that the facts are notoriously well attested. The account is too long to be here quoted.

* "Habits and Instincts of Animals," p. 24.

The same kind of judgment and sagacity are, however, shown by the Elephant when he gets into too soft a swamp.

Swainson writes:—"The cylindrical form of an Elephant's leg—which is nearly of equal thickness—causes the animal to sink very deep in heavy ground, especially in the muddy banks of small rivers. When thus situated, the animal will endeavour to lie on his side, so as to avoid sinking deeper; and, for this purpose, will avail himself of every means to obtain relief. The usual mode of extricating him is much the same as when he is pitted; that is, by supplying him liberally with straw, boughs, grass, &c.; these materials being thrown to the distressed animal he forces them down with his trunk, till they are lodged under his fore-feet in sufficient quantity to resist his pressure. Having thus formed a sufficient basis for exertion, the sagacious animal next proceeds to thrust other bundles under his belly, and as far back under his flanks as he can reach; when such a basis is formed as may be, in his mind, proper to proceed upon, he throws his whole weight forwards, and gets his hind feet gradually upon the straw, &c. Being once confirmed on a solid footing, he will next place the succeeding bundles before him, pressing them well with his trunk, so as to form a causeway by which to reach the firm ground." "He will not bear any weight, definitely, until by trial both with his trunk and the next foot that is to be planted, he has completely satisfied himself of the firmness of the ground he is to tread upon. . . . . . The anxiety of the animal, when bemired, forms a strong contrast with the pleasure he so strongly evinces on arriving at *terra firma*."

The following particulars were among those reported to the Academy of Sciences, concerning a young animal, the property of Louis XIV., which was kept for a time at Versailles:—

"The Elephant seemed to discern when anybody made a fool of him; and he remembered the affront, to be revenged of it at the first opportunity. Having been baulked by a man who feigned to throw something into his mouth, he struck him with his trunk and broke two of his ribs, afterwards he trampled him under his feet. . . . . A painter was desirous of sketching him in an extraordinary attitude, that is with his trunk erect and mouth open. The servant of the painter to make him retain that attitude threw fruits into his mouth; but afterwards he deceived him, which provoked the elephant's indignation; and, as if he had known that the cause of this deception was the painter's desire of having him drawn, he revenged himself on the master by throwing with his trunk a great quantity of water, which spoiled the paper intended for his design."

As a well-authenticated instance of the Memory of the Elephant, and of his obedience to his keeper, Swainson gives the following story recorded by Captain Williamson, and attested by the signatures of several persons who were witnesses of the occurrence:—

"An Elephant that had been some years domesticated got loose during a stormy night, and rambled into his native jungles. About *four years* afterwards, when a large drove had been captured in the 'keddah,' the keeper of the lost one, along with others of the natives, had ascended the barricade of timber by which it was surrounded, to inspect the new guests; among them he fancied he recognized his former charge, and, though ridiculed by his comrades, he called to the elephant in question by the name which it had formerly borne. To the wonder of all present the animal came towards him. The man, overjoyed at the event, got over the barrier, and ordering the elephant to lie down to be mounted, he bestrode its neck as in former times and exultingly led it forth, to the admiration and surprise of all present."

With Memory such as this, with a power of fixing its Attention, with a plastic nervous system, and with a very long life for each individual, the remarkable Sagacity of these animals may be in a measure understood.

High, however, as is the Intelligence of the Elephant, it is unquestionably much below that of many of the Quadrumana—even of some whose zoological status is inferior to that of the great 'man-like' Apes. Who, that has watched any of these creatures, does not know their varied powers of appreciating the conditions around them, and of shaping their actions into some accordance therewith—as well as the range and complexity of the Emotions which they are capable of feeling and plainly manifesting on different occasions.

In regard to the Cai, or Weeper Capuchin, one of the long-tailed New World Monkeys,—

P. M. Duncan (Cassell's "Nat. History," p. 184) quotes Rengger to the effect, that when he first gave eggs to these animals "they smashed them, and thus lost much of their contents; afterwards they gently put one end against some hard body and picked off the bits of shell with their fingers. After cutting themselves only once with a sharp tool they would not touch it again, or would handle it with the greatest care. Lumps of sugar were often given them wrapped up in paper, and Rengger sometimes put a live wasp in the paper. After this had happened once, they always first held the packet to their ears to detect any movement within."

The same writer in his account of a female Chacma, or Pig-tailed Baboon (loc. cit., p. 146), says :—

"She not only adopted young Monkeys of other species, but stole young dogs and cats, which she continually carried about. Her kindness, however, did not go so far as to share her food with her adopted offspring. An adopted kitten scratched this affectionate and selfish old thing, who certainly had a fine intellect, for she was much astonished at being scratched, and immediately examined the kitten's feet, and without more ado bit off the claws!"

The same writer also cites (loc. cit., p. 184,) the following remarkable instance of Intelligence :—

"Formerly one of the large Monkeys in the Zoological Gardens had weak teeth, and he used to break open the nuts with a stone. Mr. Darwin was assured by the keepers that this animal, after using the stone hid it in the straw, and would not let any other Monkey touch it."

The development of Intelligence, Emotion, and Volition, which becomes so obvious in lower Quadrumana, is, however, recognizable in a still more striking degree, when we come to the so-called 'man-like' Apes, viz., the Gibbons, the Chimpanzee, the Gorilla, and the Orang-utan, as a few details will show.

A writer in "Nature" (Jan. 29, 1874) says:—

"I keep in my garden a number of Gibbon apes (*Hylobates agilis*); they live quite free from all restraint in the trees, merely coming when called to be fed. One of these, a young male, on one occasion fell from a tree and dislocated his wrist; it received the greatest attention from the others, especially from an old female, who, however, was no relation; she used, before eating her own plantains, to take up the first that were offered to her every day and give them to the cripple, who was living in the eaves of a wooden house; and I have frequently noticed that a cry of fright, pain or distress from one, would bring all the others at once to the complainer, and they would then condole with him and fold him in their arms."

Concerning the largest of the Gibbons, the Siamang, a native of Sumatra, some interesting details have been given by G. Bennett,* of an animal which he brought home with him from Singapore. "Its disposition was gentle but animated and lively; and it delighted in playing frolics. With a little Papuan child on board this Siamang became very intimate; they might often be seen sitting near the capstan, the animal with its long arm round her neck, eating biscuit together. In his gambols with the child he would roll on deck with her, as if in mock combat. . . . . . His temper, however, was irritable, and on being disappointed, or confined, he would throw himself into fits of rage, screaming, rolling about, and dashing everything aside within his reach: he would then rise, walk about in a hurried manner, and repeat the scene as before. With the cessation of his fit of anger he did not abandon his purpose, and often

* Knight's "Pictorial Museum of Animated Nature," p. 31.

gained his point by stratagem when he found that violence was of no avail."

An instance of this animal's Intelligence is given which is very interesting:—

"Among various articles in Mr. Bennett's cabin a piece of soap greatly attracted his attention, and for the removal of this soap he had been once or twice scolded. One morning Mr. Bennett was writing, the Siamang being present in the cabin, when, casting his eyes towards the animal, he observed him taking the soap. 'I watched him,' says the narrator, 'without his perceiving that I did so; he occasionally cast a furtive glance towards the place where I sat; I pretended to write; he, seeing me busily engaged, took up the soap and moved away with it in his paw. When he had walked half the length of the cabin, I spoke quietly, without frightening him. The instant he found I saw him, he walked back again, and deposited the soap nearly in the same place whence he had taken it: thus betraying both by his first and last actions a consciousness of having done wrong."

M. Duvauncel says :—" If a young one be wounded, the mother, who carries it or follows it closely, remains with it, utters the most lamentable cries, and rushes upon the enemy with open mouth; but being unfitted for combat knows neither how to deal nor shun a blow. It is," he adds, "a curious and interesting spectacle, which a little precaution has sometimes enabled me to witness, to see the females carrying their young ones to the water, and there wash their faces in spite of their childish outcries—bestowing a degree of time and care on their cleanliness which, in many cases, the children of our own species might envy."

In the conformation of their brain the Chimpanzee, the Gorilla, and the Orang approach, as we have seen, most closely to that of Man; but it must never be forgotten that although in general shape, in the disposition of its

Fissures, and in the arrangement of its Convolutions, as far as they go, there is this striking resemblance to the human brain, yet in actual size or weight the brain of the 'man-like' Apes is widely separated from that of Man. The heaviest brain belonging to one of these creatures, as yet examined, has been barely one-half of the weight of the smallest normal human brains, although the weight of the entire body in the great Gorilla may be nearly double that of an ordinary Man. The brains of these three kinds of 'man-like' Apes differ considerably among themselves; as we have seen, each in some respects approaches nearer to that of Man than the others, though on the whole it is considered that the brain of the Orang is slightly higher in type than that of the other two. They likewise differ from one another a good deal in disposition and in general bearing.

Some years ago a very interesting baby Chimpanzee was obtained from the natives of the Gambia coast. His mother had been shot when he was about twelve months old, and after a short time he was sent to London, and became famous, young as he was, for his great intelligence and human-like conduct. Soon after his arrival at the Zoological Gardens, this young Chimpanzee was visited by a distinguished zoologist, Mr. Broderip, who has given the following account of him (Cassell's "Nat. Hist.," p. 54):—

"I saw him for the first time in the kitchen belonging to the keeper's apartments, dressed in a little Guernsey shirt, or banyan jacket. He was sitting child-like in the lap of a good old woman, to whom he clung whenever she made show of putting him down. . . . . . He had already become very fond of his good old nurse, and she had evidently become attached to her nursling, although they had only been acquainted for three or four days. . . . . . On another occasion, and when he had become familiar with me, I caused, in the midst of his play, a looking-glass to be brought and held before him. His attention was constantly and strongly arrested: from the utmost activity he became immovably fixed, steadfastly gazing at the mirror with eagerness, and something like wonder depicted in his face. He at length looked up at me, then again gazed at the glass. The tips of my fingers appeared on one side as I held it; he put his hands and then his lips to them, then looked behind the glass, and finally passed his hands behind it, evidently to feel if there were anything substantial there. . . . As I was making notes with a paper and pencil, he came up and looked at me inquisitively, testing the pencil with his teeth when he had it given to him. A trial was made of the little fellow's courage; for, when his attention was directed elsewhere, a hamper containing a large snake, called Python, was brought in and placed on a chair near the dresser. The lid was raised, and the basket in which the snake was enveloped was opened, and soon after Tommy came gambolling that way. As he jumped and danced along the dresser towards the basket he was all gaiety and life; suddenly he seemed to be taken aback, stopped, cautiously advanced towards the basket, peered or rather craned over it, and instantly, with a gesture of horror and aversion, and the cry of 'Hoo! hoo!' recoiled from the detested object, jumped back as far as he could, and then sprang to his keeper for protection. Tommy does not like confinement, and when he is shut up in his cage, the violence with which he pulls at and shakes the door is very great, and shows considerable strength; but I have never seen him use this exertion against any other part of the cage, though his keeper has endeavoured to induce him to do so, in order to see whether he would make the distinction. Then he went to a window, opened it and looked out. I was afraid that he might make his escape, but the words 'Tommy, no!' pronounced by the keeper in a mild but firm tone, caused him to shut the window and to come away. He is, in truth, a most docile and affectionate animal, and it is impossible not to be taken with the expressive gestures and looks with which he courts your good opinion, and throws himself upon you for protection against annoyance."

Whether these animals grow cross and savage as they get old, after the manner of Monkeys generally, is not known, for no adults have been kept in captivity; we have, therefore, also no means of forming an opinion of the degree of Intelligence which they are capable of displaying in their adult condition.*

We labour under the same disadvantage in regard to the Gorilla, though Mr. Moore, the Curator of the Free Public Museum, Liverpool, has given us some interesting particulars concerning a young male, three feet high, and between two and three years old, which was brought to that city by the German African Society's Expedition.†

"Could it have graced," says this observer, "our Zoological Gardens, it would have been the lion of the day; for in addition to the great scientific interest of the species, the abounding life, energy, and joyous spirits of this example would have made it a universal favourite. Courteously received at Eberle's Alexandra Hotel by the members of the Expedition, I found the creature romping and rolling in full liberty about the private drawing-room, now looking out of the window with all becoming gravity and sedateness, as though interested but not disconcerted by the busy multitude and novelty without, then bounding rapidly along on knuckles and feet to examine and poke fun at

* The importance of Attention as one principal factor in the intelligence of animals is illustrated by the following interesting facts communicated to Darwin by Mr. Bartlett, of the Zoological Gardens:—"A man who trains Monkeys to act used to purchase common kinds from the Zoological Society, at the cost of five pounds each, but he offered to give double that price if he might keep three or four of them for a few days, in order to select one. When asked how he could possibly so soon learn whether a particular Monkey would turn out a good actor, he answered that it all depended upon their power of attention. If, when he was talking and explaining anything to a Monkey, its attention was easily distracted, as by a fly on a wall or other trifling object, the case was hopeless. If he tried punishment to make an inattentive Monkey act, it turned sulky. On the other hand, a Monkey which carefully attended to him could always be trained." The tendency to imitation which Apes and Monkeys often manifest in a high degree, doubtless much facilitates their acquisition of new motor accomplishments.

† Quoted in Cassell's "Nat. Hist." vol. i. p. 35.

some new comer, playfully mumbling at his calves, pulling at his beard (a special delight), clinging to his arms, examining his hat (not at all to its improvement), curiously inquisitive as to his umbrella, and so on with visitor after visitor. If he becomes over-excited by the fun, a gentle box on the ear would bring him to order, like a child, only to be on the romps again immediately. He points with the index-finger, claps with his hands, puts out his tongue, feeds on a mixed diet, decidedly prefers roast meats to boiled, eats strawberries, as I saw, with delicate appreciativeness, is exquisitively clean and mannerly. The palms of his hands and feet are beautifully plump, soft, and black as jet. He has been eight months and a half in the possession of the Expedition."

This animal was very shortly afterwards taken to Berlin, and a paragraph in "Nature," Nov. 9, 1876, gives some further interesting particulars concerning him, which were communicated by Dr. Hermes to the meeting of the 'German Association of Naturalists and Physicians.'

"He nods and claps his hands to visitors; wakes up like a man, and stretches himself. His keeper must always be beside him, and eat with him." They partake of the same food. He sleeps for eight hours. "His easy life has increased his weight in a few months from thirty-one to thirty-seven pounds. For some weeks he had inflammation of the lungs, when his old friend Dr. Falkenstein was fetched, who treated him with quinine and Ems water, which made him better. When Dr. Hermes left the Gorilla on the previous Sunday the latter showed the doctor his tongue, clapped his hands, and squeezed the hand of the doctor, as an indication, the latter believed, of his recovery. In fact the Gorilla is now one of the most popular inhabitants of the Prussian capital." In July, 1877, he paid a visit to London, and fully sustained the reputation he had already acquired.

Speaking of an Orang which he had examined and watched, Buffon says :—

"Its air was melancholy, its deportment grave, its nature more gentle and very different from other apes. Unlike the baboon or the monkey, whose motions are violent and appetites capricious, who are fond of mischief, and only obedient through fear, a look was sufficient to keep it in awe. I have seen it give its hand to show the company to the door, that came to see it, and it would walk gravely with them as if one of the society. I have seen it sit at table, unfold its napkin, wipe its lips, make use of the spoon and fork to carry the victuals to its mouth, pour out its drink into a glass, touch glasses when invited, take a cup and saucer and lay them on the table, put in sugar, pour out its tea, leave it to cool before drinking, and all this without any other instigation than the signs or command of its master, and often of its own accord. It was gentle and inoffensive: it even approached strangers with respect, and came rather to receive caresses than to offer injuries: it ate of almost everything that was offered to it, but it preferred dry and ripe fruit to all other aliments. It would drink wine, but in small quantities, and willingly left it for milk, or any other sweet liquor."

Again in regard to the high degree of Intelligence of the Orang, we have the following, on the best of testimony, from Leuret, who says*:—

"One of the Orangs, which recently died at the Ménagerie of the Musée, was accustomed, when the dinner-hour had come, to open the door of the room where he took his meals in company with several persons. As he was not sufficiently tall to reach as far as the key of the door, he hung on to a rope, balanced himself, and after a few oscillations very quickly reached the key. His keeper, who was rather worried by so much exactitude, one day took occasion to make three knots in the rope, which, having thus been made too short, no longer permitted the Orang-outan to seize the key. The animal, after an ineffectual attempt, *recognizing the nature of the obstacle which opposed his desire, climbed up the rope, placed himself above the knots, and untied all three,* in the presence of M. Geoffroy Saint-Hilaire, who related the fact to me. The same ape wishing to open a door, his keeper gave him a bunch of fifteen keys; the ape tried them in turn till he had found the one which he wanted. Another time a bar of iron was put into his hands, and he made use of it as a lever."

Unfortunately nothing is said as to the age of this animal, whose power of realizing the nature of unfamiliar

* 'Anat. Comp. du Syst. Nerv.' t. i. p. 540.

conditions, as well as of dealing with them in order to effect his own ends, can only be described as highly remarkable.

The following paragraph seems, however, to refer to the emotional manifestations of an adult Chimpanzee.*

"From a study of a fine pair of Chimpanzees in the Philadelphia Zoological Garden, Mr. A. E. Brown has obtained several interesting evidences of a rather high degree of mental power in this species. One of the pair lately died, and the behaviour of the surviving one seemed to bear somewhat on the acquired nature of the physical means by which our own strongly excited emotions find relief, as well as on the origin of those emotions themselves. Evidences of a certain degree of genuine grief were well marked. The animals had been great friends; they never quarrelled. On the first cry of fright from one, the other was instantly prepared to do battle in its behalf. It was early in a morning when the female died, and when the survivor found it impossible to arouse her his grief and rage were painful to witness . . . . The ordinary yell of rage at first set up finally changed to a cry, the like of which he had never been heard to utter before, and which would be most nearly represented by 'hah-ah-ah-ah-ah,' uttered somewhat under the breath and with a plaintive sound like a moan. Crying thus, he would lift up her head and then her hands, only to let them fall again. After her body was removed he became more quiet; but, catching sight of it on its being carried past the cage, he became violent and cried for the rest of that day. The day following he sat still most of the time and moaned continuously; this gradually passed away, the plaintive cry became less frequent, but when he was angry it would be heard at the close of the fits just as the sobbing of a child after a passionate fit of crying. It soon became apparent that his recollection of the nature of the past association was becoming less and less vivid; still it was noticed that, while the two used to sleep together in one blanket on the floor, he now invariably slept on a cross beam at the top of the cage, returning to inherited habit, and probably showing that the apprehension of unseen dangers had been heightened by his sense of loneliness. A high degree of permanence in grief of this nature in all probability belongs only to man."

* *The Times*, April 19, 1879.

About the middle of the last century the celebrated David Hartley wrote*:—"It is remarkable that Apes, whose bodies resemble the human body more than those of any other brute creature, and whose intellects also approach nearer to ours—which last circumstance may, I suppose, have some connection with the first—should likewise resemble us so much in the faculty of imitation. Their aptness in handling is plainly the result of the shape and make of their fore-legs and their intellects together, as in us. Their peculiar chattering may perhaps be some attempt towards speech, to which they cannot attain, partly from the defect in the organs; partly, and that chiefly, from the narrowness of their memories, apprehensions, and associations."

If the anthropoid Apes, possessing as they do such a well defined basis of Intelligence and Emotion, were endowed with Articulate Speech, so that they might benefit and mutually instruct one another—even merely by oral traditions and communications—how great a progress in the degree and range of their Intelligence might be expected after a few hundred generations had lived under the influence of such conditions.

* "Observations on Man," 6th Ed., 1834, p. 165.

CHAPTER XIX.

DEVELOPMENT OF THE HUMAN BRAIN DURING UTERINE LIFE

In the long axis of the clear 'germinal area' of the human impregnated Ovum, there appears an opaque line of young tissue known as the 'chorda dorsalis.'

Above this, and along its entire extent, a shallow 'primitive groove' is found, which soon becomes bounded on each side by an up-growing lamina of new embryonic tissue. These laminæ gradually approach one another, and ultimately unite over the before-mentioned 'primitive groove' so as to form a distinct tube closed at each end.

The internal layer of this tube grows in thickness so that its bore becomes gradually narrower. It soon differentiates also into two distinct textures. The most internal of these, viz., that immediately surrounding the diminished central canal, is composed of embryonic nerve tissue, and is destined to develop into the Cerebro-Spinal Axis.

The diameter of this hollow, rudimentary nervous axis is not uniform throughout its whole extent. Even before the laminæ completely close over the 'primitive groove,' the anterior extremity of the embryo tube swells into three dilatations immediately contiguous to one another; and it is from the nerve tissue in these swellings, together with that of certain important outgrowths therefrom, that the several parts of the Human Brain are developed. From the portion of the tube behind the three swellings the Spinal Cord is formed.

The mode of origin of, as well as the early changes taking place in, these three nervous vesicles are essentially similar, up to certain stages, throughout the Vertebrata. From such a basis, common to all, the several types of Vertebrate Brain are developed. Our attention must, however, now be confined to tracing in brief outline the mode in which the brain of Man gradually develops from the simple stages common to it and the Vertebrata generally.

In order that the reader's attention may be more effectively concentrated upon the subsequent changes undergone by the three swellings of the primary nerve tube, it may be well here to anticipate a little, and state what are the several parts of the Brain which gradually develop from them or their derivatives.

The *Posterior Swelling* (or Hind-brain) becomes divided into two regions, of which the hindermost corresponds with what subsequently develops into the posterior half of the *Medulla*, and here in the situation of the Fourth Ventricle the upper wall of the tube becomes thinned away till all nervous matter disappears, and only a mere membrane remains ('pia mater') to roof over the space above mentioned, which is continuous with the central canal of the tube behind it. The anterior region of this swelling corresponds with the anterior half of the Medulla. From the back or sides of it there grows a distinct segment of the future brain, viz., the *Cerebellum* (fig. 122, *c b*). Much later on, when the lateral lobes of the Cerebellum have made their appearance, this region of the Medulla is crossed below by the *Pons Varolii* (*p*).

The *Middle Swelling* (or Mid-brain) affords the matrix from the upper part of which develops the *Optic Lobes* or *Corpora Quadrigemina* (fig. 122, *q*). From the lower part are differentiated prolongations from the fibrous 'columns' of the Cord and Medulla, known as the *Cerebral Peduncles* (*r*). The cavity within this swelling gradually diminishes till in Man it persists only as a narrow passage (*b*) between the cavities of the Hind and of the Fore-brain (the Fourth and Third Ventricles) (*a c*). This passage is known as the '*Sylvian aqueduct.*'

The *Anterior Swelling* (or Fore-brain) undergoes remarkable modifications, principally on account of certain extraordinary outgrowths to which it gives rise. From the sides of this swelling are developed other portions of the *Cerebral Peduncles* and also the *Thalami* which rest upon and grow as ganglionic thickenings from the latter structures. Its diminished cavity persists as the future *Third Ventricle* (*a*). Its roof becomes gradually thinned

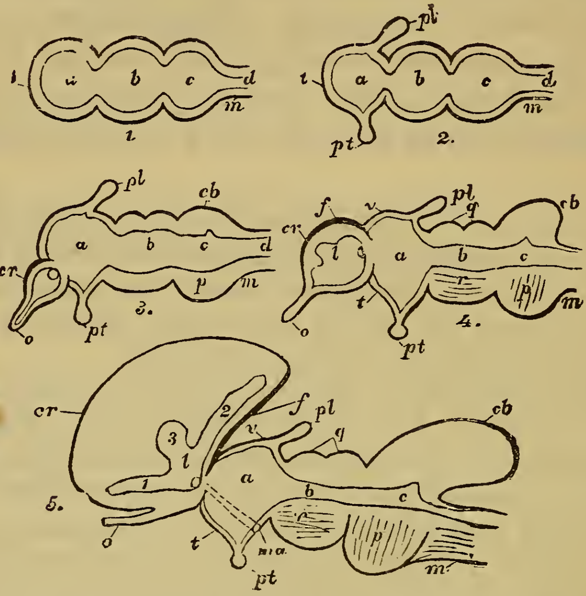


FIG. 122.—Diagrams illustrating the Progressive Changes that take place during the Early Stages of the Development of the Brain. (Mivart.)

1. Early condition of Brain when it consists of three hollow vesicles (*a b c*), the cavity of which is continuous with the wide cavity (*d*) of the primitive Spinal Cord (*m*).

2. Here the first vesicle or Fore-brain has developed the Pineal Body (*p l*) above, and the Pituitary Body (*p t*) below. The wall at the anterior end of the first vesicle is the future 'lamina terminalis' (*t*).

3. This figure shows the Cerebrum (*c r*) budding from the first vesicle, its anterior part (*o*) being prolonged as the Olfactory Lobe; the cavity of the Cerebrum (the incipient 'lateral ventricle') communicating with that of the Olfactory Lobe in front, and with that of the first Cerebral Vesicle behind (this latter cavity persisting as the future 'third ventricle'). The latter communication takes place through the 'foramen of Monro.' The walls of the three primitive vesicles are becoming of unequal thickness, and the cavity (*b*) of the middle vesicle is becoming reduced in relative size.

4. The Cerebrum is here enlarged, and the inequality in thickness of the wall of the primitive vesicles is increased. The greater development of the Cerebellum (*c b*), the Pons (*p*), and the Corpora Quadrigemina (*q*), show this distinctly.

5. This figure shows the Cerebrum still more enlarged, and containing a tri-radiate cavity (*l*, 1, 2, 3). The part destined to form the Fornix (*f*), which in No. 4 was above, has now come to look slightly downwards, and prolongations from it begin to extend towards the 'corpora albicantia' (*m a*). *v*, corresponds with the situation of the 'velum interpositum.'

away till mere membrane is left—the '*velum interpositum;*' at the posterior and upper margin of this ventricle the *Pineal body* (*p l*) appears, while its floor is prolonged into the *infundibulum*, which subsequently comes into connection with the *Pituitary body* (*p t*).

But at a very early period, and before the above described parts are distinguishable, an outgrowth (*c r*) buds on each side from the Anterior Swelling. These outgrowths, which are at first directed downwards and forwards, are hollow, and each communicates with the Third Ventricle through an aperture known as the 'foramen of Munro.' Subsequently these outgrowths undergo an enormous development and constitute the two *Cerebral Hemispheres*, while their contained cavities persist as the '*Lateral Ventricles*,' and the *Corpora Striata* develop within them. From each embryo Hemisphere another hollow bud-like outgrowth develops anteriorly, and these (*o*) constitute the *Olfactory Lobes* and their peduncles.

From the point of view of its developmental history, therefore, the entire brain is capable of division into three principal parts:—(1.) The **Fore-brain**, consisting of the Olfactory Lobes, the Cerebral Hemispheres, and the parts surrounding the Third Ventricle; (2.) the **Mid-brain**, consisting of the Corpora Quadrigemina, and the Crura Cerebri; (3.) the **Hind-Brain**, consisting of the Cerebellum, the Pons Varolii, and the Medulla oblongata. Of these principal parts, the Fore-brain admits of subdivision into three distinct segments, (*a*) Olfactory, (*b*) Hemispherial, and (*c*) Thalamary; and the Hind-brain into two segments, (*a*) Cerebellar, (*b*) Oblongate. The Mid-brain needs no further subdivision. This classification, given some years ago by Huxley, has the merit of simplicity when compared with other rather cumbrous nomenclatures now in vogue.*

In fig. 122 the beginnings of these six principal brain segments are pretty plainly indicated by the parts to which the following letters of reference are attached:—*o*, *cr*, *a*, *b*, *c*, *m*.

After this preliminary statement, a more detailed account may now be given of the changes undergone by the primitive nerve tube with its cephalic swellings, with the view of giving the reader some notions as to the order and times of occurrence of the several changes.

* *See* Gegenbauer's "Elements of Compar. Anat." (Engl. Trans.) p. 503.

At a very early stage of development, believed by Tiedemann to be about the **7th week,** the primitive nervous axis or tube undergoes a series of bendings (fig. 123, A).

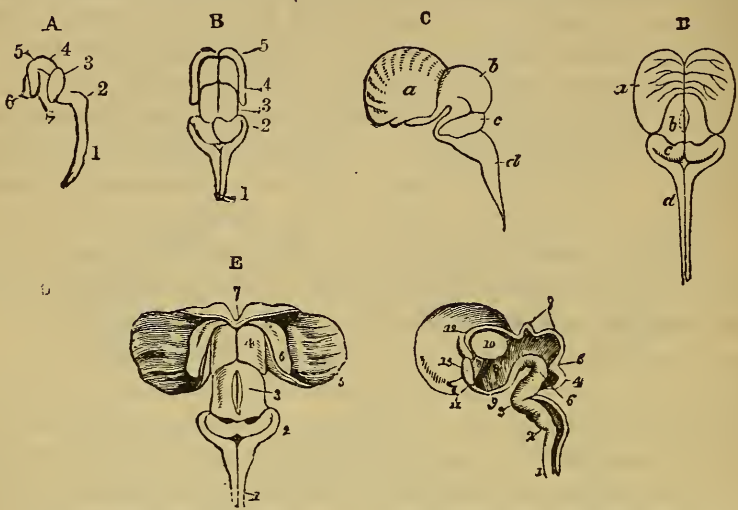


Fig. 123.—Sketches of the early form of the parts of the Cerebro-spinal Axis in the Human Embryo. (Sharpey, after Tiedemann.)

A, at the **seventh week,** lateral view; 1, spinal cord; 2, medulla oblongata; 3, cerebellum; 4, mesencephalon; 5, 6, 7, cerebrum.

B, at the **ninth week,** posterior view. 1, medulla oblongata; 2, cerebellum; 3, mesencephalon; 4, 5, thalami optici and cerebral hemispheres.

C and D, lateral and posterior views of the brain of the human embryo as it appears at the **twelfth week** of intra-uterine life. *a*, cerebrum; *b*, corpora quadrigemina; *c*, cerebellum; *d*, medulla oblongata: the thalami are now covered by the enlarged hemispheres.

E, posterior view of the same brain, dissected to show the deeper parts. 1, medulla oblongata; 2, cerebellum; 3, corpora quadrigemina; 4, thalami optici; 5, the hemisphere turned aside; 6, the corpus striatum embedded in the hemisphere; 7, the commencement of the corpus callosum.

F, the inner side of the right half of the same brain separated by a vertical median section, showing the central or ventricular cavity. 1, 2, the spinal cord and medulla oblongata, still hollow; 3, bend at which the pons Varolii is formed; 4, cerebellum; 5, lamina (superior cerebellar peduncles) passing up to the corpora quadrigemina; 6, crura cerebri; 7, corpora quadrigemina, still hollow; 8, third ventricle; 9, infundibulum; 10, thalamus, now solid; 11, optic nerve; 12, aperture leading into the lateral ventricle; 13, commencing corpus callosum.

The 'posterior swelling' becomes bent upon itself so that its two regions (2, 3) are nearly at a right angle; while thence onwards the parts form a curve (4, 5, 6), which is directed forwards and downwards.

This bent tube gradually undergoes various modifications, due to the progressive thinning away of its walls in certain places, and to local thickenings (owing to the growth and development of new nerve matter) in other parts. These latter regions of increased thickness correspond with future ganglionic centres, which gradually, in the regions already indicated, develop into the Cerebellum, Pons Varolii, Corpora Quadrigemina, Crura Cerebri, Thalami, and Cerebral Hemispheres with their enclosed Corpora Striata and 'various commissures.'

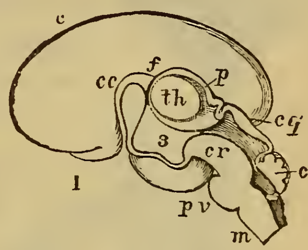


FIG. 124.—Vertical section of the Brain of a Human Embryo of **Fourteen Weeks**, magnified three diameters. (Sharpey, after Reichert.) *c*, Cerebral Hemisphere; *c c*, corpus callosum beginning to pass back; *f*, foramen of Monro; *p*, membrane over the third ventricle and the 'pineal body'; *t h*, thalamus opticus; 3, third ventricle; I, olfactory bulb; *c q*, corpora quadrigemina; *c r*, crura cerebri, and above them the 'aqueduct of Sylvius' still wide; *c'*, cerebellum, and below it the fourth ventricle; *p v*, pons Varolii; *m*, medulla oblongata.

From the 7-9th weeks, the 'middle swelling' or vesicle (Mesencephalon), representing the future Corpora Quadrigemina, is the most prominent segment of the brain. The Cerebellum even at the latter date is represented only by a thin lamella stretching across the back of the upper part of the Medulla, while the future Cerebral Hemispheres exist as mere oblong ampullæ (fig. 122, 3) projecting downward and forwards from the original 'anterior swelling.' From the under part of this same swelling (Thalamencephalon), projects the 'infundibulum,' which either at this time or a little later becomes connected with the Pituitary Body—a structure whose real nature and origin are still involved in much obscurity. From about the eighth week also the Thalamencephalon is so thinned away above (fig. 122, *v*) that the 'third ventricle' becomes covered only by membrane—the 'velum interpositum.' At the upper and posterior margin of this ventricle the 'Pineal body' soon appears, and also its 'peduncles' which extend forwards on each side.

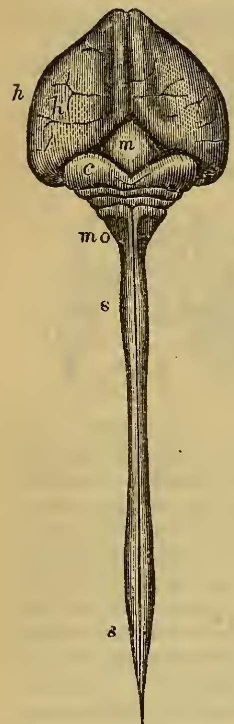


FIG. 125.—Brain and Spinal Cord of a Fœtus of Four Months, seen from behind. (Sharpey, after Kölliker.) *h*, Hemispheres of the Cerebrum; *m*, corpora quadrigemina; *c*, Cerebellum; *m o*, medulla oblongata, the fourth ventricle being overlapped by the Cerebellum; *s s*, the cervical and lumbar swellings of the spinal cord.

By the 12th week of intrauterine life, the configuration of the Brain has undergone a very marked change; first by reason of the increased size of the Cerebellum, (fig. 123, *C*, *c*) which is now thicker and marked by a median longitudinal furrow, though otherwise smooth on its surface; and, secondly, by the still more striking development of the Cerebral Hemispheres (*C*, *a*), which have already grown so much backwards as completely to overlap the 'third ventricle' (fig. 123, *F*, 8). On the under surface of each Hemisphere an Olfactory Lobe is now very distinct, as a hollow bud-like outgrowth, the cavity of which is continuous with that of the Hemisphere from which it projects.

The 'lateral ventricles' themselves are, moreover, continuous with the cavity of the Thalamencephalon, or 'third ventricle,' by an opening on each side of its anterior extremity, known by the name of the 'foramen of Munro.' Near this opening a transverse band begins to appear (above and in front), which connects the two hemispheres and is thought to correspond with the commencement of the great transverse commissure, the Corpus Callosum, and perhaps also with the Anterior Commissure. The walls of the Cerebral Hemispheres are very thin and bag-like at this stage, so that each encloses a very large 'lateral ventricle,' within which a rudimentary Corpus Striatum is to be seen, in the form of a thickening of its under and outer wall. Thus it is that these bodies come to occupy their well-known position anterior to and a little outside the Thalami.

During this same period the 'middle swelling' or Mesencephalon has not grown at all proportionately, so that it now has a much smaller relative size (fig. 124, *c q*). It is, however, marked by the appearance of a slight longitudinal furrow, and its hinder border touches the Cerebellum (*c′*). Its upper walls are comparatively thin, forming the roof of a proportionately large cavity, situated between the third and fourth ventricles, though the cavity subsequently diminishes so as to form a mere passage between these ventricles.

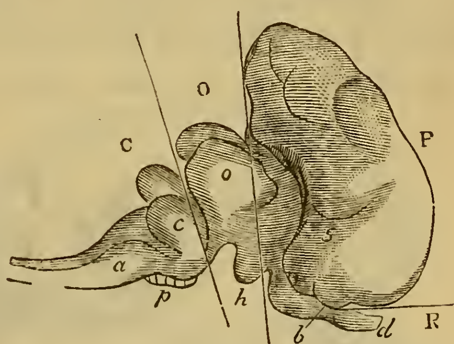


FIG. 126.—Brain of Human Fœtus, of Fourth Month, magnified about two diameters. (Owen.) Side view, with Cerebrum (P) tilted upwards and forwards, so as to uncover the corpora quadrigemina (*o o*), and the bilobed Cerebellum (*c c*).

The relatively large Medulla still preserves its primitive bend. Its upper half is bridged over by the Cerebellum, while at the back of its lower half is the widely open 'fourth ventricle,' the lower part of which is continuous with the central canal of the remaining portion of the primitive tube now developing into the Spinal Cord.

By the **end of the 4th month** the principal additional changes which have been noted are these. The Cerebral Hemispheres become still larger and tend more and more to eclipse other parts. They already stretch back over the future Corpora Quadrigemina (fig. 126).

A rudimentary 'fissure of Sylvius' is to be seen on the outer surface of each, and from this wide and deep sulcus a number of shallow fissures have been described by Gratiolet and others (corresponding with internal prominences on the walls of the lateral ventricles). These appearances are believed by some to be artificial; but whether artificial or natural, all are agreed that they disappear after a time, as the walls of the 'lateral ventricles' become thicker. Then it is that the permanent 'fissures' and 'convolutions' begin to be developed on the external surface of the Cerebral Hemispheres.

At this period, too, the Corpora Striata are distinctly

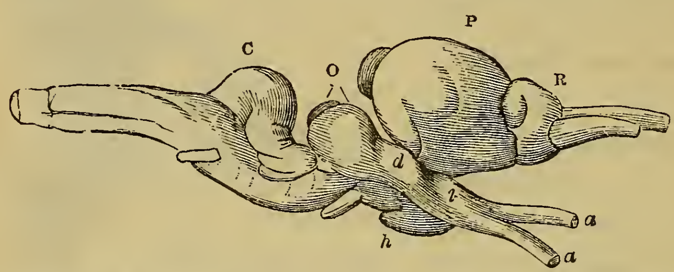


FIG. 127.—Brain of Turtle (*Chelone*), side view, for comparison with last figure. (Owen.) C, Cerebellum; O, optic lobes; P, Cerebrum; R, olfactory lobes.

larger, and not far from their anterior extremities a short and nearly vertical Corpus Callosum is recognizable (not very different from that which exists in Marsupials). The Anterior Commissure is slender but distinct. The Middle or Soft Commissure exists in the form of a large rounded projection from the inner face of each Thalamus, though the two prominences have not yet come into contact with one another, so as to form an actual Commissure.

The cavity within the Optic Lobes is even larger than it was at an earlier date. The lateral lobes of the Cerebellum have developed notably, whilst they are separated from one another (fig. 126, *c*) by a median depression—

indicative of the almost complete absence at this period of the Median Lobe.

On examining the base of the brain, the Medulla is found to be large. The 'anterior pyramids,' and the rudiments of the 'olivary bodies' outside them, are quite distinctly recognizable. A thin band, marked by a median furrow, is to be seen stretching across between the lateral lobes of the Cerebellum. This is the first trace of the 'pons Varolii.' In front of it are the Cerebral Peduncles; between these latter are the 'corpus albicans' and the 'tuber cinereum,' and in front of this last lies the 'commissure' of the Optic Nerves. All the other cerebral nerves are distinctly recognizable, though they are extremely slender at this period.

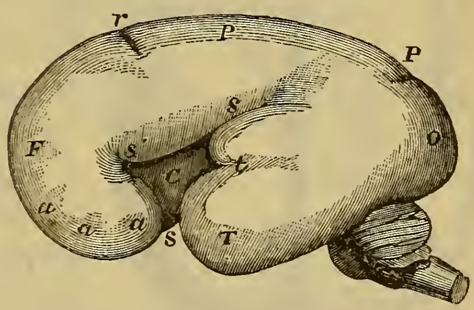


FIG. 128.—The Outer Surface of the Fœtal Brain at Six Months. (Sharpey, after R. Wagner.) This and the next figures are intended to show the commencement of the formation of the principal fissures. F, Frontal lobe; P, parietal; O, occipital; T, temporal; *a a a*, slight appearance of the several frontal convolutions; *s s*, the Sylvian fissure; *s'*, its anterior division; at the bottom of it, C, the central lobe or island of Reil; *r*, fissure of Rolando; *p*, the external perpendicular fissure.

After this epoch the development of the brain goes on, according to Gratiolet, with most surprising rapidity. By the end of the 5th month, the growth of the Cerebral Hemispheres has been so great that they completely cover not only the Corpora Quadrigemina but also the now larger Cerebellum. The 'fissure of Sylvius' is wide and open (fig. 128), so as to leave uncovered the central lobe or 'island of Reil.' The beginning of the 'fissure of Rolando' is, at this period, sometimes recognizable, while the rudiments of convolutions are to be traced upon the frontal lobes and other parts. The walls of the Hemispheres and also of the Optic Lobes have acquired a much greater thickness and the principal 'commissures' have in great part assumed their typical condition. This is the case more especially with the Corpus Callosum and the Fornix, between which the 'fifth ventricle' has begun to appear. The two halves of the Middle Commissure have also grown together.

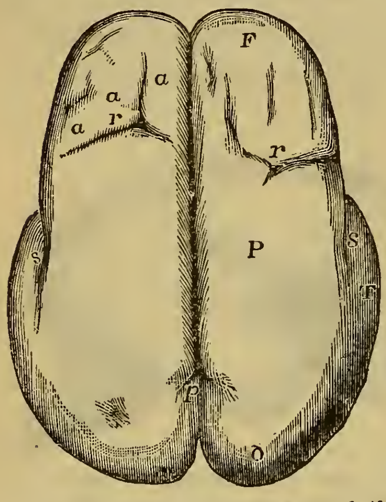


Fig. 129.—The upper surface of the Fœtal Brain at Six Months. (Sharpey, after R. Wagner.) Letters of reference as in last figure.

During the same period the Cerebellum has undergone important changes. From the end of the fourth month the development of its 'lateral lobes' takes place at a slower rate, and the previously absent 'median lobe' not only begins to appear but also becomes marked on the surface by three or four transverse folds. The 'lateral lobes' are still perfectly smooth—though by the end of the sixth month they also have acquired numerous transverse fissures. The pons Varolii, as already intimated, undergoes a development correlative with that of the lateral lobes of the Cerebellum.

In the remaining important section of intrauterine life, **from the 6th to the end of the 9th month,** the developmental changes in the Cerebrum are much more marked than they are in the Cerebellum. The walls of the Cerebral Hemispheres become thicker, and there is a proportionate diminution in the capacity of the 'lateral ventricles,' the three 'horns' of which now become quite distinct. The Corpus Callosum assumes a more horizontal direction, whilst it increases both in thickness and in length. It reaches back as far as the Optic Lobes, which are now marked by a transverse furrow, and thus appear as true 'Corpora Quadrigemina.' The Occipital Lobes of the brain become more developed. The general outline of the Hemispheres seen from above is that of an elongated oval.

During the sixth month a surprising development of the Fissures and Convolutions takes place, so that early in the seventh month all the principal of them are distinctly traceable. Those which manifest themselves first on the external surface are the 'fissure of Sylvius' and the 'fissure of Rolando.' The latter is scarcely distinct till the end of the sixth month, but rather before this period, according to Ecker, two other Fissures appear on the inner aspect of the Hemispheres, viz., the 'internal perpendicular' (fig. 130, P′) marking the anterior boundary of the Occipital Lobe and the 'calcarine fissure' which it meets below. The latter is generally regarded as a pos-

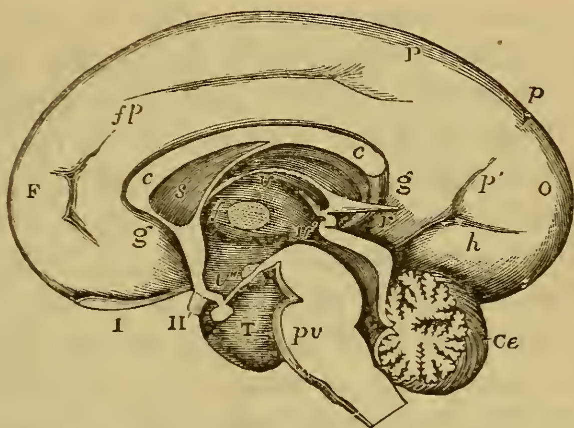


FIG. 130.—View of the inner surface of the Right Half of the Fœtal Brain of about Six Months. (Sharpey, after Reichert.) F, Frontal lobe; P, parietal; O, occipital: T, temporal; I, olfactory bulb; II, right optic nerve; *fp*, callosomarginal fissure; *p*, perpendicular fissure; *p′*, internal perpendicular fissure; *h*, calcarine fissure; *g g*, gyrus fornicatus; *c c*, corpus callosum; *s*, septum lucidum; *f*, placed between the middle commissure and the foramen of Monro; *v*, in the upper part of the third ventricle, immediately below the velum interpositum and fornix; *v′*, in the back part of the third ventricle below the pineal gland, and before the entrance to the 'aqueduct of Sylvius;' *v″*, in the lower part of the third ventricle above the infundibulum; *r*, processus pinealis passing backwards from the tela choroidea; *p v*, pons Varolii; *Ce*, Cerebellum.

terior extension of the 'fissure of the Hippocampus,' which appears about the same time, and is a marking constantly present, even in lower Vertebrates, on the inner side of the brain. Gratiolet indeed believes that this latter fissure is the first to appear on the inner side of the hemisphere. Rather later the 'parallel fissure' of the Temporal Lobe becomes distinguishable, and, as above stated, by the beginning of the seventh month, the other principal fissures of the brain have made their appearance.

Probably Ecker is correct in his view that the precise time at which the principal 'fissures' appear, as well as their exact order of appearance, is subject to some variation in different individuals. Both he and Huxley consider there is no evidence to show that the fissures of the brain of a Chimpanzee or of an Orang do not appear in essentially the same order as those of the Human Infant, notwithstanding the opinion expressed by Gratiolet to the effect that there are certain slight differences.

At the time of birth the development of the convolutions is so complete in the Human Infant that they differ from those of the adult, only by presenting a little less of complication in regard to minor details.

During the attainment of this degree of convolutional complexity, however, some important changes have been taking place in the relative development of the different 'Lobes' of the brain. At the seventh month the Parietal Lobe is notably small,* and apparently as a consequence of this the 'fissure of Rolando' is bent nearly at right angles, just as it is in the brains of the adult Orang and to a less extent in that of the Chimpanzee. At this same period the Frontal Lobe is large, and so also is the Temporal Lobe, though its convolutions are still very imperfectly marked out. The length of the Temporal

* See Gratiolet's "Anat. Comp. du Syst. Nerv.," Pl. xxxi, fig. 1.

Lobe and the extent of the posterior prolongation of the 'fissure of Sylvius' are also notable features of the fœtal brain. We have already had to refer to these characteristics in the brains of many of the Quadrumana, and we shall have occasion again to speak of the same peculiarities as existing among fully developed Human Brains of a low type.

At the period of birth, with the fuller development of the Parietal Lobe, the fissure of Rolando is much less bent. The outline of the Brain seen from above is still that of an elongated oval, though it is one which is distinctly fuller in the frontal as well as in the parietal region than that of the seventh month fœtus represented by Gratiolet—the outline of which agrees almost exactly with the outline of the brain of the adult Bushwoman given by Marshall (fig. 135).

According to S. Van der Kolk and Vrolik it appears that in their relative proportions the lobes of the Brain in a new-born Child, hold just the mean between those of a Chimpanzee and of an adult Man. In the adult Orang, however, the same proportion obtains between its different lobes and those of the new-born Child—so that in this respect, as in several others, the brain of the Orang seems rather more highly evolved than that of the Chimpanzee.

The Cerebellum in the new-born Child is comparatively small. Its proportionate weight compared with that of the Cerebrum at the same period, is lower than in either of the great anthropoid Apes. This, however, is due not to any diminution in the development of the Cerebellum, but rather to the fact that in Man the amount of increase in the size of the Cerebrum is much more considerable than in that of the Cerebellum, and because this greater increase is already, at the time of birth, more manifest in the Cerebrum than in the Cerebellum. This fact was also established by the above-mentioned Dutch Anatomists, since they found that the weight of the Cerebrum in the new-born infant was to its weight in the adult as 96 : 157 ; while the weight of the Cerebellum in the new-born infant was to its weight in the adult only as 22 : 50.

The actual ratio of the weight of the Cerebellum to that of the Cerebrum in the new-born infant was found by Chaussier to vary from 1 : 13 to 1 : 26 ; and by Cruveilhier it was ascertained to be 1 : 20. On the other hand, according to Sharpey, the ratio of the weight of the Cerebellum to that of the Cerebrum in the adult male is $1 : 8\frac{4}{7}$, and in the adult female, $1 : 8\frac{1}{4}$.

From these figures it may be seen how very considerably the development of the Cerebellum lags behind that of the Cerebrum in the Human Infant at the time of birth.

In regard to the microscopical characters of the fœtal brain one brief but important statement deserves to be recorded.

According to Lockhart Clarke*:—"In the early fœtal brain of Mammalia and Man the structure [of the cerebral convolutions] consists of one uninterrupted nucleated network. As development advances separate layers may be distinguished." But even in these layers there are only to be recognized "roundish nuclei connected by a network of fibres," or, in other parts, groups of more elongated nuclei, in place of the distinct but differently shaped Nerve Cells with inter-connecting processes, which, in a later chapter, will be described as the prevailing and characteristic constituents of the Cerebral Convolutions in their developed condition.

* "Notes of Researches on the Intimate Structure of the Brain," *Proceed. of Royal Society*, 1863, p. 721.

CHAPTER XX.

THE SIZE AND WEIGHT OF THE HUMAN BRAIN.

The size and weight of the Human Brain are capable of being estimated in two ways, the one of which may be termed 'direct,' and the other 'indirect.'

We may, of course, measure and weigh the organ when it is accessible, and an enormous amount of labour has been expended in this direction—especially by British observers—upon individuals of different ages, sexes, and conditions.

But when of the representatives of ancient peoples, of foreign nations, or of savage tribes, all that the anatomist possesses are mere brain-cases or skulls, he must, if he would acquire definite notions as to the size and weight of the organs which they previously contained, adopt some uniform and carefully worked-out method for ascertaining their exact cubical capacity. From the figures for 'cranial capacity' thus ascertained, the probable corresponding Brain-weight will, when certain other data are known, be deducible with a fair amount of exactness.

This latter 'indirect' method of procedure is warrantable and capable of giving trustworthy results, because in health the human brain invariably fills the skull to which it belongs, except for the intervention of some thin membranous envelopes with vessels and blood-spaces—for which definite allowances may ultimately be made. Much work, however, still remains to be done before the amount of these allowances or their range of variation for persons of different ages, sexes, and races can be accurately determined; and the same may be said in reference to differences in the size of the 'lateral ventricles,' since either excess or defect of the usual space thus appropriated may also occasionally intervene as a disturbing condition, tending to vitiate an 'indirect' estimation of Brain-weight. Though it is true, therefore, that certain relations ought always to obtain between 'cranial capacities' and Brain-weights, these cannot be said to have been yet determined except in a mere preliminary and tentative manner. According to the general rule laid down by Dr. Barnard Davis a deduction of about 15 per cent. from the capacity of the Cranium gives the 'capacity' of the Brain, and from this its weight may be deduced by calculation.*

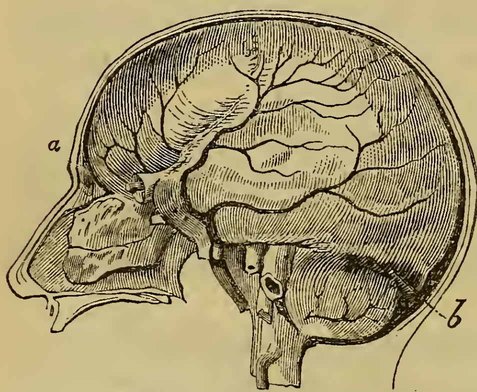


Fig 131.—One side of the Skull removed, showing the Dura Mater with its vessels enveloping the Brain. (After Hirschfeld and Léveillé.) *a*, Commencement of the great longitudinal Venous Sinus, which is continued backward towards *b*. Close to this is situated the meeting-point of several Venous Sinuses.

Both the 'indirect' and the 'direct' methods are of great utility, and either may be had recourse to by the experienced investigator according as Skulls or Brains present themselves for examination. Each method offers certain advantages, but on the whole it may be said that if Brains were always accessible, we should probably hear less on the subject of 'cranial capacities.' The 'indirect' method seems well

* See "On the Weight of the Brain in the Different Races of Man," *Philos. Trans.*, 1868, pp. 506 and 526.

calculated to afford race-averages, or prevailing-weights, where a sufficient number of skulls are carefully measured by a method likely to give uniform and correct results.

It must never be forgotten, however, that the size of the Skull, and with it the weight of the Brain, varies within certain limits according to the stature of the individual, in such a way that increments of increasing stature are accompanied by increments of increased Brain-weight, though the extent of the latter increments goes on diminishing as the stature increases. This statement rests on the authority of Marshall,* who has also calculated from the colossal tables (together with private notes) supplied by Boyd, that for English people, with a mean range in stature of 7 inches for males, the corresponding variation in Brain-weight is 2·75 oz., and that for females, with a mean range in stature of 6 inches, the variation is only 1·25 oz. In comparing the brain-weights of individuals of different stature, therefore, with the view of tracing the influence of other conditions over the weight of the organ, it must always be borne in mind that difference in stature itself is a potent cause of difference in brain-weight which ought to be allowed for in the first instance.

FIG. 132.—Human Cerebrum and Cerebellum, showing the relative size of these parts of the Brain. (After Hirschfeld and Léveillé.)

It may be well to state here, in general terms, that rather less than $\frac{1}{9}$th of a total Brain-weight will, for

* "Proceed. of Roy. Soc.," 1875, vol. xxiii. p. 564.

males, be the proportion of such total corresponding with the weight of the Cerebellum. For females, however, the relative weight of the Cerebellum is rather greater ($1:8\frac{1}{2}$), on account of the existence in them of a greater proportionate diminution in the size of the Cerebrum.

Cranial Capacities.

The average 'cranial capacity' for any race can only be ascertained by the examination of a large series of corresponding skulls, assorted according to Sex. The importance of the latter point is great, because, as Flower points out, difference in Sex, in its influence over capacity of skull, is often decidedly greater than difference of Race.

The methods of estimating the 'cranial capacity' have varied so much at different times, and as adopted by different investigators, as to make it often both difficult and unsafe to compare their results with one another.

It is most important that an international method should be agreed upon, and universally adopted by workers in different countries. We may then, after a time, get results strictly comparable with one another.*

Vogt † gives a table of cranial capacities by different observers, the most interesting items of which have been derived from the researches of Broca upon large numbers of skulls obtained from certain Parisian churchyards, the remains of which for different reasons had to be disturbed. He says:—

* See Flower in "Brit. Med. Journ.," April 12, 1879, p. 540 also a paper by the same author on "Methods and Results of Measurement of Capacity of Crania," in *Rep. of Brit. Assoc.* for 1878.

† "Lectures on Man" (Anthrop. Soc.), p. 88.

"Broca availed himself of the rare opportunity of examining a number of skulls which were found in Paris, on laying the foundation of the new *Tribunal de Commerce*, in a vault, at a depth of three metres, at a spot which was already covered with houses at the time of Philip Augustus. The crania must, therefore, at the latest, date from the twelfth century, many of them possibly from the Carlovingian period. They certainly belonged to individuals of the higher ranks, as they were found in closed vaults."

The average capacity of 115 of these twelfth-century skulls was found to be 1425·98 cubic centimetres.

Another series of skulls was obtained from the Cimetière de l'Ouest, which was used as a cemetery from 1788 to 1824. Of these, which may be called skulls of the nineteenth century, as many as 125 were examined, and they yielded an average capacity of 1461·53 centimetres.

It is not without interest, therefore, to find that in the course of seven centuries of progressive civilization the average Parisian skull seems to have distinctly increased in capacity.

It is, moreover, a remarkable fact, as Vogt points out, "that the difference between the sexes as regards the cranial capacity increases with the development of the race, so that the male European excels much more the female than the Negro the Negress."

Le Bon also has quite recently stated* that the difference existing between the average capacity of the skulls of male and female modern Parisians is almost double that which obtains between the skulls of male and female inhabitants of ancient Egypt.

This again is to be regarded as interesting evidence of

* "Compt. Rend.," July 8, 1878, p. 80. Since this chapter has been in the hands of the printer a longer paper has appeared, by Le Bon, in the *Revue d'Anthropologie*, January, 1879.

the effects of civilization in leading to an increased development of the Brain, for, as Vogt remarks,—

"The lower the state of culture, the more similar are the occupations of the two sexes. Among the Australians, the Bushmen, and other low races, possessing no fixed habitations, the wife partakes of all her husband's toils, and has, in addition, the care of the progeny. The sphere of occupation is the same for both sexes; whilst among the civilised nations there is a division both in physical and mental labour. If it be true that every organ is strengthened by exercise, increasing in size and weight, it must equally apply to the brain, which must become more developed by proper mental exercise."

Again, it has been pointed out by Le Bon that the range of variation in 'cranial capacity' to be met with among different individuals of the male sex seems to be great in proportion to the position of the race in the scale of civilization. "Thus large and small male skulls among Negroes may vary," he says, "by 204 cubic centimetres, among the ancient Egyptians by 353, among twelfth-century Parisians by 472, and among modern Parisians by 593 cubic centimetres." Consequently he holds that the real test of superiority of one race over another in regard to 'cranial capacity' is not to be ascertained by averages, which may be and often are most deceptive, but rather by discovering how many individuals per cent. for different races possess skulls of given volumes. "The superior race," according to Le Bon, "contains many more voluminous skulls than the inferior race. Out of 100 modern Parisian skulls, there will be about 11 specimens whose capacity ranges from 1700 to 1900 cubic centimetres, while among the same number of Negro skulls not a single one will be found possessing the capacities above mentioned." In his more recent and longer paper Le Bon gives the following interesting table of percentages in illustration of these views :—

CRANIAL CAPACITY IN DIFFERENT HUMAN RACES.

Cranial Capacity.	Modern Parisians.	Parisians of the 12th Century.	Ancient Egyptians.	Negroes.	Australians.
Cubic Centimetres.					
1200 to 1300 . .	0·0	0·0	0·0	7·4	45·0
1300 to 1400 . .	10·4	7·5	12·1	35·2	25·0
1400 to 1500 . .	14·3	37·3	42·5	33 4	20·0
1500 to 1600 . .	46·7	29·8	36·4	14·7	10·0
1600 to 1700 . .	16·9	20·9	9·0	9·3	0·0
1700 to 1800 . .	6·5	4·5	0·0	0·0	0·0
1800 to 1900 . .	5·2	0·0	0·0	0·0	0·0

The same writer adds :*—" The cranial capacity of the Gorilla often reaches 600 cubic centimetres, so that it follows that there are a large number of men more allied by volume of brain to the anthropoid apes than they are to some other men."

Brain-Weights.

The mode of weighing the Brain has not always been similar by different observers. Some have been accustomed to strip off its thin enveloping membranes before putting the organ into the scales, while others weigh it and them together. But the weight of 'arachnoid' and 'pia mater' is pretty well known, and would scarcely exceed ¾ or 1 oz. Again, of those who follow the latter and by far the most common method, some have weighed the brain in its entire condition almost as soon as it has been removed from the body; while one observer at least, Dr. Thurnam, has been in the habit of slicing it first and allowing serum and blood to drain away for one to two

* Loc. cit., p. 75.

hours before putting the organ into the scales. By this latter process its total weight may in some cases be diminished by from 1 to 2 oz.*

These being almost the only possible sources of variation, where ordinary care is exercised in the process of weighing, the Brain-weights of different observers are more strictly comparable with one another than are the estimations of 'cranial capacity' by different observers, using, as they mostly have done, very different methods, whose relative indices of variation have not yet been determined.

Of course most of the causes which affect the cranial capacity of individuals would also affect their Brain-weights, and *vice versâ*. But, except in regard to the comparison of ancient with modern races, these conditions have been much more fully worked out in terms of Brain-weight than in terms of cranial capacity.

Some of the principal modifying conditions will now be briefly referred to.

Age.—It was believed by the earlier anatomists, and even by Tiedemann and Sir William Hamilton, that the human brain attained its greatest development at about the seventh year. We now know this to be incorrect; yet from the extensive researches of Dr. Boyd as tabulated by Thurnam (loc. cit., Tab. ix.), it would appear that it does in the male actually reach about $\frac{5}{6}$ths of its ultimate weight by the end of the seventh year, and in the female about $\frac{10}{11}$ths of its ultimate weight by the same period. According to this table, moreover, the maximum weight of Brain, for both sexes, was met with in individuals not exceeding their twentieth year.

* See an excellent paper by Dr. Thurnam, "On the Weight of the Human Brain and on the Circumstances affecting it," *Journ. of Ment. Science*, 1866.

Thurnam from a careful consideration of previously recorded results comes to the following conclusions :—

"It may in general be admitted that the average weight of the brain undergoes a progressive increase to a period somewhere between the twentieth and fortieth year. According to all the tables before us which refer to the sane, the greatest average weight for the male brain is that for the middle decennial period, or from thirty to forty years; and this, as M. Broca observes, agrees perfectly with what we know of the continued development of intelligence during the whole of this period. For women the full average size of the brain is perhaps attained within the preceding decade of twenty to thirty years; but the difference between the two sexes in this respect is not great. From forty to fifty years there is a slight diminution in weight and a greater one between fifty and sixty. After sixty years the rate of decrease is still greater; the process of decay becomes more and more rapid, and thus in the eighth decade of existence the average weight of the brain is less by more than three ounces (80 to 90 grammes) than it was in the fourth decade. In the aged, on the average, the weight of the brain decreases *pari passu* with the intelligence. There are many exceptions to this general law, and some, particularly of the more cultivated and learned class, preserve to extreme age all the fulness and vigour of their faculties. The brain of such men, as the late Professor Gratiolet observes, remains in a state of perpetual youth, and loses little or none of the weight which belonged to it in the prime of life."

Sex.—Thurnam says :—"My own observations fully confirm those of preceding writers as to the average weight of the adult male brain being about ten per cent. greater than that of the female. As Professor Welcker expresses it: 'The brain-weight of the male (1390 grmm.) is to that of the female (1250 grmm.)* as 100 : 90.' Slight variations are observable in the brain-weights of the two sexes, as given by different observers, but it will be seen that the average difference is expressed with much accuracy by these figures."

* That is about 49 oz. and 44 oz. respectively.

The difference between the average weight of the male and female brain, according to Welcker's computation, is 4·94 oz. or 140 grmm.; but according to Dr. Peacock's observations on the Scotch, 5·3 oz. or 150 grmm.

Thurnam says:—

"Some have supposed with Tiedemann that the less size of the brain of the female is due simply to her less stature. This, however, is not the case; and it was long ago shown by M. Parchappe, though from a too restricted number of weights, that the difference was greater than could be accounted for in this way. I am able to confirm this opinion from calculations founded on the great tables of Dr. Boyd for St. Marylebone. For this purpose I have examined and compared the average stature and brain-weight for men and women at the decennial periods from twenty to sixty. . . . . Whilst the brain-weight is nearly 10 per cent. less in the female than in the male, the stature is only 8 per cent. less."

Weight of Body and Stature.—The ratio of Brain-weight to body-weight follows almost precisely the same laws as have been found to hold for lower animals; that is, the ratio diminishes with increasing weight and stature of body, so that, as Tiedemann observed, "the human brain is smaller in comparison to the body the nearer man approaches to his full growth."

It varies also with his degree of obesity. "In lean persons the ratio is often as 1 : 22 to 27; in stout persons as 1 : 50 to 100."

But, as Thurnam says:—"Though it may be questioned whether many useful physiological inferences are to be deduced from the ratio of the brain-weight to that of the body in the two sexes, the comparison of the brain-weight with the stature may yield more valuable conclusions. . . . Parchappe inferred that, other things being equal, the weight of the brain in both sexes is relatively greater in tall persons than in short ones, the difference between the two being at the rate of five per cent.; *i.e.* the brain of a tall man being represented by 100, that of a man of short stature was 95. The difference in women was a little less." This agrees pretty closely with Marshall's more recent computations.

Race.—Comparatively few observations have as yet been instituted in reference to this very large subject—viz. the question of the average or prevailing weight of the Brain in different races of Men. More has been done in this direction in regard to variations of 'cranial capacity.'

Some sort of commencement has, however, been made towards ascertaining the average weight of Brain for the English and Scottish, and, with less precision, that for the French and German people. But the observations made have, as yet, been obtained from too restricted areas, and too much from persons of the same social and educational status.

Thurnam thinks that Welcker's estimate of 1390 grammes or 49 oz. represents the mean weight of male European brains, in persons of twenty to sixty years of age, with considerable accuracy, and he gives the following table showing how the mean brain-weights for the separate people above mentioned stand in regard to it:—

RATIO OF BRAIN-WEIGHT OF DIFFERENT EUROPEAN PEOPLES.

Males.	Ounces.	Grammes.	Ratio of Brain-Weight.
Europeans (*Welcker*)	49	1390	100
English (*Boyd*)	47·8	1354	97
„ (*Peacock*)	49	1388	99
French (*Parchappe*)	47·9	1358	98
Germans, &c. (*Wagner*)	48·3	1371	98·5
Scotch (*Peacock*)	50	1417	102

It will be interesting to place next to this the table given by Thurnam embodying the average results of the weighing of twelve Negro brains.

AVERAGE BRAIN-WEIGHT OF EUROPEANS AND NEGROES COMPARED.

Males.	Ounces.	Grammes.	Ratio of Brain-Weight.
Europeans	49	1390	100
Negroes (*Tiedemann*, 4) .	44·2	1252	90
„ (*Peacock*, 5) . .	44·3	1255	90
„ (*Barkow*, 3) . .	44·5	1261	90
(Average, 12) .	44·3	1255	90

These observations, as Thurnam says, agree in "making the Brain-weight of the male Negro the same as that of the female European." He adds :—"The decided influence of race on the weight of the brain is scarcely to be questioned; and there can be little doubt that the smaller size of the brain in other melanous and lower races will hereafter be made out by direct observation. The brains of the Hindoo, Hottentot, Bushman, and Australian, are probably of less weight even than that of the Negro; but in all these comparisons the stature must be considered." *

Records of the Brain-weight of males belonging to these latter races are not as yet forthcoming; but from the ascertained weight of three female Bushwomen, as well as from what we know of the cranial capacity of the races mentioned, it may fairly be anticipated that their

* There is some reason to believe that, to a certain extent, as we go northwards the average human stature increases, and with it the average cranial capacity and brain-weight. Yet the Lapps and Esquimaux are extremely short, though their cranial capacities remain unusually high.

weight of brain would fall distinctly below that of the Negro.

The brain of a Bushwoman examined by Professor Marshall was computed to be 31·5 oz., while he has calculated that the brain of an average Englishwoman of about the same age and stature would have weighed not less than 40 oz. The brain of another Bushwoman, commonly known as the "Hottentot Venus," who was examined by Gratiolet, is said to have been a trifle larger, though the exact weight was not ascertained. Lastly—though first in order of time—Dr. Quain recorded the weight of a Bosjes girl, fourteen years of age, and forty inches in height, as 34 oz., or 963 grammes. This, as Dr. Thurnam points out, "falls short even of the average weight of the brain of the female English child between two and four years of age, in whom, according to the tables of Dr. Boyd, the brain-weight is 34·97 oz. (991 grammes), and the average stature 31·6 inches." Seeing, moreover, as Dr. Boyd's tables also show, that by the end of the seventh year the brain of the female has attained to at least ten-elevenths of its full weight, the brain of this Bosjes girl is not likely to have been much behind the weight to which it might have attained in the adult condition.

The Chinese are representatives of the most ancient and persistent, if not the most advanced civilization of the world, and quite recently the brain-weights of eleven adult males and of five adult females have been recorded by Dr. C. Clapham.* "With the exception of one individual they all belonged," he says, "to the 'Coolie,' or lowest grade of Chinese society," yet their brain-weights were remarkably high, when it is considered that they were in no way picked individuals, but mere chance victims of the great typhoon which raged at Hong Kong in September, 1874. The possible influence of Congestion, owing to the mode of death, in slightly raising these brain-weights must, however, not be forgotten.

* "Journ. of the Anthropolog. Inst.," vol. vii. p. 90.

Brain-Weights of Sixteen Chinese.

Males.

No.	Probable Age.	Weight.
1	30	$49\frac{3}{4}$
2	28	50
3	45	$53\frac{1}{2}$
4	40	56
5	50	$49\frac{3}{4}$
6	40	48
7	25	$46\frac{1}{2}$
8	48	54
9	55	$49\frac{1}{2}$
10	35	$51\frac{3}{4}$
11	30	$46\frac{1}{4}$
	Average	50·45

Females.

No.	Probable Age.	Weight.
1	26	$45\frac{1}{2}$
2	38	49
3	30	44
4	70	$42\frac{1}{2}$
5	18	$46\frac{1}{4}$
	Average	45·45

The significance of these figures will hereafter be referred to.

Mental Power and Degree of Education.—Under this head we may briefly pass in review what is known as to the correlation in the human subject of Intelligence and degree of Education, with size and weight of Brain. Many more facts are needed before much light can be considered to be thrown upon this subject; and, moreover, some of the data at present in our possession seem at first sight rather contradictory. The contradiction is, however, more apparent than real.

Some hints have already been given upon this subject, in what has been said as to the greater capacity of skull and weight of Brain in uncivilized as compared with civilized races, and also in reference to the greater cranial capacity of Parisians of the nineteenth as contrasted with those of the twelfth century. Other facts having the same general bearing may now be referred to. It was, for instance, ascertained by Dr. Thurnam, that the average brain-weight of insane males belonging to the more educated middle class in the York Retreat was decidedly above that of paupers who died in the county asylums of Somerset and Wilts.* Brooa has also made some investigations in order to ascertain the dimensions of the heads of a number of students of the École de Médecine as compared with those of a number of servants in the large hospital of the Bicêtre, with the result of showing a distinct preponderance in favour of the students. This latter statement is, however, not easy to understand, unless we are to believe that the superior education of the students has, during their own individual lives, given rise to a distinctly increased size of Brain and of head. Among the ancestors of the students and the servants it is quite possible that, in many instances, the relative degree of education and amount of habitual exercise of brain may have been reversed. If Broca could measure the heads of these two sets of persons again—that is the same individuals—after an interval of ten years, the relative difference between these two measurements of the two classes might yield some interesting information. But would any difference be observed in the two sets of measurements after such an interval, and if so could it be ascribed to the effects of superior brain exercise? These very doubtful questions remain to be solved.†

* The difference was not nearly so well marked between the brain-weights of the females of these two classes; a fact harmonious with others already, and subsequently to be, cited, showing that the range of variation in them under the influence of various conditions is less than it is for the brain of men.

† Le Bon has also given a table showing the prevailing circumferential Head measurements (which ranged from 52 to 62·5 centimetres) of individuals belonging to different social classes, at present living in Paris, and who, from their differences in

Any considerable number either of Skulls or Brains will generally be found to contain representatives of three artificial series into which it is convenient to divide them. First, those of medium capacity or weight; second, those which are more or less decidedly small (microcephalous); third, those which are more or less decidedly large (megalocephalous). For Brain-weights Thurnam has fixed upon the following numbers, as those most expedient to adopt in the separation of such classes from one another.

Microcephalous Brains.	Brains of Medium Size.	Megalocephalous Brains.
a.—Incipient Microcephaly.	Men. — 40–$52\frac{1}{2}$ oz. or 1130–1490 grammes.	*a.—Incipient Megalocephaly.*
Men. — 40–$37\frac{1}{2}$ oz. or 1130–1062 grammes.	Women.—35–$47\frac{1}{2}$ oz. or 990–1345 grammes.	Men. — $52\frac{1}{2}$—55 oz. or 1490–1560 grammes.
Women.—35–$32\frac{1}{2}$ oz. or 990–920 grammes.		Women.—$47\frac{1}{2}$–50 oz. or 1345–1417 grammes.
b.—Decided Microcephaly.		*b.—Decided Megalocephaly.*
Men.—Under $37\frac{1}{2}$ oz. or 1062 grammes.		Men.—55 oz. or 1560 grammes, and upwards.
Women.—Under $32\frac{1}{2}$ oz. or 920 grammes.		Women. — 50 oz. or 1417 grammes, and upwards.

This is a useful table, since it shows the wide range of variation to be met with in the brain-weights both of Men and of Women; it may, however, be supplemented by the conclusions of Dr. Sharpey as deduced from a

mode of life, are accustomed to exercise their Intelligence in different degrees. The prevailing measurements show a distinct decrease in the order of his four classes, whom he designates:—1, Savants et lettrés; 2, Bourgeois Parisiens; 3, Nobles d'anciennes familles; 4, Domestiques Parisiens."

careful tabular analysis made by him of the brain-weights recorded by Sims, Clendinning, Tiedemann and Reid. Having rejected from his table all those cases in which cerebral disease is reputed to have existed, Dr. Sharpey says :—

"According to this table the maximum weight of the adult male brain in a series of 278 cases was 65 oz.; and the minimum weight 34 oz. In a series of 191 cases the maximum weight in the adult female was 56 oz.; and the minimum 31 oz.; the difference between the extreme weights in the male subject being no less than 31 oz., and in the female 25 oz. The weight of the adult male brain appears, therefore, to be subject to a wider range of variety than that of the female. By grouping the cases together in the manner indicated by brackets, it is found that in a very large proportion the weight of the male brain ranges between 46 oz. and 53 oz., and that of the female brain between 41 oz. and 47 oz. The *prevailing* weights of the adult male and female brain may therefore be said to range between those terms; and by taking the mean an average weight is deduced of 49½ oz. for the male, and of 44 oz. for the female brain,—results which correspond closely with the statements generally received. . . . The general superiority in absolute weight of the male over the female brain is shown by Table 2 to exist at every period of life. In new-born infants the brain was found by Tiedemann to weigh 14½ oz. to 15¾ oz. in the male, and 10 oz. to 13¼ oz. in the female."

(*a*)—*Some of the Conditions coinciding with low Brain-weights* :—The average brain-weight of persons dying in Lunatic Asylums has been found to be distinctly lower than that of persons of the same class who are not insane. Some of this diminution of the average brain-weight among the insane generally, is doubtless due, as Thurnam suggests, to partial atrophy of the convolutions; though some of it may also be attributable to initial smallness of brain in certain of the representatives of this asylum class. But, as the same writer remarks,—"The average brain-weight of those dying in asylums is made up of weights which are above the average of the healthy brain, and of others which are materially below it." In general the latter greatly preponderate, and therefore it is that the average is low; but among Epileptics in asylums, and occasionally among simply demented patients, the brain has not unfrequently been found to be considerably above the normal or average weight for sane individuals.

In congenital Imbeciles and Idiots the average weight of the brain is still lower than it is among those in whom Chronic Insanity has supervened during adult life. From an examination of twenty-two brains of idiots, some of whom were also epileptics, Dr. Thurnam obtained an average weight for fourteen males of 42 oz., or 1,190 grammes, and for eight females a weight of 41·2 oz., or 1,167 grammes. The average of the latter is curiously enough almost identical with that of the rest of the female insane of the same series; though that of the male brains is very decidedly less. Idiocy is, therefore, not necessarily associated with a very small size of brain: though this is frequently the case, still various deficiencies in the internal structure and finer development of the brain may also entail a similar condition of mental defect.

Among 50 brains of Idiots examined by Dr. Langdon Down, whose ages ranged from 5 to 33 years, the minimum weight in a boy of 18 was 15 oz. (425 grammes); the maximum weight in a man of 22 was as much as 59·5 oz. (1,404 grammes). The latter weight was in all probability one which had been augmented to a considerable extent by morbid tissue changes of a kind to which reference will presently be made.

Where the weight of the Brain falls below a certain minimum standard, the possession by its owner of anything like ordinary Human Intelligence seems to be impossible. Gratiolet, without specifying the sex, supposed this lower limit of weight to be about $31\frac{3}{4}$ oz., or

900 grammes. Broca places it somewhat higher, fixing upon 32 oz., or 907 grammes, as the limit for the female, and 37 oz., or 1,049 grammes, as the lower limit of weight for the male brain, compatible with ordinary Human Intelligence.

The brain-weight of Idiots may, however, and frequently does, fall far below the limits above assigned, and that either from atrophic disease ensuing some time after birth or from congenital defect. Subjoined is a table given by Thurnam of the lowest fifteen brain-weights as yet recorded among Idiots:*—

BRAIN-WEIGHTS OF SMALL-HEADED IDIOTS.

Males.

No. Observer.	Age.	Weight of Brain. Oz.	Grmm.
1. Thurnam .	29	35·76	1013
2. „ .	22	35·5	1006
3. Parchappe .	45	34·2	970
4. Thurnam .	52	32	907
5. Peacock .	11	21 2	600
6. Down. .	18	15	425
7. Owen. .	22	13·12	372
8. Theile. .	26	10·6	300
9. Marshall .	12	8·5	241

Females.

No. Observer.	Age.	Weight of Brain. Oz.	Grmm.
1. Bucknill .	37	32·5	921
2. Sims . .	12	27	765
3. Parchappe .	25	25·4	720
4. Tuke . .	70	22·75	644
5. Tiedemann.	16	19·9	563
6. Gore . .	42	10	283

(*b*)—*Some of the Conditions coinciding with high Brain-weights:*—Very low brain-weights are, as we have seen, only consistent with Dementia or Idiocy. Very high brain-weights may, however, be met with, either (1) in association with these same morbid conditions or among insane persons belonging to other categories; (2) in very ordinary sane individuals; or (3) among the most highly intellectual members of society. That the latter asso-

* Loc. cit., p. 29. References to the original descriptions of these brains are cited.

ciation should be encountered is harmonious enough with commonly received beliefs, though the existence of the two former will be regarded, at first sight, as altogether anomalous. But it is not so anomalous as it may seem.

(1.) In regard to associations of the first order Thurnam found that in about 10 per cent. of the males and 7 per cent. of the females who died in the Wilts County Lunatic Asylum, the brain-weight exceeded the upper limit of the "medium size," viz., $52\frac{1}{2}$ oz. and $47\frac{1}{2}$ oz. respectively; while in from 3 to 4 per cent. decidedly megalocephalous weights were met with—that is, above 55 oz. and 50 oz. respectively. These facts agree pretty closely with the observations more recently published by Dr. C. Clapham,* although the proportion of decidedly megalocephalous weights was found by this latter observer to be slightly higher in his larger series of brain-weights obtained from a more northern English Asylum. Thus, among 700 male brains there were no less than 43 the weight of which was 55 oz. and upwards—and of these 4 weighed even as much as 60–61 oz.†

In reference to the brain-weights met with in the Wilts Asylum, Thurnam says:—

"The large brains above reviewed are with little exception those of persons in the labouring or artisan class, and if in any of them there was an unusual degree of intelligence, the sphere for its exercise must have been very limited. The heaviest brain weighed

* West Riding Asylum Reports, vol. vi., 1876.

† Is the lower percentage of decidedly megalocephalous brains met with by Thurnam, to be accounted for by the difference in geographical area from which the above two sets of patients were derived? or may it not be just as much due to the fact that Thurnam's weighings were made after previous slicings and prolonged drainage of blood and serum had taken place? (see p. 353.)

by me (62 oz., or 1,760 grammes) was that of an uneducated butcher, who was just able to read, and who died suddenly of epilepsy combined with mania, after about a year's illness. . . . . The heaviest brain-weight recorded by Dr. Bucknill is that of a male epileptic, aged thirty-seven; and in this instance the brain weighed 64·5 oz., or 1,830 grammes, which was the weight of the brain of the celebrated Cuvier. With one exception the maximum weight observed by M. Parchappe was also that of an epileptic man, aged thirty-one, in whose case the brain weighed 61·3 oz., or 1,737 grammes. The *heaviest female brain* of which I find any mention, is recorded by Dr. Skae. The patient was not epileptic, but laboured under monomania of pride, dying at the age of thirty-nine of an exhausting disease—phthisis. *The brain had, for a woman, the monstrous weight of* 61·5 *oz., or* 1,743 *grammes.*"

It is possible that these decidedly heavy Brain-weights may be met with in a slightly higher ratio among the insane than among the sane members of any particular class, and this for the following reasons:—*First*, Insanity is a condition dependent upon various morbid states which may perhaps be said to be equally prone to occur in large-brained and in small-brained individuals; *secondly*, in some of the cases of this disease, with or without the association of Epilepsy, the organ or considerable parts of it tend to become indurated, owing to a disproportionate development or actual overgrowth of the lower and functionally inert constituents of the brain—its mere connective tissue or 'neuroglia'—just as other organs of the body, the liver for instance, may be spoiled functionally though actually increased in bulk, owing to a similar connective tissue overgrowth. This is a condition apt to be met with in confirmed Epileptics. And, *thirdly*, should one of these latter patients happen to die in a fit, great fulness of the blood-vessels of the brain may operate as another cause tending to augment the brain-weight—as it is well known to do in whatever way the congestion may have been produced. Wagner has called special attention to this, and to the fact that brain-weights are affected not only by length and kind of illness, but by mode of death.*

(2.) But again, high Brain-weights have occasionally been met with by many observers in the examination of the bodies of quite ordinary, common-place individuals, who during life have neither been insane nor notable for any unusual degree of intelligence.

Perhaps the largest set of tables from which we can obtain trustworthy information on this subject has been supplied by Dr. Peacock, and concerning these Thurnam writes:—

"In Dr. Peacock's tables, out of the 157 weights of brains of adult Scotchmen, between twenty and sixty years of age, there are four in which this ranged from 61 oz. to 62·75 oz., or from 1,728 to 1,778 grammes. They were all apparently of the artisan class; the occupation of three of them being those of sailor, printer, and tailor respectively. The causes of death were fever, delirium tremens, and in two cases severe compound fracture. All were [affections] more or less liable to be attended with cerebral congestion; and there is nothing to show that these individuals were distinguished from their fellows by superior endowments."

The heaviest Human Brain as yet on record seems also to have belonged to a person of this class. A brief account of it has been published by Dr. James Morris.† The man from whom it was taken was a bricklayer, thirty-eight years of age, who died from pyæmia in University College Hospital in 1849, shortly after a surgical operation.

Dr. Morris says:—"The weight of the brain, taken immediately on removal, exceeded 67 oz. This weighing was most carefully made, and was witnessed by several students. The brain was well proportioned; the convolutions were not flattened, though the sur-

* Vorstudien, 1862, 2te Abh., pp. 93-95.

† "Brit. Med. Journ.," Oct. 26, 1872, p. 465.

face was fairly moist; it only lost about one ounce weight after the usual dissection and draining for two hours." The man's height was five feet nine inches, and he was of a robust frame. It was difficult to obtain any satisfactory history of him—his wife and his landlady gave different accounts. It seemed, however, that he was a native of Sussex; that he "had left his native village and changed his name on account of some poaching troubles; that he was not very sober; had a good memory, and was fond of politics. He could neither read nor write." Whatever his potentialities might have been, therefore, it is evident that his actual acquirements were not great.

(3.) The comments which we shall have to make on these latter cases will be better reserved till some illustrations have been given of the existence of high Brain-weights among men of great mental powers and acquirements—some of whom in their various spheres of life and occupation have been among the foremost representatives of Human Intelligence. Subjoined is a list given by Thurnam, together with eight additional brain-weights, viz., those of Schiller, Agassiz, Professor Goodsir, Sir James Simpson, Mr. Chauncey Wright, De Morgan, Grote, and Dr. Hughes Bennett.*

BRAIN-WEIGHTS OF DISTINGUISHED MEN.

Name.	Age.	Ounces.	Grammes.
1. Cuvier, *Naturalist* . . .	63	64·5	1830
2. Abercrombie, *Physician* . .	64	63	1785

* References will be found in Dr. Thurnam's paper for the place of record of most of these high brain-weights tabulated by him. The eight *additional* weights here given have been, in the above order, thus referred to, published, or ascertained:—(1) Schiller and Agassiz, by Daniel Wilson, in "Canadian Journal," Oct. 1876; (2) Goodsir's "Anatom. Memoirs," vol. i. p. 195 (1868); (3) "Med. Times and Gaz.," May 14, 1870, p. 532; (4) Thos. Dwight in "Proceed. American Acad. of Arts and Sciences," vol. xiii. (1878); (5) Examination made by Dr. Wilson Fox and the writer in 1871; (6) Examination by Prof. Marshall in 1871; (7) "Brit. Med. Journ.," Oct. 9, 1873.

Name.	Age.	Ounces.	Grammes.
3. Schiller, *Poet*	46	63	1785
4. Goodsir, *Anatomist* . . .	53	57·5	1630
5. Spurzheim, *Physician* . .	56	55·06	1559
6. James Simpson, *Physician* .	59	54	1533
7. Dirichlet, *Mathematician* . .	54	53·6	1520
8. De Morny, *Statesman* . .	50	53·6	1520
9. Daniel Webster, *Statesman* .	70	53·5	1516
10. Campbell, *Lord Chancellor* .	80	53·5	1516
11. Chauncey Wright, *Physicist* .	45	53·5	1516
12. Agassiz, *Naturalist* . . .	66	53·3	1512
13. Chalmers, *Celebrated Preacher* .	67	53	1502
14. Fuchs, *Pathologist* . . .	52	52·9	1499
15. De Morgan, *Mathematician* .	73	52·75	1496
16. Gauss, *Mathematician* . .	78	52·6	1492
17. Dupuytren, *Surgeon* . . .	58	50·7	1436
18. Grote, *Historian* . . .	76	49·75	1410
19. Whewell, *Philosopher*. . .	71	49	1390
20. Hermann, *Philologist* . .	51	47·9	1358
21. Hughes Bennett, *Physician* .	63	47	1332
22. Tiedemann, *Anatomist* . .	80	44·2	1254
23. Hausmann, *Mineralogist* . .	77	43·2	1226

It is worthy of note that in this list, in addition to the great proportion of high Brain-weights, there are also four of distinguished men, which, even after allowance has been made for some amount of atrophy consequent upon age in two of them, would more or less distinctly fall beneath the mere average weight of 49 oz.

The facts set forth in the above table as well as those detailed in the last section, are principally of interest from their bearing upon the much and long-debated question as to the existence of any necessary or invariable connection between *mere size or weight of Brain and Intelligence*. Upon this subject a few brief remarks may now be made.

In the first place then, it seems perfectly plain from the facts recorded that there is no necessary or invariable relation between the degree of Intelligence of human beings and the mere size or weight of their Brains. We have seen that some demented persons may have very large brains ; and again, that in certain very ordinary members of society, suffering neither from disease nor from congenital defect, the brain may be decidedly large and heavy. On the other hand men of great acquirements, of acknowledged mental power, and one or two even of European fame, may have been, whilst in their prime, possessed of brains either below or only slightly exceeding the average weight of the male brain in civilized races, viz., 49 oz.—showing that a well-constituted Brain of small dimensions may be capable of doing much better work than many a larger organ whose internal constitution is, from one or other cause, defective.

Looking, in fact, to the mere size and weight of a Brain, it must never be forgotten that these may be notably augmented by overgrowth of its mere inert connective tissues; or even if morbid tissue changes be absent, that an organ of large size or weight may yet be a more or less inferior perceptive or thinking instrument by reason of its inner and finer developments being defective and badly attuned for harmonious action. Or again, it may be a defective instrument by reason of some still more subtle, and mere molecular peculiarities of the nerve elements of which it is composed—whereby these are perhaps both less receptive and less 'retentive' of those Sensorial Impressions which constitute the raw material of Intelligence, and also less capable than they might be of taking part in higher Mental Operations.

There is, therefore, no invariable or necessary relation between the mere Brain-weights of individuals and their degrees of Intelligence. But should it be asked whether the proportion of megalocephalous Brains among highly cultured and intelligent people is likely to be greater than among uncultured and non-intelligent people, the answer to this question may be unmistakeably in the affirmative—and this, as Le Bon has pointed out in regard to 'cranial capacities,' is the real direction in which we ought to look for evidences of class or racial superiority.

This modified or more correct form of an old notion is based upon various facts which give it a very distinct support. As previously stated, the proportion of 'decidedly megalocephalous' male brains has been found, among the lower and less educated members of society, to range between 4 and 6 per cent. for persons under sixty years of age; while in the above table of Brain-weights of Distinguished Men (which, be it observed, is in no sense a selected list, since it comprises all such weights known to the writer as having been recorded) the proportion of those exceeding 55 oz. amounts to nearly 23 per cent., and might have been much larger still had it not been for the great age of some of the distinguished individuals whose brains were examined. For, notwithstanding a marked amount of senile atrophy in some of these brains no less than eleven of them still weighed 52½ to 55 oz. It seems quite possible that those of Sir James Simpson, Daniel Webster, Lord Campbell, and Professors De Morgan and Gauss, may each have exceeded 55 oz. in weight when these distinguished men were not only in good health but distinctly under sixty years of age. And in this case the number of 'decidedly megalocephalous' Brains among these twenty-three Distinguished Men would be raised to about 45 per cent. The list is small from which to draw any conclusions, but the difference in proportion indicated seems to be far too great to be attributable to mere chance.

Apart from the existence of actual morbid changes, the large size of an organ such as the Brain gives, perhaps, a more than average warrant that its inner development will be adequately carried out, and that the organ will be highly endowed with its own proper kind of vitality. If however it does not fall short in either of these respects, an increased size of Brain ought to be a distinct advantage for its owner; and, should the general and special conditions of life be at all propitious, would be likely to favour the development of great Mental Power or the acquisition of much Learning.

The tendency to the occurrence of high Brain-weights in much larger proportion among the civilized than among uncivilized or little civilized races has been already referred to in this chapter. This, together with the other most noteworthy and well-established fact, that such differences of brain-weight are found to be far more marked among the Men than among the Women when higher and lower races are compared, affords most valuable evidence to show the extent to which the Human Brain has, in the course of many generations, gone on increasing in size under the influence of that augmented use and exercise apt to be entailed by a life passed in a state of Civilization.

But the longer a state of Civilization has existed among any particular people, the more generally diffused among the individuals of such a people should be the tendency to inherit a brain of full dimensions. And, except it be due to some quasi-accidental and little understood race distinctions, how else are we adequately to explain the remarkable series of Chinese brain-weights published by Dr. C. Clapham? In these sixteen chance individuals of the Coolie class the brain-weights are distinctly above the average for English, French, or Germans, of the same social grade, and, though to a less extent, also above that for Scottish Lowlanders.

Be the cause what it may (and their mode of death must not be forgotten), it would scarcely be possible to point to such another series of figures for any sixteen chance individuals—with the single exception of those recorded in our table of 'Brain-Weights of Distinguished Men.'

It is not at all necessary to suppose that the individual Chinese Coolies were capable of displaying any notable amount of intellectual 'acquirement' or 'power,' in order to justify their possession of such large brains. Dr. Clapham records a fact of some significance in this connection when he says:—"Of the *capacity* of the Chinese Coolie class for learning I am not inclined to speak so lightly, but on the contrary am convinced of their natural aptitude in this direction." We have in these facts, perhaps, just what might be expected as a result of a very long-continued antecedent civilization even of a low order, viz., the inheritance of a large Brain together with a good aptitude or 'capacity' for learning.*

The Brain is different from all other organs of the body. It is often a mass of structural potentialities rather than of fully-developed nerve tissues. Some of its elements, viz., those concerned with best-established Instinctive Operations, naturally go on to their full development without the aid of extrinsic stimuli; others, however, and large tracts of these, seem to progress to such developments only under the influence of suitable stimuli. Hence natural aptitudes and potencies of the most subtle order may never be manifested by multitudes of persons, for want of the proper stimuli and practice capable of perfecting the development and functional activity of those

* See pp. 351-353, where some facts are mentioned tending to show that Civilization, acting through long periods, does help to bring about an increase in the size of the brain.

regions of the brain whose action is inseparably related to the mental phenomena in question.

The development here referred to is of the finer sort; that which, to some extent, eludes our present means of observation. Its establishment may be associated with an altogether insignificant increase of weight, and perhaps no increase in size, of the organ as a whole. Yet a development of previously embryonic Nerve Cells, together with an establishment of multitudinous new connections between them, by means of 'intercellular processes' and 'commissural fibres,' may have been taking place throughout large tracts and areas of the Brain, to an extent which it is altogether impossible for us adequately to realize.*

That this is no mere fancy is in part evidenced by other facts previously stated, viz., that the male brain actually attains $\frac{5}{6}$ths, and the female brain $\frac{10}{11}$ths of its total ultimate weight by the end of the *seventh* year—although, at this time, the inner and finer structural development of the organ is, in all its higher tracts, still in a comparatively embryonic condition. Even such data might, therefore, be considered to show, in the strongest manner, how comparatively unimportant is mere bulk or weight of Brain in reference to the degree of Intelligence of its owner, when considered, as it often is, apart from the much more important question of the relative amount of its grey matter, as well as of the amount and perfection of the minute internal development of the organ either actual or possible.

* See p. 346, for the statement made by Lockhart Clarke as to the characteristics of the embryonic or undeveloped nerve elements met with in the Cerebral Convolutions of the fœtus.

CHAPTER XXI.

THE EXTERNAL CONFIGURATION OF THE HUMAN BRAIN.

The Brain of Man belongs to the same type or pattern as that met with among Apes and Monkeys. Whatever interpretation may be put upon it, this fact itself is too obvious to admit of any doubt. The same general shape is to be seen, the same lobes, the same principal fissures.

It is true that important differences are also encountered. The relative size and development of the several Lobes is not the same. There is again in the brain of Man a much greater richness and complicacy of the 'secondary' fissures and Convolutions; whilst a difference eclipsing all others in importance is to be found on the side of weight. The maximum Brain-weights that have, as yet, been encountered among the great 'man-like' Apes, range from 12–16 oz., although the body-weight of some of these creatures equals or may even greatly exceed that of an ordinary Man.

Striking, however, as the difference is, between the brain-weights of the great 'man-like' Apes and those of ordinary human beings, it must not be forgotten that the actual range of variation met with among individual Men is still greater. Some persons may exhibit distinctly human attributes and mental powers, though possessing brains which do not exceed 32 oz. in weight, whilst the same organ in other Men may rise to a maximum of 64–67 oz. Such facts, together with others already cited, certainly imply the existence, in the Brain of Man, of a remarkable capacity for growth and development, under the long-continued influence for generation after generation of those modes of life and cerebral activity which are almost inseparable from existence in a more or less Civilized Community.

In studying the external configuration of the Human Brain, it will be most expedient, in the first place, to look

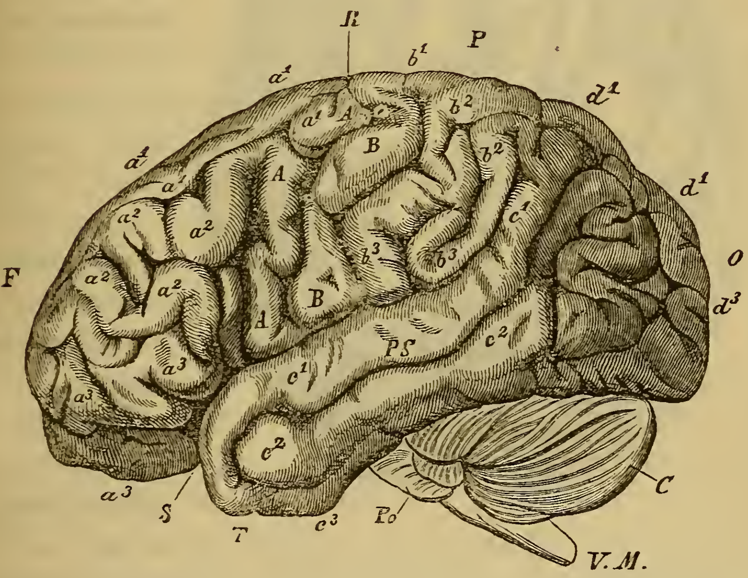


FIG. 133.—Brain of the Hottentot Venus, side view. (Vogt, after Gratiolet.) *F*, Frontal lobe; *P*, parietal lobe; *O*, occipital lobe; *T*, temporal lobe; *C*, Cerebellum; *Po*, pons Varolii; *V M*, medulla oblongata; *S*, Sylvian fissure; *R*, fissure of Rolando; *P S*, parallel fissure. a^1, Upper fold of frontal convolutions; a^2, middle fold of frontal convolutions; a^3, lower fold of frontal convolutions. *A*, Ascending frontal (or anterior central) convolution; *B*, ascending parietal (or posterior central) convolution; b^1, b^2, b^3, upper, middle and lower folds of parietal convolutions; c^1, c^2, c^3, upper, middle and lower folds of temporal convolutions; d^1, d^2, d^3, upper, middle and lower folds of occipital convolutions.

to the characters of the organ as it exists in one of the lower races of Mankind. We may then advantageously compare one of these simpler types with the more highly evolved forms of the same organ, such as are common among representatives of the higher civilized races.

The brain of the so-called 'Hottentot Venus' was carefully examined and figured by Gratiolet. Though her intelligence was not notably defective, the convolutions of her brain were relatively very little complicated. After commenting upon this fact, Gratiolet adds:—"But what strikes one, at once, is the simplicity, the regular arrangement of the two convolutions which compose the superior angle of the frontal lobe. These folds, if those of the two hemispheres be compared, present, as we have already pointed out, an almost perfect symmetry, such as is never exhibited by normal brains of the Caucasian race. . . . . This regularity—this symmetry, involuntarily recalls the regu-

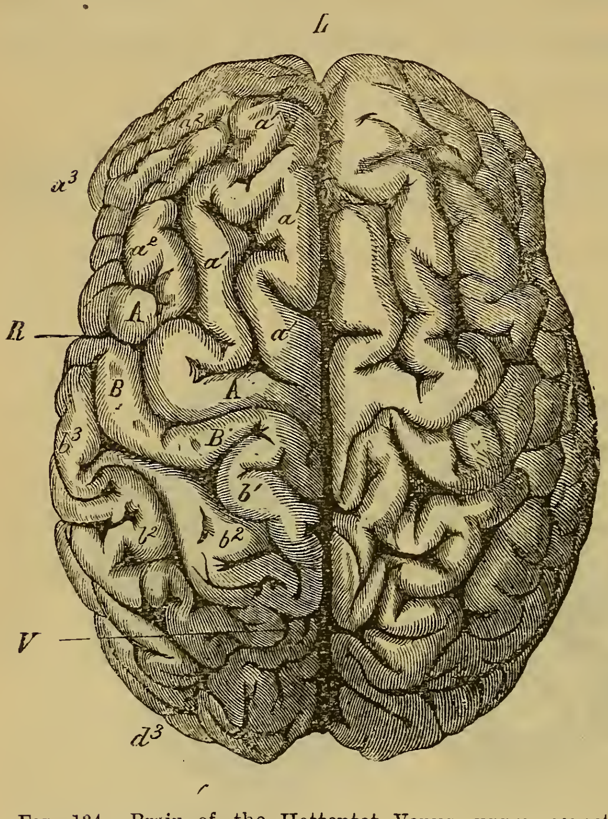


FIG. 134.—Brain of the Hottentot Venus, upper aspect. (Vogt, after Gratiolet.)

L, Longitudinal fissure; *R*, fissure of Rolando; *V*, vertical or perpendicular fissure; *O*, occipital lobe. a^1, a^2, a^3, Upper, middle and lower folds of frontal convolutions; *A*, ascending frontal, and *B*, ascending parietal convolutions; b^1, b^2, b^3, upper, middle and lower folds of parietal convolutions; d^3, lower fold of occipital convolutions.

larity and symmetry of the cerebral convolutions in the lower species of animals. There is, in this respect, between the brain of a white man and that of this Bosjesman woman a difference such that it cannot be mistaken; and if it be constant, as there is every reason to suppose it is, it constitutes one of the most interesting facts which have yet been noted."

The most complete description we at present possess, however, of the Brain of a representative of one of these lower races has been given by Prof. Marshall in his Memoir on the brain of a Bushwoman.* The organ in this South African woman was decidedly small, as will have been gathered from what has been said in regard to it in the last Chapter (p. 359). Certain portions of Marshall's description are here reproduced in his own words.

General Shape of the Cerebrum. "When viewed from above, the Bushwoman's Cerebrum, like her cranium, presents a long and narrow ovoid form. The line of greatest width corresponds with the parietal eminences, and is placed rather far back, viz., at two-thirds of the total length of the Cerebrum from its anterior border, so that one-third only is behind those eminences. From this prominent parietal region the Cerebrum slopes or falls away in all directions—very suddenly backwards and rather so forwards as far as the entrance of the Sylvian fissure, where, like the fœtal brain, it appears remarkably constricted, and then widens again a little at the outer angles of the frontal region, which is nevertheless decidedly narrow. The left hemisphere, as seen from above, is ·2 of an inch longer than the right, the increase being almost entirely behind. This relative greater

* "Phil. Trans." 1864, p. 501.

length of one hemisphere backwards (usually the left, so far as I have observed) is very common in European brains."

"Viewed laterally the parietal region is salient; the vertex is low and flattened, its highest point being placed far back; the frontal region is shallow." . . . . "The temporal lobe is narrow, the line from its point to the tip of the posterior lobe being very long; the curve formed by the under border of the Cerebrum, above the Cerebellum, is slighter, and its direction more oblique upwards and backwards than in the European brain, owing apparently to a want of downward development of the occipital region which is very shallow . . . . the tips of the temporal lobes are pointed and much incurved towards the middle line. . . . . The orbital surfaces are especially contracted, but have a square or human and not a pointed or ape-like shape."

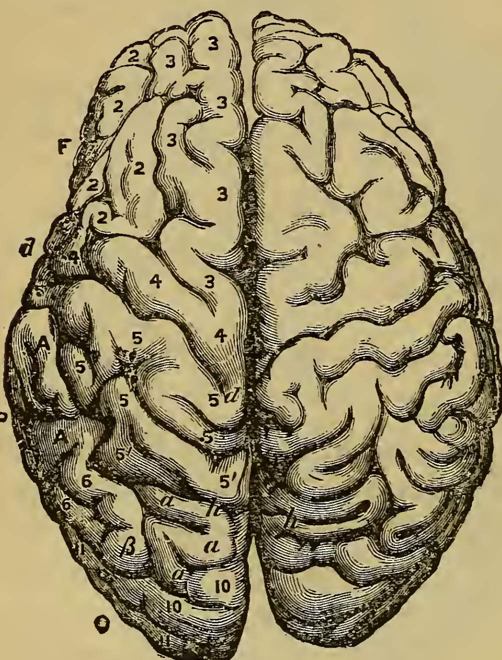


FIG. 135.—The Brain of a Bushwoman, upper aspect. (Heath, after Marshall.)

F, Frontal lobe; O, occipital lobe; *P*, parietal lobe; *d*, *d*, fissure of Rolando; *P*, parieto-occipital fissure; *A*, *A*, supra-marginal lobule. 2, 2, Middle, and 3, 3, upper frontal convolution; 4, 4, ascending frontal, and 5, 5, ascending parietal convolution; 5′, 5′, lobule of ascending parietal convolution; 6, 6, angular convolution; 10, 10, upper, and 11, 11, lower occipital convolution. α, α, first, and β, second connecting convolutions.

Taken as a whole this brain of the Bushwoman, when compared with that of the European, was found to be specially defective in depth and vertical height.

Fissures, Lobes, and Convolutions of the Cerebrum. "The fissure of Sylvius in the Bushwoman's brain extends well backwards, but inclines more upwards than in the European brain,* and its course is marked soon after its commencement by a peculiar horizontal step. . . . Its margins are not very closely adapted

FIG. 136.—The Brain of a Bushwoman, lateral aspect. (Heath, after Marshall.) Letters and figures of reference in part as in last figure. *T*, temporal lobe; *c*, island of Reil; *e*, *e*, fissure of Sylvius; 1, 1, lower or third frontal convolution; 7, 7; 8, 8; 9, 9, three temporal convolutions; *f*, *f*, and *g*, *g*, parallel, and inferior temporal fissures.

together, especially opposite the hinder border of the frontal lobe, which is here very defective. The fissure, indeed, is so patent, that without any separation of its margins, a portion of the island of Reil or central lobe (C), though small, is distinctly visible. This condition recalls to mind the fœtal state of the human cerebrum (fig. 128),

* These are marks of low development. In more highly developed brains the Sylvian fissure is shorter as well as more horizontal in direction.

but, so far as I am aware, is not present in any adult quadrumanous brain. The defect in the frontal lobe explains the remarkable constricted form of the Bushwoman's brain, already mentioned as existing at that point, a form which we may perhaps assume is a characteristic of the Bosjes brain, as it is equally present in the brain of the so-called Hottentot Venus, where it has also been noticed by Gratiolet as a fœtal character."

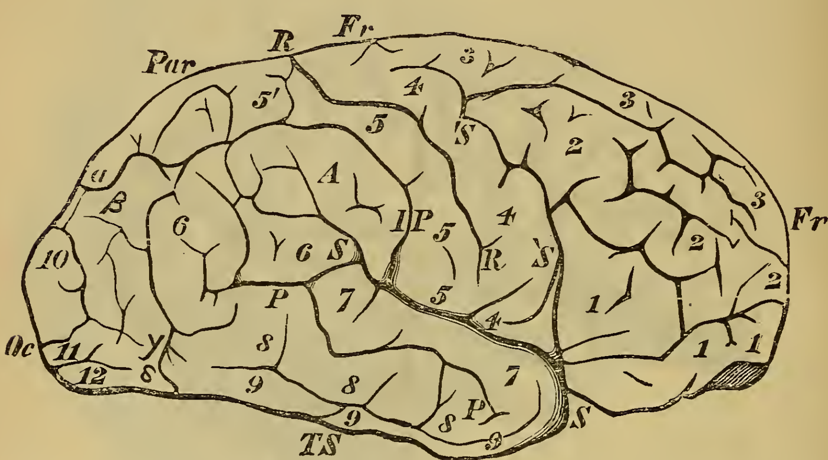


Fig. 137.—Right Cerebral Hemisphere of a Scotchman, outer aspect. (Turner.) *Fr, Fr,* Frontal lobe; *Par,* parietal lobe; *Oc,* occipital lobe; *T S,* temporo-sphenoidal or temporal lobe; *S, S,* Sylvian fissure; *'S, 'S,* ascending limb of Sylvian fissure (or 'Sulcus precentralis' of Ecker); *R, R,* fissure of Rolando; *IP,* intra-parietal, and *P, P,* parallel fissures. 1, 1, 1, Inferior, 2, 2, 2, middle, and 3, 3, 3, superior frontal convolutions; 4, 4, ascending frontal, and 5, 5, ascending parietal convolutions; 5′, outer part of postero-parietal lobule; 6, 6, angular gyrus; 7, 7, superior, 8, 8, 8, middle, and 9, 9, 9, inferior temporal convolutions; 10, superior, 11, middle, and 12, inferior occipital convolutions; *A,* supra-marginal lobule; α, β, γ, δ, first, second, third, and fourth annectent or bridging convolutions.

The *fissure of Rolando* (fig. 136, *d, d*) commences about $1\frac{1}{4}$ inches behind the tip of the temporal lobe. "It terminates considerably beyond the middle of the long axis of the cerebrum, nearly as far back as the line of greatest width of that organ; so that it passes proportionally further back than in the Hottentot Venus, or indeed than in the European."

"The *external perpendicular fissures* (fig. 135, *P*) can be traced as easily as in the Hottentot Venus (fig. 134, *V*), but are soon interrupted by the external connecting convolutions (α, β). Towards the sides these fissures are certainly more easily followed than in the European—a cir-

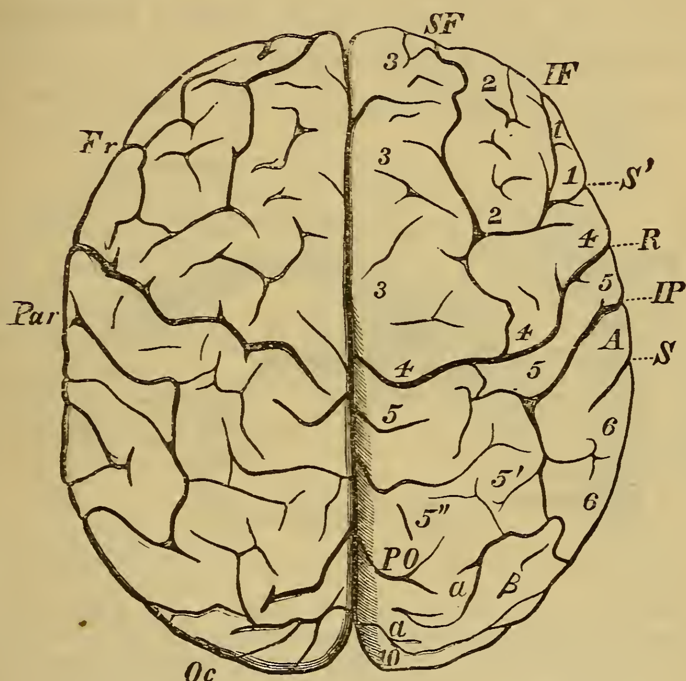


FIG. 138.—Vertex View of the Brain of a Scotchman. (After Turner.)

Fr, Frontal lobe; *Par*, parietal lobe; *Oc*, occipital lobe; *S F*, supero-frontal, *I F*, infero-frontal fissure; *R*, fissure of Rolando; *I P*, intra-parietal, and *P O*, parieto-occipital fissure; *S*, horizontal, and *S'*, ascending limb of the Sylvian fissure *A*, supra-marginal lobule. 1, 1, Inferior, 2, 2, middle, and 3, 3, 3, superior frontal convolutions; 4, 4, ascending frontal, and 5, 5, ascending parietal convolution; 5', outer, and 5'', inner part of postero-parietal lobule; 6, 6, angular convolution; 10, superior occipital convolution. α, α, first, and β, second annectent convolution.

cumstance which imparts a lower character to this part of the Bosjes brain; at the same time they are far more interrupted than in the Chimpanzee or Orang-outan. These short external perpendicular fissures join as usual the summits of the internal perpendicular fissures, and, together with the fissures of Rolando, divide the upper surface of the Cerebrum into three regions."

Of these three regions, when measured longitudinally over the vertex, the parietal is found to be specially defective in the Bushwoman's brain, since instead of being equal to or rather longer than the occipital, as is commonly the case in European brains, it is very distinctly shorter than this latter region.

The *parallel fissure* (136, *f, f*) on the outer surface of the

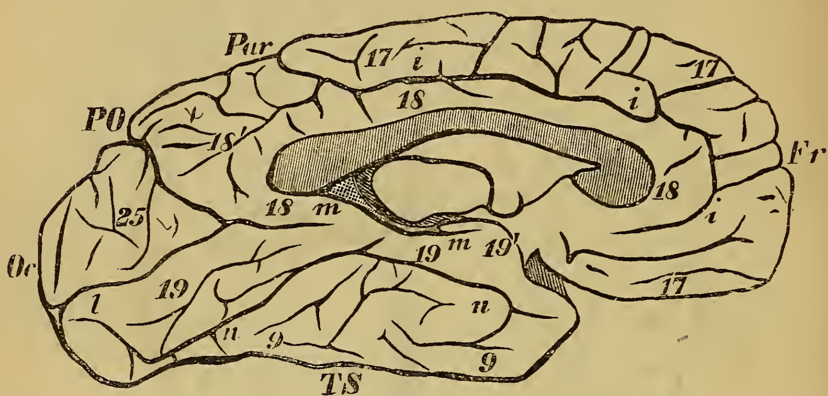


FIG. 139.—Inner Face and Tentorial Surface of the Left Cerebral Hemisphere. (After Turner,)

Fr, Frontal lobe; *Par,* parietal lobe; *Oc,* occipital lobe; *T S,* temporal lobe; *P O,* internal, perpendicular, or parieto-occipital fissure; *i, i, i,* calloso-marginal, and *l, l,* calcarine fissure; *m, m,* dentate fissure; *n, n,* collateral fissure. 17, 17, 17, marginal convolution; 18, 18, convolution of corpus callosum; 18′, quadrilateral lobule; 19, 19, uncinate convolution, of which 19′ is the 'crotchet,' or recurved part; 25, cuneus, or occipital lobule; 9, 9, inner face of inferior temporal convolution.

temporal lobe is "more tortuous on the left side than in the Hottentot Venus, though less so than in ordinary European brains."

"The *internal perpendicular fissure* (fig. 139, *PO*) is more vertical than in the European, but much less so than in the Chimpanzee—the angle formed by this fissure and a base-line drawn through the corpus callosum being in the European 123°, in the Bushwoman 115°, and in the Chimpanzee 93°. As in the European brain, however, this fissure joins the fissure of the hippocampi below (fig. 139), whilst in the Quadrumana it usually stops short of that fissure."

We cannot follow Prof. Marshall in his interesting and detailed examination of the various convolutions of the Bushwoman's brain, including his estimation of the degree of their development in relation to those of the Hottentot Venus and those of the ordinary European brain; we can only reproduce some of his most interesting general conclusions.

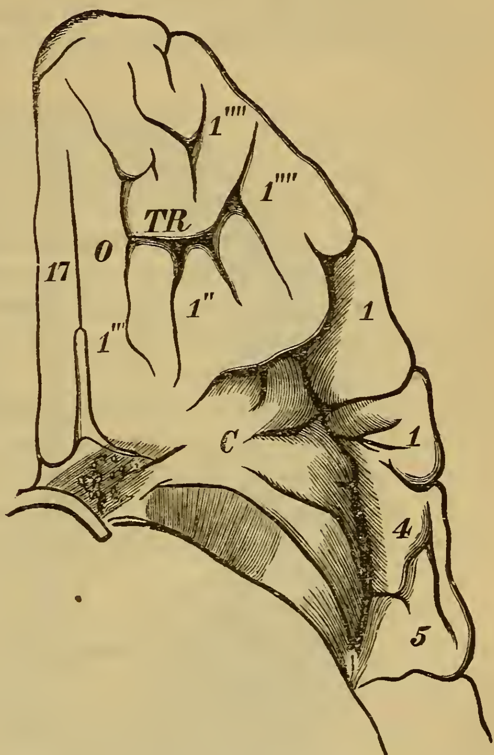


FIG. 140.—View of the Orbital Lobule and of the Island of Reil. (After Turner.)

Most of the temporal lobe has been removed for the purpose of displaying the Island. *O*, Olfactory sulcus; *T R*, triradiate sulcus; 1'', posterior, 1''', internal, and 1'''', external convolutions of the orbital lobule; *C*, Island of Reil, with its radiating convolutions; 1, 1, under surface of lower or third frontal convolution; 4, under surface of lower end of ascending frontal convolution; 5, under surface of lower end of parietal convolution; 17, marginal convolution.

All the primary convolutions which should exist in the human cerebrum "are present in the Bushwoman's brain; but, as compared with the same parts in the ordinary European brain, they are smaller, and in all cases so much less complicated as to be far more easily recognized and distinguished amongst each other. This comparative simplicity of the Bushwoman's brain is, of course, an indication of structural inferiority, and indeed renders it a useful aid in the study of the more complex European form. On contrasting the several regions of the Cerebrum, the primary convolutions of the upper frontal and outer parietal regions are, on the whole, the best developed; those of the middle and lower frontal regions, the temporal region, the central lobes, and the inner surface the next; whilst those of the orbital surface and occipital lobe are the least developed."

"Of the Connecting Convolutions, those highly important and significant folds, the external connecting convolutions are, in comparison with those of the European brain, still more remarkably defective than the primary convolutions. All four of these convolutions are present; but all are characteristically short, narrow, and simple, instead of being complex and occupying a large space; hence, though the external perpendicular fissure is soon filled up, the parietal and occipital lobes are more easily distinguishable from one another than in the European brain. . . . . The numerous sulci and convolutions, which so complicate the longer ones in the European brains, are everywhere decidedly less developed in the Bushwoman—but especially so in the occipital and orbital regions, on the bent convolution, and on the external connecting convolutions. This is a further sign of structural inferiority."

Compared with that of the Hottentot Venus, the Bushwoman's brain is, "in nearly all cases where comparison is possible, a little, though a very little, more advanced and complex in its convolutional development—the one exception being in regard to the size of the occipital and external connecting convolutions, which are smaller in the Bushwoman." But the resemblance between the convolutions of the two brains is very close, whilst the simplicity of their arrangement is not to be paralleled or even approached in normal European brains.

It remains now to point out rather more fully the nature of the principal differences presented by the brains of Europeans when contrasted with those of the lower human types to which we have hitherto been referring. This, however, is a somewhat difficult task, because wide individual differences, relating to many details of structure, are to be encountered in this organ in different Europeans. In some of them a brain is to be met with which approximates closely as regards size, relative development of lobes, and complicacy of convolutions, to the low standard

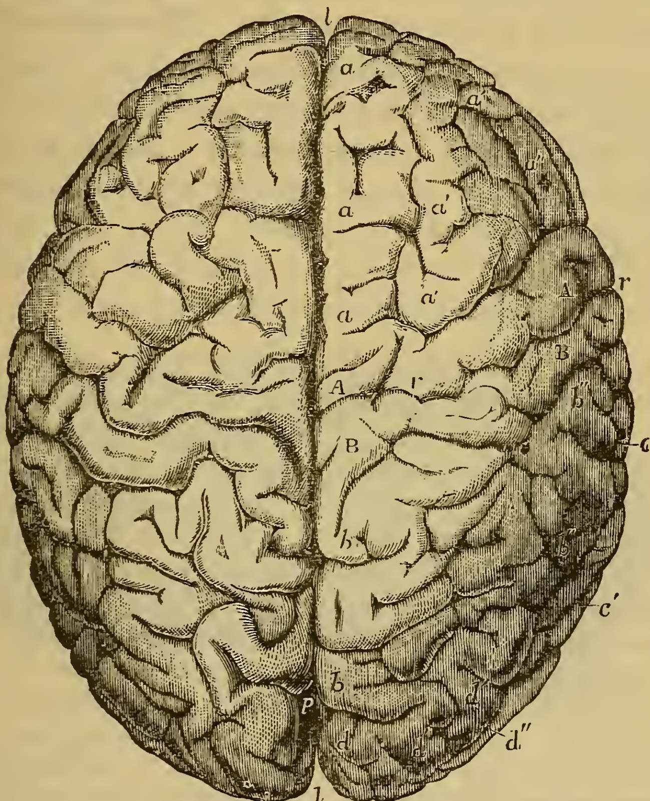


FIG. 141.—Brain of Gauss, the Celebrated Mathematician and Astronomer, upper aspect. (Sharpey, after R. Wagner.)

l, *l*, Longitudinal fissure; *a*, *a'*, *a''*, upper, middle and lower frontal convolutions; A, A, ascending frontal convolution; *r*, *r*, fissure of Rolando; B, B, ascending parietal convolutions; *b*, *b*, parietal lobule; *b''*, supra-marginal lobule; *c*, *c'*, first or upper temporal convolution; *p*, perpendicular (or parieto-occipital) fissure; *d*, *d'*, *a''*, upper, middle, and lower occipital convolutions.

afforded by the brain of the Bushwoman. In others, the majority of characters are decidedly higher, though in certain parts or situations there may be presented now one, now another, feature of a lower type. All sorts of grades and transitions are, in fact, frequently encountered, so that the remarks made in reference to this part of our subject must be suggestive and general rather than precise and particular.

Looked at from above, the shape or outline of the European brain varies considerably. The narrowed and, as it were, compressed anterior lobes in the Bushwoman, as well as the narrow tapering shape of the occipital lobes, are eminently fœtal characteristics. As a rule, this contracted condition of the anterior lobes is absent in the European brain, and in some specimens the shape is so broadly oval as even to approach the circular outline, as in that of the Scotchman represented by Turner (fig. 138).

The brain of a "celebrated naturalist" figured by Rudolph Wagner * has much the same almost circular outline when seen from above, and both in it and in the brain of the Scotchman already referred to, the posterior extremity constitutes the broad end of the oval. On the other hand the brain of the great mathematician and astronomer Gauss (fig. 141) has, when seen from above, a distinctly elliptical outline—the curve of the anterior being almost exactly equal to that of the posterior lobes, and the greatest transverse diameter being equidistant from both extremities. A similar upper outline is to be seen in the much less elaborately convoluted brain of the artizan Krebs,† although the side view of this same brain, when compared with that of Gauss (loc. cit., tab. vi.), shows it to be very deficient in depth, both in the frontal and in the parietal regions. The upper outline of the brain of the philologist Hermann, likewise depicted by Wagner, is also nearly elliptical, the posterior being very slightly narrower than the anterior extremity. Its widest transverse diameter, moreover, is situated midway between its two extremities, though this region corresponds with the supra-marginal lobule rather than with the lower end of the ascending parietal convolution, as in the brain of Gauss and in that of the artizan Krebs. A reference to fig. 135 will show that the brain of the Bushwoman is also widest in the situation of the very prominent 'supra-marginal lobules,' though these are

* "Vorstudien," tab. ij. † Wagner, loc. cit. tab. ij. fig. 4.

found to be distinctly posterior to the median axis. The brain of the eminent mathematician Dirichlet is longer and broader than either of the others figured by Wagner. Its posterior extremity is narrower than the anterior, and even notably pointed. Its greatest breadth may be seen to be only slightly posterior to its median axis, and to correspond with the hinder part of the ascending parietal convolution.

Notable variations are therefore to be met with in the shape of the Brain as seen from above, as might have been expected from a consideration of the diverse shapes of the human Skull in different races and individuals. We

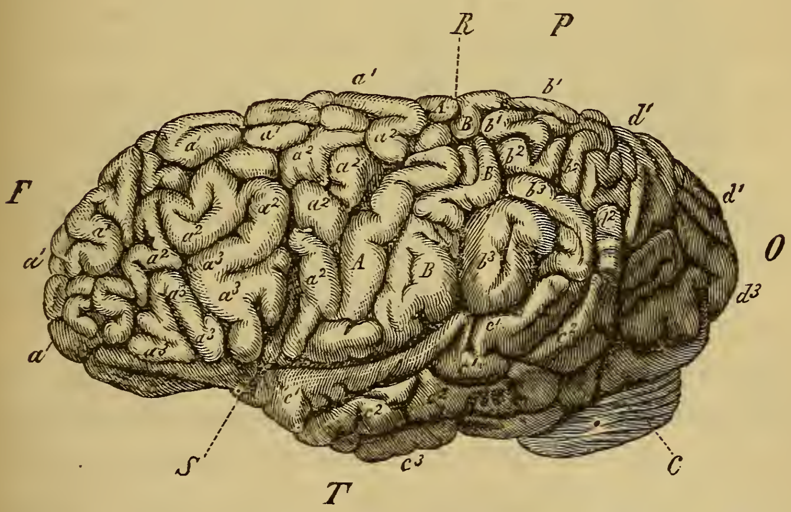


FIG. 142.—Brain of Gauss, the Celebrated Mathematician and Astronomer, side view. (Vogt, after R. Wagner.)

F, Frontal lobe; *P*, parietal lobe; *O*, occipital lobe; *T*, temporal lobe; *C*, cerebellum; *Po*, pons Varolii; *V M*, medulla oblongata; *S*, Sylvian fissure; *R*, fissure of Rolando; *P S*, parallel fissure. a^1, Upper fold of frontal convolutions; a^2, middle fold of frontal convolutions; a^3, lower fold of frontal convolutions. *A*, Ascending frontal (or anterior central) convolution; *B*, ascending parietal (or posterior central) convolution; b^1, b^2, b^3, upper, middle, and lower folds of parietal convolutions; c^1, c^2, c^3, upper, middle, and lower folds of temporal convolutions; d^1, d^2, d^3, upper, middle, and lower folds of occipital convolutions.

have extreme 'long-heads,' and extreme 'round heads,' interspersed with multitudes of individuals whose cranial diameters are more nearly equal. On the whole, it is, perhaps, most frequently found that the greatest breadth of the brain is behind its median transverse axis, and that its posterior is more bluntly rounded than its anterior extremity.

Looked at from the side, the Brain presents certain obvious differences when we compare such simple forms as that of the 'Hottentot Venus' and the Bushwoman, or even that of Krebs the artizan, with one of the highly evolved organs pertaining to a man of great and subtle intellect, such as Gauss.

One of the most notable characteristics of the Brain of Gauss is to be found in the great development of the Frontal Lobes. This is rendered evident by the fact of their comparative length, breadth and height, and also by reason of the extreme complicacy of their three tiers of convolutions (fig. 142, a^1, a^2, a^3). Wagner gives a full-size representation of these lobes, viewed from the front, and also, for comparison, a similar view of the frontal lobes of the artizan Krebs. The difference between them is very marked.

The writer has in his possession the brain of another celebrated mathematician, the late Professor De Morgan, and although in it the frontal lobes are likewise large and well developed, their convolutions are by no means so intricate as in that of Gauss. But in the brain of a Journalist (formerly a Clergyman) who died some years ago in University College Hospital, the size of the frontal lobes is distinctly greater, and the intricacy of their convolutions altogether remarkable—fully equalling, even if it does not exceed, that met with in the brain of Gauss. In other regions also this brain, of an educated though not distinguished man, is rather more highly convoluted than that of De Morgan, as it is also distinctly heavier. It was preserved, indeed, both because it was the brain of a well-educated person and because it presented a well-marked complicacy of its convolutions, with the view of subsequently comparing it with that of the recently-deceased Mathematician.

In both these brains, as well as in that of Gauss, the fissures of Rolando are very sinuous, owing to the existence of many secondary foldings of the ascending frontal and parietal convolutions.* The relative position of these

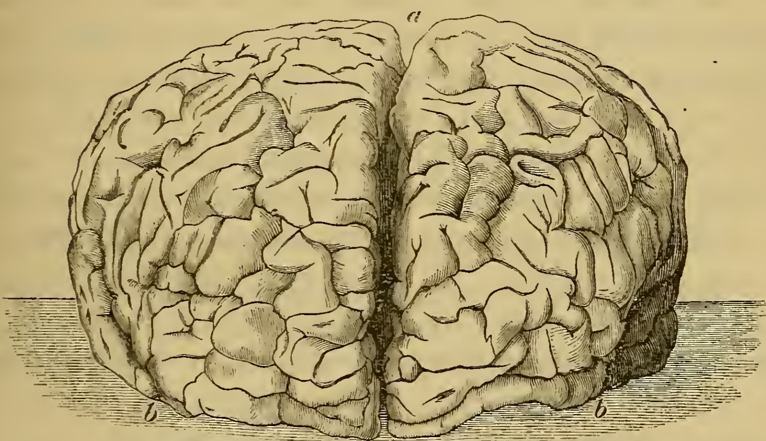


FIG. 143.—Front view of Frontal Lobes of the Brain of a Journalist, showing the extreme complicacy of its Convolutions. Owing to slight obliquity of position, the right Frontal Lobe is more fully shown than the left. (Accurately drawn by V. Horsley, from a photograph.)

fissures was, however, very different in the two brains, and in that of the Journalist the distance of the lower end of the fissure of Rolando from the tip of the temporal lobe was altogether remarkable.

As a consequence apparently of a blindness of the right eye, dating from a few days after birth, the left Cerebral Hemisphere of De Morgan's brain was notably

* No bridge-like convolution was to be seen crossing the fissure of Rolando in either brain. On the right side, but not on the left, and this only in the brain of De Morgan, the fissure of Rolando opened into the fissure of Sylvius.

smaller than the right, though the measurements of the organ, now that it has become flattened from its own weight, and is slightly shrunk in consequence of its preservation in spirits, do not show this so clearly as when it was in the fresh condition.* Still even now the left hemisphere is distinctly smaller than the right, both in length and in breadth. The occipital lobes are as nearly equal in length as they can be, but the left internal perpendicular fissure (owing to the smaller size of the frontal and parietal lobes) now lies exactly $\frac{3}{4}$ in. in front of that of the right hemisphere. The left occipital lobe is, moreover, distinctly narrower and less rounded externally than that of the right side. The temporal lobes are of equal length, but in regard to relative breadth they have been too much altered by pressure to enable any opinion to be

* This brain was removed on the third day after death, and was not in a good condition for preservation. The measurements over the vertex, then taken with great care by means of a narrow tape, were as follows :—

	Anterior extremity of Frontal Lobe to upper end of Fissure of Rolando.	Upper end of Fissure of Rolando to upper end of Perpendicular Fissure.	Upper end of Perpendicular Fissure to posterior extremity of Occipital Lobe.
	Inches.	Inches.	Inches.
L.	$4\frac{6}{8}$	$2\frac{3}{8}$	$2\frac{4}{8}$
R.	$5\frac{2}{8}$	$2\frac{7}{8}$	$2\frac{4}{8}$

Besides the special arrest of development met with in the left hemisphere, the brain generally was distinctly shrunken, partly from the effect of age, and partly from disease which had produced great and general emaciation during the last twelve months of life. Prof. De Morgan was well known to have had an exceptionally large head, so that had it not been for age and the wasting above-mentioned his brain would probably have weighed much more than it did, viz., $52\frac{3}{4}$oz. The writer found the measurements of Prof. De Morgan's head (almost free from hair) to be as follows :—Circumference, $24\frac{7}{8}$ in.; longitudinal measurement over vertex (root of nose to occipital protuberance), $15\frac{5}{8}$ in.; transverse measurement over vertex (from external auditory meatus to its fellow of opposite side), $15\frac{4}{8}$ in.

formed. The diminution in general size of the frontal and parietal lobes is still very obvious, both in breadth as well as in length; though it is not a diminution localized in any particular parts of these lobes. Nor is there any appreciable difference observable in the convolutional development of any part of the hemisphere, as compared with that of the opposite side. The region of the 'supra-marginal lobule' and of the 'angular gyrus' seems certainly to be just as well developed on the left as it is on the right side, though these are the convolutions which, according to Ferrier, are to be regarded as the principal site of the 'Visual Centre.'

Except for the degenerated condition and wasted appearance of the right optic nerve and the corresponding left 'optic tract,' there is nothing to be discovered which can possibly account for the smaller size and stunted development of the left Hemisphere. The anterior of the quadrigeminal bodies on the left side is slightly less prominent than that of the right side, and it is also slightly different in colour: but it was not examined previous to the immersion of the Brain in spirits of wine. The Cerebellum seems to be quite symmetrical; its right and left halves presenting the same measurements. And, in regard to this point, it is important to observe here that Prof. De Morgan had never suffered from any paralytic condition or affection of motility, so that my first impression that there ought to have been an associated atrophy of the opposite lateral lobe of the Cerebellum (as in many cases of atrophy of one Cerebral Hemisphere) was seen, on further consideration, not to be well-grounded. We may rightfully look for this in instances of atrophy of one Cerebral Hemisphere associated with unilateral motor Paralysis, but not in cases where the latter condition is absent, and in which one of the Hemispheres seems to be imperfectly developed merely from the fact of its having lacked the stimuli which ought to have come to it through an all-important sense like that of Sight. This is a distinction important to be borne in mind.

Some measurements have been made of this very unsymmetrical Brain of the celebrated Mathematician (whose mental powers were so great notwithstanding the inequality of its Hemispheres), and they have been placed side by side with figures obtained from other similar measurements of the well-evolved brain of the educated but comparatively obscure Journalist. The weight of this latter brain was 56oz., so that it would have taken a high place if it had been incorporated with the table on p. 370. It will be observed that the left, as is frequently the case (see fig. 135), is slightly but distinctly longer than the right Hemisphere.

COMPARATIVE MEASUREMENTS OF TWO BRAINS.

		Anterior extremity of Frontal Lobe to upper end of Fissure of Rolando.	Upper end of Fissure of Rolando to upper end of Perpendicular Fissure.	Upper end of Perpendicular Fissure to posterior extremity of Occipital Lobe.
		Inches.	Inches.	Inches.
De Morgan	L.	$4\frac{1}{8}$	$1\frac{6}{8}$	2
	R.	5	2	2
Journalist	L.	$5\frac{6}{8}$	$2\frac{1}{8}$	$2\frac{2}{8}$
	R.	$5\frac{2}{8}$	$2\frac{2}{8}$	$2\frac{1}{8}$

		Tip of Temporal Lobe to lower end of Fissure of Rolando.	Lower end of Fissure of Rolando to upper end of Fissure of Sylvius.	Tip of Temporal Lobe to end of Fissure of Sylvius.	End of Fissure of Sylvius to upper end of Perpendicular Fissure.
		Inches.	Inches.	Inches.	Inches.
De Morgan	L.	2	$1\frac{7}{8}$	$3\frac{7}{8}$	$3\frac{7}{8}$
	R.	$2\frac{1}{8}$	$1\frac{4}{8}$	$3\frac{5}{8}$	$3\frac{7}{8}$
Journalist	L.	$2\frac{4}{8}$	1	$3\frac{4}{8}$	$3\frac{7}{8}$
	R.	$2\frac{3}{8}$	$\frac{7}{8}$	$3\frac{2}{8}$	4

Another notable difference often met with in European brains of higher type, serving to separate them from such organs as that of the Hottentot Venus (fig. 133), lies in the shortness of the Sylvian Fissure. It may scarcely reach half way back to the upper end of the 'perpendicular fissure,' and may be separated therefrom by several convolutions instead of only by the descending limb of the 'angular gyrus,' as is the case in the Chimpanzee; or by this convolution together with the upper 'bridging convolution,' as in the two South African women.

The Sylvian Fissure is most elongated in some of the Quadrumana such as the Howler (p. 291), and also in the brains of the Saïmiri depicted by Gratiolet,* in each of which it extends back almost to the 'great longitudinal fissure.' It is only slightly less elongated in the Squirrel Monkey, the Macaque and other allied forms (figs. 105, 106); and is similarly long even in the Chimpanzee.† It has been already pointed out (p. 345) that the length of the Temporal Lobe, and the extent of the posterior prolongation of the fissure of Sylvius, are also notable characteristics of the human fœtal brain. This feature is well shown in Gratiolet's figure of the brain of a fœtus of about $6\frac{1}{2}$ months.‡

This Simian and fœtal characteristic of the organ reveals itself also even in the adult condition of some of the lower types of the Human Brain. It is seen, for instance, in the Hottentot Venus (fig. 133) and to a less extent in the Bushwoman (fig. 136); also in the brain of the criminal Fieschi (of 'infernal machine' notoriety) as depicted by Gratiolet,§ and in that of the artizan Krebs as represented by Wagner.|| In Leuret and Gratiolet's figure of the brain of a 'Charruas' (Pl. xix. fig. 1), however, though it presents in other respects many infantile characters, we find the fissure of Sylvius very short, just as it exists in some of the best developed human brains, *e.g.* that of Gauss, and still more notably in that of De Morgan, as well as in the Journalist above referred to. In both of these latter brains more than one-half of the Sylvian Fissure, as it exists in some of the Quadrumana, has been obliterated—since

* "Anat. Comp. du Syst. Nerv.," Pl. xxix. figs. 11 and 12.

† Gratiolet, loc. cit. Pl. xxiv. fig. 6.

‡ Idem. Pl. xxx. fig. 2.

§ Pl. xxij. fig. 2.

|| "Vorstudien," tab. vi. fig. 2.

the measurements of these brains from the upper end of the 'perpendicular Fissure' across the parietal lobe to the posterior extremity of the Sylvian Fissure, are just equal to the measurements from the latter point even as far as the tip of the corresponding Temporal Lobe.

This progressive shortening of the Sylvian Fissure appears not to have been distinctly pointed out before. Yet it would seem to be a change of precisely the same order as that which leads to the progressive obliteration of the 'external perpendicular Fissure,' to which much attention has been given by anatomists.

The above-mentioned shortness of the Sylvian Fissure in the more highly evolved brains tends to confer a corresponding shortness upon the Temporal Lobe. The proportional breadth of this segment of the brain is also decidedly diminished in the brain of Gauss. The broad simple convolutions of the Temporal Lobe in the Hottentot Venus (fig. 133) contrast notably with the much more complex corresponding gyri in the brains of the two Mathematicians as well as in that of the Journalist.*

The Occipital Lobe has a much greater depth in the brains of Gauss, De Morgan and of the Journalist, than is to be met with in the lower human types previously described. Consequently in them the inferior-posterior border of the Cerebral Hemisphere, as it extends along the side of the Cerebellum, is much more nearly horizontal than it is in either of the two African women. In these latter, however, an advance of the same kind is to be met with in comparison with what obtains in the Cerebral Hemispheres of the great 'man-like' Apes (p. 296).

* In the brain of the 6½ month Fœtus, and in that of Fieschi represented by Gratiolet (loc. cit., Pl. xxx. fig. 2, and Pl. xij. fig. 2) the Temporal Lobes are both long and broad, whilst in that of the new-born Infant (Pl. xxx. fig. 3), and in the brain of the 'Charruas' (Pl. xix. fig. 1), this same Lobe though short is still extremely broad.

In the higher forms of the Human Brain—as in those of Gauss and De Morgan, and also in the Journalist—the Temporal and Occipital Lobes of each Hemisphere together bear a much smaller proportion to the mass of brain-

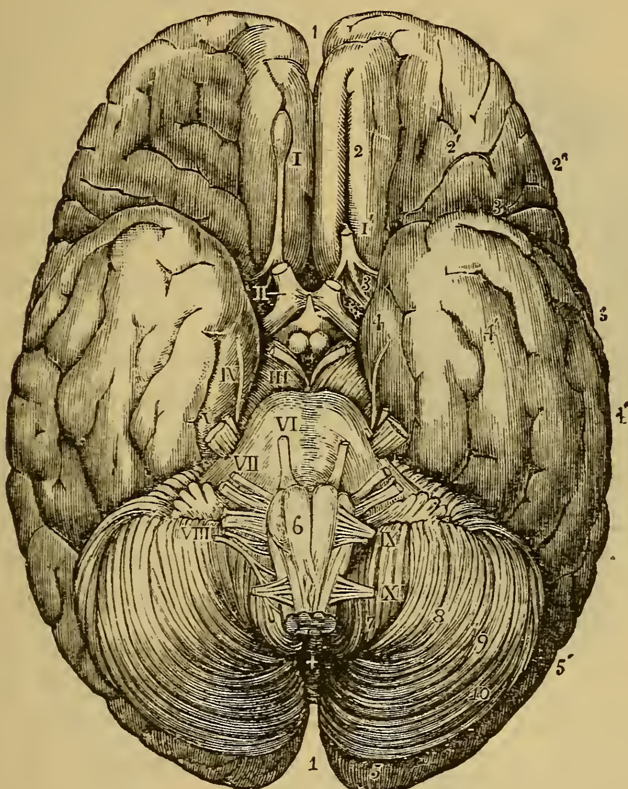


FIG. 144.—Under Surface of the Human Brain. (Allen Thomson.)
1, 1, Great longitudinal fissure; 2, 2′, 2″, convolutions of under surface of frontal lobe; 3, 3, 3, prolongation to base of the fissure of Sylvius; 4, 4′, 4″, convolutions of the temporal lobe; 5, 5′, occipital lobe; 6, anterior pyramids of medulla; +, posterior extremity of median lobe of cerebellum; 7, 8, 9, 10, lobules of the lateral lobe of the cerebellum. I–IX. Cranial nerves, all but the first more fully seen in next figure. The ninth nerve of the right side has been removed. X. First cervical nerve.

substance comprised in the Frontal and Parietal Lobes than is the case in brains of a lower type. In the lower Quadrumana, also, the Temporo-Occipital segment of the

Hemisphere, instead of being much less, is about equal to, or it may be of even slightly greater bulk than, the conjoined Fronto-Parietal segment. Thus the proportions met with in the lower human types are, as it were, intermediate between those which obtain in the higher human types on the one hand and in the Quadrumana on the other.

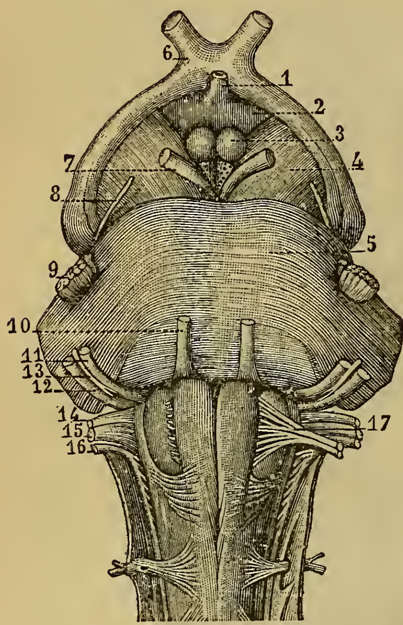


FIG. 145.—Under Surface of Cerebral Peduncle, Pons, and Medulla, showing Connections of the Cranial Nerves. (Sappey, after Hirschfeld.)

1, Infundibulum of pituitary body; 2, part of floor of third ventricle; 3, corpora mamillaria; 4, cerebral peduncles; 5, pons; 6, optic nerves, crossing in the middle line so as to form the chiasma; 7, common motor nerves of eyeball; 8, nervus patheticus; 9, trigeminus; 10, external ocular nerve; 11, facial nerve; 12, auditory nerve; 13, nerve of Wrisberg; 14, glossopharyngeal nerve; 15, vagus or pneumogastric; 16, spinal accessory; 17, hypoglossal nerve (cut away on one side).

The diminution in size of the Temporo-Occipital segment in the brain of human beings generally, is perhaps more apparent than real. The very great increase in the size of the Frontal and of the Parietal regions is, at least in part, another means of accounting for the altered proportion. It is certain, indeed, that the convolutions of the Temporal Lobes tend to become more complex in higher human brains, and it is equally certain that there is also a tendency to an actual increase in the size of the Occipital Lobes. In the more highly evolved brains these Lobes become deeper and also fuller and more rounded. There is, moreover, a notable increase in the complexity of the Occipital Convolutions.

The latter is a point of considerable importance, and not always sufficiently borne in mind by those who have dwelt upon the large size of the Occipital Lobes in many of the Quadrumana. If these parts seem to be relatively smaller in Man, it must not be forgotten that in Monkeys and in Apes their surfaces are smooth and comparatively unconvoluted, whilst in Man, in proportion to their size, the area of superficial grey matter on the Occipital Lobes becomes enormously increased by reason of the number and depth of their surface-foldings.

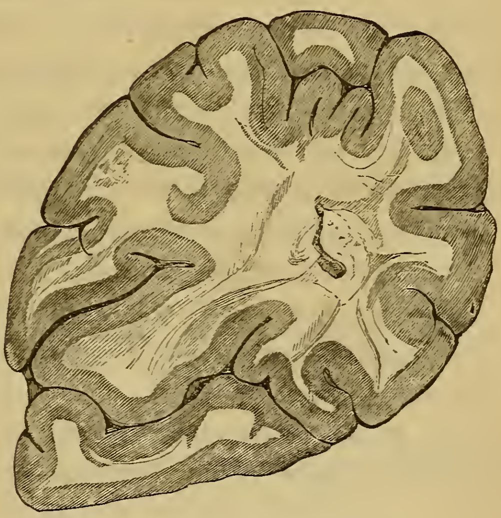


FIG. 146.—Section through the left Occipital Lobe of a Human Brain; showing the number and depth of its surface-foldings.

Thus we find in the Brain of Man not so much new parts or regions, as an enormous development of pre-existing parts and regions. Again, the degree of such increased development is by no means everywhere the same. These are both of them facts of great significance from a psychological point of view—and especially from the point of view of that Psychology which has its roots in the general Philosophy of Evolution.

One of the most notable peculiarities of the Human Cerebrum is that, in various ways, its two Hemispheres are not quite symmetrically developed.

(1.) Though the situation of the 'primary' Fissures is subject to little variation in the two Hemispheres, still in the more highly convoluted Brains many of the separate Convolutions are apt to present differences in the number and arrangement of their minor folds or indentations. Hence slight differences in the appearance of corresponding Convolutions on the two sides of the brain are occasionally to be met with; although in different individuals the regions in which dissimilarity is most marked are by no means necessarily the same, nor is the greatest complexity always to be found on the same Hemisphere in these different regions.

Much more has yet to be learned in regard to these points, but the broad conclusion is thoroughly warranted that this asymmetrical development of the convolutions is only a little more marked in the lower Human Races than it is amongst the higher Apes, and that it becomes distinctly most marked in the more highly convoluted brains pertaining to representatives of the higher or more civilized Human Races.

(2.) It has been noted by various anatomists that the left Hemisphere is very frequently slightly longer than its fellow, so that the tip of the left Occipital Lobe is apt to project distinctly behind that of the right side.

(3.) The writer noticed about fifteen years ago that a distinct difference in the shape of the tips of the Occipital Lobes frequently exists*—that of the left side being generally tapering and rudely conical, whilst the right is often rather flattened at the end and has at its inner border a groove-like depression about $\frac{1}{4}$th of an inch in diameter (fig. 147). The direction of the groove from below upwards, is also inwards and forwards.

* And subsequently called attention to it in "Trans. of Patholog. Soc.," 1869, vol. xx. p. 4.

In a large proportion of brains, and, as it would seem, especially in those of Women, this conformation of the right Occipital Lobe exists to a well-marked extent. In others, it is only slightly marked; whilst on rare occasions a more or less obvious groove exists on each side. In a still smaller number of cases a groove is met with at the tip of the left instead of the right Occipital Lobe, or it may be absent on both sides.*

The Occipital Convolutions in the situation of the groove are distinctly depressed, but no projection from the inner surface of the skull or thickening of the membranes has ever been met with which could account for its formation. Of late the writer has adopted the view that this 'occipital groove' is due to the pressure exerted by the posterior extremity of the longitudinal sinus and the right side of the 'torcular Herophili' or meeting-point of the venous sinuses (fig. 148). Why the pressure should be more

* In thirty-five consecutive post-mortem examinations the condition of the Occipital Lobes has been noted, partly by myself and partly by Mr. J. T. Gadsby or Mr. C. E. Beevor—my late able 'assistants' at University College Hospital—with the view of ascertaining the relative frequency of these different conditions. The results are embodied in the following Tables:—

TABLE I.

Side.	Sex. M.	Sex. F.	Total.
Right . .	15	13	28
Left. . .	1	1	2
Both Sides	3	1	4
Absent. .	1	0	1
	20	15	35

TABLE II.

Degree.	Sex. M.	Sex. F.
3 . . .	1	7
2 . . .	8	
1 . . .	10	1
0 . . .	1	0
	20	15

In Table II. under 'Degree,' the figure 3 signifies that the groove was 'very well marked'; 2, that it was 'moderately well marked'; and 1, that it was only 'slightly marked.'

on the right side than on the left is by no means clear. It might perhaps be occasioned by the slightly increased length of the left Hemisphere, pressing backwards against the left side of the 'torcular,' and so diverting a larger current of the blood flowing along the longitudinal sinus towards the right. It has been long known, indeed, that the groove in the occipital bone for the right 'lateral sinus' is often distinctly broader than that for the left sinus,*—

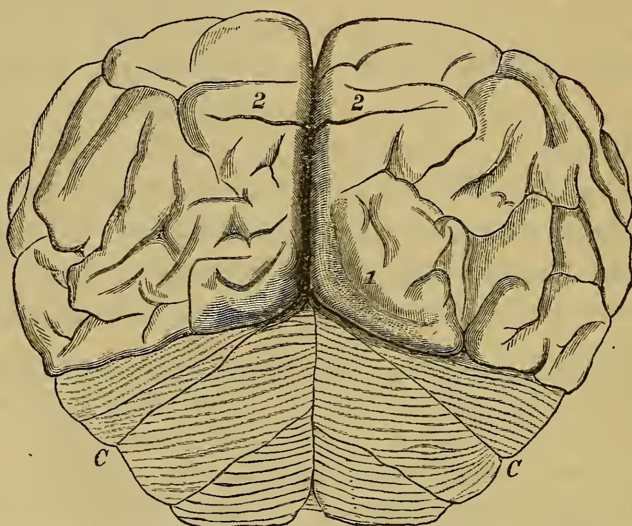


FIG. 147.—View of Occipital Lobes and of Cerebellum from behind, showing the 'Occipital Groove' at the tip of the right Hemisphere. (From a drawing by V. Horsley.) 1, The Groove; 2, 2, External Perpendicular Fissure. C, C, The Cerebellum.

thus conclusively showing that in all such cases, at least, the larger blood current is accustomed to pass away from the cranium along this side.

(4.) The left Hemisphere was said by Dr. Boyd to be generally heavier than the right by nearly half an ounce. This, however, has been questioned by some investigators,

* See fig. 23 of Gray's "Anatomy" (3rd. Edn.), where this condition is well represented.

and actually denied by others to be a usual condition. Some of the latter even affirm that though a difference often exists, the superiority in weight is most commonly in favour of the right rather than the left Hemisphere. This point cannot, perhaps, be definitely decided for the present. It is obvious that very great care is needed in making the sections through the 'cerebral peduncles' and 'corpus callosum,' preparatory to such comparative weighings of the two Cerebral Hemispheres, and also that the weighings themselves require to be made with the greatest care.

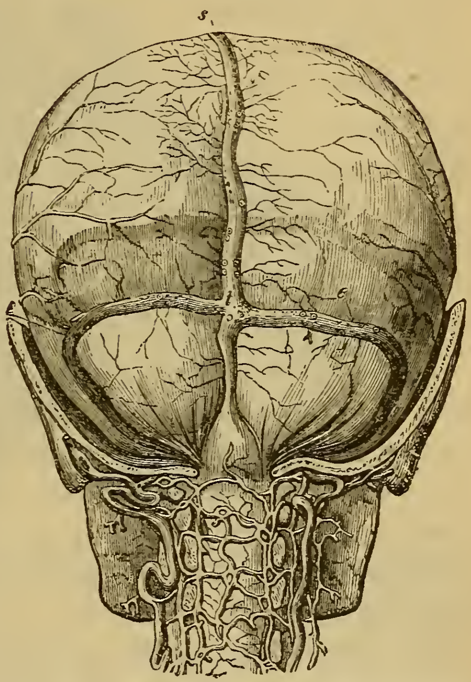


FIG. 148.—Posterior Diagrammatic View of Dura Mater with Great Venous Sinuses. (Todd.) The posterior portion of the Cranium and the posterior arches of the upper spinal Vertebræ are supposed to be removed. *s*, The longitudinal sinus; *t*, the 'torcular Herophili,' where longitudinal and occipital sinuses meet, and whence the lateral sinuses (*e*) diverge.

(5.) The writer many years ago ascertained that the specific gravity of the Grey Matter from the frontal parietal and occipital Convolutions, respectively, is often slightly higher on the left than it is on the right Hemisphere, though such superior density does not necessarily exist in each of these regions in the same individual.* This unexpected result frequently, though not invariably, showed itself, even where every care was taken to get rid of sources of fallacy. Further observations are,

* See "Journal of Mental Science," January, 1866, p. 493.

however, also needed in regard to this subject, and other convolutions than those above named should be similarly tested.*

The Cerebellum and its Lobes.

The Cerebellum or 'little Brain,' in the erect position of the body, is situated behind and above the 'pons' and Medulla (fig. 132), and lies in a posterior hollow of the skull beneath the Occipital Lobes, from which it is separated merely by a membranous partition. This membrane, named the 'tentorium,' is an internal horizontal prolongation from the 'dura mater;' the Occipital Lobes lie on it above, while the upper surface of the Cerebellum is in contact with it below.

The relative weight of the Cerebellum as compared with the Cerebrum has already been referred to, and also the fact of the great and progressive development of the 'lateral lobes' of this organ in the Quadrumana, and even more markedly in Man, as compared with that of the 'middle lobe'—which in him becomes a relatively diminutive structure.

No detailed reference to the relative development of the several parts of the Cerebellum will here be made, though the names of these parts may be ascertained by the reader who will carefully study figs. 149 and 150, and the references thereto. The comparative study of the parts of the Cerebellum has not, indeed, received that amount of attention from workers generally which has been bestowed upon the Cerebrum; and even if it had

* An increased number of 'intercellular processes' and fine 'commissural fibres' within the Grey Matter (making this matter approximate more in character to the denser 'white substance') might be causes of such slightly increased specific gravity.

been otherwise, the altogether subordinate importance of this organ in regard to Mind would quite justify us in dealing much more briefly with its external anatomy.*

The whole external surface of the Cerebellum is scored by a very large number of 'fissures,' some of which are

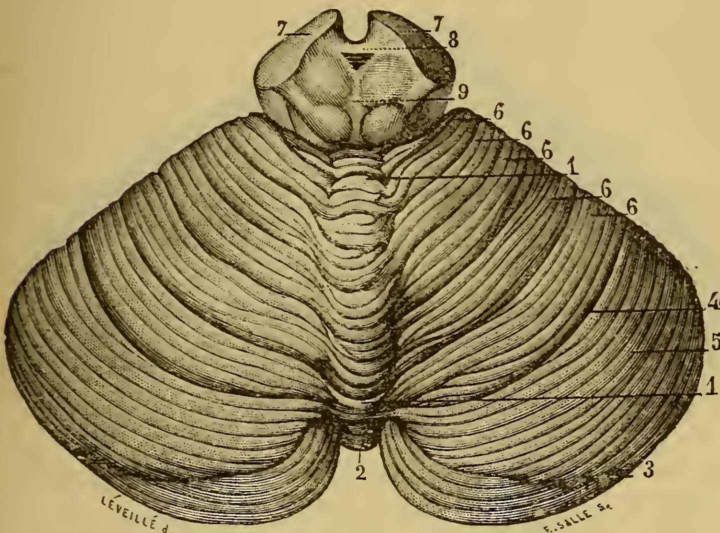


Fig. 149.—Upper Surface of the Cerebellum. (Sappey, after Hirschfeld.) 1, 1, Superior 'vermiform process' (middle lobe) whose anterior extremity has been pushed backwards in order to show the Corpora Quadrigemina; 2, posterior extremity of the superior and inferior 'vermiform processes,' and of the median fissure of the Cerebellum; 3, great circumferential fissure; 4, great fissure of the upper surface which divides it into two principal segments; 5, posterior of these segments in the form of a crescent; 6, 6, 6, 6, 6, anterior segment, quadrilateral, and composed of five secondary curved segments like the preceding—each of these segments being composed of closely packed 'laminæ' of different sizes, separated by fissures of varying depths; 7, 7, sections of the Cerebral Peduncles; 8, 'posterior commissure' of the Cerebrum; 9, Corpora Quadrigemina.

much deeper than others. These deeper fissures are comparatively few in number, and they constitute the boundaries of the several 'lobes' and 'lobules' of this organ. Between them are others more or less concentrically arranged, which vary much in length and depth.

* A very elaborate work on the Cerebellum ("Bau des kleinen Gehirns)," richly illustrated, has been issued by Stilling.

The number of these fissures of the second order has been computed to be from 600 to 800. They divide the surface of the Cerebellum into a multitude of 'laminæ,' the nature and arrangement of which will be better appreciated after an examination of figs. 156, 162, 166.

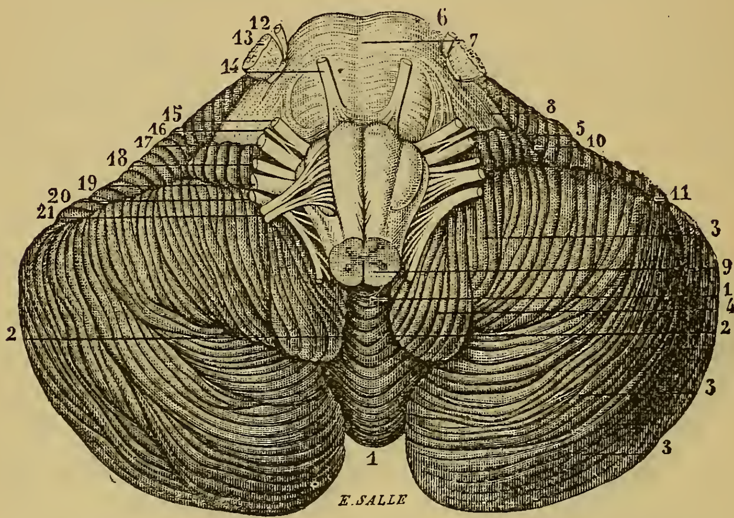


Fig. 150.—Inferior Surface of the Cerebellum. (Sappey, after Hirschfeld.) 1, 1, Inferior vermiform process; 2, 2, median fissure of the cerebellum; 3, 3, 3, lobes and lobules of the cerebellar hemispheres; 4, 'amygdala' or almond-like lobe; 5, lobule of the pneumogastric; 6, pons Varolii; 7, median groove on the same; 8, middle peduncle of the cerebellum; 9, cut surface of medulla; 10, anterior extremity of the great circumferential fissure; 11, anterior border of the upper surface of the cerebellum; 12, motor root of the trigeminal nerve; 13, sensory root of the same; 14, nerve of the external ocular muscle; 15, facial nerve; 16, nerve of Wrisberg; 17, auditory nerve; 18, glosso-pharyngeal nerve; 19, pneumogastric nerve; 20, spinal accessory nerve; 21, hypoglossal nerve.

According to Marshall, the Cerebellum of the Bushwoman was more prominent at the sides, and proportionally wider and longer than in the European, though its outline was not so full and rounded, and its actual bulk was less. As the result of laborious comparative investigations, he says, "the number of laminæ in the Bushwoman's Cerebellum agrees very closely with that in the European, the differences being probably only such as might be met with between individuals of either race." The relative number in the several parts was, however, found to be different in some of the smaller lobes, and many of the laminæ were also smaller and thinner. The slight deficiency in weight of the Bushwoman's Cerebellum, "depends essentially," according to Marshall, "not on the absence of any parts or laminæ, but on the narrowness of these latter; for they are obviously much finer than in the European brain." On the whole, he considers that "the Cerebellum in the Bushwoman is very well developed, and that, as an organ, it is far more completely evolved than the Cerebrum."

Significance of the High Convolutional Development of the Human Cerebral Hemispheres.

After the preceding description of the external configuration of the Human Brain, and now that the differences existing between it and that of the higher Apes have been detailed, such questions as these may naturally present themselves to the minds of many readers:—What is the precise significance of this more complex convolutional development of the Human Cerebrum? and what significance is to be attached to the want of symmetrical development in the corresponding Convolutions of its two Hemispheres?

It has been previously pointed out that there are three principal types of convolutional arrangement — (1) that of the Herbivora, (2) that met with among Carnivora and Cetacea, and (3) that of Quadrumana and Man. We have seen also that within each of these great groups, the development of the Convolutions peculiar to particular species has hitherto seemed to be dependent in the main upon the customary size attained by such animals*—those that are small may have none, whilst allied animals of larger size may have more or less developed convolutions. Yet it certainly cannot be said that larger animals are necessarily more intelligent than smaller animals.

As to the reason of the greater convolutional development met with in larger animals Carl Vogt says †:—

"Happily, mathematics will assist us here. On comparing two bodies of similar form but of different size, their respective volumes vary as the cube of their diameters, whilst the proportion of the surfaces is as the square of the diameters, or, in other words, the volume of a body increases more rapidly than the surface, and this more rapidly than the diameter. Every artillerist knows well that a twelve-pounder, though thrice as heavy as a four-pounder, does not nearly possess a diameter thrice as large . . . In applying this principle to the head, and especially the cranium of animals, it will be seen that in every natural group or order of mammals, the head, and especially the cranial capacity, stands in a certain relation to the body, which is nearly constant in the various species . . . that the surface of the internal cranial capacity is proportionately smaller in the larger animal, and that consequently, in order to secure a similar surface of grey matter, it must be convoluted in the large animal, whilst it may remain smooth in the small animal."

If we look then from a broad, general point of view at the problem as to the degree of importance to be attached to the great convolutional complexity of the brain of Man, it is apt to appear, at first sight, that this particular feature may be a necessary appanage or sequence of the size of Man's body, as compared with that of Monkeys and of Apes. Man, in respect of convolutional development, appears to stand far away at the head of the Quadrumanous type, just as the Elephant stands at the head of the Herbivorous type, and just as the great Whales

* See p. 276.

† "Lectures on Man" (Anthrop. Soc. Transln.), p. 105.

occupy a similar position at the head of the Carnivorous type. And further, the brains of the Elephant and of Cetacea show (like that of Man) a very decided lack of symmetry in regard to the precise disposition and shape of corresponding Convolutions in the two Hemispheres. The inferences, therefore, seem, at first, not without warrant that lack of symmetry is apt to go as a kind of mechanical accident with great complicacy of the Convolutions, and that this latter feature, if we compare animals of allied groups, is, in the main, in relation with the size of their bodies and the capacities of their Crania.

But other important considerations have to be kept in view. Thus, as Vogt says, we must bear in mind the fact that the 'cranial capacity' of Man is, in proportion to his bulk, enormously greater than that of any of the anthropoid Apes, and yet notwithstanding this very greatly increased size of the brain-chamber, the increased area thus obtained for superficial grey matter of Brain, does not prove nearly sufficient for the needs of Man's Intellectual and Moral Life: it has still to be increased by the occurrence of further secondary foldings in the Cerebral Convolutions.

A striking illustration of these all-important considerations is to be found in the fact that the convolutional development of the Gorilla's brain is much simpler than that of Man's, although the cranial capacities even of the lowest Men are so much greater than that of the Gorilla, and even though in bulk of body the great Ape often far surpasses them. We have therefore increased complicacy of Convolution showing itself in the brain of Man under such doubly adverse general conditions as to make its existence all the more significant of the enormous advance which has actually taken place in the development of the Cerebrum.

Again, seeing that the increased convolutional complexity of the Cerebrum in higher as compared with lower Human Races is also associated with an enormous increase in 'cranial capacity' and weight of Brain — though bodily stature remains practically the same—we have here further evidence as to the vast development of the Cerebral Hemispheres that has taken place during the long roll of centuries, whilst the ancestors of present civilized races have been gradually raising themselves from pristine states of savagery and barbarism.

The high convolutional development of the brain of Man is, therefore, a matter of altogether greater significance than the same feature in Elephants and Cetacea, seeing that it clearly is not in him, as it is to a considerable extent with them, a mere correlative of great comparative size of body.

It is quite possible, however, that the relation between high convolutional complexity of the Human Cerebrum and high Intellectual and Moral Attainments may be general, rather than special and invariable. This relation may, indeed, be very similar to that which has been shown to obtain in human beings between high Brain-weights and superior Mental Attainments and Powers. Prevailing tendencies decidedly favour such coincidences, and yet, as we have seen, notable exceptions may from time to time be encountered. In subsequent chapters it will be pointed out that there is a functional inequality between the two Cerebral Hemispheres, so that the asymmetrical development of their otherwise corresponding convolutions may be, at least in part, due to this fact.

CHAPTER XXII.

FROM BRUTE TO HUMAN INTELLIGENCE.

"MAN as a being who reasons is dependent upon the form of Language which he employs, to an extent that can scarcely be over-estimated. It is by virtue of this, in great part, that he attains to such skill and excellence in the carrying on of complex mental processes. And if, in attempting to bridge in the faintest way the great intellectual and moral gap which sunders man from the highest of the inferior animals, we say that he alone is possessed of the power of speaking and of using Articulate Language, we probably fix upon that power which, infinitely above all others, has had to do with the gradual progress that seems to have taken place during the lapse of ages—a progress which has enabled particular races of man to advance through the multitudinous grades of civilization intervening between those who lived in the condition of savages, and those who now constitute the flower of European civilization. If then the possession of Articulate Speech, with the superadded accomplishments growing out of this, of transmitting thought by means of written and printed symbols, have had such an overwhelming influence in aiding certain races to elevate themselves out of a condition of the rudest barbarism, it seems even more certain still that Thought in all its higher modes could not be carried on at all without the aid of Language of some kind."

This passage, which formed the introduction to an article on "The Physiology of Thinking," written some years ago,* may be taken as the text of the present chapter.

Views very similar to these had previously been enforced by Herbert Spencer, Huxley, and others, and they have grown much in public recognition during the intervening period, especially through the able advocacy of one whose loss we have now to deplore. Though the doctrines expressed by G. H. Lewes were not perhaps so novel as his language seems to imply, yet he lent them new force, and developed them in a fuller and more precise manner than had been done by other writers.

The most obvious use of Language is of course as a means of definite communication between man and man. In his "Laws of Thought," Thomson says (pp. 37–39 and 47): "We might dispense with articulate speech for certain purposes, and might make gestures and changes of the countenance, which are the language of action, supply its place. But actions and the play of features, whilst they serve to express love or hatred for some present object, need of food or rest, joy or sorrow, can but express a very small and confined list of thoughts, if we would indicate our feelings towards an absent person, or our wish for something at a distance, or would direct attention to some inward state or sentiment . . . Hence it is necessary to appropriate to every object a signal, always available, which all men by a tacit convention accept as a substitute for the object, and which, therefore, recalls the object to the fancy whenever it is employed; and such a signal is a noun or name . . . . Names, however, are representatives of things; and the different states of things must find an expression likewise;

* "Fortnightly Review," January, 1869.

hence the need of adjectives and verbs. The verb has the power of assigning to the thing at a particular time the condition of being, doing, or undergoing something. . . . When two or more names come together, it is frequently necessary to express the mutual relation in which they stand; a thing may be to, from, by, in, near, above, below another, and prepositions are inserted to determine this. Here then are the four principal parts of speech, substantives, or names to express substantives, adjectives to stand for attributes, prepositions to denote relations, and a single verb to assign attributes or relations to substantives at a determinate time."

"The various parts of speech took their origin from the noun and verb, or possibly from the noun alone. Many instances can be found of adverbs and prepositions which are distinctly substantives, and of conjunctions which are but parts of verbs. Then the close connexion between the verb and noun is indicated by the number of words which, in our own language, are both verb and noun, and only distinguished by mode of pronunciation."

"It is impossible to trace the growth of language with certainty; but it is most probable that many of the roots of the primitive language were originally imitations of the various sounds emitted by things in the natural world. A bird or animal, perhaps, received a name derived from, and resembling, its own peculiar utterance. The cry or exclamation that man emitted instinctively under the pressure of some strong feeling, would be consciously reproduced to represent or recall the feeling on another occasion: and it then becomes a word or vicarious sign. Where natural sounds failed, analogy would take the place of imitation; words harsh and difficult to pronounce would be preferred to stand for unpleasing objects, over those of a more bland and facile character, which would be appropriated to pleasant things and conceptions. There agreement among those who used the language, would be sufficient to stamp a vocal sound as the name of a certain object, where neither imitation nor analogy suggested one. But these original roots, the simplest form of substantives, would gradually become less and less discernible as the language grew richer and more intricate. Wherever new arts are practised, we may easily find opportunities of watching the growth of new names for its instruments and processes, guided by these three principles, imitation, analogy, and mere convention."

"These are but slender hints," says the author (now Archbishop of York), "of the direction in which profound and acute researches have been made. And I do not think that such attempts to dissect and analyze language, pursued with proper caution, tend at all to lower our estimate of the importance of the gift of speech, or of its marvellous nature." This will, perhaps, be a consolatory admission to many persons. It is further not without interest to find another highly acute and philosophical Doctor of Divinity writing as follows*:—

"In inquiring how far the same process, can account for the invention of language, which now takes place in the learning it, the real question at issue is simply this: Is the act of giving names to *individual objects of sense* a thing so completely beyond the power of a man created in the full maturity of his faculties, that we must suppose a Divine Instructor performing precisely the same office as is now performed for the infant by his mother or his nurse; teaching him, that is, to associate *this sound* with *this sight?*" This question may be asked in the interests of a human race naturally evolved, with as much cogency

* Dr. Mansel, "Prolegomena Logica," p. 20.

as in reference to the hypothetical man "created in the full maturity of his faculties."

An endowment like Articulate Speech, when once started —whether by some hidden and unknown process of natural development, or as a still more occult God-sent gift to Man —was by its very nature almost certain to have led its possessors by degrees along an upward path of cerebral development. How slow and tardy the process has been we are now beginning dimly to perceive, by reason of those researches which have made known to us the great antiquity of the Human Race and the far remote period of Man s appearance upon this Earth.

Anterior to historical epochs, the Men who were the contemporaries of the great Mammoths, whose remains are found in the Post-Tertiary Drift, those of the Bone-Caves, those of the Shell-heaps and the Peat-bogs, as well as those of the Cromlech period and the Early Lake-dwellings, lived for untold ages in a state of simplicity and barbarism far greater than that which still continues among many of the savage and semi-savage races covering so large a proportion of the Earth's surface.

Progress, in the early stages of human history, was necessarily so slow as to have seemed almost absent, even if we mark time by centuries. Gradually, however, as a nomad life gave place to a more complex communal life, the advantages of co-operation would show themselves in many ways. The commencement of a developing Social Organization necessarily entails a greater diversity in the relations of man with man, which would naturally become reflected in their Language, and proportionately increase the area of their thought-processes, by giving birth to new exercises, or, at all events, by greatly strengthening certain previously embryonic mental processes.

Increased Sympathy, as well as an increased recognition by each unit of the 'social organism' of what he might do for the gratification of his own wants or desires without bringing pain upon himself through the anger of his fellows, would gradually teach him the necessity of subordinating within certain limits his realization of egoistic impulses, and the need, even for the sake of his own happiness, of continually bearing in mind the wants and wishes of his fellow-men.

Sympathy we have seen to have been begotten even in the breasts of many dumb animals, when they have learned to recognize in their fellows the outward signs of that which they remember as a condition of past distress for themselves. The ideal recurrence of such a state, coupled with a perception implying the similar present suffering of another, prompts to actions for its relief. In such exercise of mere brute Sympathy, we have one of the most important germs of those altruistic feelings which attain so much breadth and power in higher races of Man.

Equally important, however, among savage races, are those limitations which 'expediency' compels the individual to recognize, as imposed by his fellow-men upon the freedom of his own actions. Such considerations, in concert perhaps with a strengthening Sympathy, gradually tend to build up within him an inward monitor, or 'Conscience,' at the same time that there arise embryo notions of Right and Duty, constituting the foundations of a dawning 'Moral Sense.' Having such an origin, the impulses of such a 'faculty' cannot fail to harmonize with prevalent opinions and influences. As G. H. Lewes says*:—

"There cannot be moral relations apart from Society . . . . The Intellect and the Conscience are social functions; and their special

* "Problems of Life and Mind," vol. i. p. 173.

manifestations are rigorously determined by social Statics, *i.e.* the state of the Social Organism at the time being, which they in their turn determine. The Language we think in and the conceptions we employ, the attitude of our minds, and the means of investigation, are social products determined by the activities of the Collective Life. The laws of intellectual progress are to be read in History, not in the individual experience. We breathe the social air: since what we think greatly depends on what others have thought."

The power of Language in aiding cerebral development and thinking processes, although it must have been great from the first, and ever tending to increase, did not reveal itself so forcibly till means had been adopted for the preservation and communication of human experience and thought from generation to generation, by means either of Hieroglyphics or more modern forms of Writing. When these came into common use, and when, more especially, Printing had been adopted and books began to circulate, then at last Language began to exercise its full influence as an aid to and developer of Thought. For although oral tradition is vastly better than no means at all, for communicating 'experience' and Thoughts from one generation to another, it is poor indeed compared with the facilities afforded by printing and the common distribution of Books. With these latter means in existence, the Thoughts of man may go on accumulating from age to age, forming a record of his complex relations to nature generally, to his fellows, and to that Social Organism, in particular, of which he and they form parts.

Language is, however, indispensable not merely to the communication, but to the formation of Thought, since it favours the birth of Concepts or General Notions, and is essential both for their 'preservation' and familiar 'use.'

In his "Prolegomena Logica" (pp. 19, 20, 29-31), Mansel says:—

"To the child learning to speak, words are not the signs of thoughts, but of intuitions ['Presentations of Sense']: the words *man* and *horse* do not represent a collection of attributes, but are only the name of the individual now before him. It is not until the name has been successively appropriated to various individuals, that reflection begins to inquire into the common features of the class. Language, therefore, as taught to the infant, is chronologically prior to thought and posterior to sensation . . . . All concepts are formed by means of signs which have previously been representative of individual objects only . . . . Similarities are noticed earlier than differences; and our first abstractions may be said to be performed for us, as we learn to give the same name to individuals presented to us under slight, and at first unnoticed, circumstances of distinction. The same name is thus applied to different objects, long before we learn to analyze the growing powers of speech and thought, to ask what we mean by each several instance of its application, to correct and fix the signification of words used at first vaguely and obscurely. To point out each successive stage of the process by which signs of intuition become gradually signs of thought, is as impossible as to point out the several moments at which the growing child receives each successive increase of its stature."

This important opinion of Mansel, that without 'signs' or Names we could not form Concepts at all, is in opposition to a commonly entertained view, that "we must have had the concept before we could have given it a name," but it is one which, as J. S. Mill * puts it, Mansel justly enough bases upon the view that "names when first used are names only of individual objects, but being extended from one object to another under the law of Association by Resemblance, they become specially associated with the points of resemblance, and thus generate the Concept." Sir William Hamilton thinks, however, that we may be able to 'form' simple concepts, though scarcely to 'preserve' them without the aid of

* "Exam. of Sir Wm. Hamilton's Philosophy," p. 324.

signs. "A word or sign," he says,* "is necessary to give stability to our intellectual progress, to establish each step in our advance as a new starting-point for our advance to another beyond. A country may be overrun by an armed host, but it is only conquered by the establishment of fortresses. Words are fortresses of thought. They enable us to realize our dominion over what we have already overrun in thought; to make every intellectual conquest the basis of operations for others still beyond . . . . Though, therefore, we allow that every movement forward in language must be determined by an antecedent movement forward in thought; still, unless thought be accompanied at each point of its evolution, by a corresponding evolution of language, its further development is arrested." On a previous page he had said:—"The concept thus formed by an abstraction of the resembling from the non-resembling qualities of objects, would again fall back into the confusion and infinitude from which it has been called out, were it not rendered permanent for consciousness, by being fixed and ratified in a verbal sign."

While there seems to be good reason for believing with Mansel, that General Notions or Concepts cannot be formed without the aid of Signs, this doctrine must be received with a certain reservation, which tends, however, to support the opinion of Sir William Hamilton. Signs are necessary; but, for the formation of simple General Notions, 'Visual Images' may take the place of Words.

On this subject J. S. Mill says:—"The signs need not be artificial; there are such things as natural signs. The only reality there is in the Concept is, that we are somehow enabled and led, not once or accidentally, but in the common course of our thoughts, to attend specially, and more or less exclusively, to certain parts

* "Lectures," vol. iii. pp. 138–140.

of the presentation of sense or representation of imagination which we are conscious of. Now, what is there to make us do this? There must be something which, as often as it recurs either to our senses or to our thoughts, *directs* our attention to those particular elements in the perception or in the idea: and *whatever performs this office is virtually a sign;* but it need not be a word: the process certainly takes place to a limited extent, in the inferior animals; and even in human beings who have but a small vocabulary, many processes of thought take place habitually by other symbols than words. It is a doctrine of one of the most fertile thinkers of modern times, Auguste Comte, that besides the logic of signs, there is a logic of images, and a logic of feelings. In many of the familiar processes of thought, and especially in uncultured minds, a visual image serves instead of a word. Our visual sensations—perhaps only because they are almost always present along with the impressions of our other senses—have a facility of becoming associated with them. Hence the characteristic visual appearance of an object easily gathers round it, by association, the ideas of all other peculiarities which have, in frequent experience, co-existed with that appearance: and summoning up these with a strength and certainty far surpassing that of the merely casual associations, which it may also raise, it concentrates the attention on them. This is an image serving for a sign—the logic of images. The same function may be fulfilled by a feeling. Any strong and highly interesting feeling, connected with one attribute of a group, spontaneously classifies all objects according as they possess or do not possess that attribute. We may be tolerably certain that the things capable of satisfying hunger, form a perfectly distinct class in the mind of any of the more intelligent animals; quite as much so as if they were able to use or understand the word food."

Whilst it seems possible, therefore, that simple General Notions may be formed around and called up by Feelings, and consequently by the Images of these (and especially by Visual Images), it is also clear that Words are much more potent Signs, since in addition to the aid which they afford in the formation of General Notions, they carry with them the power of being used as means of communicating Thoughts, and, therefore, of strengthening them by repetitions and mutual interchanges, during the daily life of the units of any tribe, race, or nation of Human Beings.

As Thomson says * :—"Language, the close-fitting dress of our thoughts, is always analytical, it does not body forth a mere picture of facts, but displays the working of the mind upon the facts submitted to it, with the order in which it regards them . . . . the same language becomes more analytic as literature and refinement increase. This property indicates, as we should expect, corresponding changes in the state of thinking in different nations, or in the same at different times. With increasing cultivation, finer distinctions are seen between the relations of objects, and corresponding expressions are sought for, to denote them; because ambiguity and confusion would result from allowing the same word, or form of words, to continue as the expression of two different things or facts . . . . A discovery can hardly be said to be secured, until it has been marked by a name which shall serve to recall it to those who have once mastered its nature, and to challenge the attention of those to whom it is still strange. Such words as inertia, affinity, polarisation, gravitation, are summaries of so many laws of nature, and are so far happily chosen for their purpose, that, except perhaps the third, each of them guides us by its etymology towards the nature of the law it stands to indicate . . . . Names then are the means of fixing and recording the results of trains of thought, which without them must be repeated frequently, with all the pain of the first effort . . . . As the distinctions between the relations of objects grow more numerous, involved, and subtle,

* "Laws of Thought," p. 28.

it becomes more analytic, to be able to express them: and inversely those who are born to be the heirs of a highly analytic language, must needs learn to *think up* to it, to observe and distinguish all the relations of objects, for which they find the expressions already formed, so that we have an instructor for the thinking powers in that speech, which we are apt to deem no more than their handmaid and minister."

Leibnitz, in an important passage concerning the symbolical nature of many of our processes of cognition or thought, was the first to call attention to a kind of fusion or identification of Thought and Word, which is habitually taking place in our ordinary mental processes. General and abstract names or words are often, as Thomson says,* "Symbols both to speaker and hearer, the full and exact meaning of which neither of them stops to unfold, any more than they regularly reflect that every sovereign which passes through their hands is equivalent to 240 pence. Such words as the state, happiness, liberty, creation, are too pregnant with meaning for us to suppose that we realize their full sense every time we read or pronounce them. If we attend to the working of our own minds, we shall find that each word may be used, and in its proper place and sense, though perhaps none or few of its attributes are present to us at the moment."

The process of Conception by which such general or Abstract Notions are arrived at, is only possible by a prior use of Language; and the marking of these complex notions by Words subsequently to be used as 'symbols' or counters equivalent to such Notions, is a fusion into one of cerebral Thought-processes and Word-processes—the Word in future is the Thought.

* Loc. cit. p. 36.

After these brief observations concerning the growth and functions of Language, and as to its use in aiding the development of Mind, we may turn to the views of G. H. Lewes concerning the transition from Brute to Human Intelligence, and on the subject of the further powerful influence exerted by Language, when acting in concert with Social Influences generally—the influences that is, which are brought to bear upon Men as units in a gradually developing Social Organization.

He says *: "That animals have sensations, appetites, emotions, instincts, and intelligence—that they exhibit memory, expectation, judgment, hope, fear, joy—that they learn by experience, and invent new modes of satisfying their desires, no philosopher now denies. And yet the gap between animal and human intelligence is so wide, that Philosophy is sorely puzzled to reconcile the undeniable facts." . . . "Animals having organs closely resembling our own, and feelings closely resembling our own, have little or nothing of the highest order of mental activity; Animals are intelligent, but have no Intellect; they are sympathetic but have no Ethics; they are emotive, but have no Conscience." . . . When it is said that Animals however intelligent have no Intellect, the meaning is that they have perceptions and judgments, but no conceptions, no general ideas, no symbols for logical operations.† They are intelligent, for we see them guided to action by Judgment; they adapt their actions by means of guiding sensations, and adapt things to their ends. Their mechanism is a sentient, intelligent mechanism. But they have not Conception, or what we

* "Problems of Life and Mind," vol. i. pp. 152, 154, and 156.

† To a limited extent, as already stated, there is reason to believe that animals do carry on some such mental processes, not of course by Word-Symbols, but by means of Visual Images.

specially designate as Thought, *i.e.* that logical function which deals with generalities, ratios, symbols, as Feeling deals with particulars and objects, *a function sustained by and subservient to impersonal, social ends.* Taking Intelligence in general as the discrimination of means to ends—the guidance of the Organism towards the satisfaction of its impulses—we particularize Intellect as a highly differentiated mode of this function, namely, as the discrimination of symbols. This differs from the rudimentary mode, out of which it is nevertheless an evolution, as European Commerce differs from the rudimentary Barter of primitive tribes. Commerce is impossible except under complex social conditions out of which it springs; and its operations are mainly carried on by means of symbols which take the place of objects; the bill of invoice represents the cargo; the merchant's signature represents the payment. In like manner Intellect is impossible until animal development has reached the human social stage; and it is at all periods the index of that development; its operations are likewise carried on by means of symbols (Language) which represent real objects, and can at any time be translated into feelings . . . between the extremes of human Intelligence—say a Tasmanian and a Shakespeare—there are infinitesimal gradations, enabling us to follow the development of the one into the other, without the introduction of any essentially new factor. But between animal and human Intelligence there is a gap, which can only be bridged over by an addition from without. That bridge is the Language of symbols, at once the cause and effect of Civilization."

Again, the same writer remarks *:—"An animal suffers from a physical calamity, seeks to escape from it,

* Loc. cit. pp. 168, 169.

but never seeks to understand and modify its causes. The savage also suffers, and seeks to escape. But he wonders, speculates on the causes, hopes to master them by invocations, or incantations. The civilized man tries to understand the causes, that he may modify them when they are modifiable, and resign himself to them when they are unmodifiable. The animal has only the Logic of Feeling to guide his actions. He observes and concludes, never explains. The man has besides this the Logic of Signs: he observes and explains the visible series by an invisible series. The one has only knowledge of particular facts, the other a knowledge of general facts."

In the progress of Intellectual Development there is exhibited an ever-increasing tendency to deal with more and more remote Conceptions, and with indirect mental processes which detach the mind further and further from Sensible Observation. It may be illustrated, as G. H. Lewes says,* by the stages of numerical calculation.

"Man begins by counting things, grouping *them* visibly. He then learns to count simply the numbers, in the absence of the things, using his fingers and toes for symbols. He then substitutes abstract signs, and Arithmetic begins. From this he passes to Algebra, the signs of which are not only abstract but general; and now he calculates numerical relations not numbers. From this he passes to the higher calculus of relations . . . . In consequence of this development of Intellect—*i.e.*, of the interest in remote means substituted for direct ends—man acquires his immense superiority over animals in achieving the final end. It is thus, and thus only, that he is enabled to modify the course of events. It is thus that Sentience becomes Science, facts are condensed into laws, and direct vision is multiplied and magnified by remote prevision."

"The absurdity of supposing that any ape could, under any normal circumstances, construct a scientific theory, analyze a fact into its component factors, frame to himself a picture of the life led

* Loc. cit. p. 171.

by his ancestors, or consciously regulate his conduct with a view to the welfare of remote descendants, is so glaring, that we need not wonder at profoundly meditative minds having been led to reject with scorn the hypothesis which seeks for an explanation of human Intelligence in the functions of the bodily organism common to man and animals, and having had recourse to the hypothesis of a spiritual agent superadded to the organism."

"But," he adds,* "the savage is not less incompetent than the animal to originate or even understand a philosophical conception; the peasant would be little better than the ape, in presence of the problems of abstract science; and it would be hopeless to expect either of them to weigh the stars, or to understand the equations of curves of double curvature. Nor are the moral conceptions of the savage much higher than those of the animal. His language is without terms for Justice, Sin, Crime: he has not the ideas. He understands generosity, pity, and love, little better than the dog or the horse does. His intelligence is mainly confined to perceptions and sentiments. His aims are almost all immediate and practical, rarely remote, never theoretical. The most intelligent inhabitants of Guiana, though far removed from primitive Savagery, could not believe that Humboldt had left his own country and come to theirs 'to be devoured by mosquitos for the sake of measuring lands which were not his own.' . . . . All the materials of Intellect are images and symbols, all its processes are operations on images and symbols. Language—which is wholly a social product for a social need—is the chief vehicle of symbolical operation, and the only means by which abstraction is effected. Without Language there can be no meditation, no theory, no Thought, in the special meaning of that term."

But as we have already hinted, concurrently with the development of Man's Intellectual Nature, there gradually emerges, in response to other aspects of the same general influences and conditions, what is known as his Moral Nature.

As Lewes says †:—"Man's individual functions arise in relations to the Cosmos; his general functions arise in relations to the Social Medium; thence Moral Life

* Loc. cit. pp. 158, 167. † Loc. cit. pp. 159, 173.

emerges. All the animal Impulses become blended with human Emotions. In the process of evolution, starting from the merely animal appetite of sexuality, we arrive at the purest and most far-reaching tenderness; from the merely animal property of Sensibility we arrive at the noblest heights of Speculation. The Social Instincts, which are the analogues of the individual Instincts, tend more and more to make Sociality dominate Animality, and thus subordinate Personality to Humanity. . . . . Thus the human Intellect emerges from animal Intelligence, and develops a vast independent creation, having the whole Cosmos and Humanity for its material. Concurrently with this, the Moral Intelligence develops its system. Both Intellect and Conscience are products of the animal impulses and social impulses acting and reacting. While the Intellect is mainly occupied with the relations of the Cosmos and its History, having the ultimate aim of making these subservient to practical needs, the Conscience, or Moral Intelligence, is mainly occupied with the relations of humanity—human needs and human actions—having the ultimate aim of conforming our conduct to those relations, harmonising our impulses with the impulses of others, thus aiding others and gratifying ourselves."

CHAPTER XXIII.

THE INTERNAL STRUCTURE OF THE HUMAN BRAIN.

THE internal structure of the Human Brain is so complex, and at the same time so very imperfectly known, as to make it difficult to give any account of it which shall be intelligible to the majority of readers. The adequate comprehension even of its general plan or groundwork will require a full amount of attention. In the present chapter multitudes of technical details, whose significance is either unknown or incapable of being appreciated by any one who has not previously made a close study of the subject, will be excluded. The discussion of such details may be found in more technical and purely anatomical works.

By tracing upwards some of the more elementary forms of the Nervous System met with among Invertebrates, and afterwards describing the principal external or grosser variations of the Brain as they present themselves in the Vertebrate Series, the best preparation has perhaps been made for such a study of the structure of the Brain of Man, as is compatible with the plan of this work. The reader will thus have been gradually introduced to the representatives of the several parts of the Human Brain, and the description of this organ ought thereby to have been rendered both simpler and more interesting than it would otherwise have been. No parts absolutely new will be met with, though it will not be difficult to note many differences in regard to the absolute or relative size of divisions of the Brain, with which the reader is already familiar from their occurrence in lower animals. The possession of a basis of comparison of this kind can scarcely fail to infuse great additional interest into the study of the brain of Man, and it will often obviate the necessity for anything like lengthy descriptions.

What is to be said in this chapter as to the internal structure of the Human Brain may be most conveniently grouped under the following headings:—(1) Internal Topography of the Human Brain; (2) Distribution of the Fibres composing the Cerebral Peduncles, with an account (*a*) of their relation to the Thalami and Corpora Striata, and (*b*) their relations (as well as that of Fibres which simply issue from, or go to, these great Ganglia) with different parts of the cortex of the Cerebral Hemispheres; (3) The microscopic anatomy of the Cerebral Convolutions; (4) The relations of the Commissures of the Brain, including (*a*) those connecting similar regions in the two Hemispheres, (*b*) those connecting different regions in the same Hemisphere, and (*c*) those bringing the Cerebellum into relation with the Cerebral Hemispheres; (5) The general structure of the Cerebellum and its relations with other parts; (6) The microscopic anatomy of the Cortex of the Cerebellum; (7) The central connections of the various Cranial Nerves; (8) The relations of the Visceral System of Nerves with the Brain.

1.—Internal Topography of the Human Brain.

The nature of the 'lateral' and other Ventricles, and the relations of all of them, except the fifth, to the originally wide canal of the primitive Cerebro-Spinal Nerve Tube, has already been indicated (pp. 267, 333, 338).

The Lateral Ventricles in the healthy and well-developed Human Brain are comparatively narrow cavities, represented in the main by three spurs or 'cornua.' (Fig. 151.) The arrangement of parts in and about these Lateral Ventricles is essentially similar to that met with in the higher Apes, in whom the previously much-talked of 'posterior cornua' exist, as well as the small swelling ('hippocampus minor') on its inner side, which corresponds externally with the calcarine sulcus (see p. 304). The Corpora Quadrigemina and adjacent structures also present no distinct peculiarities.

As there are no fresh structures met with in these regions of the Human Brain, no special description of its internal topography is needed, other than what is to be gathered from figs. 151–153, with their explanations. These the reader will do well to study, and compare with figures of the same parts belonging to some of the lower animals (figs. 86, 87, 115). Some few details concerning the structure of the Corpora Striata and Thalami will moreover be found in the next section.

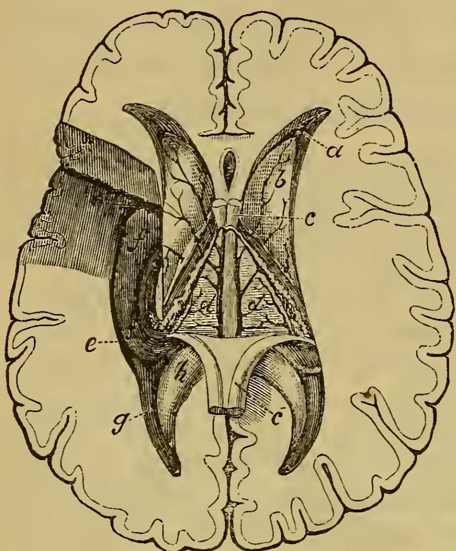


FIG. 151.—The Lateral Ventricles and their Cornua, with Contiguous Structures. (After Sharpey.) The upper portions of the Hemispheres have been cut away; the Fornix (*c*) has been cut across and reflected, so as to show the 'velum interpositum' (*d*, *d*) and the great veins of Galen which convey blood away from the central parts of the Brain, including the Corpora Striata (*b*); *a*, *e*, *g*, are the three cornua of the Ventricles; *f*, Hippocampus major (to show which the brain substance has been cut away still more on the right side); *h*, Hippocampus minor.

2.—The Distribution of the Fibres Composing the Cerebral Peduncles.

Serious attempts have been made during recent years to unravel the precise course of the different bands of fibres which pass from the Spinal Cord into the Brain, and *vice versa.* The laborious investigations of Stilling, Lockhart Clarke, Meynert and others in regard to the intimate structure of the Medulla, valuable as they are, will be but little referred to here, because they have revealed details far too complex and technical to be now set forth, and also because a statement of the general arrangement of its principal parts will be all that is really needful for the carrying out of our present plan.

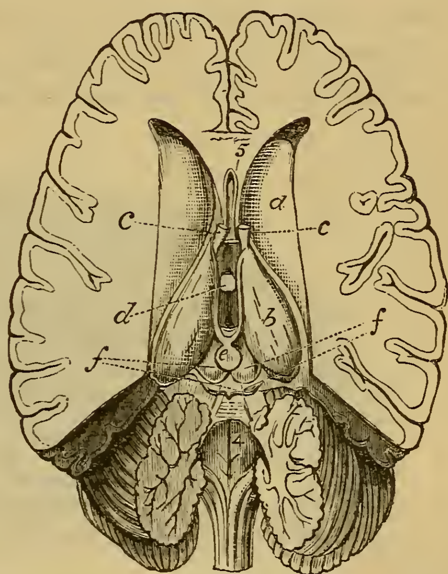


FIG. 152.—Third and Fourth Ventricles of the Brain exposed by removal of the 'velum interpositum' and further cutting away of Cerebral Hemispheres and portions of Cerebellum. (After Sharpey.) *a*, Corpus striatum; *b*, Thalamus; *c*, anterior pillars of Fornix; *d*, soft or 'middle commissure' stretching across third ventricle; *e*, Pineal body; *f*, *f*, Corpora quadrigemina; *g*, *g*, superior Cerebellar Peduncle with (*h*) part of the 'valve of Vieussens' lying between them and forming the roof of (4) the fourth ventricle.

The intimate structure and distribution of fibres in higher parts of the Brain is a study of no less extreme difficulty, which in recent years has been dealt with principally by Meynert, Luys and Broadbent. Concerning many points these observers are far from being in accord with one another. The views of Meynert on this difficult subject, have of late received what they much needed in the way of re-arrangement and clearer exposition from Professor Huguenin of Zurich, and the value of his work has been further enhanced in its French translation by the incorporation of new matter contributed by its editors, MM. Duval and Keller.* This treatise will well repay careful study by those who will not be repelled by its technicalities, and are capable of understanding them. It seems more than doubtful, however, whether Meynert is right in his general point of view as to the separate representation of sensory and motor channels for Automatic and Voluntary Movements respectively. Luys, in addition to the opportunity afforded by his larger systematic work,† has again stated his views in one of

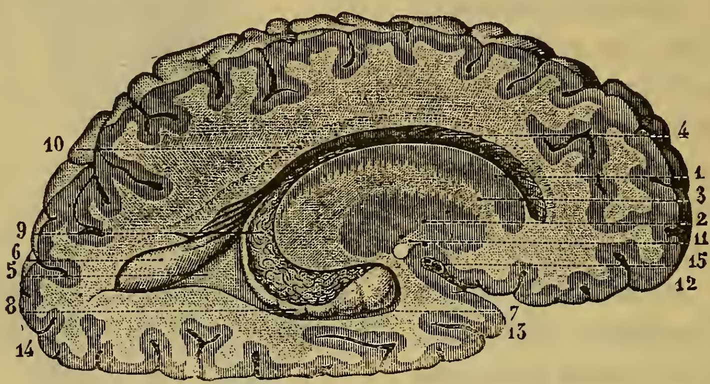


FIG. 153.—Longitudinal Vertical Section through the Left Hemisphere, showing the Lateral Ventricle and its three Cornua. (Sappey, after Hirschfeld.) 1, 2, intra and extra ventricular portions of the Corpus Striatum separated by (3) a stratum of white fibres; 4, junction of the body of the Ventricle with its 'anterior cornu'; 5, 'posterior cornu'; 6, Hippocampus minor; 7, descending or 'middle cornu'; 8, Hippocampus major covered by (9) the choroid plexus; 10, section of the corpus callosum; 11, anterior commissure; 15, fissure of Sylvius.

the volumes of this series.‡ If little reference be made to his opinions in this chapter it is partly for these reasons and partly because the investigations of Broadbent, so far as they have gone, have been more especially directed to some of the points which can be here most advantageously

* Anatomie des Centres Nerveux, par Huguenin, Paris, 1879.

† Sur le Système Nerveux Cerebro-Spinal, 1865.

‡ Le Cerveau et ses fonctions, 1876.

discussed—partly, moreover, because his observations seem to the writer to have been conducted with great care, and also to have been interpreted from a correct general standpoint. Thus, though the investigations of Broadbent have as yet only been published in abstract,* they will principally be cited in this and in the following sections.

One of the most fundamental facts in regard to the structural relations of the Cerebral Hemispheres and their Peduncles, is that the left half of the Brain is specially in connection with the right half of the body, and the right half of the Brain with the left half of the body. This arrangement exists not only in Man, but in Vertebrates generally (though with varying degrees of completeness), and it is due to the fact that the 'ingoing' fibres to each Cerebral Hemisphere come from, whilst its 'outgoing' fibres are distributed to, the opposite half of the body.

Speaking in general terms, it may be said that the 'ingoing' fibres which enter the Cord and Medulla on either side throughout their whole length, soon cross over, as Brown-Séquard has shown, to the opposite side of these centres; and that they thence follow an ascending course towards—though they do not necessarily go as far as—the Cerebral Hemisphere of the same side. Similarly, an important section at least of the 'outgoing' or motor fibres, viz., those forming part of the 'anterior pyramids', decussate with their fellows in the Medulla, so as to pass over to the opposite 'lateral column' of the Cord. Thus, even allowing for the fact that some of the Cranial Motor Nerves decussate by themselves higher up, in the sub-

* "The Structure of the Cerebral Hemisphere," *Journal of Mental Science*, 1870; and also "The Construction of a Nervous System," *Brit. Med. Journ.*, March & April, 1876.

stance of the 'pons Varolii' (fig. 154), the sites in which decussation of motor channels takes place, are altogether limited in area when compared with what obtains for sensory channels.

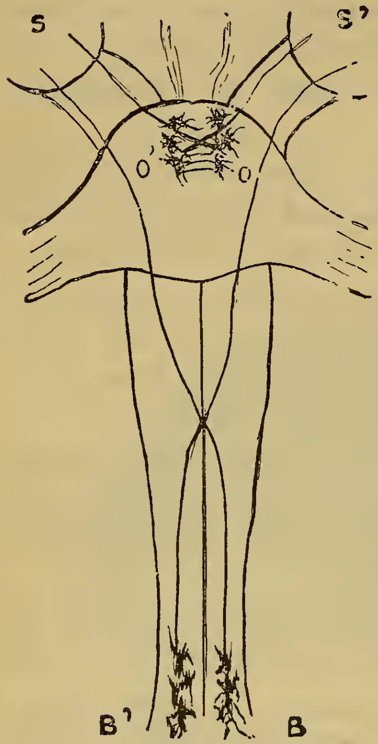


FIG. 154. — Diagram illustrating the place and mode of 'decussation' of Motor Fibres in the Medulla and in the Pons. (Broadbent.) B, B', two sets of nuclei of brachial plexus, not connected by transverse commissures; O, O', two sets of oculo-motor nuclei in Pons, freely connected with one another by transverse commissural fibres. S, S', motor fibres from Corpus Striatum.

The longitudinal fibres of the Spinal Cord are in the main divisible (if we exclude those specially in relation with the Cerebellum) into three categories, viz., (1) fibres transmitting 'ingoing' currents towards the Brain; (2) fibres which transmit 'outgoing' currents; and (3) fibres of a 'commissural' order, serving to connect separate groups of cells or centres in different parts of the Spinal Cord itself, or in the Spinal Cord and Medulla.

The Spinal Cord being, moreover, a bilaterally symmetrical organ, the groups of cells above referred to are similarly represented in each half of it (fig. 19); and the similar Motor and Sensory regions of these two halves of the Cord and Medulla are to a considerable extent brought into structural relation with one another by means of numerous transverse 'commissural' fibres.

The first two sets of longitudinal fibres, above referred to, pass on each side in compact columns through the Medulla, and through that continuation of it which is crossed by the 'middle peduncles' of the Cerebellum (viz., the pons Varolii). Beyond this point, both sets of fibres of the one side diverge from those of the other (fig. 154) so as to form what are known as the **'Cerebral Peduncles.'** These parts are seen on the under surface of the brain, especially when the tips of the Temporal Lobes are drawn outwards or removed (fig. 155, *r c*). Each Peduncle soon disappears within the corresponding Cerebral Hemisphere, and then its future course,

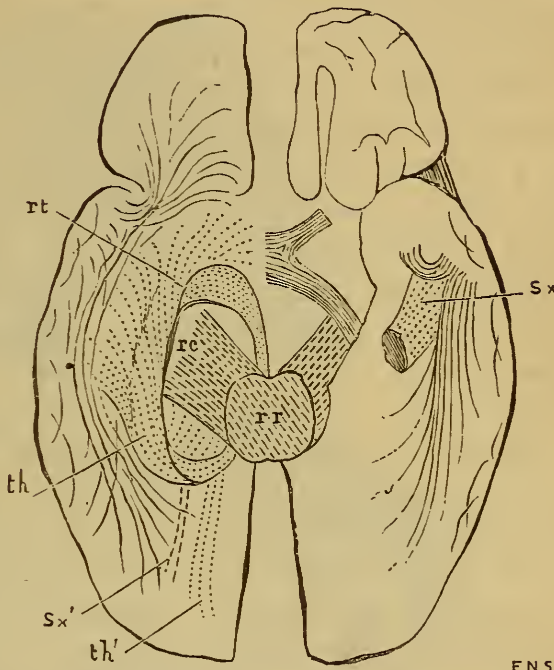


FIG. 155.—On right side shows plane of fibres underlying superficial convolutions on inferior aspect of Temporal Lobe, and forming the floor of Descending Cornu. The Cornu has been opened anteriorly, and fibres (*s x*) from the apex of the lobe to the extra-ventricular Corpus Striatum are seen. On the left side of figure, the dissection has been carried further, and the Optic Tract has been removed. *r r*, Crura Cerebri. *r c*, Crusta. *r t*, Fibres of Tegmentum (and from Thalamus) turning round anterior edge of Crusta. *t h*, Tail of Thalamus, turning round posterior edge of Crusta, forming 'Collar of Crus,' and distributing fibres to Sylvian margin of Temporal Lobe. *th'* and *sx'*, Fibres from Thalamus and extra-ventricular Corpus Striatum respectively to Occipital extremity of Hemisphere. The longitudinal fibres not indicated by letters belong chiefly to the system of the Gyrus Uncinatus. (Broadbent.)

or that of its constituent fibres, can only be made out by the most careful dissections. It spreads out rapidly into a fan-like expansion, the 'corona radiata,' the edges of the fan being directed, as Broadbent says, "forwards and backwards, the surfaces inward and outward, but sloping outwards, so that the outer surface looks downwards, and is concave, the inner looks upwards, and is convex."

On cutting across one of the Peduncles in front of the Pons it is found to be separated into two layers of fibres by a grayish black streak of ganglionic tissue, known as the 'locus niger.'* Looked at from the under surface, the most superficial stratum (that is, the under and anterior stratum in the natural position of the Brain) is known as the '*Crusta*,' and is made up of white fibres. It doubtless consists of the bulk of the outgoing fibres, which lower down are clustered together into the 'anterior pyramids' of the Medulla, together with other fibres terminating in 'motor' cell-groups in the Pons and Medulla. Mixed with these, in all probability, are fibres which suffice to connect the Corpus Striatum with the Cerebellum through the intermediation of its 'middle peduncles.' The deeper stratum (that is the upper and posterior parts of the Peduncles in the natural position of the Brain), constituting what is known as the '*Tegmentum*,' is not so white in colour, and seems to be mainly composed of 'ingoing' fibres derived from the Cord and Medulla.

"The Crusta and Tegmentum," Broadbent says, "can be separated from each other for some distance upwards, as they spread out to form the fan-like expansion spoken of; but before they emerge from the central ganglia the fibres of one sink in between those of the other, and they become mixed together, so as to be no longer distinguishable."

* Its colour being due to the abundance of pigment granules contained within the large nerve cells of this region.

a. Relation of the Cerebral Peduncles to the Central Ganglia: Thalami and Corpora Striata.—According to

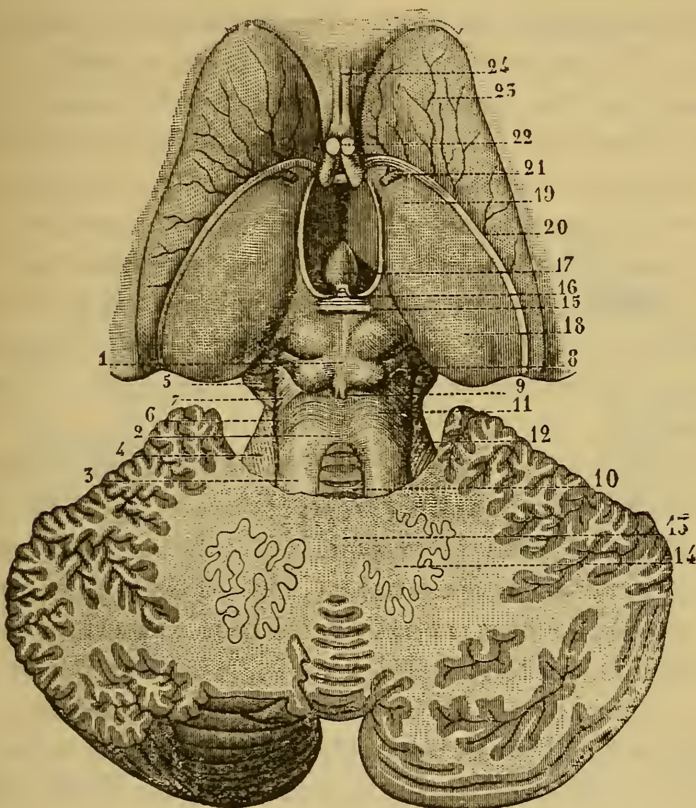


FIG. 156.—Central Ganglia of the Brain, together with the Cerebellum and its Superior Peduncles. (Sappey, after Hirschfeld.) 1, Corpora quadrigemina; 2, Valve of Vieussens; 3, superior Cerebellar Peduncles; 4, upper part of the middle Cerebellar Peduncles; 5, upper part of the Cerebral Peduncles; 6, lateral groove of the isthmus; 7, ribbon of Reil; 8, cord extending from the 'testis' to the internal 'geniculate body'; 9, column of the Valve of Vieussens; 10, grey lamella of the same; 11, posterior fibres of the triangular bundle of the isthmus; 12, upper fibres of middle Cerebellar Peduncles; 13, white centre of the Cerebellum; 14, grey rhomboidal nucleus of Cerebellum; 15, 'posterior commissure' of Cerebrum; 16, peduncles of the 'Pineal body'; 17, 'Pineal body' turned forwards so as to show last two structures; 18, posterior tubercles of the Thalami; 19, anterior tubercles of same; 20, Tænia semicircularis; 21, veins of the Corpus Striatum; 22, anterior pillars of the Fornix, between which the 'anterior commissure' is seen; 23, Corpus Striatum; 24, Septum Lucidum and 'fifth ventricle.'

the above-quoted anatomist, "The Thalamus and Corpus Striatum may be said to sit astride the posterior and anterior edge respectively, of the fan formed by the Crus as it expands, each having an intra-ventricular and an extra-ventricular division. The Thalamus is much the smaller of the two ganglia, and may be said to be embraced by the Corpus Striatum, which is also on a rather higher level. Both in structure and in their relations with the crus on the one hand, and the convolutions of the hemisphere on the other, there is a remarkable contrast between the Thalamus and the Corpus Striatum."

The **Thalamus** consists of an admixture of fibres and grey matter, and has a whitish colour on the surface—distinctly contrasting with the greyer tint of the Corpus Striatum.

By far the larger part of the Thalamus seems* to project into the 'lateral ventricle' as it "rests upon the tegmentum of the crus, from which it can be raised from behind, forwards and upwards, the diverging fibres of this part of the crus appearing to pass onwards beneath the ganglion without ending in it." But as Broadbent further remarks:—"It is possible that communication, by means of cell processes, exists between the radiating fibres and the overlying ganglion, bringing them into a relation equivalent to the direct termination of fibres and cells."

The portion of the Thalamus that actually has the appearance of lying outside the ventricle, consists "only of a prolongation from the body of the ganglion which bends round the posterior edge of the crus, and curves forwards in the roof of the descending cornu of the lateral ventricle, becoming pointed anteriorly."

The **Corpus Striatum** is divided into two distinct parts by the radiating fibres of the Crus which pass

* See pp. 269, 270 note, and fig. 122.

through it. "The intra-ventricular portion consists of a deposit or bed of soft grey matter, not intermixed with distinct fibres visible to the naked eye, thicker and wider anteriorly in the anterior cornu of the ventricle—narrowing to a point posteriorly. It rests upon the radiating fibres of the tegmentum and thalamus which pass on-

FIG. 157.—Transverse section of the Cerebrum, just behind Infundibulum. S V, Intra-ventricular, and S X, Extra-ventricular Corpus Striatum. *Th*, Thalamus. rc, Crusta, and r t, Tegmentum of Crus Cerebri; R, radiating expansion of white fibres ('corona radiata'); rc, r t, and R together form what has been called the 'internal capsule' of the Lenticular Nucleus. Cx, 'external capsule' (including the Claustrum); C, Corpus Callosum; FS', Fissure of Sylvius; L M G, Longitudinal Marginal Gyrus. S M G, S M G', Sylvian Marginal Gyrus; - - - - -, indicate lines of derivation of fibres of Corpus Striatum; . . . ., Fibres of distribution of Thalamus. (Broadbent.)

wards beneath it to the hemisphere proper." Between the bundles of radiating fibres this upper and anterior portion is continuous with the lower and outer 'extra-ventricular' portion of the Corpus Striatum, which is more bulky than the part already described, though it is, like it, also larger in front than behind. It is a somewhat pear-shaped mass of soft grey matter, bounded above and within by the radiating fibres of the Crus (*'internal capsule'*); and externally (fig. 157, C x) by a thin stratum of fibres (*'external capsule'*) issuing from its interior for distribution to various regions of the Hemisphere, though forming in the first part of their course to the convolutions (together with some other fibres from the 'fasiculus uncinatus' to be hereafter described) an outer wall, serving to separate this inferior portion of the Corpus Striatum from the immediately adjacent convolutions of the 'island of Reil'—the situation of which has been already defined (see pp. 301, 341, 381).

b. Relations of fibres composing the Cerebral Peduncles as well as of fibres issuing from or going to the Central Ganglia, with different Convolutions of the Cerebral Hemispheres.—It is easily to be demonstrated, according to Broadbent, that "fibres of the crus in large numbers pass uninterruptedly through or by the Central Ganglia to the Convolutions." And he adds, "In the case of the fibres of the posterior edge of the Crus there is scarcely room for error on this point, as they do not come at all into relation with grey matter on their way." *

Other fibres of both 'tegment' and 'crust,' seem to end in or take their origin from the grey matter of the Corpus Striatum, though Broadbent is inclined to believe that "no fibres of either division end in the Thalamus." †

From both Thalamus and Corpus Striatum, however, many independent fibres appear to issue, which serve to connect these ganglia with Convolutions in different parts

* Some of these fibres which merely pass through or by the Central Ganglia may, as certain anatomists suppose, serve to connect the Cerebral Cortex with the Cerebellum, by way of its 'middle peduncles.'

† This seems a very doubtful proposition. The anatomical relations of the Thalami are, however, as yet, as uncertain as are their functions.

of the Hemispheres.* These two sets of fibres do not proceed to the grey matter of the Convolutions separately, but are for the most part inextricably mixed with those fibres of the Peduncle (above referred to) which pass uninterruptedly through the Central Ganglia. Outside these bodies, moreover, all three sets of fibres become further intermixed with those of the great transverse commissure between the hemispheres—the Corpus Callosum.

But some further account must be given of the course of these three sets of fibres—answering to the 'projection system' of Meynert. Their mode of distribution is necessarily a matter of great importance, if any coherent notions are to be formed even as to the simpler modes of action of the Brain. The reader ought, therefore, carefully to study the particulars given below, making, as he proceeds, frequent references to those figures in which the relative position of the Convolutions alluded to may be seen. The substance of Broadbent's description is subjoined.†

The fibres of Crus, Thalamus, and Corpus Striatum always run, more or less, in company with one another to the same parts. For brevity, they may be spoken of as 'radiating' fibres.

(But, wherever 'radiating' fibres go, thither also go fibres of Corpus Callosum—though not necessarily in the same proportion. Thus it happens, that those Convolutions in which 'radiating' fibres terminate or commence, are also bilaterally associated through the Corpus Callosum, and are thereby fitted for conjoint activity.)

These 'radiating' and 'callosal' fibres are not distributed equally to *all* the Convolutions. Many of the latter do not receive a single fibre from Crus, Thalamus, Corpus Striatum, or Corpus Callosum, but have only an *indirect* communication with the cen-

* Broadbent says ("Journ. of Ment. Science," Ap. 1870, p. 9):—"A comparison again, of the sectional area of the fibres thus seen issuing from the Central Ganglia with the area of the Crus as it emerges from under the Pons, will show that the ascending fibres have been largely reinforced by additions from the Ganglia."

† "Brit. Med. Journ.," April 8, 1876, p. 433.

tral ganglia or great commissure, by means of looped fibres passing to them from Convolutions which are directly connected with 'radiating' and 'callosal' fibres.

The following summary statements made by Broadbent * in regard to the exact distribution of the 'radiating' and 'callosal' fibres, and as to the Convolutions to which they do not proceed, will be found to contain important particulars.

"The convolutions to which the radiating and callosal fibres go, are chiefly those along the margins of the Hemisphere: the margin of the great longitudinal fissure on one hand; the margins, superior and inferior, of the Sylvian fissure on the other, continued forwards by the inferior frontal, backwards by the inferior occipital gyri, to the frontal and occipital extremities of the Hemisphere respectively, which are well supplied; the free margin, again, formed by the hippocampus major. To these must be added the ascending convolutions on each side of the sulcus of Rolando, named ascending frontal and parietal, or sometimes anterior and posterior ascending parietal; and perhaps the second frontal. Callosal fibres pass more abundantly to the margin of the longitudinal fissure; radiating fibres to the Sylvian border of the hemisphere."

The Convolutions, on the other hand, which receive no 'radiating or 'callosal' fibres are "all those on the flat internal surface of the hemisphere, those on the inferior aspect of the temporo-sphenoidal lobe and orbital lobule, the convolutions of the island of Reil, and those on the convexity of the occipital and parietal lobes not near either margin, as far forwards as the ascending convolution which lies behind the sulcüs of Rolando." Broadbent adds:—"It may seem less strange that there are convolutions without central or callosal fibres, if we recollect that *nowhere do these fibres pass to the grey matter within the sulci, but only to the crests of the gyri, so that by far the greater part of the cortex is without them.*"

The same investigator also says:—"The statement that the fibres of the Crus, Thalamus, Corpus Striatum, and Corpus Callosum always go together to the same convolution, may appear to go beyond what is demonstrable,

* Loc. cit. p. 433.

seeing that they are so mixed up as not to be traceable separately; and it is not quite what might have been expected." At certain parts, however, as Broadbent points out, a triple if not a quadruple mode of supply is easily shown, and in illustration he cites the following facts * :—

The fibres which pass to the tip of the Occipital Lobe from three of these sources, viz., Corpus Striatum, Thalamus, and Corpus Callosum, form distinct masses at their point of departure, and only blend with one another near their termination in the Convolutions.

A similarly-independent communication exists with certain Convolutions so situated, that in order to reach them fibres of one or other of the three orders in question, have to take an extraordinary course. Thus, the Convolutions of the anterior extremity and of the upper margin of the Temporal Lobe, are directly connected with (1) the adjacent Corpus Striatum, by fibres which stretch across the fissure of Sylvius; (2) the fibres of the Thalamus, to the same convolutions, are given off from that part of it which bends round in the roof the descending cornu of the ventricle, whence these afferent fibres diffuse themselves so as to reach the Convolutions in the regions specified; whilst (3) the 'commissural' fibres for these same parts are chiefly represented by those of the Anterior Commissure,—which from a functional point of view, is to be regarded as a detached portion of the great transverse commissure or Corpus Callosum. The 'commissural' fibres are, however, also represented by certain anterior fibres of the Corpus Callosum itself, which, near the anterior perforated space, cross to the apex of the Temporal Lobe.

Even more extraordinary is the separate course taken by those of the three sets of fibres to which we are referring that happen to be in relation with the Hippocampus Major. This structure, Broadbent says,—"is in communication with the Corpus Striatum, at its uncinate extremity; with its fellow in the opposite hemisphere by the reflected part of the splenium corporis callosi, which I have called the commissure of the hippocampi; † but its

* Loc. cit. p. 433.

† Corresponding with the 'psalterial fibres' already referred to in a previous chapter (pp. 273, 274).

situation on the outer side of the great transverse fissure of the brain seems to cut it off from the Thalamus. The connection, however, is effected by the fibres of the Fornix, which, as is well known, arise from the Thalamus, make a figure-of-8 turn in the corpora albicantia, then take the circuit upwards, and then backwards, described by this body [*i.e.*, the Fornix], and pass to the Hippocampus in the tænia."

3.—The Microscopic Anatomy of the Cerebral Convolutions.

It has been already stated that the Convolutions differ much as regards their relations to one another, to the Central Ganglia, and to the fibres of the Crus.

All the Convolutions, however, present certain common characters. When a section is made through either one of them in a direction transverse to its long axis, a stem or projection of white matter is seen continuous with the 'white substance' of the hemisphere. External to this white substance, a superficial layer of Grey Matter exists, having an average thickness of about one-fourth of an inch, which is continuous over the whole external surface of the Hemisphere—since it lines the 'sulci' as well as the Convolutions (fig. 158).

This layer of cortical Grey Matter, has a greater depth over the frontal and parietal than over the occipital convolutions. Its specific gravity, moreover, varies in these situations, being often three or four degrees higher in the occipital than it is in the frontal region (1032 : 1028)—whilst that of the parietal convolutions is more or less intermediate.

In the grey matter of the Occipital Lobe, especially that of the Convolutions of its inner and inferior surface, a distinct lamination is generally very apparent, either to the naked eye or with the aid of a pocket lens. These convolutions were examined and originally described by Lockhart Clarke* in 1863.

He observed the divergence of bundles of fibres in a fan-like manner from the central stem of white substance, and their passage between long vertical groups of nerve-cells situated in the deeper grey layers (fig. 159). Some of the fibres, he believed, were continuous with the processes of the cells, whilst others turned round and pursued a horizontal course (either in a transverse or in a longitudinal direction). The bundles of fibres in this manner become reduced in size, and at the same time the component fibres become finer as they approach the surface—apparently in consequence of the branches which they give off, in their course, to contiguous nerve cells. When they arrive at the third layer from the surface, they "are reduced to the finest dimensions, and form a close network with which the nuclei and cells are in connection." The two layers superficial to this are paler in colour and

Fig. 158.—Transverse section through anterior part of left Frontal Lobe, showing shape of Convolutions and relative thickness of Grey Matter. *a*, Third frontal Convolution, a magnified section of which is shown in the next figure.

* Proceed. of Royal Society, vol. xii. p. 716.

are composed for the most part of an extremely delicate reticulum of fibres (probably most akin to the 'neuroglia'), that composing the outermost layer being in direct continuity with the thin and very vascular membrane (the 'pia mater') which covers the whole surface of the Brain and dips down between the sulci.

The fibres of the central white stem itself are crossed transversely and obliquely by a variable number of other fibres, generally most numerous near its base, where, according to Lockhart Clarke, they cross one another in all directions. These, he thinks, probably consist, for the most part, of 'commissural fibres,' such as will be described in the next section.

Other investigators have since examined the structure of the Grey Matter in several Convolutions situated in different parts of the Hemisphere. Although differences of detail exist, there is nevertheless considerable uniformity in the type of structure met with. Over much of the Frontal and Parietal Lobes, Meynert describes the Grey Matter as divisible, not so much by ordinary sight as by the microscopic characters of its constituents, into five layers or 'laminæ.' He gives a figure of the arrange-

Fig. 159.—Section through one of the Folds of the Third Frontal Convolution of Man. Magnified 65 diameters. (Ferrier, after Meynert.) 1, Layer of small scattered corpuscles, principally belonging to the 'neuroglia'; 2, layer of close-set small pyramidal cells; 3, layer of large pyramidal cells; 4, layer of small close-set irregularly shaped corpuscles (this lamina in some regions is occupied by 'giant' cells); 5, layer of spindle-shaped corpuscles; *m* white or medullary lamina.

ment of the constituents of these layers, as seen in a section through the 'third frontal" convolution (fig. 159). Quite recently, moreover, Bevan Lewis and H. Clarke have described a very similar arrangement of nerve elements in the 'ascending frontal' and other adjacent Convolutions. Their paper is accompanied by excellent illustrations.*

They give the following description of the five layers of the 'ascending frontal'—beginning with the most superficial. The **first** is a delicate friable stratum containing no real nerve elements. It is made up of the usual network of 'neuroglia' with finely granular matrix, in which are distributed numerous small nuclei and

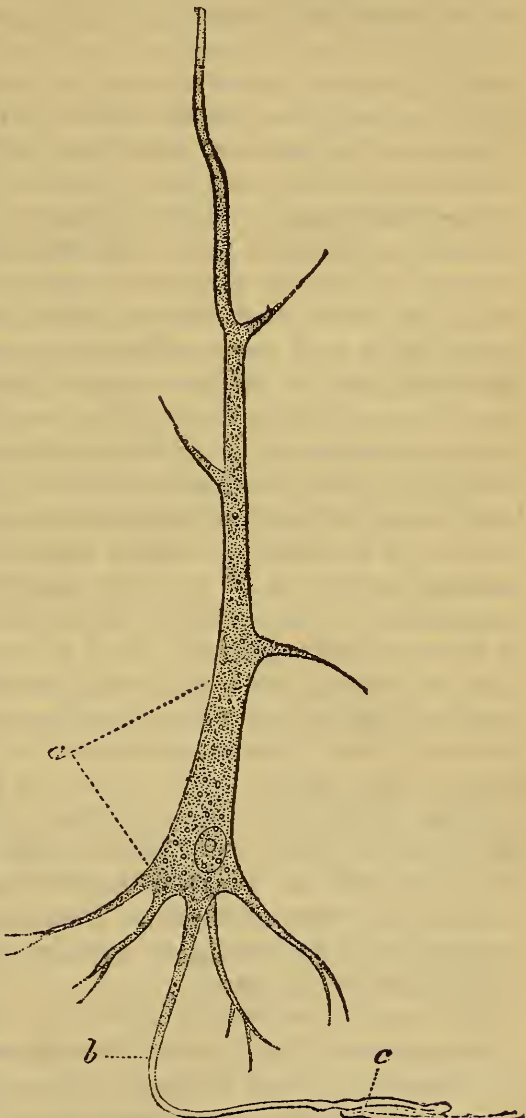


FIG. 160.—Large Pyramidal Cell, with its processes, from fourth layer of Cortical Grey Matter—so-called 'Giant Cell.' (Charcot.) *a*, Body of the Cell tapering away into a branched pyramidal prolongation; *b*, Its basal prolongation which come into relation with (*c*), the white fibres of the Convolution (highly magnified).

* Proceed. of Royal Society, 1878, p. 38.

branched connective tissue cells. The **second** layer has about the same depth as the first; to the naked eye it is apparent as a reddish-grey band abruptly marked off from the pale layer beneath it. On microscopic examination it is found to consist "of a series of closely aggregated pyramidal and oval cells of small size, whose apical processes are arranged radially to the surface of the cortex. Numerous other processes arise from the basal angles, and radiate outwards and downwards from the cell, including an extensive area in their distribution." Each of these cells contains a large nucleus of round or pyramidal form. The **third** layer is about three times as broad as the last and contains nerve elements of precisely the same kind except that they are larger and not nearly so closely packed. The cells seem uniformly to increase in size from above downwards, and in the lower part of this stratum they are two or three times as large as those of the second layer. This statement is, however, subject to the qualification that some smaller cells exist throughout, interspered amongst those of larger size. The **fourth** layer is not radically different from the last. It has only about one-third of its depth, and differs, moreover, by reason of the great increase in the size of its cells—otherwise similar in type. In consequence of their considerably superior size these cells appear to be more closely packed. They are on an average about three times as long and broad as those of the third layer. Interspersed between them are a number of small angular cells: and in certain portions of this 'frontal convolution' the small cells alone exist as representatives of the fourth layer—the above described large, or so-called 'giant cells,' being, in these parts, wholly absent. The **fifth** layer is again much broader than the fourth. It contains irregularly fusiform or spindle-shaped cells of a smaller and pretty uniform size, often arranged in irregular columns owing to the interposition of the bundles of medullary fibres which ascend from the subjacent white matter.

More recent observations still* have shown, (1) that in many other portions of the Cerebral Hemispheres a six- rather than a five-laminated Cortex is found — the additional stratum in the six-laminated regions being produced by the interposition, between the above described 'third' and 'fourth' layers, of one containing "small pyramidal and angular cells": (2) that the five-laminated

* See Bevan Lewis, "On the Comparative Structure of the Cortex Cerebri," Proceed. of Royal Soc., June, 1879, p. 234.

type of Cortex is most distinct in those parts of the frontal and parietal convolutions which constitute the excitable or so-called 'motor area' of Ferrier (see p. 575), though in by far the largest part of the Hemispheres the convolutions have rather a six-laminated type: (3) that in the five-laminated regions the so-called 'giant-cells' of the fourth layer have generally a grouped or clustered arrangement, owing to these bodies existing in irregular aggregations (the 'nests' of Betz); the principal exception to this lying in the fact that at the bottom of the 'sulci' (where the grey layer has also less depth than at the summit and sides of the Convolutions), even in these regions, such large cells are disposed in a regular but solitary manner, so that in vertical sections they appear to be ranged in linear series: (4) that in the much more extensive six-laminated areas of Cortex, in addition to the existence of the extra layer of small pyramidal and angular nerve-elements above referred to, another distinctive character is to be found in the fact that the large cells have in all parts of the convolutions that laminar or solitary arrangement which in the so-called 'motor area' exists only at the bottom of the 'sulci'*: (5) that transition regions, or convolutions, exist where the six-laminated arrangement seems to be giving place to the five-laminated arrangement, and that almost precisely similar transitions are to be seen even in the five-laminated regions on passing from the bottom of the 'sulci' to the sides of the Convolutions.

Although they differ so much in size the proper nerve elements of the second, third, and fourth layers are essentially similar in shape, and there is really no good ground for separating these strata from one another. It may be warrantable as a mere artifice for facilitating description, but is not warrantable if the fact of such

* The fact that these two layers (*i.e.*, the 'fourth' and the 'fifth' of the six-laminated areas) are, as Bevan Lewis points out, always developed in inverse proportion; and the fact that where the former is nominally absent (*i.e.*, in the five-laminated areas) "small angular cells" still exist, intermixed with the so-called 'giant cells', make it possible that we have here the above two layers merged into one, owing to the extreme development of some of the nerve elements otherwise existing as small pyramidal cells.

division is to be taken as implying that there is any difference in kind between these pyramidal elements, although they differ so much in size in different situations. To speak of the largest of these cells only, viz., those of the fourth layer as 'ganglionic' cells, and of this layer in particular as 'the ganglionic layer,' carries with it misleading implications. Even the largest of the clustered cells differs only in degree from similarly-shaped cells found in the layer above, and also in the same layer throughout those other portions of the cortex which do not possess these cells in 'nests' or clusters.

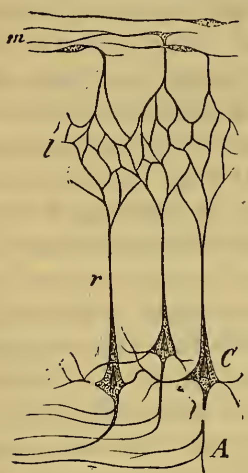


Fig. 161.—Section of the Involuted Layer of the Hippocampus (or Cornu Ammonis). *A*, White fibres, which here, owing to absence of spindle and small cell layers, attach themselves immediately to *C*, the pyramidal cells equivalent to the inner half of the third layer of the five-laminated cortex; *r*, 'stratum radiatum,' corresponding to outer half of third layer; *m*, *l*, equivalents of the first and second layers.

The most consistent conclusion to be drawn from these facts, by those who adopt Ferrier's views, would be for them to say that all convolutions contain 'motor cells'—and that too in more than one layer—unless the mere fact of the nest-like 'grouping' of the cells in certain situations is to be taken as an indication that such cells have assumed 'motor functions,' and are on that account to be designated as 'ganglionic.' Either of these positions would, however, probably seem to the ordinary reader to be very poorly based on anything like reasonable considerations.

It is worthy of note that in the involuted grey layer of the 'Hippocampus major,' the structure of the cortical matter, as Meynert points out,* is extremely simplified,

* Stricker's "Human and Comp. Histology," vol. ii. p. 395.

since the nerve elements of this region are represented by a single stratum of pyramidal cells, which differ also only in size from the so-called 'giant cells' of the parietal or frontal Convolutions.

There is in fact, in the writer's opinion, no valid reason for supposing, as many do, that these 'giant-cells' differ at all in kind from others of smaller and smaller size with which they are intermixed, or which, in the corresponding layer, alone exist in so very many of the convolutions of the Cerebrum.

Similar kinds of cell elements to those found in the Convolutions of the Human Brain, and similarly arranged, are to be found in the Convolutions of Apes and Monkeys.

In lower animals the greatest portion of the Cortex is also six-laminated, but in certain special and limited (though varying) regions in each kind, a five-laminated Cortex exists. These laminæ, according to Bevan Lewis, are also, to a considerable extent, identical in composition, though the first (which is, in the main, a mere connective tissue layer) has generally a greater comparative depth in the Sheep, the Pig, and other lower animals, than in Man. He says:—"It is in the essential character of the individual cells of these layers, in the relationship of these anatomical units the one to the other, and in their general distribution, that we detect divergence from the type normal to the higher Mammalia."

In Man, the Ape, the Cat, and the Ocelot, the 'giant' cells are swollen and more rounded (owing to their giving off a larger number of processes), than in such animals as the Sheep and the Pig. In the latter these cells are more simply pyramidal, and have a smaller number of inter-connecting processes. Such cells are, moreover, scattered over a wide area. But in the Cat and other Carnivora, the area in which the 'giant' cells are found is very restricted—much more so than in Man and the Quadrumana.

Again, according to Bevan Lewis, a peculiar kind of 'globose' cell with few connecting processes, is to be found amidst the other elements in the second and third layers of the Pig and Sheep, and also in Apes—though such elements have been met with in Man only in the brains of Idiots or Imbeciles.

4.—The Principal Commissures of the Brain.

The connecting or, as Meynert terms them, the 'association system' of fibres of the Brain belong to three principal categories, each of which will be now briefly described.

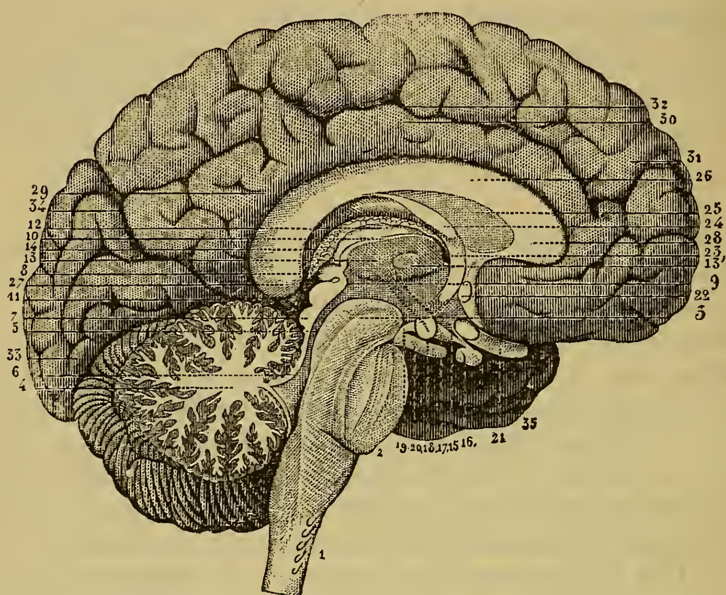


Fig. 162.—Longitudinal Section through the centre of the Brain, showing the inner face of Left Cerebral Hemisphere. (Sappey, after Hirschfeld.) 1, Spinal Cord; 2, Pons Varolii; 3, Cerebral Peduncle; 4, 'Arbor Vitæ' of cut surface of Middle Lobe of Cerebellum; 5, Sylvian aqueduct; 6, Valve of Vieussens; 7, Corpora quadrigemina; 8, Pineal body; 9, its inferior peduncle; 10, its superior peduncle; 11, middle portion of the great Cerebral Cleft; 12, upper face of the Thalamus; 13, its internal face, forming one of the walls of the middle or third ventricle; 13′, Grey or Middle Commissure; 14, Choroid plexus; 15, Pituitary pedicle; 16, Pituitary body; 17, Tuber cinereum; 18, Mammillary body; 19, interpeduncular perforated lamella; 20, third or common Oculo-motor nerve; 21, Optic Nerve; 22, Anterior Commissure; 23, Foramen of Monro; 24, section of the Cerebral trigone; 25, Septum lucidum; 26, Corpus Callosum; 27, its posterior extremity or 'bourrelet'; 28, its anterior extremity or 'genu'; 29, 30, Gyrus fornicatus, or Convolution of the Corpus Callosum; 31, Anterior part of Marginal Convolution; 32, Calloso-marginal sulcus; 33, Occipital Convolutions; 34, 'internal perpendicular fissure' separating Occipital from Parietal Lobe.

These fibres are of great importance, and so numerous, that, Broadbent says,* "the radiating fibres must bear a

* "Journ. of Ment. Science," Ap. 1870, p. 9.

small proportion to the fibres passing from one part of the surface to another."

a. Commissures connecting similar parts in the two Hemispheres.—These are generally spoken of under the name of 'transverse' Commissures. They include the Corpus Callosum, the Anterior Commissure, together with the Middle and Posterior Commissures. A part of them have been hitherto referred to, in the quotations from Broadbent's descriptions, as 'callosal' fibres.

The **Corpus Callosum** is by far the largest and most important of all the commissures. When the two Cerebral Hemispheres are separated it may be seen as a broad band of fibres extending from the one to the other. Its antero-posterior diameter is over three inches, whilst laterally it extends into the substance of each Hemisphere, where it forms the roof of the 'lateral ventricles.' On section it is seen to be thickened at each extremity (fig. 162, 27, 28).

Various notions have been held by older anatomists as to the distribution of the fibres of the Corpus Callosum which need not now be discussed, though it may be mentioned that Foville thought its fibres served to bring the Crus of one Hemisphere into relation with that of the other; and that, according to Gratiolet, its fibres suffice to bring the Crus of one side into connection with the convolutions of the opposite Hemisphere. The investigations of both Meynert and Broadbent, however, lead them to believe that the first of these views is altogether erroneous and that the second, if at all, is only very partially true, since in the main the fibres of the Corpus Callosum serve to unite similar Convolutions in the two Hemispheres.* Its fibres are not, however, distributed to all alike, but only to some of them. And, as before

* "Journ. of Ment. Science," Ap., 1870, p. 18.

stated, the Convolutions that are thus brought into relation in the two hemispheres are precisely those with which the 'radiating fibres' of the Crus are also in relation. The names of these Convolutions have been already given (p. 444).

The **Anterior Commissure** is a distinct band of white fibres which crosses the anterior part of the 'third ventricle' and on each side penetrates the substance of the Corpus Striatum (fig. 164, 6). It is not, however, as it seems to be, a Commissure connecting these bodies. Careful dissection suffices to show that its fibres merely pass through the Corpus Striatum on each side (where they lie in a distinct groove or canal), that they emerge on the under and outer surface of these bodies, and that they are thence distributed

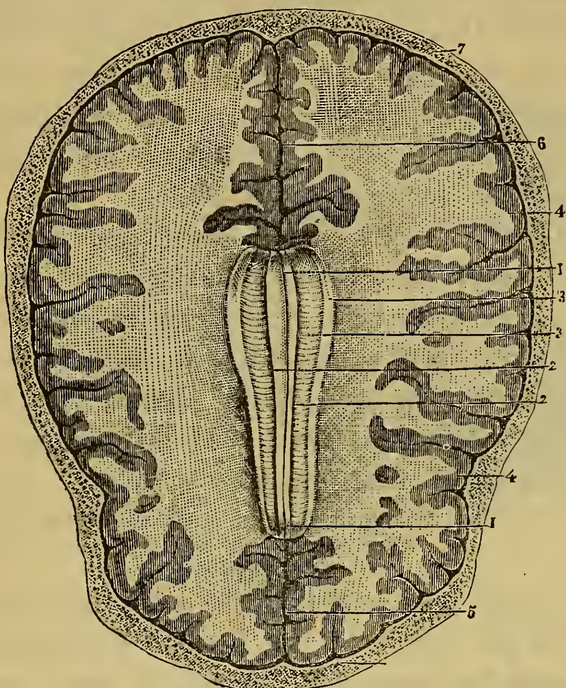


FIG. 163.—Horizontal Section through the Cranium and Cerebral Hemisphere just above the level of the Corpus Callosum, showing the so-called 'centrum ovale' of Vieussens. (Sappey, after Vicq d'Azyr.) 1, 1, Median furrow of the upper face of the Corpus Callosum; 2, 2, longitudinal fasiculi of this face ('nerves of Lancisi'); 3, the transverse fasiculi of its main body; 3′, section of the medullary substance at the level of the border of the Corpus Callosum; 4, 4, grey layer of the Convolutions forming an irregular festoon around the 'centrum ovale' of Vieussens; 5, anterior part of the great longitudinal fissure of the Cerebrum; 6, posterior part of this longitudinal fissure; 7, 7, section of the walls of the Skull.

to the convolutions forming the tip and inner or under surface of the Temporal Lobe. It is, as Broadbent says, and as other anatomists had previously recognized, a sort of accessory Corpus Callosum connecting those parts of the two Temporal Lobes which could not otherwise be easily brought into relation with one another.

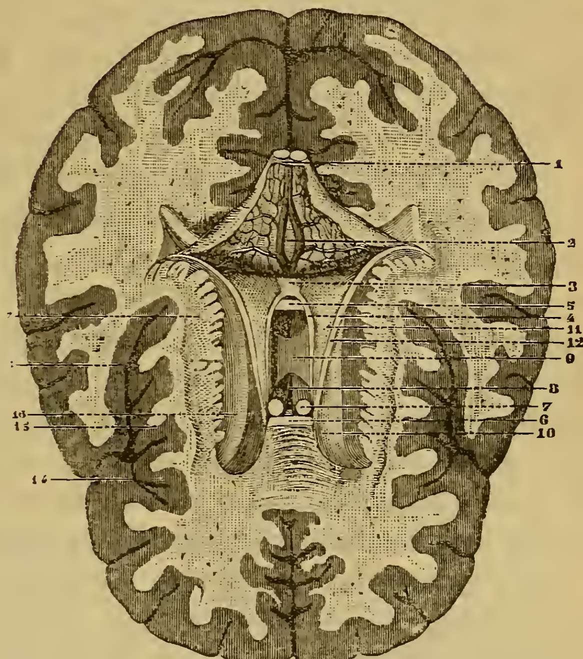


Fig. 164.—Horizontal Section through the Cerebrum at a deeper level, showing the Third Ventricle and its Commissures and the relations of each Corpus Striatum to the Island of Reil. (Sappey.) 1, Fornix, together with Velum Interpositum turned backwards in order to reveal the Third Ventricle: 2, Veins of Galen; 3, anterior extremity of the Pineal body; 4, its superior peduncles; 5, Posterior Cerebral Commissure; 6, Anterior Commissure; 7, section of anterior pillars of Fornix; 8, Third or Middle Ventricle; 9, Grey or Middle Commissure; 10, Corpus Striatum, the upper and external strata of which have been sliced off; 11, Thalamus; 12, Tænia Semicircularis; 13, 14, 15, section of Convolutions of the Island of Reil; 16, section of the intraventricular nucleus of the Corpus Striatum; 17, section of the White Substance of the Hemisphere, at the part which intervenes between the Island of Reil and the upper part of the Corpus Striatum.

In some of the lower animals that have large Olfactory Lobes and 'tracts,' these are directly connected with one another by means of fibres which form part of this Anterior Commissure.

The **Middle Commissure** is a soft bridge of grey matter that passes across the 'third ventricle' from one Thalamus to the other (figs. 164, 9; 157, *Th*), and may therefore serve to bring parts of these bodies into functional relation with one another.

The **Posterior Commissure** is a small white band which passes across the upper and posterior boundary of the 'third ventricle' (fig. 164, 5), and bends downwards through the Thalamus on each side so as to terminate in the ganglionic matter of the Tegmentum.

The existence of these commissural connections between the Thalami are specially worthy of note, when we find the two Corpora Striata quite unconnected by Commissures of any kind. It is, however, important that the various centres in relation with 'ingoing' impressions should be in functional connection with one another, while no similar necessity exists for such Commissures between the great superior motor ganglia—since each Corpus Striatum transmits and regulates those motor incitations only which emanate from its own Cerebral Hemisphere.

b. Commissures connecting dissimilar parts in the same Hemisphere.—Of these that which is by far the best known is the **Fornix.** This is generally spoken of as a longitudinal commissure, but the term is misleading, though its fibres do for the most part take a longitudinal direction. They serve to bring the inner aspect of the Thalamus and the Hippocampus Major of the same hemisphere into relation with one another—these being parts which are almost in the same vertical transverse plane. The course and functional uses of its fibres have been already indicated (p. 272).

Two accessory sets of fibres come into relation with the 'anterior pillars' of the Fornix;—(1) a narrow band of fibres on each side known as the *tænia semicircularis*, which, after separating from the 'anterior pillar' of the same side passes backwards in the groove between the Corpus Striatum and the Thalamus and disappears within the substance of the latter after turning round to the roof of the descending cornu *; and (2) the 'peduncles' of the Pineal Body, which pass forwards along the Thalamus at the upper limits of the 'third ventricle,' gradually diminishing in size and at last apparently blending with the 'anterior pillars' of the Fornix near the anterior extremity of each Thalamus.†

Many other sets of 'commissural fibres' exist on each side whose office also is to bring different more or less *distant* Convolutions in the same Hemisphere into relation with one another. Some of the principal of these Commissures are longitudinal in direction, and are disposed in the following manner:—‡

1. A great '*axial longitudinal system*' runs through the upper portions of the Hemispheres. It contains fibres from the Occipital and Temporal Lobes which pass on to the tip of the Frontal lobe, receiving or giving fibres along this route to many overlying convolutions.

2. The '*longitudinal system of the fasiculus uncinatus*' is a set of fibres situated at a lower level than the former, though it connects the same main divisions of the Hemisphere. Its middle portion, forming the band from which it takes its name, is to be seen on the lateral aspect of the hemisphere, crossing the bottom of the Sylvian fissure from the Frontal to the Temporal Lobe. Anteriorly its fibres pass beneath the Corpus Striatum, whence some proceed to the third frontal convolution, others spread out beneath the orbital convolutions to reach the anterior extremity of the Corpus Callosum and the convolutions at the adjacent margin of the orbital region, though the great majority of the fibres pass on beneath the orbital convolutions to end along the anterior edge of the Hemisphere. Posteriorly, the fibres of the fasiculus uncinatus pass to the tip of the Occipital Lobe and to the convolutions along the lower and outer edge of the Hemispheres, whilst a con-

* This, therefore, would seem to contain fibres serving to connect two distant portions of the same 'Thalamus' with one another.

† As these 'peduncles' of the Pineal Body are continuous with one another posteriorly, they may form a sort of 'transverse commissure' for those regions of each Thalamus from which the 'anterior pillars' of the Fornix proceed.

‡ See "Journ. of Mental Science," Ap. 1870, pp. 10–16.

siderable group of them also proceeds to the tip of the Temporal Lobe.

3. Other *inferior and more superficial longitudinal fibres* pass from the tip of the Temporal Lobe backwards (diverging as they go) into the floor of the 'descending cornu' and into that of the posterior cornu, where they become mixed with fibres of the Corpus Callosum.

4. The Convolutions on the flat internal surface of the hemisphere, especially the '*gyrus fornicatus*,' contain longitudinal fibres. These latter are said to extend from the 'anterior perforated space' in front (Corpus Striatum) backwards over the Corpus Callosum, round its posterior extremity, and thence, according to Foville, onwards to the tip of the Temporal Lobe.

5. Certain longitudinal fibres ('*nerves of Lancisi*') are situated on the upper surface of the Corpus Callosum in two sèries on each side (fig. 163). In front they also are said to come into relation with the 'anterior perforated space,' whilst posteriorly their destination is doubtful. According to Foville they join the 'posterior pillars' of the Fornix.*

Other sets of 'commissural fibres' are not so distinctly longitudinal in direction, and they serve, moreover, to bring more immediately *adjacent* Convolutions into relation with one another.

We still possess a very inadequate knowledge of these multitudinous sets of fibres, but it would be quite impossible here to attempt to render an account of all that has been made out in regard to them. A few illustrations of the best marked of these connections may, however, be given in order to convey some idea of the extent of interrelation existing between contiguous Convolutions.

Broadbent says †:—"The second or great ascending parietal

* These last two sets of fibres may therefore possibly pass by circuitous routes from 'sensory' regions in the Temporal Lobe to the corresponding Corpus Striatum. Other regions of this Lobe seem to be connected with the same body in a much more direct manner, *i.e.*, by fibres which cross the Sylvian fissure (p. 445).

† Loc. cit. p. 11.

gyrus has complicated connections with the adjacent convolutions behind it, and receives large bands of fibres from the posterior part of the hemisphere by means of the axial longitudinal system; it is also extensively connected with the anterior parietal convolution, and sends forwards, deeply, fibres to all the three frontal convolutions. The second frontal, besides receiving fibres from the axial system and parietal convolutions, is connected with the first and third frontal gyri, between which it lies, by numerous large laminæ, which do not simply dip transversely under the intervening sulci, but run tortuously forwards or backwards, their intertwinings being too complicated to admit of either description or representation. Fibres, moreover, cross transversely under the second frontal gyrus from the first to the third."

The convolutions of the Temporal Lobe are most distinctly connected with others in the Occipital and in the Parietal Lóbes, and Broadbent adds,* it is "worthy of mention that between the inframarginal Sylvian and parallel gyri separated by the deep parallel sulcus, there is the most extensive commissural connection to be found between adjacent convolutions in the entire brain." Recent physiological experiments, as we shall see in the next chapter, render this observation one of great importance.

The bulk of the fibres from the radiating convolutions of the 'island of Reil,' form a thick layer that is in relation with the convolutions into which its anterior and upper margins pass, viz.: those of the posterior border of the orbital lobule, the third frontal and the ascending parietal gyri. The course of these fibres is very intricate. Fibres also pass between the convolutions of the 'island of Reil' and the posterior part of the hemisphere; whilst a few proceed from, or pass between, the centre of the island from the overhanging tip of the Temporal Lobe. No fibres connecting these convolutions with the Corpus Striatum or Thalamus have yet been recognized, although they lie immediately outside the former body, and may therefore receive a few filaments from its extra-ventricular grey nucleus.

From what has been said concerning the distribution of the fibres of the Corpus Callosum, of the various longitudinal sets of 'commissural fibres,' and of those which pass in different directions between more or less con-

* Loc. cit. p. 15.

tiguous Convolutions, the reader will not find it difficult to believe what seems for many reasons probable, that in the white substance of the Hemispheres, the mass of which is so large, fibres of the Crus or from the Central Ganglia on their road to or from the surface must, as Broadbent points out, bear a small proportion to the fibres passing from one part of the surface to another either in the same or in opposite Hemispheres—or, to put it in the phraseology of Meynert, the fibres of the 'projection system' are, in the aggregate, small, when compared with those of the 'association system.'

c. *Commissures bringing the Cerebellum into relation with the Cerebrum.*—These correspond with what are known as the Upper Cerebellar Peduncles, though it is possible that the Middle Peduncles ought also to be included under this category. The distribution of these parts will be referred to in the next section. The Lower Peduncles, though they pass through a portion of the Medulla, serve in the main to place the Cerebellum in relation with the Spinal Cord.

5.—The General Structure of the Cerebellum, and its Relations with other parts.

The Cerebellum or 'Little Brain,' unlike the Cerebrum, is a solid organ whose two halves are continuous with one another. If a horizontal section be made through the middle of the Cerebellum, there will be seen, in its interior, on each side, a plicated bag-like nucleus of Grey Matter, whose open extremity is directed forwards and inwards (fig. 156, 14).

The different Lobes of which the Cerebellum is composed have been already referred to, as well as the manner in which they are subdivided. But the extent and mode of subdivision of the surface of the organ will be best comprehended from figs. 156, 162, 165. These show the ramified nature of the peripheral segments of the Cerebellum and the large proportional bulk of its surface grey matter, when compared with the mass of 'white substance' which this matter everywhere encloses, except in the direction of its Peduncles.

The **Peduncles** of the organ, of which there are three pairs, are the parts that serve to connect it with other divisions of the Brain and with the Spinal Cord.

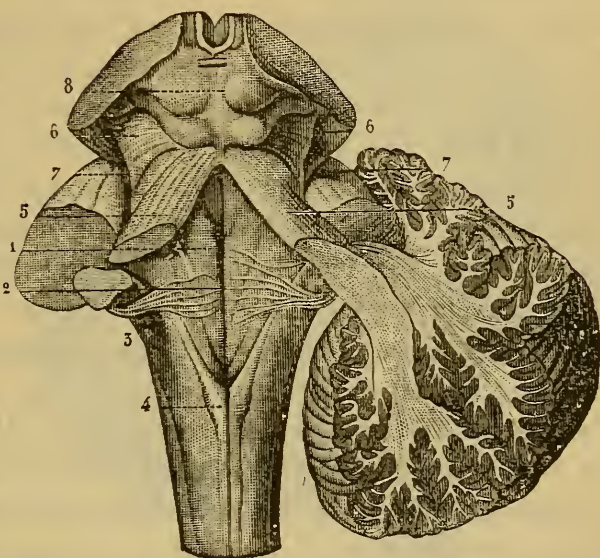


FIG. 165.—The Upper Peduncles of the Cerebellum, the Fourth Ventricle, and contiguous parts. (Sappey, after Hirschfeld.) 1, Median groove in floor of fourth ventricle; 2, white fibres by which the auditory nerve terminates; 3, inferior Cerebellar Peduncle; 4, posterior median column; 5, superior Cerebellar Peduncle, crossing the inferior on its inner side; 6, 7, upper and posterior aspect of the Cerebral Peduncle; 8, Corpora quadrigemina.

The **Upper Peduncles** of the Cerebellum are thick bands of fibres that proceed from its anterior border in a slightly convergent direction to the posterior pair of the 'quadrigeminal bodies,' beneath which they pass. In this situation they *decussate*, and the fibres of each set then proceed to a large nucleus of ganglionic matter, in the upper or sensory portion of the Crus Cerebri, usually known as the 'red nucleus.' Thence the course of these or of related fibres is uncertain, but they are now commonly believed to pass under the posterior extremity of the Thalamus, and from this body to different regions of the Cerebral Cortex—though they have not been actually traced further than into different parts of the 'corona radiata.'

Nothing, therefore, is known as to the particular Convolutions with which the Cerebellum is brought into relation through these fibres of the Upper Cerebellar Peduncles. On the Cerebellar side, however, these particular fibres are thought to be partly in immediate relation with the cortex of the inferior portions of the Middle Lobes (fig. 165); whilst others of them, on each side, are in communication with, or enter the bag-like grey nucleus (fig. 156) before passing to different portions of the Cerebellar Cortex.

Between these converging Upper Peduncles there is a thin lamina of nerve matter known as the 'valve of Vieussens' that suffices to connect the Middle Lobe of the Cerebellum with the Corpora Quadrigemina. This is a structure which in lower Vertebrates, such as Fishes, is proportionately more developed, and serves to bring their large 'optic lobes' into structural connection with the only portion of the Cerebellum that they possess, viz., the Middle Lobe. This lamina forms the roof of the upper or anterior half of the 'fourth ventricle' (fig. 152) and also of the first part of the passage between this cavity and the 'third ventricle.'

The **Lower Peduncles**, or 'restiform bodies' as they are also termed, connect the Cerebellum with the Medulla and Spinal Cord (fig. 165). Within the Cerebellum the fibres of these Peduncles are said not to come into relation with the central bag-like grey nuclei, but to pass at once to different regions of the cortical grey matter.

The inner portion of each Lower Peduncle appears to be made up by the centripetal prolongations of the Auditory Nerve; the fibres of which are traceable from its own 'external nucleus' to the 'nucleus du toit' of Stilling on the same and on the opposite side. But the outer portion of the Peduncle, Meynert says, is derived from the opposite 'posterior column' of the Cord in the following manner. The fibres of the posterior median column ('funiculus cuneatus et gracilis') enter or come into relation with the ganglion cells of the corresponding 'olivary body'; thence they cross the median line of the Medulla, behind the 'anterior pyramids,' to pass round the opposite olivary body before emerging in the form of 'arcuate fibres' at the posterior and lateral region of the Medulla. Here they

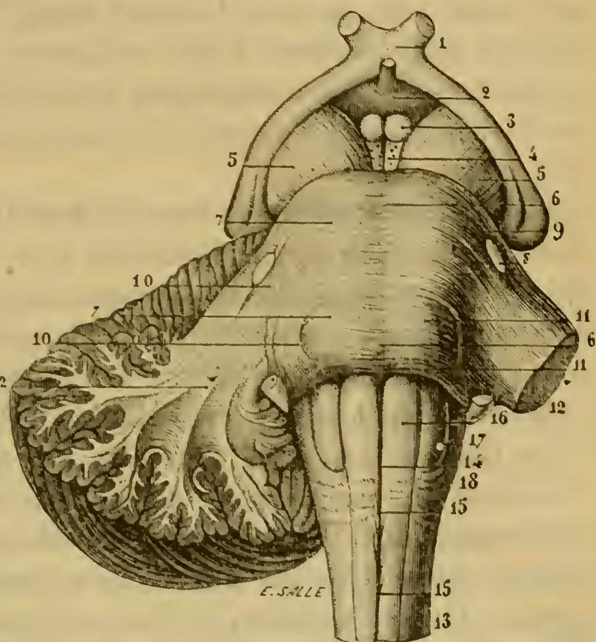


Fig. 166.—The Middle Cerebellar Peduncles and Pons, with Contiguous Parts. (Sappey, after Hirschfeld.) 1, Optic Commissure; 2, Tuber Cinereum and Pituitary pedicle; 3, Corpora mammillaria; 4, Inter-peduncular space; 5, Cerebral peduncle; 6, 6, Median groove on Pons, with (7) a slight prominence on each side; 8, origin of the trigeminus; 9, superior transverse fibres of the Pons; 10, 10, its median fibres; 11, its lower fibres dipping beneath the former; 12, 12, middle Cerebellar peduncles, formed by the union of these three sets of fibres; the left peduncle is divided near its origin, the right is in part dissected out. 13, Spinal Cord; 14, median furrow of the Medulla; 15, 15, decussation of the pyramids (16); 17, Olivary body; 18, Arciform fibres.

throw themselves into, and ascend as part of, the Lower Peduncle. Thus, the fibres of each 'posterior column' sink beneath the surface of the Spinal Cord, and after passing through the corresponding 'olivary body' and thence crossing the middle line of the Medulla and passing round the opposite 'olivary body,' they emerge as parts of the 'restiform body' or Lower Peduncle of the Cerebellum. This arrangement is not to be regarded as established beyond the reach of doubt: it is in fact denied by Luys.

The **Middle Peduncles** together form the 'pons Varolii.' The fibres of each (fig. 166) emerge from different parts of the cortical substance of the corresponding 'lateral lobe' of the Cerebellum; and whilst a few of its fibres are believed to be 'commissural' in nature, and merely to pass across from one to the other of these lateral lobes, the majority of the fibres of one side decussate, at the middle line, with those of the opposite Middle Peduncle. By their intervention each half of the Cerebellum is brought into relation either with the motor fibres descending from the opposite Corpus Striatum (in the corresponding Cerebral Peduncle); or else with some of the cells of the Corpus Striatum itself, owing to some of the Cerebellar peduncular fibres bending upwards from the 'pons' to end in these ganglia—just as others, taking a similar course, are thought to pass through them on their way to the Cerebral Convolutions.

All that is positively known is, that each 'lateral lobe' of the Cerebellum is principally in relation, through its Middle Peduncle, with the 'motor tract' from the opposite Cerebral Hemisphere. And this fact itself is one of some importance, since, amidst all the other doubts concerning the Cerebellum it would seem positively to imply that the bulk of the fibres of these particular

Peduncles are 'outgoing' or motor fibres—a conclusion, which is harmonious with other evidence. Whether, however, there are points of junction with cerebral motor fibres of the opposite side in, or in the neighbourhood of, the 'pons' itself, as Luys imagines; or whether such cerebellar fibres really pass upwards to the cells of the Corpora Striata—or even beyond them, to some portions of the Cortex of the Cerebral Hemispheres—are details which cannot at present be decided.

6.—The Minute Structure of the Grey Matter of the Cerebellum.

The cortical Grey Matter is uniform in appearance all over the innumerable folds of the surface of the Cerebellum. To the naked eye it is divisible into two layers (fig. 167), an outer clear grey, and an inner, as well as narrower, greyish red layer. Within the grey layer of each fold is a stem of white substance.

In the deepest part of the outer layer there is a single row of large ganglion cells $\frac{1}{1000}$ to $\frac{1}{800}$ of an inch in diameter, whose large branching arms ramify throughout the whole of this stratum, becoming finer as they approach the surface (fig. 167, *b*, *b*). The ultimate ramifications of these nerve processes, together with a kind of connective tissue substance, unite to form a most delicate matrix of fibres, amidst which are interspersed a number of small corpuscles. These are either mere nucleoid bodies or small angular cells, and like the similar corpuscles in the grey matter of the Cerebrum it is impossible to say which should be regarded as belonging to the connective tissue, and which have a right to the title of nerve elements. Many of them, as W. H. O. Sankey has ascertained, are in direct continuity with the ramifications of the ganglion cells. Running along the inner part of this layer across the direction of the large branches of the ganglion cells are a number of fine nerve fibres.

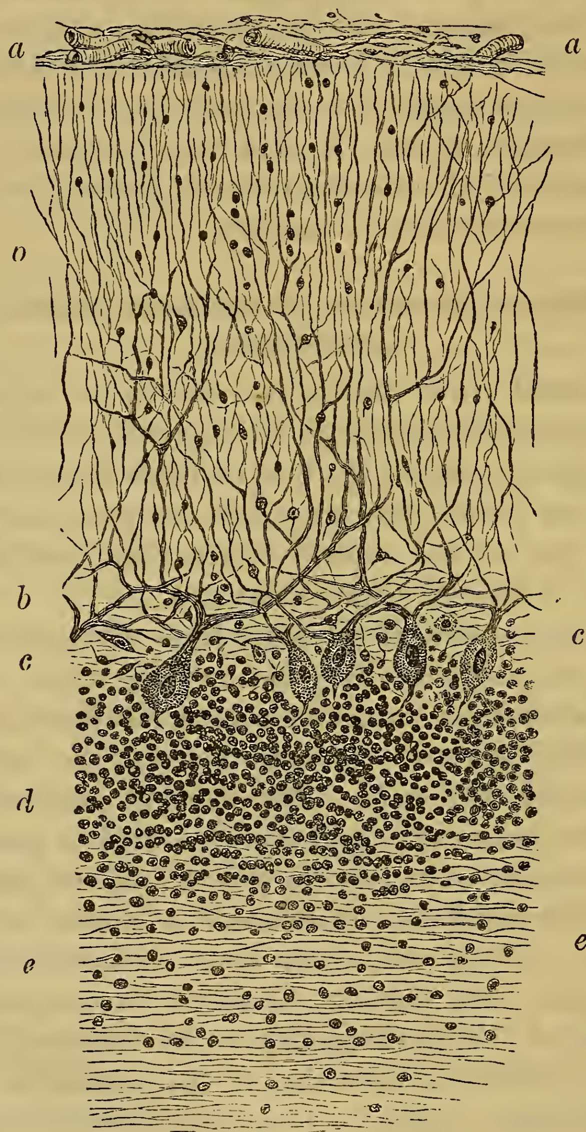


FIG. 167.—Grey Matter of the Cerebellum, Section of, magnified about 400 diameters. (Sharpey, after Sankey.) *a*, pia mater of Cerebellum; *b*, *b*, outer grey layer; *c*, great ganglion cells; *d*, inner greyish-red, or so-called granule layer; *e*, stem of white fibres.

The great ganglion cells encroach upon the outer border of the next stratum, which is the so-called 'granule layer.' Here are massed together a multitude of corpuscles from $\frac{1}{4000}$ to $\frac{1}{2500}$ of an inch in diameter, very similar to those more sparingly scattered through the outer layer. The inner process of each large ganglion cell is said to be single and undivided, but as it is very fine it is soon lost to view in the dense 'granule layer' into which it passes. The mode of connection of the central stem of white fibres with the granule layer and with the elements lying outside it, is at present very uncertain. 'Granules,' or corpuscles of the same kind, are also, though more sparingly, scattered through this white substance.

It seems most probable that some of the fibres in each stem of white substance are 'afferent,' and that others conduct 'efferent' impressions or impulses. The former fibres may divide in the 'granule layer,' so as to come into relation with two, three, or more of the great ganglion cells; and the outgoing stimuli may pass from these groups of cells through their ramifying branches in the outer layer, and thence through continuous rootlets of 'outgoing' fibres which, coalescing as they go, pass through the 'granule layer,' and away through the stem of white substance.

This latter is a hypothetical arrangement, but one which seems to the writer to be most in accordance with the actual structure of the grey matter of the Cerebellum.

7.—The Central Connections of the Olfactory and Optic Peduncles, as well as of other Cranial Nerves.

The Olfactory Peduncles or 'tracts,' and the Optic Peduncles or 'tracts' are generally regarded as something different from ordinary nerves. They are looked upon as special out-growths or prolongations from the Brain. A distinction of this kind is undoubtedly legitimate in regard to many of the lower animals. It is so, for instance, in Fishes as well as in some Reptiles and Mammals, in which the Olfactory Centres are extremely well developed; and also in Insects and Cephalopods in which the eyes and Optic Centres are very large. But in Man, in whom neither the sense of Smell nor the sense of Sight is so inordinately developed, and in whom the corresponding primary Centres are relatively small, any such distinction is less obvious. In his case, indeed, there is no good reason for maintaining it, in regard to the Optic 'tracts,' since these parts differ little in appearance from ordinary nerves. There is more reason, however, for such a distinction in reference to the Olfactory 'tracts,' because even in Man the Olfactory Ganglia exist as outlying portions of the Brain, from which minute Olfactory Nerves descend to the nasal passages.

The course and central connections of these parts require to be briefly set forth.

The Olfactory 'tract' is connected with the posterior region of the orbital surface of the Hemisphere by three roots; of these the external goes outwards to the inferior extremity of the Temporal Lobe of the same side, as may be easily recognized in those Mammals in which the Olfactory Lobes are large, though only with some difficulty in Man. The inner root enters the Hemisphere near its inner border, and a little in front of the Optic Commissure. The further relations of the fibres of the Olfactory Tracts, and the fact that they come into relation on each side with Convolutions of the corresponding and not with those of the opposite Hemisphere will be subsequently referred to (see pp. 482, 488).

The Optic 'tracts' are the continuations of the Optic

Nerves backwards, behind the Optic Commissure. Each 'tract' is in contact with and turns round the outer border of the Cerebral Peduncle, becoming flattened as it proceeds. Here each of them comes into relation with two small ganglionic nodules (known respectively as the internal and external 'geniculate bodies') situated at the posterior extremity of the Thalamus (figs. 168, *e, i*; 156, 8), contiguous to the adjacent anterior segment of the Quadrigeminal Bodies, with which, as well as with the Thalamus itself, many of its fibres, if not all, come into relation before being continued onwards to certain regions of the cortex of the corresponding Cerebral Hemisphere.

Although the subject is by no means free from doubt and uncertainty, the weight of evidence seems now most in favour of the view that the 'decussation' at the Optic Commissure is as complete in Man as it is known to be in lower Vertebrates.* This subject will be again referred to in a subsequent chapter in connection with the question, as to what parts of the Cortex of the Hemispheres are most intimately concerned with Visual Impressions.

Thus it would appear that Olfactory Channels do not decussate at all, and that Optic Channels decussate completely. Yet the crossing of the latter channels takes place outside the substance of the Brain, so that in this respect the arrangement differs from that which will be found to obtain for the next two sensory 'Cranial Nerves,' viz.: the Fifth and the Auditory.

The position of the Fifth Nerve and its superficial connection with the lateral aspect of the 'pons Varolii' may be seen in (fig. 168, v). Its sensory fibres after passing through the 'Gasserian' ganglion are gathered together into the 'greater root,' the fibres of which, like those of the 'posterior roots' of the Spinal Nerves, soon

* See Ferrier, "Functions of Brain," pp. 70 and 166.

cross over to the opposite side, and go to form part of the sensory tract or 'tegmentum' of the opposite Cerebral Peduncle (see p. 478).

The Auditory Nerve enters the side of the Medulla just below the 'pons' in close relation with the root of the Facial Nerve. About the subsequent very complicated course of its fibres we still have much to learn. A large section of them, at least, seem to enter the Cerebellum, and the mode by which the opposite Cerebral Hemisphere is brought into relation with its fibres and nuclei of origin is altogether obscure. Meynert even says:*—"We may regard it as certain that no extensive *immediate* connection of the auditory nerve with the Cerebral lobes exists, but that such a connection, the existence of which may be assumed as a necessary physiological truth, can only come to pass *indirectly* through the *Cerebellum*."

How far this view of Meynert's is absolutely correct cannot at present be determined. We do know, however, from evidence which will be subsequently referred to in regard to Hemi-anæsthesia (p. 487), that a decussation of auditory channels takes place, and that these channels ultimately become incorporated with other fibres of the Cerebral Peduncles comprised within the posterior third of what is known as the 'internal capsule.'

It must, moreover, not be forgotten that, according to Cyon (p. 218), what is named by him as the Space-nerve (Raumnerv) is also bound up with, and forms part of the trunk commonly known as the 'Auditory.' The internal course of the portions belonging to each of these nerves will, if this view be correct, have to be subsequently determined and differentiated. It may be that it is the fibres of this Space-nerve more especially which come into immediate relations with the Cerebellum (see p. 506).

* Stricker's Histology, vol. ii. p. 500.

The other two sensory nerves of the Medulla, the Glosso-pharyngeal and the Pneumogastric, will be referred to in the next section. The situation of the 'motor'

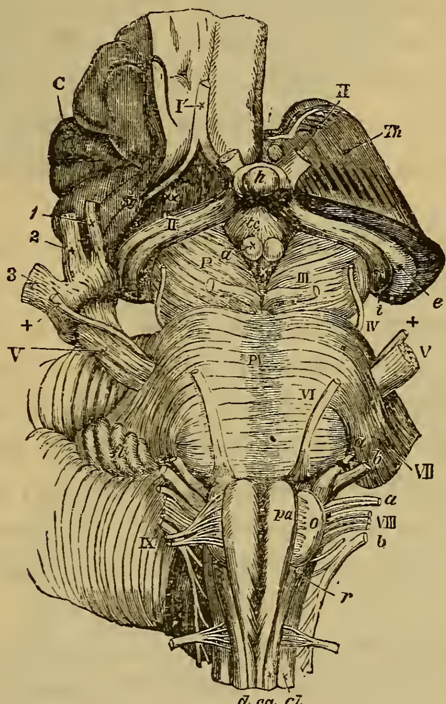


FIG. 168.—Enlarged View of part of the Base of the Brain to which the Cranial Nerves are attached. (Ferrier, after Allen Thomson.)

On the right side the Convolutions of the Central lobe (*C*), or Island of Reil, have been left, on the left the incision has been carried between the Thalamus (*TH*) and the Hemisphere. I', Olfactory Nerve cut short; II, Optic Nerve in front of Commissure; II', Right Optic tract. *e*. The external, and *i*, the internal 'corpus geniculatum'; *h*, Pituitary body; *tc*, Tuber cinereum and infundibulum; *a*, one of corpora mammillaria; *P*, Cerebral peduncle. III, Third nerve (oculo-motor); IV, Fourth nerve (patheticus); *P V*, Pons; V, the greater root of Fifth nerve (trigeminus). +, The lesser or motor root; on the right side this is placed on the Gasserian ganglion. 1, 2, 3, The three divisions of the Fifth nerve; 6, Sixth nerve; VII*a*, the Facial; VII*b*, the Auditory; VIII, the Vagus or Pneumogastric; VIII*a*, the Glosso-pharyngeal; VIII*b*, the Spinal-accessory; IX, the Hypo-glossal; *fl*, the 'flocculus' of Cerebellum; *pa*, anterior Pyramid; *o*, Olivary body; *r*, Restiform body; *d*, anterior median fissure of the Spinal Cord, above which is the 'decussation' of the Pyramids; *ca*, the anterior, and *cl*, the lateral column of the Spinal Cord.

nerves will be seen by an examination of fig. 168, though no further reference to them is here needed.

8.—The Connection of the Visceral System of Nerves with the Brain.

The relation of the Systemic Nerves to the Brain is not essentially different in Man from what obtains in the great majority of higher Vertebrates. In all alike the Visceral System of Nerves is divisible into two parts, whose connections with the Brain are partly 'direct' and partly 'indirect.'

1. **The Cerebral Systemic Nerves.**—The lowest segment of the Brain—the Medulla—is placed in immediate relation with the greater number of the viscera of the body through the intervention of the Glosso-pharyngeal and the Vagus, as 'ingoing' nerves. They connect it with the whole length of the alimentary canal below the buccal cavity; with the respiratory organs; with the heart and some of the great vessels; with the liver, the spleen, the kidneys, and possibly also with the internal organs of generation.

From the same region of the brain (the Medulla) certain 'outgoing' fibres are also given off to some of the above-mentioned internal parts or viscera. These efferent or motor fibres are not gathered together into separate trunks; they are principally wrapped up with, and constitute parts of, the Glosso-pharyngeal and the Spinal Accessory Nerves. The viscera which do not receive 'outgoing' fibres from this source are supplied with them from the Spinal Cord and the nervous apparatus now to be mentioned.

2. The '**Great Sympathetic**' is an elaborate and extensive system of nerves, and consists of the following parts:—(*a.*) *A ganglionated cord* lying on each side of the vertebral column, each of which is connected above with the 5th, the 6th, the 7th, the 8th, and the 9th

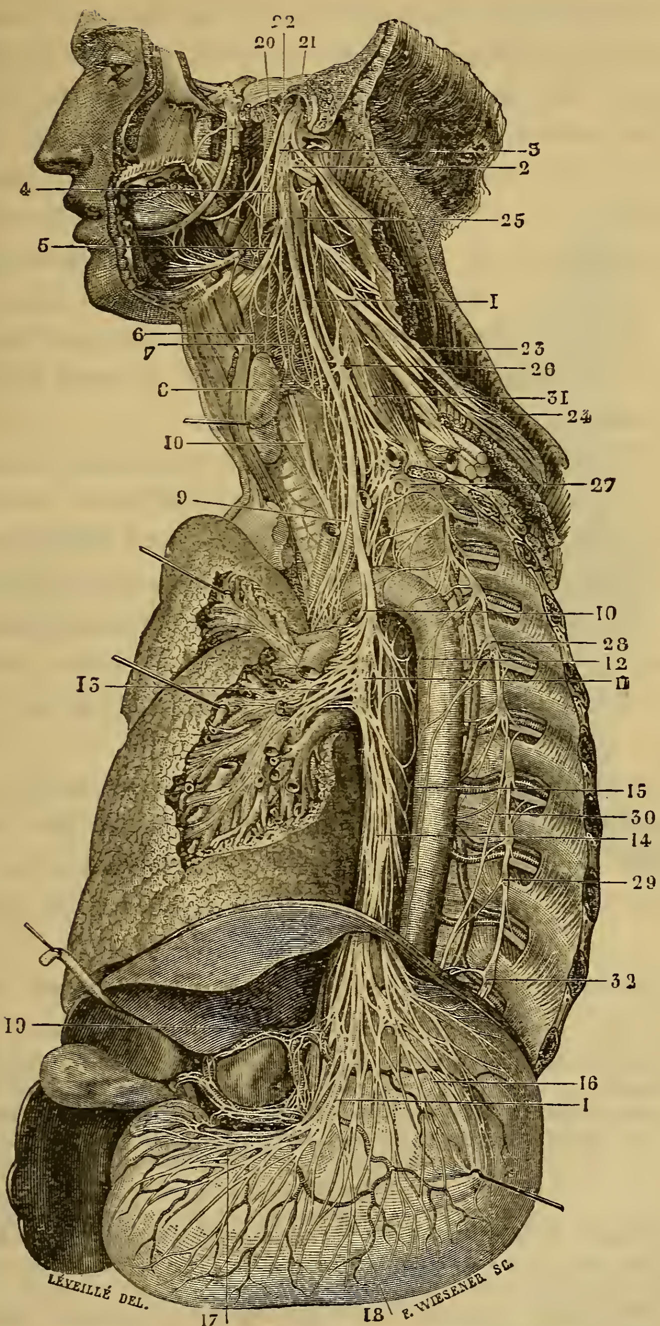


FIG. 169.—Left Pneumogastric Nerve with Cervical and Thoracic Portions of the Great Sympathetic. (Jamin, after Hirschfeld.)

1, 1, Pneumogastric; 2, Anastomoses of the Pneumogastric with the Hypoglossal;

pairs of Cranial Nerves, and also with the anterior branches of the several Spinal Nerves along the whole length of the Cord. The latter communications are mostly brought about, on each side, by pairs of filaments (some of whose fibres are 'afferent' whilst others are 'efferent'), passing between the several anterior spinal nerves and the corresponding ganglia of the 'Sympathetic'—the latter being situated a little in front of the spinal nerves (fig. 170). Other Ganglia, moreover, are found at the junctions of some of the above-mentioned Cranial Nerves with the lateral cords of the 'Great Sympathetic.'

(*b.*) From the ganglionated cord on each side, numerous *internal branches* are given off which unite with one another, with those of the opposite side, and with filaments of the Vagus Nerves, so as to form either great *Plexuses or Ganglia*, or both together, whence multitudes of nerves are sent to or received from the various Viscera. On the course of these latter nerves smaller ganglia are often found.

The principal systemic Plexuses are situated about the heart and roots of the respiratory organs; in the neighbourhood of the stomach ('solar plexus'); and also in the vicinity of the bladder and internal organs of generation.

The nerves in connection with those Plexuses which

3, its anastomoses with a branch of the Spinal-accessory; 4, Pharyngeal branch; 5, superior Laryngeal nerve; 6, external Laryngeal; 7, Laryngeal plexus; 8, superior Cardiac nerve; 9, middle Cardiac; 10, 10, recurrent Laryngeal nerve; 11, Pulmonary ganglion; 12, its anastomoses with the great Sympathetic; 13, posterior pulmonary plexus; 14, Œsophageal plexus; 15, anastomoses of the right with the left Pneumogastric; 16, branches of the Cardiac extremity of the Stomach; 17, branches of the smaller curvature; 18, branches of the anterior face; 19, Hepatic branches; 20, Glosso-pharyngeal nerve; 21, Spinal-accessory; 22, its internal branch anastomosing with the Pneumogastric; 23, its external branch proceeding to the Trapezius and anastomosing with (24) the fourth Cervical nerve; 25, superior, and 26, middle Cervical ganglion; 27, inferior Cervical ganglion united with the first Dorsal; 28, 29, 32, Dorsal ganglia; 30, great Splanchnic nerve; 31, origin of the Phrenic nerve.

In this figure, the Heart has been cut away, the left Lung drawn forward and its root partly dissected, and the Liver has been partly reflected from the Stomach.

proceed from or to the Viscera are mostly distributed along the course of the Blood-vessels. Some of the fibres of this system are specially distributed to the coats of the Vessels, and are, from the nature of their functions, known as 'vaso-motor nerves.' A portion of these must have 'afferent' functions whilst others transmit 'efferent' impulses, causing the vessels to contract, so that by means of such nerves, the amount of blood flowing through particular vascular territories may be easily regulated. The 'vaso-motor' nerves are connected with small ganglia distributed over the vessels. To some extent motor stimuli emanate from these, though the whole 'Vaso-motor' system of the body seems to be amenable to the influence of a 'regulative centre' situated in the Medulla, together with other subordinate centres in the Spinal Cord.

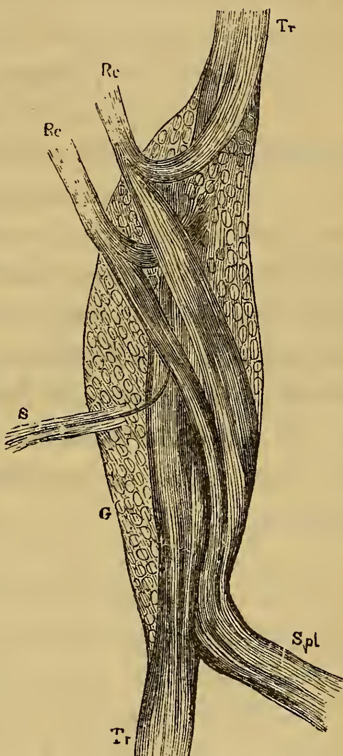


FIG. 170.—One of the Sympathetic Ganglia from the right Lateral Cord of the Rabbit. (Owen, after Kölliker.) *Tr*, Lateral cord of Sympathetic; *Rc*, *Rc*, two communicating branches; *Spl*, Splanchnic or Visceral nerve; *s*, small nerve; G, ganglion cells and fibres. (× about 40 diameters.)

Whilst the Sympathetic System probably contains its own intrinsic afferent and efferent nerves, it also seems to send (through the before-mentioned communicating filaments) afferent nerves to the grey matter of the Spinal Cord, and to receive therefrom certain efferent motor and other fibres. This great Sympathetic System of nerves is to a certain extent an independently developed system, though it also holds relations to the Spinal Cord closely resembling those which exist between the two 'Cerebral Systemic Nerves,' and the Medulla.

By the arrangements above described, not only is the harmonious activity of related Viscera facilitated, but the simultaneous activity of Visceral and Cerebro-spinal Nerve Centres is ensured, where such conjoint activity is needed—as in the respiratory processes, in oviposition and in parturition, or in the voiding of excreta. Again, by reason of the direct or indirect connection of the Viscera with the Brain, the organic states of the various organs are capable of influencing the 'temper' or mental state of the individual, either unconsciously or consciously. Visceral states may, independently of their conscious realization, prompt to automatic or Instinctive Acts; or, they may impress themselves upon the Conscious Life of the individual, and lead more or less directly to a series of Voluntary Actions.

CHAPTER XXIV.

THE FUNCTIONAL RELATIONS OF THE PRINCIPAL PARTS OF THE BRAIN.

We now pass from the consideration of details of structure to the question of their significance, and shall attempt to enable the reader to form some notions—meagre though they may be—of the way in which the Brain acts in the performance of the simpler of its functions.

In this attempt we shall have to be guided by three sets of facts and inferences:—(1) Those gathered from the study of the Anatomy of the Nervous Systems of lower animals and of Man; (2) those derived from Experiments with lower animals, in which Nerves or other portions of the Nervous System have been either stimulated or destroyed; (3) those reported by medical men who have paid special attention to the symptoms arising from irritative or destructive Diseases or Injuries of different portions of the Brain in Man.

In each of these directions our knowledge has, within recent years, been making very appreciable strides and is still progressing.

In this preliminary chapter on the mode of action of the Brain, the reader's attention will be called to what is known concerning three sets of structural relations which are of fundamental importance.

1.—The Cross Relation existing between the Cerebral Hemispheres and the Lateral Halves of the Body.

The bodies of the great majority of Invertebrates, as well as of Vertebrate Animals, are bilaterally symmetrical—at least as regards all external organs and all parts of their Nervous System. So that if a median vertical plane were to divide one of these animals in a longitudinal direction, each half of the body would be found to be similar to the other in all respects externally, and each, also, would contain the half of a Nervous System similar to that of its fellow.

So far as we know at present, however, the relation which the double Nervous System of the Invertebrate bears to its double body is different altogether from the relation subsisting between the same parts in the Vertebrate. In the former the half of the Brain contained in either half of the body is in immediate connection with the sensory organs and surfaces, as well as with the motor nerves and muscles, of the same side of the body. In Vertebrates, on the other hand, it is not so. In lower members of the series to some extent, and in the higher forms (including Quadrumana and Man) to a more perfect extent, a cross relation exists between the Brain and the body, so that each half of the Brain is connected with the Sensory Organs and surfaces of the opposite half of the body, and also with its Muscles. The former relation is brought about by the 'sensory' channels decussating at the base of the Brain and along the Spinal Cord; and the latter is due to the fact that the nerve-channels for 'outgoing' or motor stimuli pass from each half of the Brain to the opposite side of the body, decussating with one another in the Medulla.

Very few explanations have as yet been attempted of the mode of origin of this crossed relation between the Brain and the body. The subject is generally passed over in silence, and though our knowledge of the exact anatomical relations existing in lower animals is not yet ripe enough for a thoroughly satisfactory answer, a few suggestions may here be offered which, if they do nothing else, will perhaps serve to direct more attention to this very interesting question, and at the same time indicate some of the directions in which more precise information is needed.

The essential nature of the problem comes out most distinctly if the reader attempts to picture to himself the existence of a double Nervous System in Vertebrates in all respects similar to what it is, except for the fact that neither its sensory nor its motor channels decussate. With the two halves of the Brain and Spinal Cord, as freely connected by transverse 'commissures' as they are at present, a direct relationship of this kind would seem to be the most natural arrangement, and it is not, therefore, at all clear why such a plan should not exist and work as well for Vertebrates as it does for Invertebrates. The question to be answered, then, is—What conditions have arisen in Vertebrate Animals tending to initiate, and finally to perfect, such a crossed relation between the Brain and the body as we find existing in Man and the higher Mammalia generally?

The following considerations seem to the writer to throw some light upon this subject:—

1. Movements take place in response to sensory impressions of various kinds, and (for our present purpose) they may be divided into two classes:—(*a*) those in which related muscles on the two sides of the body are called into simultaneous activity—as with the trunk muscles concerned in the locomotions of Fishes and many

limbless Reptiles; and (*b*) those in which muscles on one side, and especially of one limb, are called into activity alone—either in an ordinary reflex or in a volitional manner.

2. The great bulk of the movements of Fishes and of Ophidian Reptiles would belong to the former category, and as Broadbent* first pointed out (in regard to Man) we have evidence to show that movements of this class may be equally well evoked by a stimulus passing from either side of the Brain to one of the halves of their double but intimately combined Spinal Centres. This being so, it would, perhaps, be a matter of comparatively little importance for such creatures whether some particular leading sense organs, such as the eyes, were respectively in structural connection through their optic nerves, with the half of the brain on the same side or with that of the opposite side.

3. Fishes are the animals in which we first find a cross arrangement of certain important sensory channels. Their Optic Nerves decussate in a very complete manner.† We do not know for certain, however, that any of their other sensory channels are similarly disposed; neither is there any evidence to prove that the fibres constituting their motor channels decussate with one another.

4. In Fishes, then, we have to do with what may be, and probably is, a mere partial initiation of the cross relation between the Brain and the body; and it seems conceivable that such a relation may have been determined in some of the earliest Fishes, or at least favoured, by two or three of the physical peculiarities of such creatures. The elongation of the head of a Fish—a conformation which is doubtless in intimate relation with the animal's life and movements in an aquatic medium—together with the lateral position of its eyes, may have had something to do with the fact of the occurrence of a decussation of the budding optic tracts in some of the early forms of Fishes.‡

* "Brit. and For. Med. Chir. Review," 1866.

† Though according to Siebold an exception to this rule is to be found in the case of *Bdellostoma*, one of the Myxinoid or lowest class of Fishes.

‡ Marshall (" Outlines of Physiology," vol. i. p. 602) endeavours to account for this one primary decussation by supposing it to depend upon the lateral reversion of optic images occasioned by the concave shape of the retina in Fishes. But his reasons seem unsatisfactory, because with a similarly shaped retina no cross

5. But when distinct limbs appear in higher Reptiles, and when in Birds and Mammals the movements of more or less similar limbs become increasingly volitional and independent of one another, two additional results might be expected to follow the primary decussation of the Optic Nerves (howsoever this may have been determined):—(*a*) those other 'sensory' channels whose impressions are most concerned in the instigation of limb movements would also tend to decussate, because it would be very essential that more or less unilateral Tactile and Auditory Impressions should be brought into relation centrally with Visual Impressions coming from the same side of the body; (*b*) coincidently with the establishment of a decussation of the 'sensory' channels—and especially those of the Tactile Sense and common sensibility—in animals accustomed to perform unilateral voluntary movements, we might expect that there would be a tendency to the establishment of an answering cross-relation between the 'motor' channels of the Cerebro-Spinal System. Thus, that half of the Brain which has first received the instigating sensorial impressions would be enabled to send forth the motor stimuli—both for the reflex and for the volitional movements of limbs on one side of the body. And, if there is to be no separate decussation for the channels of reflex and volitional motor incitations respectively, such crossings of motor channels as we find existing in the Medulla of Man and many other Vertebrates (*i.e.* at the 'decussation' of the Pyramids) would seem to be the only natural arrangement.

6. This more complete cross arrangement seems only to be perfected to the extent indicated, in higher Mammals and in Man.

relation exists in Cuttlefishes; secondly, because there is no evidence to show that the 'motor' channels undergo any similar decussation (though this hypothesis assumes its existence) in the lower limbless Vertebrates, in whom the decussation of the optic tracts becomes initiated; and, thirdly, because the experience of workers with the microscope tends to show the ease with which adaptation of the movements of the hands to meet the case of a reversal of the optic image—involving as it does, moreover, a reversal of upper and lower, as well as of lateral parts—is brought about. This latter reason helps to show that no important anatomical changes would be needed, as Marshall seems to suppose, to meet the case of a mere reversal of the optic images.

7. A cross arrangement of sensory channels would seem to be less essential in the case of Taste and Smell than for either of the other kinds of ingoing impressions, first, because the organs subservient to these endowments are situated more in the middle line of the body than either of the others; and, secondly, because impressions of Taste and Smell are perhaps less immediately provocative than those of other senses, of unilateral limb movements. The nerves of Taste being, however, bound up with or forming part of two nerves of common sensibility (the Fifth and the Glosso-pharyngeal) they, as it were, follow the lead of the nerve trunks to which they belong, and decussate with them. But in regard to Olfactory channels, it is, as matter of fact, notable that they are the only ones in which no decussation is known to occur, either in the lower animals or in Man. The Olfactory Centres of the two hemispheres are, however, very amply connected by means of commissural fibres—principally gathered together in, and for the most part constituting, the 'anterior commissure.'

Thus, in brief, the writer's view is this:—That the cross relation between the halves of the Brain and the body may have been initiated in some Fishes in a quasi-accidental manner, and that in the first stage of its existence it was, and still is, represented only by the decussation of the Optic Tracts; that in higher animals possessed of well-formed limbs reflex and volitional movements of those of one side are very often evoked in response to unilateral sensory stimuli, so that in such creatures there would be a distinct advantage if other sensory channels, by decussating, were to be brought into relation, at their central termini, with those of the Visual Sense; finally, the same influences, whatever they may be, which determine this additional sensory decussation, would lead to an establishment of the equally necessary sequential decussation of the motor channels for the limbs. The cross arrangement of sensory and motor channels met with in Man and higher Mammals is, therefore, to be regarded as an almost necessary sequence, from the point of view of the evolution theory, of a primary and perhaps quasi-accidental decussation of the Optic Tracts in Fishes.

2.—The Functional Relations of the Cerebral Hemispheres with one another: the Duality of Body and the Unity of Mind.

The two Cerebral Hemispheres are now generally admitted to contain the ultimate prolongations of the 'ingoing' nerves, or nerves of Sense, and to be constituted by the aggregation of the organic centres (abundantly interconnected by 'commissural' fibres) of all those higher mental processes which we have traced as derivatives of the exercise of conscious Sensibility, viz., the specially automatic processes of Perception, Ideation, Emotion, Conception, Reasoning, together with the more volitional processes of Attention, Recollection, Imagination, and Constructive Thought. The Cerebral Hemispheres contain, however, in addition to the Sensory Centres and those for the derivative processes above indicated, multitudes of fibres and some Centres for the conduction and proper grouping of 'outgoing' currents.

Of the various transverse commissures, already described, that connect these parts with one another, one, of more importance than the others, now deserves some further attention. This is the great transverse commissure, or **Corpus Callosum,** which, showing itself first in lower Mammals, increases in size in higher members of the series, till we find it attaining its maximum development in the brain of Man. As stated in the last chapter, the fibres of the Corpus Callosum pass across from Hemisphere to Hemisphere, so as to bring into relation corresponding areas of convolutional Grey Matter. It does not pass equally between all convolutions, but especially between those which are also in relation with the great basal ganglia (Broadbent). The **Anterior Commissure,** though a morphologically distinct part, seems to have an essentially parallel function, since its fibres also serve to connect similar convolutions on the two sides—viz., some of those situated in the Temporal Lobes. A similar function must also be assigned to the 'Psalterial Fibres,' which in part constitute the posterior bent portion ('genu') of the Corpus Callosum itself (p. 443, note †).

These transverse 'commissural' fibres are of much interest, because there is reason to believe that they are, to a considerable extent, in relation with that unification of Consciousness which unquestionably exists (as everyone can testify) in spite of the fact that the organs of Sensorial Activity are double throughout. Such Commissures are also, in all probability, very essential for the carrying on of the higher mental processes. In cases recorded by Dr. Langdon Down and others the non-development of this part of the Brain in human beings has been associated with more or less marked Idiocy; but then, the arrest of development has for the most part not been strictly limited to the Corpus Callosum. The Middle Commissure, the Fornix, or some convolutional regions have been often at the same time deficient. In some of the recorded cases in which the Corpus Callosum has been only partially absent, there has been less degradation of the Intellectual Powers than might have been anticipated. In certain of these latter cases, however, the persons have either died so young, or the morbid conditions have been so complicated, as to make them of comparatively little value for settling the question as to the real importance of the Corpus Callosum in the carrying on of mental processes.*

According to the anatomical data furnished by Broadbent† it is the Sensorial Regions of the two hemispheres

* See Knox, in "Glasgow Medical Journal," April, 1875, where fifteen cases are referred to.

† See p. 442.

(or the Sensorial and what some regard as the Volitional) which are immediately brought into relation by means of the Corpus Callosum. But even if this supposed arrangement be the one that actually exists, it would by no means indicate that the organic seats of the more complex derivative processes are not also *mediately* brought into relation with one another. The more specialized Emotional, Intellectual, and Volitional Regions in each hemisphere, wherever they may be, and however they may be related to one another, are necessarily, by means of the 'association system' of fibres, brought into intimate communion with their corresponding Sensorial Regions of various kinds. It is in this indirect way, therefore, that the higher functional regions of the two Hemispheres may be brought into relation with one another, through the medium of the fibres of the Corpus Callosum. There is manifestly a unity in our Emotional, Intellectual, and Volitional—as well as in our Sensorial Consciousness—that is, in the 'derivative' as well as in the 'primary' mental processes.

There can be little doubt that Sensorial Activity and the action of those portions of the Brain which are directly concerned therewith, affords the primary or essential basis of Consciousness. We are most fully conscious when we are most receptive of external impressions, and we lapse into a completely or partially unconscious condition when the advent of such impressions is for a time prevented, or when we are intensely absorbed in some train of thought (Ideal or Reflective Consciousness)—that is, when the activity of other portions of the Cerebral Hemispheres in some way dwarfs or eclipses that of the sensorial regions proper. An admirable illustration of the former truth has been lately given by Dr. Strümpell,*

* "Pflüger's Archiv," vol. xv. p. 573, and translated in "Nature," December 13, 1877.

which is so instructive as to be worth quoting in full.

"In the autumn of last year there was received into the medical clinic of Leipzig a youth aged 16, in whom various phenomena of anæsthesia gradually developed themselves to an extent which has very rarely been observed. The skin of the whole surface of the body was completely insensible, and that in respect to every kind of sensation. The most powerful electric current, or a burning taper held to the skin, was not able to produce any pain, or even a sensation of touch. Almost all the accessible parts of the mucous membrane of the body exhibited the same insensibility to pain. Also, all those sensations which are classed together under the name of 'muscular sense' were entirely absent. The patient, when his eyes were closed, could be carried about round the room, his limbs could be placed in the most inconvenient positions, without his being in any way conscious of it. Even the feeling of muscular exhaustion was lost. In addition, there came on also a complete loss of taste and smell, amaurosis of the left eye, and deafness of the right ear.

In short, here was an individual whose only connection with the outer world was limited to two doors of sense—to his one (right) eye and his one (left) ear. Moreover, both these remaining doors could at any time be easily closed, and in this way it was possible to investigate the consequences of completely isolating the brain from all external stimulation through the senses. I have frequently made the following experiment, and often showed it to others:—If the patient's seeing eye was bandaged and his hearing ear was stopped, after a few (usually from two to three) minutes the expression of surprise and the uneasy movements which at first showed themselves ceased, the respiration became quiet and regular; in fact, the patient was *sound asleep*. Here, therefore, the possibility of artificially inducing sleep, at any time, in a person simply by withholding from the brain all stimulation by means of the senses was realized.

The awakening of the patient was as interesting as the sending him to sleep. He could be awakened by an auditory stimulation, as, for example, by calling into his hearing ear, or by visual stimulation, by allowing the stimulus of light to fall upon his seeing eye; but he could not be wakened by any pushing or shaking. If he was left to himself he did eventually wake up of his own accord in course of the day, after the sleep had lasted many hours; the awakening being due, it might be, to intrinsic stimuli started in the brain, or it might be to slight external unavoidable stimuli acting through his still functional sense organs, and making themselves felt in consequence of the sensitiveness of the brain being increased during the repose of sleep."

Nothing could show more distinctly than such a case as this the importance of the activity of the Sensorial Regions of the Hemispheres for the production of what we know as Consciousness. It seems clear, indeed, that if Consciousness is not in some way an immediate appanage of the activity of these very regions of the Hemispheres, their activity is, at all events, an essential forerunner of that of some other regions between whose activity and Consciousness there is such an immediate association.

On the other hand, it is equally clear that the stimulating sensorial impressions are double, coming to each Hemisphere of the Brain from opposite halves of the body, and that their subjective accompaniments are merged into a single Consciousness of this or that kind. The final proof of this position is afforded by the effects of injury to certain portions of the Brain on one side only in some of the lower animals, and by the effects of unilateral disease of corresponding regions of the Brain in Man. Thus, where we have to do with injury or with disease of the posterior third of what is known as the 'internal capsule'—that is, of that portion of the expansion of the Cerebral Peduncle which lies between the posterior part of the Corpus Striatum and the Thalamus—there is found to be complete loss of sensibility on the opposite half of the body (Hemianæsthesia). No touch can be felt, and all the other avenues of sense on this side are similarly closed—the tongue and side of the mouth are dead to flavours, the ear is dead to sounds, the eye is blind, and the corresponding nostril is similarly insensitive to all odours.*

But in Hemi-anæsthesia, although the avenues of sense are closed on one side, the general Consciousness of the individual appears to remain unaffected, and his Mental Activity may be but little impaired. This comparatively unaltered mental condition, notwithstanding the absence of direct sensorial stimulation of one Hemisphere, is probably possible only through the intervening activity of the Corpus Callosum—since by means of its fibres the stimulus to the one side of the Brain may be propagated to the other. Both Hemispheres may thus be brought into relation with the various sensorial stimuli emanating from one side of the body; and in this way it is possible for the general Con-

* The explanation of the loss of the sense of Smell in the corresponding nostril presents some difficulties. It seems, at first sight, to be altogether at variance with anatomical facts, since the relations of the organs of smell with the hemispheres are, as already pointed out (p. 468), exceptional. They are certainly direct rather than crossed, and it would also tend to contradict existing anatomical knowledge if fibres from the Olfactory Ganglia on the road to their 'perceptive centres' were to be found anywhere in the neighbourhood of the posterior part of the *corona radiata.* But a very plausible explanation of the loss of the sense of Smell in these cases of Hemi-anæsthesia is to be found, as Dr. Ferrier points out ("Functions of the Brain," p. 191), in the well-known experiments of Magendie, as to the functions of the fifth nerve. He ascertained that Smell was lost when the sensibility of the nostril was abolished—*e.g.*, after the fifth nerve had been cut; not because the fifth is the nerve of Smell properly so called, but because "the integrity of the fifth is necessary to the due functional activity of the olfactory nerves." If the unilateral loss of Smell in these cases of Hemi-anæsthesia be really due only to the loss of common sensibility in the corresponding nostril, then the same loss of Smell ought to occur in Man with those lesions of the 'pons Varolii' in which the common sensibility of one side of the body is annulled: and the writer's experience leads him to believe that this loss does occur in such cases.

sciousness of the individual to remain unaltered, even in the absence of sensorial stimuli from one half of the body.

It is most important to recollect that the results above described follow lesions of the posterior third of the Cerebral Peduncle, just before its fibres come into relation with the Thalamus. The effects are very different when lesions exist above or outside the great 'basal ganglia' (see p. 493), even though these lesions may involve extensive destruction of one Hemisphere.

It is only in the sphere of the three higher senses,

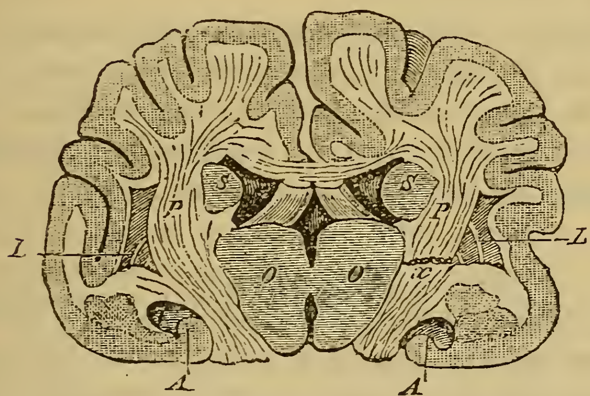


FIG. 171.—Transverse section through the Cerebrum of a Dog opposite the middle of the Thalami, showing the portion of the 'internal capsule,' the section of which produces Hemi-anæsthesia. (Charcot after Duret.) *O, O,* Thalami connected by Middle or Soft Commissure; *P, P,* posterior third of Cerebral Peduncle ('internal capsule'). On the right side these fibres are represented as cut across at *x*; *S,* intra-Ventricular, and *L,* extra-ventricular Corpus Striatum.

however, that a blending of the subjective accompaniments of impressions from the two sides of the body occurs, so as to produce single Perceptions. An object which is smelt is perceived as one; a body which is seen is recognized as single; and similarly a sound, though stimulating both auditory organs, is heard as one sound. And although we can localize gustatory impressions to one or other side of the mouth, when our attention is directed to the subject, we are not accustomed to do so, and there would be little use in making such discriminations. The case is altogether different, however, in regard to the sense of Touch, or common sensibility. By means of Smell, Sight, and Hearing we are brought into relation with distant phenomena, but in the exercise of Taste and Touch there is actual contact with different portions of the extended surface of our bodies, and therefore, in the latter case more especially, there ought to be, as there is, a thoroughly independent power of appreciating the impressions impinging upon each side of the body, and, indeed, of pretty accurately localizing them.

This unity of result accompanying the action of a great part of the Sensorial Regions of the two Hemispheres, as well as in those which are subservient to Emotional and Intellectual Activity, is very remarkable, and difficult to understand, especially if we bear in mind the fact that there is not even a perfect symmetry in the naked eye conformation of many of the homologous Convolutions of the two sides (to say nothing of their microscopical structure); that their vascular supply is independent, and therefore subject to variations which may affect one side only; and that an inequality of working power on the two sides might also easily be brought about by some inherent or acquired differences in the molecular (or functional) activity of the corresponding nerve elements on the two sides of the Brain.

Notwithstanding our difficulty in comprehending how a double mechanism of this kind can work as it does, so as to lead to a single Consciousness, or so as to enable it to carry on the processes of a single Thinking and Willing personality, the facts of our own Consciousness may assure each one of us that it is so.

Yet, though it may be the rule for the two Hemispheres to be called into simultaneous and harmonious activity in Perception, Emotion, Thought, and Volition, evidence is not altogether wanting to show that they are capable of working more or less independently—either (*a*) where both hemispheres exist, and there is a supposed lack of harmony, with resulting 'double Consciousness'; or (*b*) in the more positive and definite cases in which there has been no impairment of Sense or Intellect noted, although the greater portion of one Cerebral Hemisphere may have been destroyed. On each of these subjects a few words may be said.

(*a*.) The evidence in favour of the possibility of a separate and dissimilar, though simultaneous, activity of the two Hemispheres of the Brain is of a very doubtful nature, though there are facts familiar enough to physicians which have been thought to support this notion.

The question was, for instance, raised by Sir Henry Holland* in 1840,—"Whether some of the aberrations of mind, which come under the name of insanity, are not due to incongruous action of this double structure [the two hemispheres], to which perfect unity of action belongs in the healthy state?" He adds:—"The subject is very obscure, and all proof of difficult attainment; but I think it more probable than otherwise that such inequality may be a cause of some among the many forms of mental derangement. . . . . It has been a familiar remark that in certain states of mental derangement, as well as in some cases of hysteria which border closely upon it, there appear, as it were, two minds; one tending to correct by more just perceptions, feelings, and volitions, the aberrations of the other; and the relative power of the two influences varying at different times. . . . It is remarkable how distinct an expression to this effect may occasionally be had from patients themselves. I have recently seen a case of which the most marked feature was a frequent and sudden outbreak of passion upon subjects, partly real, partly delusive, but generally

* "Medical Notes and Reflections," 2nd Ed., 1840, p. 172.

without obvious or sufficient reason at the moment; these excesses attended with loud screaming, execrations, and acts of violence in striking or breaking things within reach. Here the patient himself described to me the kind of separate consciousness he had when these violent moods were upon him; his desire, but feelings of inability to resist them; his satisfaction when he felt them to be passing away. It was a painfully exaggerated picture of the struggle between good and ill."

Nothing much more definite could then be said upon this subject, nor has there since been any appreciable advance of our knowledge in regard to it.* It is, of course, possible that two seemingly simultaneous states of Mind may be never strictly coincident in time, so that in the cases to which reference has just been made, there may have been merely a rapidly alternating action of the organ as a whole, rather than a simultaneous independent action of the two hemispheres of the Brain. Some of the phenomena of dreams present precisely the same difficulties—indeed the evidence in favour of a double Consciousness is here even more striking, since most of us may be able to add our own personal experience to the testimony of others. We refer more especially to those cases in which the dreamer appears to be carrying on a long conversation with some other person; where two distinct trains of thought are being evolved; and where, occasionally, there may be evidence to show that the whole dream has been so rapidly produced as to make it more easy to explain the phenomena by the supposition of a simultaneous and independent action of the two Hemispheres than by an alternating different action of the Brain as a whole.†

* Dr. Wigan's work on "The Duality of the Mind," 1844, is a diffuse and by no means well-arranged contribution dealing with the same subject.

† The consciousness of the dreamer may be distinguished under the name of Ideational Consciousness, from the ordinary conscious-

(*b.*) If we look, on the other hand, to the question as to what amount of Intellectual Power is possible where one Hemisphere of the Cerebrum has been very much damaged or atrophied; there can be little doubt that, as a rule, the psychical powers would be found very much blunted or paralyzed. This, however, is far from being universally the case, for there are instances on record in which, with atrophy or extensive disease of one Hemisphere, the Intellectual Faculties appeared to be in their normal condition.

Preservation of any considerable Mental Power when there is great damage to one Hemisphere is, however, very rarely met with when the damage occurs late in life. It is much more likely to be encountered when the disease or damage has set in or happened in early childhood: at a time, that is, when the growth and textural development of the Brain is capable of undergoing considerable modifications that may fit it for the more or less isolated activity of the one Hemisphere—which, in the cases supposed, may be almost all that is possible. Such an early onset of the disease is, indeed, found by the writer to have existed in many of the best authenticated cases belonging to this category.*

Perhaps the most remarkable of all the cases of this sort on record is one which was observed and reported by Andral. A man, who died in his twenty-eighth year, had a fall when three years old, after which he continued paralyzed on the left side. The right hemisphere of the brain was found to be so completely atrophied

ness of the waking state. In each case the sensorial regions of the hemispheres would seem to be the initial or central tracts whose activity is roused—in the one case, by real, and, in the other, by revived, sensorial impressions.

* "Atrophy of the Left Hemisphere." New Sydenham Soc., vol. xi. p. 153. Several cases are here referred to by S. Van der Kolk, including the one recorded by Andral.

that a great part of the 'pia mater' on this right side formed a cyst, in which not a trace of cerebral matter remained. This membrane constituted the upper wall of a large cavity, the floor of which alone was formed by the Thalamus, the Corpus Striatum and all the parts on a level with these two bodies. No nervous matter existed, therefore, above the level of the great ganglia on the right side—and yet Andral says:—"Cet individu avait reçu de l'éducation et en avait profité; il avait une bonne mémoire; sa parole était libre et facile; son intelligence était celle du commun des hommes."

Cases of a similar character have been recorded by Cruveilhier and others, and it is a remarkable fact that there has been not only a preservation of such an amount of Intellectual Power, as to have given the appearance, at all events, of no loss in this direction, but that the special modes of Sensibility (such as Sight and Hearing) have not been abolished on either side—there has been no unilateral Blindness or Deafness even although the greater part of the opposite Hemisphere may have been destroyed. This preservation of the special senses, in such cases, the writer has elsewhere endeavoured to explain by an extension of Broadbent's hypothesis concerning the single or double activity of 'motor' centres, to the problem as to the conditions regulating the single or combined activity of the 'sensory' centres.*

These previously recorded cases of disease of the greater part of one Hemisphere and preservation of the special Senses on both sides, stand out in notable contrast with the more recently published cases of lesion of the posterior third of the 'internal capsule' in which *Hemi-anæsthesia* has been produced (see p. 489). In the latter class of cases there is a limited lesion in the 'sensory' region of the Cerebral Peduncle just before it comes into relation with the Thalamus; whilst in the cases in which there is little or no impairment of Sense on either side the lesion has mostly involved the frontal and parietal regions of the Hemisphere above the level of the Thalamus

* "Paralysis from Brain Disease," 1875, p. 106.

and Corpus Striatum, and perhaps, therefore, without much implicating the convolutions of the Temporal Lobe, which, as will be shown in the next chapter, appear to contain centres or regions of special importance for sensory perception. These latter cases are of great interest, but more accurate information would be required before we could safely come to any definite opinion in regard to them. The old observations were not made or, at all events, were not recorded in that rigorously precise manner which the importance of the subject, from our present point of view, clearly demands.

But whilst our 'Will' is, like our Intellect, single (although it is the product or accompaniment of the activity of a double organ), we are here, on the occasion of its exercise, brought to the turning point where 'mental' gradually give place to 'non-mental' phenomena.

The outcome of many Volitions is to be found in muscular contractions and relaxations, and the mere passage of 'outgoing currents' has no conscious accompaniment of any kind.* After the Wish or Desire with 'a sense of effort' (which together seem to make up what we individually know of a Volition—so far, that is, as it reveals itself to us as a phase of Consciousness), we have to do with molecular currents passing, it may be, through several sets of fibres and cells, but having no conscious side whatever, and apparently lying just as much outside the sphere of Mind as the molecular changes in the muscle which these 'outgoing currents' evoke.

It was for these reasons that, in an earlier chapter, the writer was led to limit the sphere of Mind, and to regard that portion only of the Nervous System as its organ which has to do with the reception, the transmission, and with the vastly multiplied co-ordinations of

* On this subject see what Sir Wm. Hamilton says in his "Lectures," vol. ii. pp. 391, 392; also in his "Dissertations on Reid," pp. 866, 867.

'ingoing currents' in all kinds of nerve centres. On the other hand, we were led to regard the phenomena of the 'outgoing current' as non-mental, and the regions of the nervous system concerned therewith as not strictly constituting parts of the 'Organ of Mind.'

Certain it is that directly we pass from the purely mental side, or from the starting-points of a Volition, we find two main pathways by which its associated stimuli (in the form of molecular movements), may pass away from the cortex of the Cerebral Hemispheres to Muscles on each side of the body.

The muscles of the right or left limbs, or such groups of them in other parts as are usually called into action independently of their fellows on the opposite side of the body, receive their 'volitional' stimuli, as we have stated, only through the Cerebral Hemisphere of the opposite side. But bilaterally situated muscles that habitually act together, may be stimulated indifferently from either Hemisphere (Broadbent), owing to the existence of intimate commissural connections, binding together the duplicate Spinal Centres in relation with such muscles so closely as to make each pair in effect one Centre.

A highly important exception to this latter rule seems to exist, however, in the case of the bilaterally acting muscles concerned in the Articulation of Words—that is, in ordinary Speech. Usually the stimulus that passes over from the Cortex to incite these muscular acts issues from one Cerebral Hemisphere only, and in the great majority of cases the Left Hemisphere is the source of such Speech-incitations. The proof of these statements, and further particulars in regard to the paths of outgoing stimuli generally, will be given in subsequent chapters.

3. The Functional Relations of the Cerebellum with the Cerebral Hemispheres and the Spinal Cord.

We pass now to another subject of surpassing interest but of great obscurity. What are the functions of the Cerebellum? This is a question which seems most simple, though it is one that has perplexed physiologists for over two centuries, and may still be considered to hold its place as a thoroughly unsettled problem. The most varied views have been entertained by different physiologists on the subject.

Willis and others have regarded the Cerebellum as the principal regulative centre for involuntary movements as well as for the functions of vegetative life; Foville and others have regarded it as a 'sensorium commune,' or principal centre for ingoing conscious impressions; Gall and some of his followers looked upon it as an organ chiefly concerned with the 'instinct of propagation' or the 'sexual appetite'; Flourens, Longet and others have taught that the Cerebellum is the seat of a faculty for co-ordinating voluntary and other muscular movements; Lussana, endeavouring to explain the mode in which it co-ordinates voluntary movements, makes it the seat of the 'muscular sense'; Reil, Rolando, and some modern writers, such as Luys, Weir-Mitchell and others, have regarded the Cerebellum as an organ for engendering and distributing the nerve-force needed for the instigation of all kinds of movements, and even for stimulating other non-motor nerve centres. This by no means exhausts the list of views which have, at one time or another, been held concerning the functions of the Cerebellum. Other notions in regard to this organ will, indeed, be referred to in subsequent pages.

How are we to choose from amongst these bewilderingly different theories? Vulpian,* after carefully reviewing the whole subject in 1866, felt unable to accept any one of them. He contented himself in the main by drawing certain negative conclusions. "The Cerebellum," he

* "La physiolog. du Syst. Nerveux," pp. 601–641.

said, "takes no part in cerebral functions proper. It appears to have nothing at all to do with the manifestations of Instinct, of Intelligence, or of Will." Whether absolutely correct or not, this is a notion commonly entertained. On the other hand, that certain ataxic disorders of movement are caused by lesions of the Cerebellum, Vulpian felt compelled to admit; though he rejected the commonly entertained hypothesis of Flourens, that it is "a centre by which the co-ordination of voluntary and other movements is effected."

The great uncertainty that has always prevailed in regard to the functions of the Cerebellum is due to various causes. It is attributable partly to the complicacy of the connections of this organ with other regions of the central Nervous System, as well as to the obscurity which reigns as to the several sources of its 'ingoing,' and the destination of its 'outgoing,' fibres—for to suppose with Luys that the peduncles of the Cerebellum are composed of 'outgoing' fibres only seems to the writer as opposed to fact as it would be to the plan of Nerve Centres generally. But the uncertainty as to the real functions of this organ, is due also to the variety and obscurity of the symptoms resulting from its injury in any of the lower animals, and from a like variability of relation between symptoms and lesions, revealed to those who study the effects of diseases of the Cerebellum in Man.

These latter variations are attributable partly to the intimate connection of the Cerebellum with other important portions of the Brain. This makes it difficult to experiment with the organ in the lower animals without great risk of irritating or injuring, now one, now another of these adjacent parts; and equally difficult, on the other, to get uncomplicated disease of the Cerebellum—disease that is limited to this organ and unassociated with symptoms resulting from pressure on, or irritation of, other important parts, such as the Medulla or 'pons Varolii.'

But the effects of the foregoing sources of uncertainty are probably increased by what we shall find to be the well-grounded consideration, that the Cerebellum, whatever may be the precise nature of its functions, does not commonly act alone, but to a very considerable extent in conjunction with the Cerebrum in the performance of certain functions common to both. Thus it seems not at all unlikely that in cases of injury or disease of the Cerebellum there may be some compensatory increased action of the Cerebrum—especially where the disease has lasted long or has commenced at an early age, as in the case of atrophy of this organ in the girl examined by Combette, and whose case is recorded by Cruveilhier. Lastly, another cause of difficulty, tending to complicate the interpretation of the results of disease of the Cerebellum, may arise from the possibility that, in the case of unilateral lesions, the sound half of the organ may be capable of taking on and discharging after a fashion—perhaps with a mere difference in degree—the functions of the disabled part (see p. 509, note).

In the face of all these difficulties of interpretation it may be well to turn back and look at the problem as to the functions of the Cerebellum by the light of general principles, aided by any additional illumination which we may be capable of obtaining from our modern knowledge (so far as it goes), as to the precise anatomical connections of the organ with different parts of the Cerebrum and with different tracts of the Spinal Cord.

The Cerebro-Spinal System of Vertebrates contains a series of 'sensory' and 'motor' centres throughout the whole length of the Spinal Cord and Medulla, each of which, whilst capable of performing independent functions, is also in subordinate relation with other higher Nerve Centres.

Something similar obtains among Worms and Arthropods.

But the Brain in all Vertebrates differs from that of Invertebrates, in the fact that it possesses two double morphologically distinct parts, unrepresented among the latter, or, at least, unrepresented by similarly separable parts. These are the Cerebral Lobes and the Cerebellum. Making their appearance as comparatively small segments in Fishes, their relative size and development increases among higher Vertebrates, so as at last to throw all other divisions of the Brain into the shade.

There are, therefore, in Vertebrates some fundamental specializations of function, which are, in all probability, carried much farther than in any of the lower animals, the existence of which seems to become marked by the development of parts so distinct morphologically as the Cerebral Lobes and the Cerebellum.

But it is to be regarded as one of the best established of physiological facts that the Cerebral Hemispheres or Lobes are the principal organs of Conscious Intelligence—including under this term Sensation and Perception, Ideation and Reasoning, together with the primary phenomena of Emotion and Volition. The two Hemispheres together, therefore, constitute the supreme organ, the last term of the series of centres, in which 'ingoing' impressions are brought into relation with one another.

But two things are now almost equally certain in regard to the Cerebellum; first, that it has no appreciable share, as an independent organ, in the carrying on of any of these processes which, in their totality, are comprised under the head of Conscious Intelligence; and, secondly, that its activity is unmistakeably mixed up *in some way* with the animal's power of executing Movements.* In what precise manner it is related to the execution of Movements, and to what Movements it is so related, are the problems principally requiring to be solved, and to these subjects we must now turn our attention.

If we look then to the fact that throughout the Nervous Systems of lower animals 'sensory' and 'motor' nerve centres exist in correlated pairs; if we look to the simultaneous appearance of the Cerebral Lobes and the Cerebellum in the animal series; if we consider that the Cerebral Lobes or Hemispheres have been proved to be the supreme centres for 'ingoing' impressions; and if the Cerebellum has been almost equally well proved to be a great 'motor' centre of some kind, it seems a fairly legitimate inference from the foregoing facts that the Cerebellum is the supreme motor centre co-ordinate with the Cerebrum, and that they form the

* See Owen, "Anat. of Vertebrates," vol. i. pp. 487, 488. The hypothesis of Gall, that the Cerebellum is the seat of the 'sexual instinct,' has little or nothing to be said in its favour which may not be otherwise much better explained (see ' Ferrier's Functions of the Brain," p. 122).

final 'sensory' and 'motor' couple, organized or attuned to some extent, like inferior couples, for conjoint activity.

It may, however, be at once acknowledged that the relation between these supreme ingoing and outgoing centres in Man and higher animals, must necessarily be very different and much more complex than that existing between lower couples in the same animals, or than that existing between the higher couples of such animals as a Centipede, a Gasteropod (fig. 27) or any other Invertebrate.

The relations between ingoing impressions and responsive actions through the intervening activity of lower centres in Man, or the higher centres of a lower animal, are comparatively simple and direct; but in higher animals, just as the organ of Conscious Intelligence increases in internal complexity and bulk, so do the chances increase of the intervention of complicated nervous processes between the reception of certain Sensorial Impressions and any actions which may ultimately result therefrom. The acts that follow in such a case, as a result of 'deliberation,' may be of a new and unaccustomed order—consciously conceived and instigated.

As Sensorial Consciousness, and the Intelligence that grows out of its exercise, increases in intensity and complexity, this side of life becomes all engrossing and the Consciousness of the animal (or its Attention) is proportionately diverted from its Visceral Sensations and Movements, as well as from the greater part of the multitudinous 'automatic' and 'secondary-automatic' Movements concerned with its external life, or 'Life of Relation.' The 'area' of Consciousness is limited in one direction and widened in another, and new acquirements would never be made, either in the sphere of Sense, of Intelligence or of Voluntary Movement, unless habitual and ever recurring Impressions might of themselves (without engaging our Consciousness) evoke related Movements—that is, unless these latter could be executed and regulated under the superintendence of some great centre in response to mere 'unfelt' Impressions. Thus it becomes obvious that it would be highly advantageous, if not absolutely necessary, for animals in whom Conscious Intelligence obtains a high development, that their principal motor centre, the Cerebellum (and, for the present, we assume it to be some such organ), should be in relation with the various 'ingoing' nerves of the body and with their corresponding nerve centres, from the lowest to the highest—or, at all events, from some of the lower to the highest.

By its connection with the highest 'sensory' centres, namely, those of the cortical grey matter of the Cerebrum, the Cerebellum would be enabled (*a*) to take part in Voluntary and all other Movements which follow (immediately or remotely) the instigation of Conscious Impressions; and by its connection with lower centres of different grades, it would be enabled (*b*) at the instigation of 'unfelt' Impressions, to take a much larger share in the production and maintenance of complex 'automatic' and 'secondary-automatic' Movements generally—just such a share, in fact, as the lower spinal motor centres take in the execution of spinal 'reflex' Movements.*

The mechanism of Voluntary Movements will be subsequently referred to. It is only needful here to point out that 'Volition' proper is inseparable from Sensorial Activity, Intelligence, and Reason, so that the starting points of Volitional 'stimuli' must be somewhere in the

* In an animal like the Frog, in which the Cerebellum is very small and ill-developed, even movements of locomotion are capable of being executed under the guidance of the Spinal Cord alone. It is very surprising to find that a Frog, whose Cerebrum and Cerebellum have been destroyed, can still stand, and even leap. It is surprising, that is, if we look at it from the point of view of what would happen to one of the higher animals under similar circumstances, but much less so if we consider the degree and kind of locomotor powers that would be possessed by many Insects similarly mutilated.

organ of Conscious Intelligence, viz., the Cerebrum. It is the 'Actuation,' or carrying into effect of a Volition destined to issue in Movement, which devolves upon Motor Centres, and there is reason to believe that the Cerebellum co-operates with the Corpora Striata in the realization of this secondary part or phasis of an ordinary Volitional Act and its consequence.

Two principal questions present themselves, therefore, as a result of what has been hitherto said concerning the probable functions of the Cerebellum. (1) What evidence is there to show that the Cerebellum is largely concerned in the production of 'automatic' and 'secondary-automatic' Movements in response to 'unfelt' Impressions? (2) What evidence is there to show that the Cerebellum is concerned in the execution of Voluntary Movements?

The answers to these questions, so far as they can be given—and that by way of suggestion rather than as positive affirmations—may be best set forth in connection with some statements as to what is known of the composition of the several Peduncles of the Cerebellum.

There is reason to believe that it is principally through the intervention of the *Upper and Lower Peduncles* that the Cerebellum receives impressions of an unconscious order, which enable it to take part in the production of certain responsive 'automatic' and 'secondary-automatic' Movements.

The reasons in favour of this view are, first, that the Upper and Lower Peduncles contain many different kinds of 'ingoing' fibres, although it has been abundantly proved that the Cerebellum is in no sense an organ of Conscious Intelligence; secondly, it is supported by the fact that in Fishes and Reptiles these Peduncles alone exist—the Middle Peduncles, and with them the 'pons Varolii,' being notoriously absent. For it is reasonable to suppose that the mere 'automatic' or 'sensori-motor' functions of the

Cerebellum would be established earlier than those in relation with Voluntary Actions, in animals in whom the former class of Movements are much more frequent and numerous than the latter.

To suppose that the ingoing (or 'sensory') fibres of the Cerebellum merely convey to this organ incitations, which cause certain ganglionic elements in its cortical Grey Matter to 'discharge' themselves along definitely correlated outgoing fibres (so as to arouse various lower Motor Centres in particular modes of combination), enables us to account for the sensory relations of the Upper and Lower Cerebellar Peduncles without looking upon the Cerebellum itself as a kind of '*sensorium commune*'—as it was erroneously regarded by Foville and others.* If it is to minister to the execution of 'automatic' Movements, instigated by all kinds of 'ingoing' Impressions, it is obvious that it must be brought into relation with these (perhaps mainly through 'internuncial' fibres), though it is not at all necessary that the incidence of such Impressions upon the Cerebellum should be attended by any phases of Consciousness.

Lower motor centres in the Spinal Cord are in immediate relation, through 'internuncial' fibres, with corresponding sensory centres. The Cerebellum would seem also to be in relation with multitudes of fibres of this type reaching it from more or less distant 'sensory' centres of different kinds. There is no more reason, however, in consequence of such a relation, for attributing 'sensory' functions to the Cerebellum, than there would be for attributing similar functions to the grey matter in the anterior horns of the Spinal Cord. Such relations with 'sensory' nuclei or centres are indispensable for a Motor Centre, whether its position be high or low: only the higher it is the more numerous are these connections likely to be.

Although some of the facts concerning the connections of the Cerebellum with 'ingoing' nerves have been better substantiated in the Brains of lower Vertebrates than in that of Man, they are

* Or without having recourse to any such hypothesis as that of Herbert Spencer ("Principles of Psychology," vol. i. p. 61), to the effect that "the Cerebellum is an organ of doubly-compound co-ordination in *space*," concerned with the co-ordination of co-existent Impressions and Acts, just as the "Cerebrum is an organ of doubly-compound co-ordination in *time*," and therefore concerned with sequential Impressions and Acts.

scarcely less valuable or suggestive on this account, since the functions of the Cerebellum, like its ultimate structure, are probably uniform in kind throughout all classes of the Vertebrata.

By means of the *Upper Peduncles* there is good reason to believe that the Optic Lobes of Fishes are brought into immediate relation with their rudimentary Cerebellum. The fibres constituting these peduncles pass from the septum between the Optic Lobes to the median portion of the Cerebellum. In Man the same peduncles, starting from the 'red nucleus' in the sensory tract of the Crus, decussate beneath the Corpora Quadrigemina, and thence proceed in a slightly divergent direction to the anterior portion of the Cerebellum. It is highly probable, therefore, that in Man also these Upper Peduncles in part serve to bring the Optic Centres into relation with the Cerebellum.

Again, according to Meynert,* a portion of the great root of the Fifth Nerve or 'Trigeminus,' lies on the upper and outer border of this Upper Peduncle, and a portion of the root of the Auditory Nerve is similarly disposed. In some Fishes the ganglion at the root of the Fifth Nerve is, according to Owen, directly connected, by means of some vertical fibres, with the Cerebellum.

Thus, though almost nothing is known as to any relations of the Olfactory Lobe with the Cerebellum, it seems certain that the next three sensory cranial nerves (viz., the Optic, the Fifth and the Auditory) come into relation with the Cerebellum through its Upper Peduncles.

But it seems possible that the various cortical 'Perceptive Centres' in the Cerebral Hemispheres, may also be brought into relation with the Cerebellum, by internuncial fibres passing through the 'red nucleus' of the Tegmentum and the Upper Cerebellar Peduncles. In such a case, these fibres might convey 'afferent' stimuli in relation with Ideo-Motor and Voluntary Movements, whilst those coming to it from Sensory Nerves or their Ganglia may convey 'afferent' stimuli capable of evoking movements which have become 'automatic' or which are of the 'secondary-automatic' order. Other fibres, however, next to be referred to, seem also to belong to this latter category. Whether the Upper Peduncles contain afferent fibres only, we have no means at present of deciding.

Each *Lower Peduncle* of the Cerebellum in Fishes is in close relation with the two 'visceral' sensory nerves, viz., the Vagus and

* Stricker's "Histology," vol. ii. p. 460.

Glosso-pharyngeal, and also with the great 'lateral nerves,' which are usually tributaries to the second root of the Vagus. The whole of this latter root enters the Lower Peduncle just below, or by the side of, the Cerebellum. This relation is not so distinct in some other Vertebrates, though in all of them the roots of the Vagus are in close relation with the Lower Peduncle (or 'restiform body'). There is, moreover, good reason for believing that the great majority of the fibres of these Peduncles are afferent fibres, which come (perhaps by a doubly decussating course through the Spinal Cord and Medulla) from Viscera, Muscles and Skin, on the same side of the body—instead of entering them directly like the great 'lateral nerves' or the Vagus itself.

But in addition to sensory nerves from internal and external parts of the body generally, the Lower Peduncles of the Cerebellum also transmit to this organ numerous fibres of the Auditory. This arrangement obtains in Man as well as in lower Vertebrates.

In reference to the views of Cyon (p. 218), that there are two distinct nerves included under what is commonly known as the Auditory, it is not without interest to find some of its fibres going to the Cerebellum by the Upper, and others by the Lower Peduncle. The extensive connections of this double nerve with the Cerebellum are also of considerable interest, in view of the relations of analogous nerves in the majority of Mollusks (and in such Insects as they are known to exist) with their principal motor centres.

It seems quite certain that each Lower Peduncle of the Cerebellum also contains some efferent or outgoing fibres, and that these (though probably existing also in other parts) are gathered into a small fasciculus (first described by Solly), which passes over the outer border of the corresponding Peduncle, and thence sweeps round the lower extremity of the 'olivary body' to join the anterior column of the Cord just above the 'decussation' of the Pyramids.

There is reason to believe that it is through the intervention of the *Middle Peduncles* that the Cerebellum principally co-operates with the Cerebrum in the actual execution of Voluntary Movements—though its incitations to take part in these movements may also come, as we have already suggested, from the 'perceptive centres' in the Cerebral Hemispheres, by way of the 'red nucleus' and the Upper Peduncles.

The fact that the Cerebellum does co-operate with the Cerebrum in some way is clear, because it has been proved that atrophy of one Cerebral Hemisphere leads to atrophy of the opposite half of the Cerebellum.* And that the Cerebellum responds to stimuli from the Cerebrum, rather than *vice versâ*, seems shown by the fact that atrophy of one half of the Cerebellum has, on the other hand, no tendency to cause atrophy of the opposite hemisphere of the Cerebrum.

The notion that the Middle Peduncles are the parts by which the relation between the Cerebrum and the Cerebellum is principally brought about in Volitional Action, is strongly supported by two sets of facts; first, by the later development of these Middle Peduncles and of the lateral lobes of the Cerebellum with which they are principally connected in the animal series, as well as by their progressive increase in still higher animals, and by their maximum size in Man;† secondly, the view is also borne out by what we know of their anatomical relations. Broadbent's, as well as Meynert's, descriptions give us some warrant for believing that fibres pass from each Middle Peduncle of the Cerebellum to the opposite half of the 'pons Varolii,' and thence (by way of the Crus Cerebri) in part direct to the cortex of the Hemisphere, and in part to the Corpus Striatum only. Other of its fibres may, perhaps, pass down to motor centres in the Pons itself, or to similar centres in the Medulla.‡

* That is when the atrophic process of the Hemisphere involves such parts as to entail a Hemiplegia—or paralysis of the opposite side of the body. (See p. 393.)

† Meynert (Stricker's "Histology," Eng. Trans., ii. p. 456) calls attention to the fact that as the Cerebral Hemispheres increase in size, so do the motor divisions of the Crus, and so also do the Middle Peduncles and 'lateral lobes' of the Cerebellum. (See p. 278 for some remarks touching this kind of correlation.)

‡ From the cells of the Corpus Striatum, according to Meynert, there descend "two subsequently diverging tracts, one running into the Spinal Cord, the other into the Cerebellum." The latter ascends as a thick fasciculus in the Middle Peduncle (loc. cit. p. 375). This fasciculus may contain ascending ('afferent') cerebellar

As these 'efferent' fibres of the Cerebellum proceed to the opposite motor tracts of the Cerebrum—above their seat of 'decussation' in the Medulla—the half of the Cerebellum whence they issue would (by reason of this lower 'decussation' of the Anterior Pyramids) be brought into relation with the limbs of the corresponding side of the body. This direct, rather than cross, relation is also indicated by experimental observations with lower animals, and by the phenomena of disease observable in Man.

Putting all these facts together, it seems that the Cerebellum may be regarded as an enormously developed supreme 'motor centre,' the Lateral Lobes of which cooperate in cross-relation with those of the Cerebrum in the actual execution of Voluntary Movements; though it is also an organ accustomed to act—perhaps to a far greater extent and more continuously—in the execution of complicated Automatic Movements, in response to 'unfelt' impressions coming to it (mainly through internuncial fibres) from 'sensory nuclei' of all kinds.

Though the Upper and Lower Peduncles would seem to be the principal channels through which these latter afferent impressions reach the Cerebellum, only a part of their related outgoing stimuli may go along the Lower Peduncles; others of them may, in higher animals, traverse the Middle Peduncles. However this may be, it would appear that all afferent Cerebellar impressions that are destined to excite Automatic Movements, and which happen to emanate from one half of the body, proceed to the corresponding half of the Cerebellum—whether they go direct (as seems to be the case with fibres from the Fifth, the Auditory and other cranial nerves), or only after two decussations (as seems to be the case with fibres from

fibres as well as descending ('efferent') fibres, if Meynert's conclusions are correct; though the writer's notion is that some at least of the Cerebral 'afferent' fibres reach the Cerebellum by the 'upper peduncles.'

the Optic Nerves, and with the ordinary Sensory Nerves of the body).

In the relations, therefore, of the Cerebrum with the Cerebellum for the execution of Voluntary Movements, cross connections exist analogous to those between the Cerebral Hemispheres and the opposite halves of the Spinal Cord. Whilst in the part which it plays as a supreme motor centre in connection with the higher kinds of Automatic Movements, the Cerebellum is again called into activity precisely as if it were a very specialized segment of the Spinal Cord itself.*

If we are to attempt shortly to sum up its functions, it may be said that the **Cerebellum** *is a supreme Motor Centre for reinforcing and for helping to regulate the qualitative and quantitative distribution of outgoing currents, in Voluntary and Automatic Actions respectively*: or, more briefly still, that it is **a supreme organ for the reinforcement and regulative distribution of outgoing currents.**

After what has been already set forth, and in face of all the difficulties previously enumerated, it is easy to imagine that the Cerebellum might appear to some to be an organ largely concerned with the 'co-ordination of movements'; that it might be regarded by others as the seat of a 'muscular sense'; and that it should seem to others still, to have to do with the 'supply or liberation of motor force for movements generally.' On the other hand, that it should appear to have nothing to do with Instinct,

* See p. 502. Many of these 'sensori-motor' or Automatic Movements would, however, be of a bilateral type; and such Movements would probably be excitable through either half of the Cerebellum (as it is with the Cerebrum). Hence we have another reason why unilateral diseases of the Cerebellum should often be associated with obscure and ill-defined motor defects.

with Intelligence, or with Conscious Sensibility, notwithstanding the fact that it is a recipient of fibres from all kinds of 'sensory' nuclei is as much in harmony with reason as with experiment—in view of the reflex functions which have been assigned to it. And if the function of the Cerebellum be merely to discharge or give off molecular energy for the initiation of Muscular Movements, in response either to definitely localized Volitional Incitations coming to it from the Cerebral Hemispheres, or in response to equally well localized though 'unconscious' Impressions, coming from the most various 'sensory' nuclei at the base of the Brain and in the Spinal Cord; we might expect that its microscopic structure would be practically the same throughout all parts of its vastly convoluted and extended superficial Grey Matter—and this it is found to be; we might expect also that in so far as it is related to the Cerebral Hemispheres, the Cerebellum would act only in response to their incitations—which also seems to be the case. The view here put forward seems, therefore, to be in harmony with a great body of known facts, and to be also capable of including under it a number of opinions in regard to the functions of this organ which have from time to time been enunciated, and which have, perhaps, been faulty only by reason of their more or less narrow and exclusive nature.

CHAPTER XXV.

PHRENOLOGY: OLD AND NEW.

The stages by which we have arrived at what knowledge we possess as to the Structure and Functions of the Brain have been very gradual. Only within the last century, indeed, has the great bulk of our present knowledge in regard to it gradually taken shape from amidst the clouds of error with which the opinions of the ancients and the mere speculations of many of the anatomists of later centuries had enshrouded it.

A few particulars in regard to these earlier notions may here be given, which have been culled and condensed, for the most part, from the writings of Prochaska.*

According to Aristotle, the heart was the seat of the 'rational soul,' and the nerves (of whose relation to sensation and motion he was not ignorant) arose therefrom. The Brain was described by him as an inert viscus, cold and bloodless, and scarcely to be enumerated amongst the other organs of the body—seeing that it was of no use except to cool the heart.

Erasistratus, the grandson of Aristotle, renounced the views which he had been taught by the great master. He and Herophilus (about 300 B.C.) were probably the first to dissect the Human Brain. He originally said that the sensory nerves arose from the meninges, or membranes of the brain, and the motor from the cerebrum, though much later in life he modified this doctrine and declared that both classes of nerves arose from the medullary

* "Dissertation on the Functions of the Nervous System." (Sydenham Society's Translation, 1851.)

matter of the brain; also that the 'animal spirits' proceeded from the brain, and the 'vital spirits' from the heart. He recognized that the Convolutions were most developed in the Brain of Man, and attached importance to them in relation to his superior Intelligence.

Galen (about A.D. 150) set himself to refute the doctrine of Aristotle. He showed that the brain of animals was hot instead of cold, and that it was well supplied with blood. He further maintained that its elaborate structure was against Aristotle's notion of its being a mere refrigerator, since for this purpose a "rude and formless sponge," would have sufficed. He pointed out that the brain was of the same substance as the nerves, but softer, "as it necessarily should be, inasmuch as it receives all the sensations, perceives all the imaginations, and then has to comprehend all the objects of the understanding, for what is soft is more easily changed than what is hard." Since double nerves are necessary, the soft for sensation, the hard for motion, so also is the brain double, the anterior being the softer, the posterior being the harder. The superior or 'lateral ventricles,' were, according to Galen, endowed with the highest functions. They received air through the nostrils (by way of the ethmoidal bone and the 'corpora mammilara') mixing this with the 'vital spirits' brought from the heart into the ventricles by means of the arteries, and therefrom elaborating the 'animal spirits' which were thence transmitted from the brain to the nerves for the purposes of motion and sensation. The lateral ventricles were also held to receive by the same entrance 'sensible objects,' and odoriferous particles. Galen likewise taught that the brain had a double movement, a diastolic for the reception of air and 'vital spirits', and a systolic, by means of which the ventricles distribute the 'animal spirits' to the nerves. Later he held that the animal spirits were not contained in the ventricles only, but were diffused throughout the whole substance of the cerebrum and the cerebellum. "The use of the fornix, to which also the corpus callosum belongs, is the same," he says, "as of the arches of buildings; namely, to support commodiously and safely the whole of the superjacent part of the brain." The corpora quadrigemina perform the functions of a janitor, since they serve to open or shut the passage by which the 'animal spirits' are transmitted from the anterior to the posterior ventricle through the Sylvian aqueduct.

Some centuries afterwards, according to Prochaska: "The Arabs distributed the animal functions amongst the ventricles of the brain, so that one of the anterior ventricles they made the seat of common sensation, the other of the imaginative faculty, the third ventricle was the seat of the understanding, and the fourth of memory." This doctrine was also maintained by Duns Scotus, Thomas Aquinas, and other theologians. And as late as the first half of the seventeenth century, "Descartes maintained that the animal spirits were secreted from the brain through pores opening into the ventricles, and that there accumulating, the slightest disturbance of them excites the soul seated in the pineal gland; and contrarily, that the animal spirits in the ventricles are moved by the will acting through the pineal gland, and distributed thence through the nerves to all parts of the body *."

But about the end of the sixteenth and the beginning of the seventeenth century, Casper Bauhin, Varolius, Spigelius and other anatomists, had been striving to show, in opposition to Galen, that the ventricles of the brain are not the factories and storehouses of the 'animal spirits,' and that they are more properly to be regarded as "accidental structures which have no other use than to receive the excreta and residuum formed during the nutrition of the brain, and in the production of the animal spirits, and to pass them away through the infundibulum to the fauces."

After it had been fully agreed that the 'animal spirits' are not generated in the ventricles of the brain, nor produced in the substance of the brain to be collected in the ventricles, it was still generally believed that these cavities were receptacles for effete matters, which discharged themselves principally into the nostrils through the ethmoid bone and through certain imaginary ducts indicated by Galen, and much later by Vesalius, as passing from the pituitary gland and through the sphenoid bone to the fauces. This view had, therefore, in its turn, to be overthrown, and C. V. Schneider (1655) did much in this direction. Lower, Willis, and others, also became convinced that nothing could pass from the ventricles to the nostrils in the way specified; they thought, nevertheless, "that the serum of the ventricles passed through the infundibulum to the pituitary gland, and thence through peculiar ducts to the jugular veins, where it was mixed with the blood." Haller

* Even towards the end of the last century, a celebrated anatomist, Sömmering, announced his belief that the fluid of the ventricles of the brain was the real *sensorium commune* and proper organ of Mind.

admitted that the infundibulum was hollow, but denied the existence of the last mentioned ducts, and maintained that the ventricles required no special outlet for the evacuation of serum.

In regard to the mode of generation of the 'animal spirits' it was contended by Malpighi, Willis (1664) and others, that they are secreted in the cortical substance of the brain, and thence received into the white or medullary substance, whence they are distributed through the nerves to the whole body. "The faculties of the mind, such as perception, imagination, understanding, and memory, were banished from the ventricles together with the animal spirits, and were located by some in the solid mass of the brain; by others were affirmed to be properties of the immaterial and rational soul alone, and in no wise dependent on the body." Malpighi considered the cortical substance of the brain to be a true glandular structure.

Willis has been styled the "father of phrenology," on account of the extent to which he assigned to each particular part of the brain a special influence on the mind. He held, "that the cerebrum subserves the animal functions and the voluntary motions, the cerebellum the involuntary; that a perception of all the sensations takes place in the ascending fibres of the corpora striata, and that through the descending, voluntary movements are excited; that the understanding is seated in the corpus callosum, and memory in the convolutions, which are its storehouses; that the animal spirits are generated in the cortex of the cerebrum and cerebellum from the arterial blood; that they collect in the medulla, are variously distributed and arranged to excite the animal actions, and distil through the fornix as if through a pelican; that the animal spirits secreted in the cerebellum are ever flowing, equally and continuously, into the nerves which regulate involuntary movements; but those of the cerebrum, tumultuously and irregularly, according as the animal actions are vehemently performed or quiescent. To excite sensations the spirits flow along the nerves to the brain . . . As to the loops of nerves with which the arteries here and there are encircled, he states their use to be to relax or close the arteries, and thus during various emotions of the mind to admit the blood in greater or less quantity to certain parts. He decided that the pineal body is not the seat of the soul, but a lymphatic gland."

The successors of Willis adopted some of his doctrines but refuted others. Much bootless discussion was carried on by Boerhave and others as to the essential nature of the animal spirits, and in the early part of the eighteenth century the following views were also expressed as to the uses of certain portions of the brain. Vieussens placed the seat of imagination in the centrum ovale; Lancisi and Peyronie maintained that all sensation is felt and motion excited in the corpus callosum. Meyer placed the seat of memory in the cortical matter, sensation at the origin of the nerves, and abstract ideas in the cerebellum; many, however, acknowledged that it was not possible to determine the seat of the mental faculties with any accuracy, although there could be no doubt that nature had not formed so many and so various divisions of the cerebrum and cerebellum without an object.

Now came another crisis in the history of opinions concerning the brain and its functions. In preceding times the notion of the existence of 'animal spirits' was received in an unquestioning manner; there had been much discussion as to their mode of origin, as to their principal seat, and as to their essential nature; but these problems were at last set aside for one which ought to have preceded them. What evidence was forthcoming as to their very existence? The supposition that what had been termed 'animal spirits' existed at all now seemed to many a gratuitous assumption. After much discussion amongst the Stahlians and their opponents, we find Boerhave, Haller (1766) and Tissot acting as the last champions of the doctrine and striving to establish it as a truth. "Notwithstanding," says Prochaska, "the authority of these great names, the love of truth excited distinguished men, who advanced doubts as to this hypothesis of the animal spirits, and who showed that the arguments adduced in its favour proved nothing when carefully analysed, and that the whole hypothesis was altogether devoid of truth." Writing, therefore, in 1784, Prochaska says: "We will term the cause latent in the pulp of the nerves, producing its effect and not, as yet ascertained, the *vis nervosa;* we will arrange its observed effects, which are the functions of the nervous system, and discover its laws."

The same writer considered it "by no means improbable that each division of the intellect has its allotted organ in the brain," though as he himself frankly admitted, nothing definite could at that time be said on the subject. "Hitherto, it has not been possible," he adds, "to determine what portions of the cerebrum or the cerebellum are specially subservient to this or that faculty of the mind. The conjectures by which eminent men have attempted to determine these are extremely improbable, and that department of physiology is as obscure now as ever it was." It must not be forgotten, however, that it was Prochaska himself who first fully described the nature of 'reflex movements.' "The *sensorium commune*," he says (loc. cit. p. 446), "reflects the sensorial impressions into motor by definite laws peculiar to itself, and independently of consciousness." Prochaska, moreover, recognized that the same kind of process might take place in the systemic ganglia, since he says (p. 438): "It seems probable, therefore, that besides the *sensorium commune*, which we conjecture to be in the *medulla oblongata*, *medulla spinalis*, *pons Varolii*, and *crura* of the *cerebrum* and *cerebellum*, there are special *sensoria* in the ganglia and plexuses of the nerves, in which external impressions ascending along the nerves are reflected, that need not ascend all the way to the *sensorium commune*, to be reflected thence."

The space available in this work does not permit of an attempt to trace, even in bare outline, the successive steps by which during the last hundred years we have been slowly tending to acquire a more exact (though still wholly inadequate) knowledge of the Functions of different parts of the Brain. Something of this sort may, however, be gathered from the work of Vulpian* on the "Physiology of the Nervous System," and from other sources. What has here been already said will indicate how much required to be done; and what is about to be said will give some faint notion as to the present paucity of real knowledge, and as to the need in which we stand of much further light in many directions.

Having considered the relations of the Cerebral Hemispheres with one another, with the Cerebellum, and with the halves of the body, the reader's attention must now be limited to the Hemispheres themselves, in order that he may learn, in this and in the next chapter, something of what has been made out concerning the parts of these all-important organs which appear to be more especially con-

* "Lecons sur la physiologie du systême nerveux," 1866.

cerned with Perceptions, Volitions, and other Mental Processes.

Again, we shall have to rely upon the same three classes of facts as constituted the basis for our conclusions in the previous chapter, though they will not be appealed to in quite the same relative proportions.*

The notion that the Brain is the principal organ of Mind, and that there is a localization of function in its several parts, was, as we have seen, a fundamental position fully realized by Prochaska and others, long before Gall and Spurzheim (1805-1826) began zealously to study the anatomy of the organ and to promulgate in connection therewith a 'Physiognomical System' which soon attracted great attention under the name of 'Phrenology.' Its authors were enthusiasts who attempted to systematize an extremely complex subject prematurely, when knowledge in regard to it was altogether in its infancy—and that, too, without professing to have much special knowledge or ability for the carrying out of at least one half of the work involved in such an enterprise.

Gall and Spurzheim were well abreast of, and even leaders of the knowledge of their day in regard to the anatomy of the Brain, yet at the time they elaborated their doctrines nothing was known to them, any more than to their predecessors, as to the real physiological distinction existing between the 'grey' and the 'white' substance of the Cerebrum. They, like those who had gone before them, regarded the white matter of the hemispheres as the essential nervous substance, while the Grey Matter was considered to be "the matrix of the nervous fibres"—a formative material, in fact, which, wherever it was found, served only as a nucleus for the adequate production of nerve fibres.† The Grey Matter of the Convolutions, there-

* See p. 477. † See Spurzheim's "Anatomy of the Brain," p. 7.

fore,—the matter which we now believe to be so largely concerned with the most delicate and subtle of Brain-functions—was by the founders of Phrenology considered to have no proper nerve functions at all.

No attempt, indeed, was made to take any account of more than about one half of it. Their analysis of the Human Mind was supposed to have been complete. The various Faculties, Emotions, and Propensities were assigned to their respective seats, corresponding externally with the upper and outer parts of the skull. But the Convolutions of the base of the Brain, those resting on the 'tentorium Cerebelli,' and those of the contiguous inner faces of the Hemispheres, were credited with no share of mental functions. The use of this convolutional Grey Matter being altogether differently estimated by the Phrenologists from what it is at present, their 'System' was devised and their organology defined with no special reference thereto. Incredible as this may seem to many persons at the present day, it is strictly true. The haphazard constitution and boundaries of their so-called 'organs' may indeed be learned from the words of Spurzheim himself. "The organs," he says,* "are not confined to the surface of the brain: they extend from the surface to the great swelling of the occipital hole (medulla oblongata) and probably include even the commissures; for the whole mass of the brain constitutes the organs."

It need scarcely be said, at the present day, that no such divisions of the Brain as are here indicated, either internally or externally, have any real existence; and if the convoluted surface of the organ itself presents no such divisions as are to be seen on a phrenological cast, by which the several supposed 'organs' could be marked off

* "The Physiognomical System," 1815, p. 239.

from one another, it needs little anatomical knowledge to imagine how much more impossible it must be to divine such boundaries through the skull and its integuments. If we take the organ of 'philoprogenitiveness,' for instance, whose assigned situation at the back of the head may be seen in any phrenological bust, we find that it corresponds with a bony prominence, which varies greatly in thickness in different individuals, whilst internally it corresponds to the point of union of four great venous sinuses, and within these as much to the tips of the Occipital Lobes as to a part of the upper and posterior border of the Cerebellum.*

The division of the human Mind into distinct 'faculties,' after the fashion of the phrenologists, is, however, an error in itself, quite apart from the unsatisfactory nature of their particular analysis. "Every form of intelligence being," as Herbert Spencer says,† "in essence an adjustment of inner to outer relations, it results that, as in the advance of this adjustment the outer relations increase in number, in complexity, in heterogeneity, by degrees that cannot be marked, there can be no valid demarcations between the successive phases of intelligence . . . . fundamentally considered, intelligence has neither distinct grades nor is constituted of faculties that are truly independent . . . . its highest phenomena are the effects of a complication that has arisen by insensible steps out of the simplest elements."

This philosophical view of Herbert Spencer is one which is quite harmonious with what we know of the progressive development of the Brain in the animal series.

But the crudity of the psychological analysis of the Phrenologists is well capped by the simplicity of the mode in which they proceeded to assign the sites of the several 'organs.' Spurzheim says:—"Two persons at Vienna

* See figs. 147, 148. † "Principles of Psychology," 1st Ed. p. 486.

were known to be remarkable for their extreme irresolution; and therefore one day in a public place Gall stood behind them and observed their heads. He found them extremely large on the upper and posterior part of both sides of the head; and this observation gave the first idea of this organ." Such was the kind of haphazard tentative method by which, after multitudinous observations conducted, it is true, upon persons of all kinds, ages, and stations in society, the details of their 'System' were finally established.

The 'system of Phrenology' of Gall and Spurzheim was, therefore, fallacious in almost every respect. It was altogether defective in its psychological analysis, eminently unsatisfactory in its localizations, and was, in short, as unreliable in its methods as it was inconclusive in its results. It would have been almost needless, indeed, to have dwelt so long upon this subject but for the fact that amongst the general public there are probably very many who, if not actual believers in the 'Phrenology' of Gall and Spurzheim, may be glad to know upon what precise grounds the system should be rejected.

Are we, however, to run into the opposite extreme, and subscribe to such doctrines as those put forth by Flourens (1840)? This eminent physiologist, who may be said almost to have been the initiator of experimental research as directed to the determination of the Functions of the Brain, felt entitled to draw from his own well-known investigations the following conclusions, altogether opposed to any localization of functions in detail—that is, of special functions in special regions of the Cerebral Hemispheres. His conclusions are these ("Rech. Expériment.," p. 99):—

"Ainsi 1°, on peut retrancher, soit par devant, soit par derrière, soit par en haut, soit par côté, une portion assez étendue des lobes cérébraux, sans que leurs fonctions soient perdues. *Une portion* *assez restrainte de ces lobes suffit donc à l'exercice de leurs fonctions.*"

"2°. A mesure que ce retranchement s'opère, toutes les fonctions s'affaiblissent et s'éteignent graduellement; et passé certaines limites, elles sont tout-à-fait éteintes. *Les lobes cérébraux concourent donc par tout leur ensemble à l'exercice plein et entier de leurs fonctions.*

"3°. Enfin, dès qu'une perception est perdue toutes le sont; dès qu'une faculté disparait, toutes disparaissent. *Il n'y a donc point de sièges divers ni pour les diverses facultés, ni pour les diverses perceptions.* La faculté de percevoir, de juger, de vouloir une chose reside dans le même lieu que celle d'en percevoir, d'en juger, d'en vouloir une autre; et conséquemment cette faculté, essentiellement une, réside essentiellement dans une seule organe."

But, notwithstanding the fact that these early and difficult experimental investigations seemed, as Flourens thought, to entitle him to draw some such conclusions, his views could not claim a ready assent. If we are to regard the Brain as the principal organ of Mind, and to look upon each mental operation as one of the manifestations of its functional activity, all analogy and even probability would point to the conclusion that a definite order must be observed, and that identical mental operations will always be associated with the functional activity of identical tracts of nerve fibres and cells in the Brain and its dependencies. We know that the Olfactory, the Optic, and the Auditory Nerves, each go to different parts of the Brain, so that the primary processes in relation with the exercise of the corresponding Senses are distinct from one another. Can we believe that in their later or higher phases the tracts for such impressions lose their distinctness? Again, I touch the table at which I am now writing, with my forefinger: the impression thus produced travels by means of nerve fibres along a perfectly definite route from the part touched to my Spinal Cord. Can I doubt that the route by which it reaches the Brain is just as definite (though not so well known), and that a similar impression would always follow the same route, so long as the conducting channels remained uninjured? In some such sense as this 'localization' would seem to be a simple *à priori* necessity. But if it holds good for Sensorial Operations it will be equally likely to obtain for Intellectual Operations and Emotions. Order and regularity could scarcely be absent in the carrying on of the functions of those parts of the Brain alone, where, from the subtle nature and multiplicity of the molecular actions involved in myriads of cells and fibres, these particular characteristics of lower Brain-actions would se m to be so preeminently needful.

The fundamental question of the existence, or not, of real 'localizations' of function (after some fashion) in the Brain must be kept altogether apart from another secondary question, which, though usually not so much attended to, is no less real and worthy of our separate attention. It is this: Whether, in the event of 'localization' being a reality, the several Mental Operations or Faculties are dependent (*a*) upon separate areas of Brain-substance, or (*b*) whether the 'localization' is one characterized by mere distinctness of cells and fibres which, however, so far as position is concerned, may be interblended with others having different functions. Have we, in fact, to do with *topographically separate areas of Brain-tissue* or merely with *distinct cell and fibre mechanisms existing in a more or less diffuse and mutually interblended manner?*

The latter kind of arrangement seems, on the whole, to be an even more probable one than the former, and may commend itself most to many persons. The existence of some such arrangement would help to throw light upon some of the results obtained by Flourens, and, indeed, upon doctrines advocated by Brown-Séquard at the present day. It makes it possible to recognize a certain amount of truth in them, without thereby involving us in a denial of the all-important principle of 'localization,' as applied to cells and fibres.

Brown-Séquard has indeed of late * expressed himself most positively in favour of the diffuse and interblended arrangement. He thinks he can prove, beyond question, that—"motor or other centres, as commonly conceived, that is to say, as agglomerations of cells, having one and the same function, and which form a more or less definitely limited mass, do not exist." The existence of the other mode of arrangement would equally with the latter make it necessary to admit that cells having the same kind of functional activity should be in communication with one another by means of processes. And, as he contends, the functional activity of similar cells might, in either case, be conjointly and equally well carried on through the intervention of intercellular processes. It would, in fact, make comparatively little difference whether such similar cells were closely packed together or whether they were scattered over comparatively wide areas of the Cerebral Cortex. So far, at least, the writer finds himself thoroughly in accord with Brown-Séquard.

Thus, whilst a topographically separate localization of independent 'faculties' seems to the writer altogether improbable,† he fully believes that certain portions of the Cerebral Hemispheres—the Anterior Lobes for instance—are always concerned in the carrying on of Intellectual and Volitional Operations of practically the same nature, though of different degrees of complexity in different individuals. Yet it can scarcely be said of "carrying on," but rather of assisting and aiding to carry on, cer-

* "Archiv. de Physiol. norm. et path.," 2nd Ser. IV. p. 412.
† See "Journal of Mental Science," January, 1869.

tain Intellectual and Volitional Operations; for it seems improbable that even such a large division of a Cerebral Hemisphere as the Anterior Lobe has a distinct set of functions peculiar to itself. The division into 'lobes' is, in the main, an entirely artificial one, and the grey matter of the anterior region is, as we have seen, intimately related to the grey matter of the middle and posterior parts of the Hemispheres; so that, just as our psychical nature consists of one great complicated but unbroken network in which are bound together Sensations, Perceptions, Judgments, Emotions, and Volitions, so is the physical organ corresponding to these also represented by the most complicated and intricate network of nerve-cells and nerve-fibres, mutually bound together and brought into functional relation with one another. Whilst, therefore, it may truly be said that the Anterior Lobes are always concerned in the carrying on of Intellectual and Volitional Operations of the same nature, they may be mainly instrumental in some functions, and they may take part, to a minor degree, in the execution of certain other Mental Operations depending more especially upon the functional activity of different parts—the Parietal, the Temporal, or the Occipital Lobes, singly or in combination.

Perception, Intellect, Emotion, and Volition are so intimately associated with one another in our ordinary mental processes that, if we were even to attempt a definite mapping out of their territories, so as to allot a separate province in the Cerebral Hemispheres for each of these great divisions of Mind, we should probably fall into a grievous error. In precisely those parts of the Cerebral Hemispheres that are most concerned when we look upon a fine painting or a fine piece of statuary, may we imagine the emotions of admiration kindled, to which the sight of these objects of art has given rise—however much the activity of other centres may co-operate; and just as the sight of ripe fruit upon a tree may incite a 'desire' to possess, followed by a Volitional Stimulus for the purpose of obtaining the desired object; so in this case the parts concerned in the manifestation of the 'desire,' and those in which the Volitional Stimulus originates, are probably situated within some portions of that same area of convolutional grey matter which was concerned in the Perceptive Act itself.

On the other hand, as the writer has elsewhere said,* "inasmuch as we have certain distinct avenues of knowledge (through the Sense Organs and their proximate nerve ganglia), and the Cerebral Hemispheres are the parts concerned in the elaboration of impressions so derived, we can well understand that the impressions entering through one gate or sense-avenue, may pass through the substance and towards the periphery of these Cerebral Hemispheres in certain definite directions, and according to accustomed routes. Then, the impressions entering through another gate of knowledge, or avenue of sense, may, and probably do, pursue a different direction through its substance, so that at the periphery the fibres and cells concerned in the conduction and elaboration of these impressions may exist in maximum quantity in different portions of the surface of the Hemispheres—though in part they may occupy jointly the same area, and be intertwined with the fibres and cells concerned in the elaboration of the previously mentioned set of impressions. And so on with the various sense organs and their ultimate expansions in the form of what I would call 'Perceptive Centres' in the Cerebral Hemispheres. Thus, though there may be much and compound overlapping of areas, and though the area pertaining to the impressions of any particular sense in

* "Journal of Mental Science," January, 1869.

the Cerebral Hemispheres may be a very extended one (not to speak of the still further complication brought about by the communication established between the nerve cells of one sense area with those of others in the same Hemisphere, and of the probable union by means of commissural fibres between analogous parts of the two Hemispheres), still it may well be that certain portions of the surface of the Cerebral Hemispheres might correspond more especially to the maximum amount of nerve cells and fibres pertaining to some one or other of the various senses. . . . Just as certain of the senses contribute in a preponderating degree towards the building up of our mental impressions and their corresponding volitional results (*e.g.*, those of Sight, Hearing, and Touch), so we may imagine that these sense organs would be connected internally with a comparatively wide area of cortical substance in each Hemisphere.* It would be fair to infer as a probability, therefore, that the 'perceptive centres' for visual impressions, and also those for acoustic impressions, would have a wide-spread seat in the cerebral hemispheres, whilst those pertaining to the gustatory and olfactory senses would have a more limited distribution."

With merely a few verbal alterations the views above stated were put forth by the writer in papers written in 1865 and 1869. And simple as the notion may now seem that we have a right to look for distinct 'Perceptive Centres' in the cortical substance of the Hemispheres, which should be in direct structural relation with their respective sensory nerves and lower ganglia (or 'nuclei'), in or near the Medulla—no mention of this kind of 'localization' was up to that period to be found in medical or physiological

* A notion of this kind has lately been supported also by Prof. Croom Robertson in "Mind," 1877, p. 97.

works;* although, as the writer then first attempted to show, such notions threw much light upon Cerebral Physiology, and upon certain defects of Speech resulting from disease of the Brain.† The writer's views were shortly afterwards endorsed and extended by Dr. Broadbent, in a valuable paper on the "Cerebral Mechanism of Speech and Thought." ‡

Soon, moreover, physiologists began in earnest to search for such 'Perceptive Centres' in the cortical grey matter. The first to do this was Dr. Ferrier, though he makes no reference to the writer's views. He took up the enquiry, perhaps independently—certainly in a thoroughly systematic manner—and his results deserve to be most carefully studied.§ The notion that there ought to be such 'perceptive centres' evidently commended itself to Ferrier, and, with characteristic energy, he sought to throw light upon their localization, as he had previously—instigated by the views of Hughlings Jackson—sought to establish the existence

* No such conclusions were to be inferred, from the views concerning Cerebral Physiology put forward in this country generally. There is a philosophical opposition, in fact, between them and doctrines which have been widely promulgated by Dr. Carpenter (see an article on "*Sensation and Perception*," "Nature," Dec. 23, 1869, and Jan. 20, 1870, p. 309).

† See "Physiology of Thinking" ("Fortnightly Review," January, 1869), and "Defects of Speech in Brain Disease" ("Brit. and For. Med. Chir. Rev.," January and April, 1869).

‡ "Med. Chir. Trans.," 1872, p. 180. Writing, indeed, in the "Journal of Mental Science" for April, 1870 (p. 23), Broadbent says:—"These convolutions then which receive central fibres, and are bilaterally associated by the C. callosum, will constitute the perceptive centres of Dr. Bastian."

§ His first communication on this subject was presented to the Royal Society, in April, 1875, and is to be found in Pt. II. of that year's "Phil. Trans.," p. 445.

of distinct 'motor centres' in the cortex of the Cerebral Hemispheres.

Till quite recently there has been a notable dearth of evidence in medical literature in regard to the existence and localization of any such 'Perceptive Centres'—either in man or in the lower animals. We have, as already explained, good reason for believing that sensory or 'ingoing' fibres from the body generally pass to the Cerebral Hemispheres in the upper or posterior layers of the Cerebral Peduncles; and that in the situation where each of these expands within its own Hemisphere into the so-called '*corona radiata*' such ingoing fibres correspond to the posterior third of this fan-like expansion, and are there joined by fibres coming from the lower ganglia or 'nuclei' in relation with the organs of Sight, Hearing and Taste. Destruction of this portion of the peduncular fibres is found to cut off all sensory impressions—special as well as general—proceeding from the opposite half of the body (p. 490). But, whilst our knowledge is good to this extent, we are still much in the dark as to the relations of these sensory fibres with the Thalamus (and, indeed, as to the precise functions of this body generally), as well as concerning the ultimate distribution of the several sets of fibres to particular regions of the cerebral cortex—where alone their respective impressions seem to culminate and become associated with subjective phenomena, or States of Consciousness.

The fact of this absence of evidence in regard to the situation of the 'Perceptive Centres' of Man seems at first very surprising, since it might be imagined that a study of the multitudinous records of local disease implicating the surface of the Brain which exist in medical works would soon settle the problem. This, however, is far from being the case, and that for many reasons which need not now be detailed. Suffice it to say, that local lesions of the mere cortex of one Cerebral Hemisphere in man have apparently never been known to be definitely associated with loss of Smell, of Sight, or of Hearing on either side of the body.* This peculiar circumstance seems to be specially related, as the writer pointed out in 1874,† to the duplicate nature of the Brain, and to the fact of the connection of each of its Hemispheres with the double and intimately united lower ganglia or nuclei of each of the Special Senses.

In consequence of such an anatomical arrangement one Hemisphere seems often, in a very short time after the occurrence of damage or injury to its fellow, to be capable of being brought into relation with sensory impressions from both sides of the body, so that although the 'perceptive centre' for the sense of Sight, of Smell or of Hearing, may be destroyed in the convolutions of one hemisphere, no blindness of the opposite eye or no unilateral loss of smell or hearing, as the case may be, is produced. It is quite possible that, in the first instance, there may be some unilateral loss or weakness of one or other of the special Senses when one of its convolutional centres is damaged, although this defect, in the early days of an illness, may easily pass unobserved. Failure of observation in regard to such points as these, is a matter of very common occurrence at the commencement of an acute disease of the Brain, both on the part of a patient and of his medical attendant. Such defects would, very probably, *not* be noticed or ascertained unless they were specially looked for, as Ferrier has of late rightly enough maintained. Still the extreme rarity of unilateral impairments of Smell, Sight, or Hearing, as immediate effects, in association with diseases or injuries of one hemisphere of the Brain stands out, as a very notable fact, in regard to which all the best observers are unanimous.

If light is to be thrown, therefore, upon this very interesting question within any brief period, recourse must be had to experiments with some of the lower animals. Of these, Monkeys are obviously the most suitable of all, on account of the general resemblance

* An approximation to this knowledge had, however, been arrived at in regard to Smell. For reference to cases, see Ferrier's "Functions of the Brain," p. 191.

† "Lancet," July 25, 1874, p. 111.

which obtains between the Brain of these animals and that of Man. Such experiments have been made with much skill and judgment by Dr. Ferrier,* to whose writings the reader must be referred for full details as to his numerous observations, and the validity of the tests adopted. Here there is space only for a brief enunciation of the results and conclusions at which he has arrived.

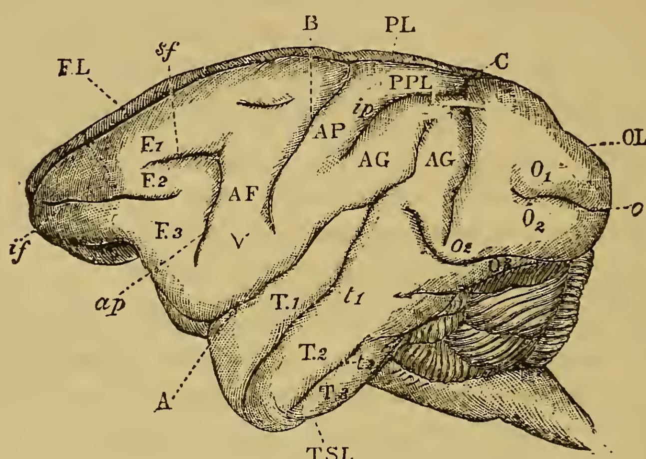


FIG. 172.—Left Hemisphere of the Brain of a Monkey (*Macacus*). A, fissure of Sylvius; B, fissure of Rolando; C, Parieto-occipital, or, perpendicular fissure; F L, Frontal Lobe; P L, Parietal Lobe; O L, Occipital Lobe; T S L, Temporal Lobe; F, upper, F_2, middle, F_3, lower Frontal Convolution; *sf*, supero-frontal Sulcus; *if*, infero-frontal Sulcus; *ap*, antero-parietal Sulcus; A F, Ascending Frontal, and A P, Ascending Parietal Convolution; P P L, Postero-Parietal Lobule; A G, Angular gyrus; *ip*, intra-parietal Sulcus; T, T_2, T_3, Upper, Middle, and Lower Temporal Convolutions; t_1, t_2, Upper and Lower Temporal Sulci; O_1, O_2, O_3, Upper, Middle, and Lower Occipital Convolutions; o_1, o_2, first and second Occipital Fissures. (Ferrier.)

These experiments of Ferrier are supposed by him to support the notion that 'perceptive centres' limited in area, and topographically distinct from one another, exist in the cortex of the Cerebral Hemispheres. His facts, however, do not necessarily carry with them any such interpretation. They are quite capable of being explained in accordance

* See "Philos. Trans. 1875," Pt. II., and "The Functions of the Brain," 1877, chap. ix.

with what we hold to be the more probable theory, viz.: that such 'perceptive centres' or mechanisms are diffuse in seat and interblended with others. This, indeed, has been pointed out by Prof. Croom Robertson,* who says:—"so there is no intrinsic improbability—rather the reverse—in the view, that impressions received by any organ of sense are all carried up first to a particular region of the cortical substance before they are brought into relation with other impressions and with motor impulses, or are otherwise elaborated in the brain. It may well be that there are special sensory regions in the brain-cortex, and that Dr. Ferrier has given the first rough indication of their locality." Each set of sensory fibres might, in fact, direct themselves towards some particular part of the cerebral cortex, whence the fibres might diffuse themselves more or less widely. These 'first cortical stations,' or regions from which sensory fibres diffuse themselves in different directions, may have no real claim to be considered as 'centres,' and yet the same kind of results may follow from their destruction or stimulation as if they were real 'centres.'† And owing to the subsequent diffusion of the several kinds of fibres, other regions are not likely to be revealed by experimental investigation which would have any similar claims to be regarded as 'sensory centres.' Croom Robertson truly says, sensations themselves "can neither be supposed to be consummated at their first

* See a review of Dr. Ferrier's work in "Mind," 1877, pp. 96, 97.

† C. Robertson aptly remarks, "Peripheral impressions may be utterly prevented from coming into consciousness by the cortical lesion; but it does not follow that the last act of the nervous process involved in a conscious sensation of touch is naturally consummated there and nowhere else in the brain, or that in all that region there is no work done but such as (objectively) we call touch."

cortical station, nor be either traced or thought likely to be traced farther by any experimental means yet devised."

Although Ferrier's determination of the sites which are of most importance for each Sense require more confirmation by other workers than they have yet received, before they can be finally accepted as correct, the discrimination and ability with which his experiments have been conducted should ensure for them that careful and thorough testing which their importance deserves.

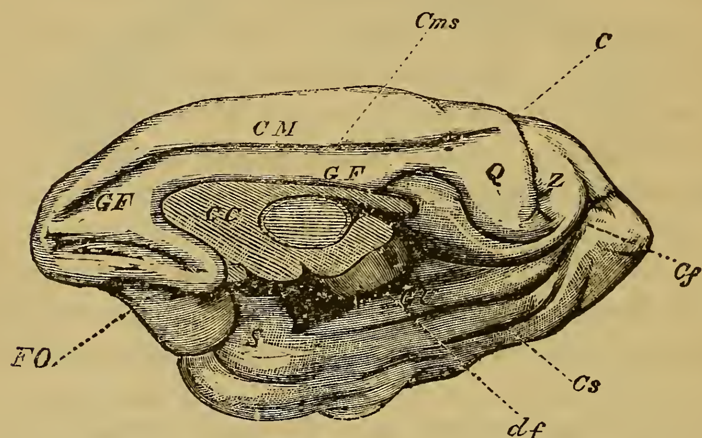


FIG. 173.—Internal Aspect of the Right Hemisphere of a Monkey (*Macacus*). *CC*, Corpus Callosum divided; *C*, internal parieto-occipital Fissure; *Cm s*, Calloso-marginal Fissure; *Cf*, Calcarine Fissure; *df*, Dentate Fissure; *Cs*, Collateral Fissure; *G F*, Gyrus fornicatus; *CM*, Marginal Convolution; *G U*, Uncinate Convolution; *S*, Crochet, or subiculum cornu Ammonis; *Q*, Quadrilateral Lobule; *Z*, Cuneus; *FO*, Orbital Lobule. (Ferrier.)

Well conducted experiments upon animals are peculiarly needed and suitable for throwing light upon this obscure problem as to the possible localization of 'perceptive centres' in the Hemispheres, because when numerous trials, as to the effects of local stimulation or destruction of different regions of the Hemisphere, may have enabled the experimenter to fix upon some portion of the cortex as the main seat of one of such centres, it is then in his power at will to call into existence conditions which almost never exist in the case of disease in the human subject—that is, he can produce symmetrical destructions in corresponding regions of the two Hemispheres, and knowing that such lesions alone exist, can thereafter most carefully test the animal's condition in respect of the sense-endowment supposed to be interfered with.

Taking first of all the case of the sense of **Sight**, we find Ferrier localizing its 'perceptive centre' in the 'angular gyrus' and part of the 'supra-marginal lobule' (fig. 174).

FIG. 174.—Brain of Monkey, showing shaded area corresponding with so-called Visual Centre in the cortex of left Cerebral Hemisphere. (Ferrier.)

Destruction of such parts on one side in an animal rendered insensible by chloroform, seemed to produce blindness of the opposite eye for a day or more—judging from the effects of bandaging the other eye for a time and then removing the bandage, so as to be able to watch and contrast the animal's behaviour under these different conditions. After a day or two, the animal experimented upon again appeared to see with both eyes. Where, however, these regions of the cortex had been destroyed in both Hemispheres, the creature became blind in both eyes, and did not subsequently recover from this condition. Instead of a temporary defect on the side opposed to the unilateral lesion, the animal's sight was now permanently lost on both sides.*

After comparative observations upon the effects of unilateral and double destructive lesions, Ferrier localized the 'perceptive centre' for the sense of **Hearing** in the upper half of the 'superior temporal convolution' (fig. 175).

FIG. 175.—Brain of Monkey, showing a shaded area corresponding with the so-called 'Auditory Centre' in the Cortex of the right Cerebral Hemisphere. (Ferrier.)

Here again destruction of this region in one Hemisphere was found to lead only to a very temporary deafness in the ear of the opposite side of the body; whilst destruction of the same region in both Hemispheres caused a lasting and total deafness on both sides. Referring to

* See p. 393 for the notification that in the brain of Prof. De Morgan there was no appreciable difference in the appearance of the 'angular gyrus' and the 'supra-marginal lobule' on the two sides of the brain, although this celebrated mathematician had been blind on *one* side almost from birth. In the examination of the Brain of a deaf and dumb woman, moreover, Broadbent ("Jrnl. of Anat. and Physiol.," vol. iv. p. 218) neither records the existence of nor represents any special atrophy in the 'superior temporal convolutions.

one of the animals on which he studied these effects, Ferrier says :*.

"The angular gyrus had just been cauterized on the left side, with the effect of causing blindness in the right eye alone, and without any affection of hearing or the other senses. The superior temporo-sphenoidal convolution was then exposed and cauterized on both sides, the lesion, as was ascertained *post-mortem*, being confined to this region. After complete recovery from the operation, the various senses and powers of voluntary motion were tested repeatedly. Touch, taste, and smell were perfect; and sight, as indicated by the animal's perfect freedom of movement and ability to find its food and drink, practically unimpaired twenty-four hours after the operation. As regards hearing it was difficult to devise a satisfactory test owing to the alertness of the animal, and the attention that it gave to everything around it. A loud sound close beside it caused a start, which, however, could not be taken as a test of hearing proper as distinguished from reflex actions† . . . . . In order to avoid attracting its attention by sight, I retired behind the door and watched the animal through a chink, while it sat comfortably before the fire. When all was still I called loudly, whistled, knocked, &c., without attracting the animal's attention to the source of the sound, though it was sitting perfectly awake and looking around. On my cautiously approaching it, it remained unaware of my proximity, until I came within the field of vision, when it started suddenly and made grimaces as if in terror or alarm. On repeating these tests when the monkey was sitting quietly along with a companion monkey whose powers of hearing were unquestionable, the companion invariably became startled at the sounds, and came peering curiously to ascertain their origin, while the other remained quite still."

In regard to the seat of the 'perceptive centre' for the sense of **Smell** we have anatomical indications of great value. The connection of the 'olfactory tract,' with the

* "Functions of the Brain," p. 174.

† These startings produced by near noises are, as Ferrier very justly says, "to be regarded as reflex phenomena of the same nature as those observed by Flourens, in the case of pigeons deprived of their hemispheres, when a pistol was fired close to the head."

tip of the Temporal Lobe (or, indeed, the actual continuity which exists between these parts in many animals), as Ferrier says, "might of itself be regarded as establishing strong grounds for a physiological connection between this region and the sense of smell." He adds: "In the monkey and in man the direct connection between the outer root of the comparatively small olfactory tract and the subiculum * is not so evident, though in the monkey it is more apparent than in man. The origin of this so-called root from the subiculum is, however, thoroughly established by microscopical investigation."

A lesion of one subiculum was found to cause diminution or abolition of Smell on one side, viz., the side of lesion—thus confirming the direct relation above indicated. For, as Ferrier points out,† "Neither the inner roots which fuse with the gyrus fornicatus on each side, nor the outer roots which are connected with the subicula, and thence through the posterior pillars of the fornix with the optic thalami, undergo decussation, and hence there is no anatomical basis of cross connection between the olfactory bulbs and their cerebral centres." Destruction of both these regions, was found to cause loss of Smell on both sides, of a permanent character.‡

* This name is given to the inner part of the tip of the Temporal Lobe, or more precisely to the tip of the 'uncinate convolution.'

† Loc. cit. p. 185.

‡ An attempt to explain the lack of decussation of the olfactory channels has been hazarded on p. 482. The sense of Smell (the organs of which are situated on each side of the middle line of the body) is just that mode of sensibility in which no discrimination is ever made between the impressions coming from the two sides. No sort of disturbance or embarrassment would therefore seem likely to be produced from the fact that impressions of smell from the *right* nostril, are brought into relation in the corresponding Cerebral Hemisphere with gustatory, visual, auditory, and tactile impressions emanating from the *left* side of the body, and *vice versâ.*

Owing to the protected position of the tip of the Temporal Lobe, accurate limitation of lesions in this situation was found to be almost impossible. Hence, though the 'centre' for **Taste** is believed by Ferrier to be immediately contiguous with that for Smell, viz., in "the lower part of the middle temporo-sphenoidal convolution," at the tip of the Temporal Lobe, he is unable to speak with so much certainty as to this localization. "The abolition of taste," he says, "always coincided with

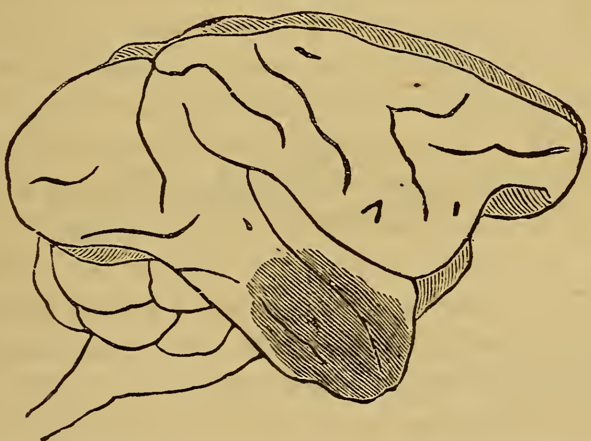


FIG. 176.—Brain of Monkey, showing shaded area in Temporal Lobe, the destruction of which caused loss of Smell on the same side, and loss of Taste on the opposite side. (Ferrier.)

destruction of regions situated in close relation to the subiculum;" whilst in favour of the part above defined being the centre for Taste, he remarks that irritation of this portion of the 'middle temporal convolution' leads to movements of the lips, tongue, and cheek pouches, which he regards as "reflex movements consequent on the excitation of the gustatory sensation." Destruction of this region on one side produced temporary loss or impairment of Taste on the opposite side of the tongue; whilst the loss of this sense became complete, double, and permanent, when the same part was destroyed on both sides.*

Destruction of the whole of the tip of one Temporal Lobe, was found to produce a temporary loss of Smell on the same side and loss of Taste on the opposite side.

In regard to the seat of the 'centre' for **Tactile** and **Common Sensibility,** some difficulty was at first experienced in fixing upon any site which seemed especially concerned with such impressions. Ferrier says: "After numerous experiments, in which almost the whole outer surface of the hemisphere had been successively destroyed without causing loss of the sense of touch, it seemed to me strange if such an important intellectual sense should not, like the others, have a special centre in the hemisphere. My attention was, therefore, directed to the inner aspect of the temporo-sphenoidal lobe, and to devise a method by which this region might be reached and destroyed." Ferrier soon succeeded in getting at this region from behind, and his subsequent experiments induced him to regard the 'hippocampus major' and the overlying 'uncinate convolution' as the parts which are specially to be regarded as the centre for Tactile Impressions (fig. 177). Destruction of this region causes complete loss of sensibility in the opposite half of the body, and that, too, of a more permanent character than the diminution which occurs in other modes of sensibility from unilateral destruction of their convolutional 'centres'—a result which is so far in exact accordance with what may be frequently recognized as the effect of disease of the Brain in Man.†

* Ferrier says: "With the abolition of taste, cutaneous sensibility of the tongue was also abolished, a fact indicating the association in the hemisphere of the centres of tactile and special sensation in the tongue." (Loc. cit. p. 189.)

† "Paralysis from Brain Disease," 1875, pp. 109, 121.

As regards the establishment of the existence or absence of Tactile Sensibility in an animal under observation, the same kind of difficulty is encountered as in regard to the other senses, owing to the uncertainty besetting the discrimination of a mere reflex reaction to stimulation, from one which has resulted from a conscious Perception. Ferrier therefore "endeavoured to apply such tests as might clearly distinguish between the two cases, relying more on the evidence furnished by the spontaneous

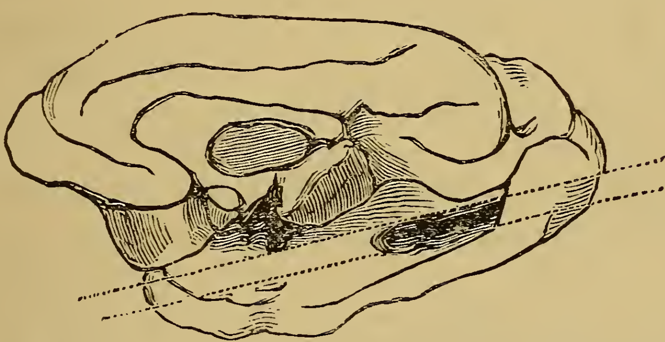


FIG. 177.—Internal Aspect of the right Hemisphere of the Brain of a Monkey, showing a darkly shaded area corresponding with the so-called 'Tactile Centre,' and, by dotted lines, the direction in which an instrument was inserted for the destruction of this area. (Ferrier.)

activity of the animal than on mere response to cutaneous stimulation."

He operated upon a Monkey which was in the main left-handed, that is, one which took things offered to it preferably with the left hand. "For this reason the right hippocampal region was destroyed, with the view of affecting the sense of touch in the limb which the animal usually employed." The results are thus described.*

"After recovering from the operation and the narcotic stupor, sight and hearing were found to be unimpaired, and the intelligence quick and active as before. But cutaneous stimulation by pricking,

* Loc. cit. p. 179.

pinching, or pungent heat sufficient to cause lively manifestations of sensation when applied to the right side of the body, failed in general to elicit any reaction whatever on the left side, whether face, hand, or foot. Only occasionally when the stimulus was intense or long continued, did reaction at all ensue. This most remarkable absence of response of any kind rendered the fact of annihilation of tactile sensibility almost completely proved without further evidence."

An alteration in the character of the Movements capable of being executed by the left limbs also existed, which, as Ferrier thinks, was of the kind "due to the loss of tactile sensation by which movements are guided." It seems almost more than doubtful, however, in the face of much recent evidence, whether 'ataxy' of Movement is necessarily or even ever occasioned by mere loss of cutaneous sensibility (see pp. 582, 700).

But a digression becomes needful at this point, on account of the complex nature of Tactile and Common Sensibility, and their relations to the so-called sixth or 'Muscular Sense.' It is highly important that definite notions should, if possible, be arrived at in regard to the latter endowment, in order that we may learn how far anything worthy of the name exists, apart from the various modes of Tactile and Common Sensibility—and also, incidentally, what mode of sensibility it is by which Movements are principally guided.

Under the head of Tactile and Common Sensibility are to be included many different kinds of Impressions more or less distinct from one another. Thrown into a tabular form they may be thus arranged:

a. From *Skin* and *Mucous Membranes.*	1. Tactile impressions proper. 2. Impressions of contact and pressure. 4. Impressions of temperature. 3. Impressions of pain.

b. From *Muscles.*	1. Impressions (ill defined) of strain or tension. 2. Impressions of pain (rare).
c. From *Fasciæ, Tendons,* and *Bones.*	1. Impressions (ill defined) of strain or pressure. 2. Impressions of pain (rare).
d. From *Viscera.*	1. Impressions of contact or pressure (rare). 2. Impressions of pain (more common).

The different modes of sensibility both in Skin and in Mucous Membranes are found to vary in their acuteness in certain diseases of the Cord or Brain, quite out of relation to one another. Thus the ability to discriminate between heat and cold, or the sensitivity to painful impressions may, either separately or together, be abolished in parts which are still sensitive to impressions of contact (tactile sensibility or touch proper), or *vice versâ*. Hence it is that some distinguished physiologists believe these different kinds of Impressions to be conducted by separate nerve fibres; whilst others, with as much evidence in favour of their view, consider that the same nerve fibres are capable of being impressed in different modes, so as to conduct different kinds of molecular vibrations—and that they may hence give rise to Impressions, whose subjective phases differ to the extent above mentioned.

Passing from considerations of this kind, we have now to face the related, though much more important, set of questions, as to the existence, nature, and origin of a separate endowment, commonly spoken of as the **Muscular Sense.** These questions have much occupied the attention of physiologists, pathologists, and psychologists —and especially the latter—during recent years. So much importance, indeed, is assigned to the 'Muscular

Sense' impressions by psychologists that it becomes above all things necessary for clear and comprehensive notions to be entertained as to the real nature of any such endowment. Prof. Bain, for instance, maintains that unless certain views are held in regard to the muscular sense—unless it be deemed, as he terms it, an 'active' mode of sensibility directly dependent upon motor nerves and motor centres—"the most vital distinction within the sphere of mind is bereft of all physiological support."* This may or may not be true; but in any case it shows the importance of being able to arrive at correct notions concerning an endowment upon the nature of which so much of philosophical doctrine is supposed to depend. Croom Robertson has also of late† referred to the subject as "one of the first importance in the psychology of the present day."

The views expressed at different times in regard to the 'Muscular Sense,' and the means by which we appreciate 'resistance' have been so various and contradictory as to make it almost impossible to give the student of this question any adequate notion of the real problems requiring solution without bringing together some historical notes illustrative of the various opinions that have been held on the subject. Some of these notes of earlier date were originally supplied by Sir Wm. Hamilton; but, as much light has recently been thrown upon the subject by observations of cases of Hemi-anæsthesia occurring in the human subject it is in all respects convenient, and even necessary, that the whole question should be reconsidered. This has been done; but as the discussion of the question constitutes a digression too lengthy to be introduced into this chapter, and as it is evidently technical in nature, it

* "Senses and Intellect," 3rd ed., p. 77.
† "Mind," 1877, p. 98.

has been thought better to relegate it to an Appendix (p. 691), and here merely to introduce the view which seems best supported by the evidence there adduced, together with some suggestions which may, perhaps, be calculated to obviate confusion in the future.

The conclusion there arrived at is that the term 'Muscular Sense' ought to be abolished, as being in several respects misleading, when applied (as it often is) with totally distinct significations, partly referring to some and partly to all the impressions which we derive from our moving members, or from Movements generally. We may much more reasonably and conveniently, in the face of all the disagreements concerning the 'muscular sense,' speak of a **Sense of Movement,*** as a separate endowment, of a complex kind, whereby we are made acquainted with the position and movements of our limbs, whereby we judge of 'weight' and 'resistance,' and by means of which the Brain also derives much unconscious guidance in the performance of Movements generally, but especially in those of the automatic type. Impressions of various kinds combine for the perfection of this 'sense of movement,' and in part its cerebral seat or area coincides with that of the sense of Touch. There are included under it, as its several components, cutaneous impressions, impressions from muscles and other deep textures of the limbs (such as fasciæ, tendons, and articular surfaces), all of which yield Conscious Impressions of various degrees of definiteness; and in addition there seems to be a highly important set of 'unfelt' Impressions, which guide the motor activity of the Brain by automatically bringing it

* Or in one word, Kinæsthesis (from *κινέω*, to move and *αἴσθησις*, sensation). To speak of a 'Kinæsthetic Centre' will certainly be found more convenient than to speak of a 'Sense of Movement Centre.'

into relation with the different degrees of contraction of all Muscles that may be in a state of action.

Such impressions, in such groups, differ from those of all other Sense Endowments inasmuch as they are 'results' rather than 'causes' of Movement, in the first instance; and are subsequently used only as guides for promoting the continuance of Movements already begun (p. 69). But in other cases the 'ideal' revival of some such impressions will cooperate with certain sensorial or 'volitional' stimuli for the renewal of Movements that have been executed at some previous time.

The experiments of Ferrier are thought by him to show that the sensibilities pertaining to Muscles, Fasciæ, Tendons, and Joints depend upon Impressions which diffuse themselves in and from *the same cortical area as that which is related to the more superficial Cutaneous Impressions.* By certain cortical lesions, as well as by lesions of the posterior part of the 'internal capsule,' all these modes of Tactile and Common Sensibility have been thought to be impaired or abolished together.

It is quite possible, however, to find that in certain diseases of the Spinal Cord, the sensibility of the Skin may be impaired or lost, whilst that of the Muscles and other deeper structures is retained; or in other cases for the sensibility of the Skin to be preserved whilst that of the Muscles is lost; * and in others still, for ordinary superficial and deep sensibility to be preserved, whilst the transit of the 'unconscious' impressions from Muscles, above referred to, is more or less interfered with, so that whilst, in such a case, there is neither motor nor sensory paralysis, there may be an inability to co-ordinate Movements without the aid of Sight.†

* Jaccoud, "Les paraplégies et l'ataxie," 1864.

† Landry, "Traité des paralysies," 1859.

In regard to **Visceral Impressions**, the reader must now be well aware that sensations are not habitually received from internal organs, and that vague impressions only are felt at intervals so long as these organs continue in a healthy condition. That impressions, however, habitually pass from some of the viscera to the Brain, although devoid of conscious accompaniments, can be shown by good indirect evidence. Systemic impressions are, in this manner, liable to exercise an important influence upon the general current of our Thoughts and Emotions, and they may also modify to a marked extent the activity of the Brain within the spheres of one or more of the Special Senses. Thus, though not themselves attended by Consciousness, it is unquestionably true that various 'visceral impressions' powerfully modify the Conscious Life of lower animals as well as of Man.

It is more than probable, therefore, that these Systemic Impressions pass by definite routes through the Medulla and lower parts of the Brain, and thence upwards to some definite region of the Cerebral Cortex, whence they possibly radiate in different directions. The fact that the impressions are of an 'unconscious' type need not inspire doubts as to whether they reach the Cerebral Cortex. The probabilities are greatly in favour of their doing so.

The parts of the Cortex, however, to which such impressions principally proceed is at present unknown. Ferrier is inclined to believe that they go to the Occipital Lobes. But the evidence adduced by him seems to the writer inadequate to support such a conclusion, and he himself does not strongly insist upon it.* Apart, moreover, from the dubious nature of the special evidence upon which Ferrier's opinion in regard to the cerebral localization of Visceral Impressions is based, this conclusion is one

* "Functions of the Brain," p. 192

which does not commend itself very highly when judged by general evidence open to all. It is surely a little repugnant to warrantable inferences to be asked to believe that impressions so primordial as the 'systemic' throughout the Vertebrate Series (and which would seem to diminish rather than increase in importance in the higher members of the series) should have most to do with one of the latest evolved and most specialized portions of the Cerebrum. This general evidence, indeed, as the writer has elsewhere suggested, points rather to the greater proportionate implication of the Occipital Lobes with the higher Intellectual Activity of which the animal is capable.* The latter notion has also been supported by Dr. Hughlings Jackson and others, because of its accordance with many facts supplied by sufferers from diseases of the Brain.

It does not at all follow that Visceral Impressions from the two sides of the body should, like the majority of sensory impressions, decussate in some part of their course to the Cerebral Hemispheres. No similar advantage would result from the decussation of such impressions. In the first place, no uniform bilateral symmetry is met with throughout the Viscera; and secondly, if the crossing of other sensory strands has been brought about in the manner we have attempted to indicate (p. 478) no object would be gained by a similar decussation of Visceral Impressions. This is obvious when we consider that Visceral Impressions carry with them no tendency or need to evoke the activity of merely one side of the body. So far as they pass to the Cerebrum, and excite the action of 'organs of relation,' they would appear to act only through the

* "The Human Brain," *Macmillan's Magazine*, Nov. 1865. The same view, it appears, was put forward by Dr. Carpenter in the *Brit. & For. Med. Chir. Review* for Oct. 1846.

intermediation of impressions from the Special Senses, the centres of which have been awakened and rendered more receptive by being brought into relation with distinct though 'unconscious' Visceral Impressions.

It would seem, indeed, from some observations which have been already made, that in many cases of Hemianæsthesia, the viscera remain at least as tender as ever under firm pressure upon both sides of the body; and this, of course, would indicate that the cerebral channels for these impressions do not intermix, in the region of the 'internal capsule,' with those of other modes of sensibility.

And, though their so-called 'Centres' may also be differently situated, it is pretty certain that Visceral Impressions must either radiate into, or be brought into intimate connection with, some parts of the province of each of the Special Senses, since they all so frequently interact in the manner already referred to. The interaction does not, however, only take place in one direction. There is on the part of the 'Sexual Appetite,' as Prof. Bain points out, "a many-sided susceptibility to inflammation, through all the senses, through the trains of thought, and through emotions that are not sensations." To a less extent a similar 'inflammability' by means of sensorial impressions also obtains in regard to the 'Appetite for Food.'

CHAPTER XXVI.

WILL AND VOLUNTARY MOVEMENTS.

"We find in ourselves," says Locke (1690), "a Power to begin or forbear, continue or end several Actions of our Minds and Motions of our Bodies, barely by a Thought or preference of the Mind."

Here the scope of that ability, which goes by the name of 'Will' or 'Volition,' is clearly enough marked out by one who may be styled the father of our modern Psychology.

In regard to the second of the spheres above-mentioned for the exercise of Will, viz., its influence over "the Motions of our Bodies," Locke ventured upon no details; and even at a much later period Hume (1747) was still only able to proclaim the complete, and, as he thought, hopeless ignorance which reigned thereon. "The motion of our bodies," he said, "follows upon the command of our Will. Of this we are every moment conscious. But the means by which this is effected; the energy by which the Will performs so extraordinary an operation; of this we are so far from being immediately conscious, that it must ever escape our diligent inquiry."

Hartley, in his "Observations on Man," published only one year later than Hume's "Inquiry," made, however, some valuable and very sagacious remarks on the causes, modes of acquisition, and mutual relations of the different kinds of Movements which we are capable of executing. So just were his observations that they still represent the basis of our knowledge on this subject.

Hartley sought also, though with less success, to make a first rough classification of Movements, from the point of view of the mental state or process by which they were preceded, when he said:—"Of the two sorts of Motion, viz., Automatic and Voluntary, the first depends upon Sensation, the last upon Ideas."

This, even apart from certain necessary qualifications which Hartley would have himself assented to, cannot be regarded as a very correct generalization. Some automatic actions, such as those of the Heart, Intestines, and other viscera, are due to 'unfelt' Impressions which can scarcely be called Sensations; whilst others are incited by those 'internally initiated' feelings known as Emotions—which are more akin to Ideas than to Sensations. Again, Ideas are sometimes provocative of automatic movements, as when—to name only one of the best instances—a ludicrous Idea impels us to Laughter; though in multitudes of other instances it is perfectly true that Ideas are the primary incitors of Voluntary Movements. Between these extremes, moreover, numerous insensible gradations are to be met with: we have movements, for instance, that are scarcely to be termed Automatic, and yet which physiologists have also deemed desirable to mark off from the category of strictly Voluntary Movements—as they have shown by their application to them of the epithet 'Ideo-motor.'

That actions, which are at first Voluntary, tend, after a time, when frequently repeated, to become truly Automatic, Hartley was, of course, fully aware. It was he who first proposed to class such actions as 'Secondary Automatic,' in opposition to those of his 'Primary Automatic' category

—including under this latter head actions which the individual has, from the first, performed automatically. He endeavoured to formulate some of the grounds for distinguishing Voluntary Actions from those which are, as he says, "to be esteemed less and less voluntary, semivoluntary, or scarce voluntary at all."

This latter subject was, however, discussed more effectively, at a later period, by James Mill. It is one of considerable importance, since it involves an attempt to discover the real nature or elementary constituents of that phase of Mind which we name **Volition.** On this subject James Mill* advances the following opinions:—

> "There appears no circumstance by which the cases called voluntary are distinguished from the involuntary, except that in the voluntary there exists a Desire. Shedding tears at the hearing of a tragic story we do not desire to weep; laughing at the recital of a comic story we do not desire to laugh. But when we elevate the arm to ward off a blow, we desire to lift the arm; when we turn the head to look at some attractive object, we desire to move the head. I believe that no case of voluntary action can be mentioned in which it would not be an appropriate expression to call the action 'desired.'"

If there is interpolated, therefore, between a Sensation or an Idea, and the Movement which it may evoke, a feeling of an emotional order, known as *Desire,* a movement which would otherwise have been described as 'Sensory-motor' or 'Ideo-motor,' becomes entitled to be known as a Voluntary Movement.† This is the first and

* "Analysis of the Human Mind," 1830, p. 279.

† Hartley's view was very similar. He says:—"The *Will* appears to be nothing but a desire or aversion, sufficiently strong to produce an action that is not automatic, primarily or secondarily . . . . . . The Will is, therefore, that desire or aversion which is strongest for the present time." Which mental mood is to prevail is sometimes immediately settled, and, at other times, only after a

most important distinction drawn by James Mill. But, as the same philosopher afterwards points out, something else accompanies or immediately follows the emotion of Desire—viz., an *Idea or Conception of the kind of Movement needed* for the gratification of the Desire.

It seems generally admitted, therefore, by the philosophers above quoted, as it is by others, that the motions of our bodies are begun, continued or ended, as Locke put it, "barely by a Thought or preference of the Mind." Impressions, Sensations, Emotions, Thoughts—these are the mental states which, singly or in combination, are followed by Movements. As to any details pertaining to their incitation and actual accomplishment, little or nothing more is known with any degree of certainty. Writing in 1830,* James Mill said: "We do not undertake to say what physical links are between the Idea and the Contraction, any more than between the Sensation and Contraction. *The Idea is the last part of the Mental operation.*"

If, however, this be really so, if beyond the mental states or processes above enumerated, we have in Voluntary Acts mere physical changes in nerve and muscle, as Hume and James Mill averred, there is the less reason for surprise that some philosophers, such as Dugald Stewart and Dr. Thomas Brown, should have deliberately omitted to discuss 'Will' as a distinct section of our Conscious Life. "To know all our sensitive states or affections," the

process of Deliberation, and, concerning this process, Hobbes says: —"The whole sum of desires, aversions, hopes and fears, continued till the thing be either done or thought impossible, is what we call *Deliberation.*" . . . . . . "Appetite, therefore, and aversion are simply so-called as long as they follow not deliberation. But if deliberation have gone before, then the last act of it, if it be appetite, is called *will;* if aversion, *unwillingness.*"

* Loc cit. II. p. 266.

latter says,* "all our intellectual states, all our Emotions, is to know all the states or phenomena of the Mind." The precedence of one or other of these subjective phases, or of compound conditions derived therefrom, would correspond, as he thought, to what we know as 'Will.' Beyond these subjective phases, we should pass in the execution of Voluntary Movements from the sphere of psychology into that of physiology pure and simple.

The distinctness of the *Idea or Conception of the Movement* (which we shall presently find to be of complex origin), as one of the Conscious Components of a Volition, will be found to vary much with the degree of familiarity, or ease of execution, of the Movement. And in this latter respect, of course, all gradations exist between the simplest kinds of Voluntary Movements and those of the most complex order.

We may, for instance, 'voluntarily' perform some movement which frequent repetition has already made easy, but which, for the most part, we now perform 'automatically.' The fingers of a sleeping child may close over an object gently brought into contact with its palm; or when awake the child may excite a similar movement voluntarily. An object brought close to the eyes may cause a person to wink involuntarily, but he is also capable of performing the same act in a voluntary manner. We may lift the arm instinctively to ward off an impending blow, or we may raise it in the same manner voluntarily. In all such cases the *Idea or Conception of the Movement needed* scarcely obtrudes itself at all as a conscious element of the 'Volition'; this is a part of the process which has here become more or less latent.

But in the other more complex category of Voluntary

* "Philosophy of the Human Mind," Lect. xvii.

Actions, efforts are made to perform some new combinations of movements, the complicacy of which renders them at first very difficult to execute. This is the case, for instance, when a child is learning to write, or when a youth is learning to dance or to play upon some musical instrument. In every such case, some *Idea or Conception of the kind of Movement needed* is to be recognized as a more or less distinctly conscious component of the 'Volition' in question.

When commencing a Voluntary Movement which we have often previously executed, we initiate it with certain pre-determined qualities almost intuitively given to it, and yet in the selection of which we are evidently guided by past experience and education. A simple case will illustrate this. I know that objects having certain visual characters have usually given me certain impressions of 'weight' and 'resistance' when I have previously handled them; and, therefore, this previous experience enables me, on seeing such an object again and desiring to handle it, to conjure up a 'conception' of the Movement needed, which, though it may be very indistinctly realized in Consciousness, enables me, in some way, to give the Volitional Act its necessary qualifications.

This power, partly instinctive and partly a result of individual education, has been made the subject of much mystification. Some ascribe it to a 'locomotor instinct,' pure and simple, and thereby ignore the fact that it is a power the manifestation of which is greatly regulated by individual education. Some appeal with vague gravity to the intervention of what they term 'motor intuitions'—meaning, thereby, something pertaining to, or having their origin in, the Motor Centres *about* to be called into activity, but which yet, beforehand, in some way help to determine the mode of their own activity.*

* There are, in all probability, in Motor Centres multitudes of different combinations of cell-and-fibre connections which have been gradually established, and through the agency of which Volitional Incitations may be *necessarily* distributed along certain 'outgoing' fibres, so as to call into activity in definite modes particular groups of Muscles. There seems no good reason, however,

James Mill held, with more show of reason, that what have been commonly termed 'Muscular Sense' impressions intervene, and come into joint operation as determining agents, at a stage immediately posterior to the Conception above referred to, and anterior to the actual occurrence of the Voluntary Movement. If we substitute for these so-called 'muscular sense' impressions, our Kinæsthetic Impressions,* we may, on such broader terms, adopt this view of James Mill as fairly typifying the probable mode of execution of, or rather order of processes involved in, the initiation of Voluntary Movements.

The same parts of the Brain as are called into play for the **initiation** of any set of Voluntary Movements would probably remain in activity during the **continuance** of such movements, though perhaps not exactly in the same relative proportions. Thus an 'ideal' recall or 'conception' of the sensory qualities of the Movements needed operates as the starting point, enabling the individual, from an already existing and in part instinctive basis, to determine *how to act and what force to employ;* whilst, during the continuance of the Movements, he would be also partly influenced by actual 'sensations' realizing themselves in the same parts of the Brain, and telling him *how he is acting and what force he is employing.*† Yet in the two cases, the relative amount of activity of the sensory centres concerned may not be equal.

Thus, if we suppose the centres specially called into activity as guiding centres to be the Visual and the Kinæsthetic, it may be that the former has the dominating influence in the production of the initial Conception; whilst, during the continuance of the Movements, impressions impinging upon the Kinæsthetic Centres may, in their turn, have a more potent guiding influence. If a person should attempt to take from a table a small bundle of cotton wool

why any such organizations, or rather the functional activity of such organizations, should be spoken of as 'motor intuitions,' or why these should be deemed, as Dr. Maudsley says ("Physiology and Pathology of Mind," in Chap. on 'Motor Centres'), to constitute an "important motorial region of mental life"—whatever that may mean. Dr. Maudsley's views on this subject do not seem to be very clearly realizable, though his Chapter on 'Volition' is extremely good and free from all ambiguity.

* See p. 543.

† See Appendix.

into the middle of which, unknown to him, a heavy leaden weight had been introduced, his initial determination of the Movement deemed to be adequate would need rectification, and in such a case it would certainly be rectified in the main at the instigation of Kinæsthetic Impressions.

Hitherto reference has been made to the simpler class of Voluntary Movements—to those in which the movements themselves are familiar or easy of execution. But where the movements which it is desired to execute are complex and difficult, and we have to learn them by **imitation** of the movements of other persons, the sense of Sight is then doubly brought into play. It is necessary at the commencement, and during the continuance, of our efforts to copy such movements, to look alternately at our model and at our own moving members. A long time and much practice is, in fact, required before a person learning to dance, or to play upon some musical instrument, is able to execute either of these actions without the aid from moment to moment of guiding Sight impressions. "In learning to dance," as Hartley says, "the scholar desires to look at his feet and legs, in order to judge, by seeing, when they are in a proper position. By degrees he learns to judge of this by feeling; but the visible idea left partly by the view of his master's motions, partly by that of his own, seems to be *the chief associated circumstance that introduces the proper motions.*" During the process of learning, therefore, the Visual Centre evidently exercises a dominating influence.

In time, however, the impressions pertaining to the 'Sense of Movement' (which are, of course, always to some extent associated with those of Sight) become, by way of their organized channels, sufficiently freely associated with them and with the newly organizing 'motor' nerve channels and mechanisms, to permit the Movements we have been practising to be performed under the immediate guidance of Kinæsthetic Impressions only—without further necessity for a conjoint direction through the sense of Sight. As Jaccoud, however, points out (*Les paraplégies et l'ataxie*, p. 601) the sensorium requires to *learn*, in the first instance, what conditions and positions of the moving parts are related to such and such tactile and other impressions coming from them. And thus it is only at the termination of this apprenticeship that it is enabled to conclude directly from Kinæsthetic Impressions as to the precise conditions of the moving parts. This process of education can only proceed correctly by reason of the comparisons which we are accustomed to make from moment to moment, between the positions and movements of the limbs as revealed to Sight, and the sum total of Kinæsthetic Impressions simultaneously received from the same parts.

This kind of education being once completed in regard to any particular Movements, the knowledge subsequently derivable through the Kinæsthetic Centre becomes as real and as capable of passing over into appropriate action as that previously coming through the Visual Centre. Thereafter its impressions alone—even when they very imperfectly, or not at all, rouse our Consciousness of their existence—suffice to inform us (that is, suffice to excite the proper Cerebral 'centres' in ways definitely related to different positions and tensions) as to the exact position of our limbs, and as to the nature and degree of their Movements. It is by Kinæsthetic Impressions that we are afterwards continually instructed as to the qualities of the Movements actually produced; through them we know whether to continue with our present mode of action, or whether, the better to attain the desired end, the quality of the 'Volition' should be altered. And if, during the execution of a complex Movement, any alteration should be desired in respect to one of its 'volitional' qualities—that is, either as regards the strength, the rapidity, the direction, or the continuance of one of its component motions, this, "barely by a Thought or preference of the Mind," can be immediately effected, though the great majority of mankind would have no knowledge whatsoever of the nature and degree of the individual changes brought about in the actions of the different Muscles concerned.

The mode of acquisition above indicated seems well to accord with our other interests and with the daily necessities of our Life. The sense of Sight greatly facilitates the process of learning, and its vivid impressions speedily enable the 'sensorium' to appreciate aright the meaning of the more vague and occult impressions coming to it simultaneously through the 'sense of Movement.' Soon, however, the Visual Sense, which we need for so many other important purposes, no longer requires to be concentrated merely on the performance of Movements. Later still, our 'attention' or Consciousness becomes further freed from disturbing details connected with Movements. The possibly conscious impressions pertaining to the 'sense of Movement' at last habitually pass unheeded, and then we come to perform multitudes of daily actions under the guidance of mere 'unconscious' Kinæsthetic Impressions.

Thus the working of the 'motor' side of our complex nervous-mechanism, even when it is concerned in executing the behests of

'Will,' proceeds so smoothly, and is practically so much unheeded as to leave us free to follow up the threads of our Conscious Life unhindered by the multitudinous details pertaining to the varying states of innumerable Muscles acting in ever-changing combinations. We may truly be thankful that we have not in reality any such 'muscular sense,' as some psychologists imagine for themselves, and that even in Voluntary Movements the Mind knows nothing concerning the Nerves or the Muscles by the intervention of which the processes are accomplished.

From our own individual experience, as well as from what has been above set forth, it would appear obvious that careful practice alone is needed, in order that previously strange, difficult, and complex Movements should be capable of being performed with ease; and that, after a time, during the process of learning, first the 'Conception' of the Movements needed, and subsequently the Desire which originally prompted to their execution, may alike vanish as conscious states by which they are necessarily preceded. When this latter stage of perfection has been achieved, the actions previously 'Voluntary,' in the strictest sense of the term, become promoted to the 'Secondary Automatic' category, since the occurrence of a Sensation, an Emotion, or an Idea may be immediately, and without the intervention of any other conscious state whatsoever, succeeded by one of the complex Movements in question. Thus Movements, the possibility of performing which has been slowly and with so much difficulty acquired by the individual, have now, in fact, become almost as easy for us as sucking, swallowing, coughing, or any other of those 'Primary Automatic' actions, the power of performing which was born with us—as an inheritance from untold generations of human and other ancestors.

In many cases, indeed, there is good reason for believing that the alliance between 'Primary Automatic' and some 'Secondary Automatic' actions is even more fundamental than has been above indicated. The reasons for this opinion must be set forth in detail.

The Mechanisms for Primary Automatic Movements, and their Modes of Origin.

The nervous connections representative of a certain number of Movements which have been commonly performed by the present and many past generations of any race of animals exist in an organized condition in the Spinal Cord and Medulla of such animals. They are represented by the development of certain cell-and-fibre connections in the anterior, or what are known as the 'motor' regions of the Grey Matter of these parts—such mechanisms being in continuity in front with the roots of 'outgoing' nerves, and in relation behind with groups of smaller nerve cells with which the 'ingoing' nerves of the posterior roots are, in their turn, in some sort of structural relation. It is along these latter channels that the sensory Impressions prompting to the Movements of which we have been speaking reach the Spinal Cord or Medulla.*

Many of the corresponding groups of 'motor' Cells, situated at the same level in the right and left halves of the Cord and Medulla, are intimately connected by **transverse** 'commissural' fibres—in fact, wherever joint action of the nerve units on the two sides is a matter of common occurrence (fig. 154, o o').

Many of the groups of motor cells, at different levels of the cord are also connected with one another into single or multiple combinations, by **longitudinal** 'commissural' fibres whose length varies according to the distance apart of the cell groups thus united for conjoint activity. These **longitudinal** connecting fibres of different lengths, as they pass from cell-group to cell-group, have been ascertained (on the basis of clinico-pathological evidence supplied by persons suffering from spinal disease) to traverse, in part at least, the 'posterior columns' of the Cord.

Bilateral groups of these cells, existing at various levels in the two 'anterior cornua,' though differing much from one another in the number of the units involved and in the width of the area over which they are distributed, are conceived to be the Spinal and Medullary Nervous Mechanisms needful for the execution of a vast multitude of Reflex, or Primary Automatic Movements, also of all

* See pp. 26, 52.

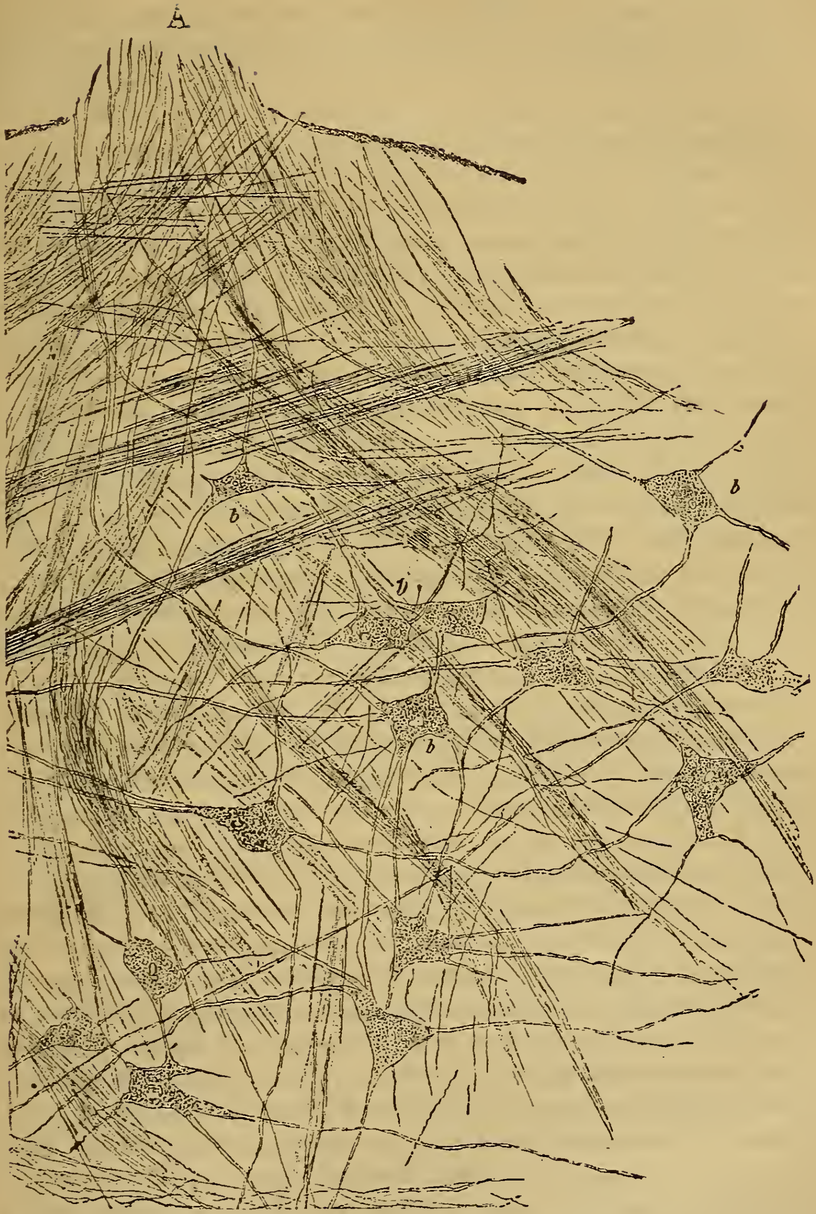


FIG. 178.—Groups of Cells in connection with the Anterior Roots of the Spinal Nerves, as seen in a transverse section through one of the Anterior Cornua in the Spinal Cord of a Sheep. (Flint after Dean.) A, Emergence of the anterior roots from the Cornua of Grey Matter; *b, b, b,* Cells connected with one another by long, slender, 'intercellular' processes, and also with the fibres of the Anterior Roots. Bundles of fibres are seen crossing one another in almost every direction.

degrees of complexity. It is probably because these several cell-and-fibre mechanisms are so perfect in their arrangement, that each one of the Movements in question is capable of being evoked with machine-like regularity in response to appropriate stimuli impinging upon and passing through them.*

The 'mechanisms' for the production of many of such Movements may have been originally developed far back in the history of our race or of antecedent races. But others of them—those, for instance, which are concerned in the acts of Deglutition—however much they may have been from time to time modified in detail, must have been originally organized in creatures the combination of whose vague efforts and desires would scarcely be considered to produce anything like what we know as 'Volition.' In all probability such feelings and the power of concentrating Attention, which is their indispensable correlative, only gradually attain to the degree of precision and intensity of which we, as human beings, are conscious. This would probably be conceded by all, and if so it must be concluded that the organic nervous bases of many of the Primary Automatic Movements of higher animals have had their origin, or have come into being, independently of anything like such an agency as that which we know as 'Volition.'

Thus, the further back we go in the animal series, the more vague, in all probability, would be the influences prompting to new developments of Nerve Tissue which could be ranged under the 'Volitional' type, and the more we should be compelled, if we strive to learn the causes of such new developments, to fall back upon *those obscure but, nevertheless, potent original tendencies or conditions, under the influence of which the first rudimentary Nerve Elements became developed in the tissues of lower Organisms* (p. 19).

This mere organic *nisus*, or set of vital conditions, favouring the first differentiation of Nervous Tissues, would probably continue to act as the most potent influence governing all future phases of their development—though it seems evident that such developmental proclivities, even in the Spinal Cord, are capable of being favoured in some mysterious manner by Cerebral Influence when 'Volition' is strongly exercised—that is when a sensorially active Brain is dominated in such ways as to be productive of certain

* That Hartley (1748) distinctly realized and foresaw the nature of what we now term 'Reflex Actions,' seems evident from a passage in his "Observations on Man," Prop. xviii.

'Desires,' and further influenced in certain correlative tracts by that mode or degree of activity which on its subjective side we call 'Attention.'

Deferred Primary Automatic Movements.

Much difference exists among different Animals as to the degree of perfection *at the time of birth* of these inherited cell-and-fibre connections, and, therefore, similar differences exist among such Animals, in regard to their power at birth of executing the several Movements with which such Nervous Mechanisms are in relation.

Thus, in some Birds at the time of their emergence from the egg, and in some Quadrupeds at birth, much of the nervous mechanisms concerned with Automatic Movements habitually performed by such creatures, are so far perfected that these animals are capable almost at once of performing the most complex Movements—without in any way requiring to 'learn' how to execute them. The experiments of D. A. Spalding with Chickens and young Pigs have revealed interesting facts in illustration of this position (see pp. 188, 229).

Many instances of an opposite character may, however, be cited —cases, that is, in which at the time of emergence from the egg, or at the time of birth, other Birds or Mammals are in a much less mature state of development, and in which their powers of executing complex Movements of a similar order are notably less advanced.

The young of Canaries and many other birds, for instance, remain for ten days or a fortnight unable to feed themselves or to walk, and they may continue for nearly twice this time unable to fly. But this backwardness in power of executing such Movements, is obviously only one of the signs or accompaniments of their generally backward condition of development. A bird can no more fly without the aid of properly developed internal Nervous Mechanisms than without wing-feathers, and the one set of structures are probably almost as abortive as the other in young Canaries and in the young of other birds.

The performance of many Movements that are 'primarily' Automatic in the Chick and birds like it, are, therefore, **deferred** in Canaries and their allies till such times as the related nervous and other mechanisms have had time to develop. Ground is thus given for the supposition, commonly entertained, that such creatures have to 'learn' how to perform these Movements—which, if true, would make it necessary to classify them as 'secondary' rather than 'primary' Automatic Movements.

The valuable experiments of Spalding with young Swallows and other birds that emerge from the egg in an immature condition have, however, shown that in them the manifestation of 'primary' Automatic Movements, dependent upon inherited Nervous Mechanisms, is merely deferred till the time when such developments have been achieved—and that then, without any process of 'learning,' the Movements are readily capable of being evoked (p. 230).

The helpless condition of the infant Monkey and of the Human Infant at birth are similarly to be ascribed, in great part, to the immature condition of their great Nervous Centres at this period. Many of the Movements which they slowly 'learn' to perform are doubtless rendered possible by, and acquired coincidently with, *the actual development of those nerve cells and fibres in the Spinal Cord and Medulla which are instrumental in the execution of such Movements.* Thus, when we say that the young child 'learns' to perform these movements, it should be understood that this word is here applicable only in a very qualified sense. Its vague efforts serve, perhaps, merely as incitations tending to arouse or perfect the already existing (because inherited) tendencies to development of certain Motor and other Nerve Centres—of mechanisms, that is, which in many other creatures have reached their full term of development by or almost immediately after birth.

But for the existence of this organic *nisus* (in the form of an inherited tendency to develop in certain modes and directions) the Human Infant could never so readily as it does acquire the power of executing the excessively complex Movements which are concerned in Standing, in Walking, or in Articulate Speech (see p. 607).

Relations of Voluntary and Automatic Movements.

The complex movements last referred to being some of the most typical of the 'secondary' Automatic Movements of Hartley, the above considerations will suffice to show that many of those hitherto placed in this category, are but 'primary' Automatic Movements, the power of executing which has been somewhat deferred. Previously, the guiding influence of Volition has been supposed by many to be principally instrumental in enabling the child to execute them, whilst here it is contended that their acquisition by the individual is much more largely dependent upon the gradual development of inherited Nervous Mechanisms—due to the successive education of many preceding generations. They are clearly not new Movements, acquired afresh by each individual, as would be the case, for instance, with those persons who learn to swim, to dance, or to play upon any musical instrument. In the one set of cases Volitional Efforts are met more than half way by inherited developmental tendencies; whilst in the other set, and in the case of all new Volitional Movements acquired by adults, the Volitional Influences are aided only by those natural organic proclivities to the development of new nervous mechanisms, which originally (under the influence of suitable stimuli) led to the primary genesis of Nerve Tissues, and which may safely be deemed to be still operative in all animals, whether high or low.

Classification of Movements.

Movements Acquired by the Individual.		*Movements Inherited by the Individual.*
I. Volitional.	*a.* Where the Movements themselves are familiar and easy.	
	b. Where the Movements themselves are unfamiliar and difficult.	
II. Secondary Automatic. (Hartley.)	*a.* Movements learned by each individual for himself which, subsequently, after long practice become familiar and easy of execution.	
	b. Movements which *appear* to need learning by each individual, merely because their nervous mechanisms are not developed at the time of birth.	*a.* **III. Primary Automatic.**
	Movements learned by antecedent generations of animals, now capable of being instinctively performed at birth, owing to inherited mechanisms being at this time sufficiently developed.	*b.*

Volitional acts are, therefore, merely Automatic acts in process of formation, first of all for the Individual, and subsequently, it may be, for the Race. Where such Movements have been acquired or learned for the Race, unless the inherited correlative Nervous Mechanisms are developed at the time of birth, Volitions may in each Individual again intervene and act as stimuli during the time that such inherited Mechanisms are undergoing their proper degree of development.

Taking the Spinal and Medullary Motor Mechanisms as being either developed or in process of development, we may now turn our attention more particularly to a consideration of the parts whence, and of the channels through which, Cerebral Incitations pass (on their way down from cortical grey matter) in Emotional, Ideo-motor, or Volitional Movements.

One part of the route has been pretty clearly ascertained, and this may be first referred to.

From the evidence supplied by disease in the human subject, from experiments upon some of the lower animals, and from other sources of knowledge, it has been ascertained that the **Corpora Striata** are great motor ganglia in some way concerned with the execution of Voluntary, Emotional, and Ideo-motor Movements.

Motor stimuli—that is stimuli which are to evoke movements—pass, therefore, from certain parts of the Cerebral Cortex downwards to the corresponding Corpora Striata. These bodies are called into activity in a way which cannot be defined, though from them the motor stimuli seem to be continued and redirected towards the 'motor mechanisms' of which we have previously been speaking, in the Medulla and Spinal Cord.

The tracks of these latter stimuli are fairly well known. They pass from each Corpus Striatum through the inferior layers of the Crus Cerebri, and through the Pons Varolii on the same side; whilst below this bridge they are gathered together in the 'anterior pyramid' of the Medulla, which, after a course of a little more than one inch, decussates in part with its fellow—in such a manner that many of the fibres of each pyramid pass over into the opposite 'lateral column' of the Cord,* whilst some continue to descend on

* It would appear, from common phenomena occasioned by disease of the great Nerve Centres in Man, that the cerebral channels through which limb-movements, at least, are called into activity, must undergo such a 'decussation.'

the same side in the 'anterior column.' The motor fibres which decussate and pass downwards in the lateral columns of the Spinal Cord enter the anterior cornua of Grey Matter in the cervical, the dorsal or the lumbar region, according to the situation of the groups of cells concerned with the Movements which the particular cerebral stimuli traversing these channels are destined to evoke.

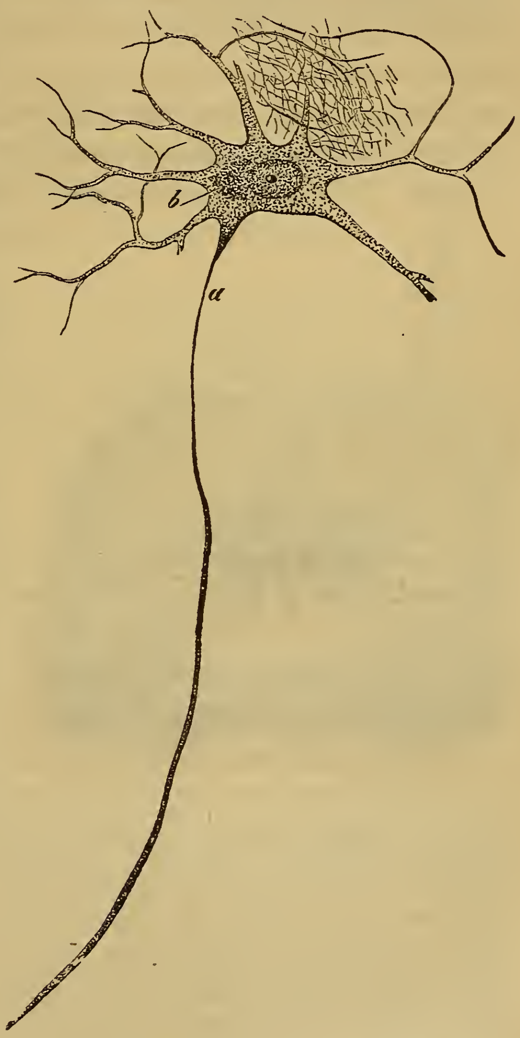


FIG. 179.—Nerve Cell with many branches from one of the anterior Cornua of a Human Spinal Cord. (Max Schultze.) *a*, Unbranched Cell-process passing into, or joining the axis cylinder of one of the 'anterior root' fibres, the other processes being branched; *b*, an aggregation of pigment-granules on one side of the large nucleolated nucleus. (× 150 diameters.)

The passage of Cerebral incitations or stimuli through one or other of these Spinal Mechanisms is followed by an outpouring of graduated Molecular Movements along certain of the fibres of the 'anterior roots' with which such Mechanisms are continuous: and these, traversing the Motor Nerves at the rate of about 111 feet per second, speedily excite definite groups of Muscles in definite ways, with the effect of producing the desired Movements.

The mode in which physicians and pathologists have acquired this knowledge as to the route followed by cerebral stimuli from the Corpora Striata downwards to the Muscles, is too intricate and technical to be here discussed. We must content ourselves for the present with the above simple statement of facts, in addition to the following brief explanation.

FIG. 180.—Transverse section of the Brain of a Dog slightly in front of the Optic Commissure, showing the anterior part of the 'internal capsule,' the section of which on either side produces **Hemiplegia.** (Carville and Duret.) *S, S*, intra-ventricular nuclei of the Corpus Striatum; *L*, extra-ventricular nucleus of the same; *P*, peduncular expansion ('internal capsule'); *Ch*, Optic Commissure; *x*, section of the anterior part of the 'internal capsule,' producing Hemiplegia of the opposite side of the body.

The effects resulting from disease of the Corpora Striata in man, whether in the form of Softening or Hæmorrhage, demonstrate the importance of these bodies in relation to Voluntary Movements, and prove that they have to do with the transmission and proper distribution of 'volitional' incitations. The destruction or serious damage of one Corpus Striatum by disease produces, among other results, a complete loss of voluntary power over the Limbs on the opposite side of the body (Hemiplegia)—though the trunk muscles which are called into simultaneous activity do not share in this paralysis, for reasons first given by Broadbent (p. 480). Each Corpus Striatum transmits, therefore, the 'volitional' incitations for the Limb-movements of the opposite half of the body; whilst it would appear that either of them may transmit incitations capable of calling into action the closely united double groups of Spinal Nerve-cells which minister to the bilateral movements of the trunk. The case in regard to the bilateral movements concerned in Speech will be specially referred to in a subsequent chapter.

The precise mode in which the Corpus Striatum acts can only be dimly conjectured. No one has expressed the kind of view which has been held by many, better or more fully than Broadbent, when he says*:—

"The Corpus Striatum is the motor ganglion for the entire opposite half of the body. It translates volitions into actions, or puts in execution the commands of the Intellect; that is, it selects, so to speak, the motor nerve nuclei in the medulla and cord appropriate for the performance of the desired action, and sends down the impulses which sets them in motion. These impulses are transmitted through fibres, and the fibres must start from cell processes in the corpus striatum. *A given movement, therefore, must be represented in the Corpus Striatum by a group or groups of cells giving off downward processes, which become fibres of the motor tract of the cord.* When the movement is simple, or when the co-ordination required can be effected by the cord as in walking, the cell group will be small, and the descending fibres few. When the movement is complex and delicate, and guided by vision or by the conscious attention, as in writing or drawing, the cell-groups will be large and definite, and the descending fibres numerous. There will not be a separate group of cells for each movement; but the same cells may be differently combined, just as different combinations of carbon, hydrogen, oxygen, and nitrogen form the basis of all organic substances. Words which require for their utterance the simultaneous co-operation of muscles of the chest, larynx, tongue, lips, etc., and the exquisite and rapid adjustment of their movements concerned in phonation and articulation, must be represented in the Corpus Striatum by very large groups of cells, and not in that of one side only but in both."

This view as to the functions of the Corpora Striata in regard to Voluntary Movements may be supplemented

* "Brit. Med. Journal," April 1, 1876.

by the same writer's notion as to the functions of the Cerebellum in the production of such Movements. The respective parts which he is inclined to assign to each of these organs will thus be seen. He says :—

"*The Cerebellum co-ordinates movements guided by vision, or combines the general movements of the body rendered necessary by special actions ordered by volition.* For instance, to illustrate the latter function, I wish to strike a blow. I am conscious only of the desire to hit the object and hit it hard; this is the only action realized in consciousness. But in order to carry out the intention, not only must the fist be clenched and the arm shot out, but the feet must be firmly planted, the legs made rigid, the body thrown forward, the chest fixed; and this is what is done for me by the Cerebellum . . . . . . We can see that there is no such relation between visual impressions as between these and tactile impressions, and any mechanism, such as that for reflex response to the latter, is impossible as regards vision . . . . . . How the Cerebellum is acted upon by the Cerebrum or sensori-motor ganglia, and in turn acts upon the cord, we do not yet know."

The above notions entertained by Broadbent in regard to the functions of the Cerebellum, are, in part, not very different from what have been expressed in Chap. xxiv. There are, indeed, good grounds for believing that the Cerebellum acts in some way at the instigation of the Cerebrum in the production of Voluntary Movements (see p. 507); and in these cases, as already explained, the movements are mostly guided by Vision. On the other hand, it seems obvious that the Cerebellum also assists in the performance of 'automatic' Movements of the highest or most general order, such as might well be conceived to fall to the share of a great Motor Ganglion standing at the head of, but in intimate relation with, all other subordinate motor centres in the Medulla and Cord. Being concerned as it is, therefore, both with new and with old actions it has an essentially double function ;

and what we as yet know of its anatomical connections is harmonious enough with this view.

In what precise way the Cerebellum acts in the performance of these functions, and more especially those in which it co-operates with the Corpora Striata for the execution of Voluntary Movements, remains at present wholly unknown. Neither, however, can we do more than conjecture, when we try to realize the mode in which the Corpora Striata themselves react under Intellectual Incitations upon the motor nuclei of the Medulla and Cord. How is it that the initiating Idea, the Desire for a related 'end,' and the two-fold Conception of the necessary Movements, as co-operating stimuli, are enabled to influence the Corpora Striata, so as to evoke the Movements in question? The obscurity prevailing in regard to this problem cannot at present be removed. We possess no real knowledge on the subject, and merely suppose that Intellect as it passes over into action—that is at the turning point or 'bend of the stream'—whilst seeming to engender a psychological ghost named '**Will**,' operates by transmitting suitable stimulations to the Corpora Striata; and that here again, perhaps under conjoint stimulation from the Cerebellum, in some manner wholly unknown, other sequential molecular actions are roused, as a result of which incitations are sent to and through motor 'nerve-nuclei' in the Medulla and Cord, appropriate for the performance of the desired Movements.

But another final set of questions in regard to the execution of Voluntary Movements now remains to be considered. We have pointed out the track taken by cerebral incitations in their passage downwards from the Corpora Striata, through the Cerebral Peduncles, Medulla, and Cord, and thence through the anterior roots of Spinal

Nerves to the requisite groups of Muscles. The upper part of the route still remains, however, to be specified. We have to consider whether it is from special parts of the surface of the Cerebral Hemispheres—and if so, from what parts—the before-mentioned Intellectual Incitations (which in their subjective embodiment are commonly known as 'Will' or 'Volition') pass downwards to the great Motor Ganglia—the Corpora Striata?

Previous to the experiments of Fritsch and Hitzig (1870) and of Ferrier (1873) it had been generally believed that physical irritations of the surfaces of the Cerebral Hemispheres were not capable of evoking any definite Movements. These investigators, however, found that some definite Movements were capable of being produced by electric irritation; and that though the Movements varied in character they were more or less similar when the same limited regions of the surface Grey Matter were, on different occasions, stimulated to a like extent. Fritsch and Hitzig originally obtained such results principally by making use of weak 'voltaic' currents; whilst Ferrier's subsequent though more extensive observations were made with the aid of weak 'induced' currents. The Movements thus produced by the stimulation of certain parts, were found, on the other hand, to be abolished when these same parts of the Cerebral Cortex had been destroyed—that is, such Movements were no longer capable of being performed by the animal, either of its own accord or as a sequence of external stimulation.

Some of the principal facts bearing upon this question of the excitation or abolition of definite Movements as a result of the stimulation or destruction of definite portions of the cortex of the Brain in Monkeys* may, perhaps, be

* The Movements of these animals being most allied to those of Man, and their Brains being also most similar to his, it will be

most briefly set forth by quoting Ferrier's description of some observations made upon an animal, certain parts of whose Cerebrum had been previously submitted to electrical stimulation, and in whom the initial irritative changes were speedily followed by destructive morbid processes, involving the same parts of the Cerebral Cortex.

Ferrier says ('Functions of the Brain,' p. 200):—"The first experiment I have to record is instructive as showing the respective effects of irritation and destruction of the convolutions bounding the fissure of Rolando. The right hemisphere of a monkey had

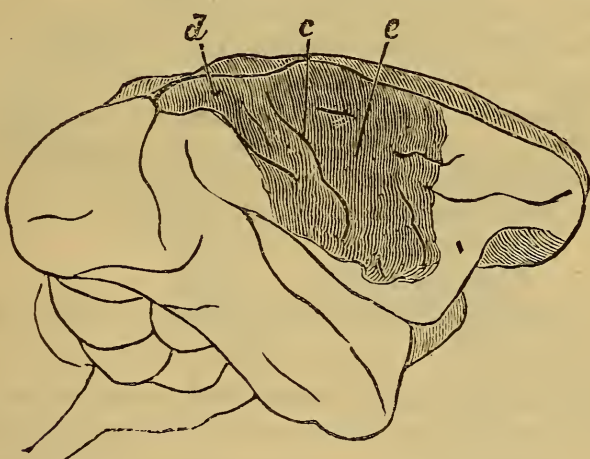


FIG. 181.—Lateral View of the Brain of a Monkey, showing the boundaries of the so-called 'motor area' of the right Cerebral Hemisphere. (Ferrier.) *c*, Fissure of Rolando; *d*, the parietal lobule; *e*, the ascending frontal convolution.

been exposed and subjected to experimentation with electrical irritation. The part exposed included the ascending parietal, ascending frontal, and posterior extremities of the frontal convolutions. The animal was allowed to recover, for the purpose of watching the effects of exposure of the brain. Next day the animal was found

better in the brief space which we can here devote to this subject to confine our observations to the results of experiments with these particular animals, though many others have been experimented upon by Dr. Ferrier.

perfectly well. Towards the close of the day following, on which there were signs of inflammatory irritation and suppuration, it began to suffer from chronic spasms of the left angle of the mouth and left arm, which recurred repeatedly, and rapidly assumed an epileptiform character, affecting the whole of the left side of the body. Next day left hemiplegia had become established, the angle of the mouth drawn to the right, the left cheek-pouch flaccid and distended with food, which had accumulated outside the dental arch; there being almost total paralysis of the left arm, and partial paralysis of the left leg. On the day following the paralysis of motion was complete over the whole of the left side, and continued so till death, nine days subsequently. Tactile sensation, as well as sight, hearing, smell and taste were retained. On *post-mortem* examination it was found that the exposed convolutions were completely softened, but beyond this the rest of the hemisphere and the basal ganglia were free from organic injury . . . . . . In this we have a clear case, first, of vital irritation producing precisely the same effects as the electric current, and then destruction by inflammatory softening, resulting in complete paralysis of voluntary motion on the opposite side of the body, without affection of sensation."

The important observation previously made by Hughlings Jackson that irritative disease of the corresponding region of the Brain, or of some part of it, in the human subject, is specially apt to be associated with a liability to unilateral convulsions, complete or partial, of the opposite side of the body, was thus verified so far as it could be by these experimental observations upon the Monkey. There is reason for believing, also, that destructive disease of the Cerebral Convolutions in this region may lead, in the human subject, as it did in the monkey, to a condition of complete **Hemiplegia**. In each, therefore, both in man and monkey, irritation of certain surface regions of one of the Cerebral Hemispheres is followed by choreiform twitchings or by actual Convulsions on the opposite side of the body, whilst destruction of the same parts is followed by an opposite unilateral Paralysis. Irritation and destruction of other regions of the surface of the brain in Monkeys, were followed by no such excitations or abolitions of Movements.

Details cannot here be given as to the effects produced by localized irritations or destructions of limited parts of the Convolutions within this 'excitable area.' For these the reader is referred to Chap. viii. of Ferrier's work. The principal conclusions at which he has arrived may, however, be gathered from a careful study of Figs. 182, 183,

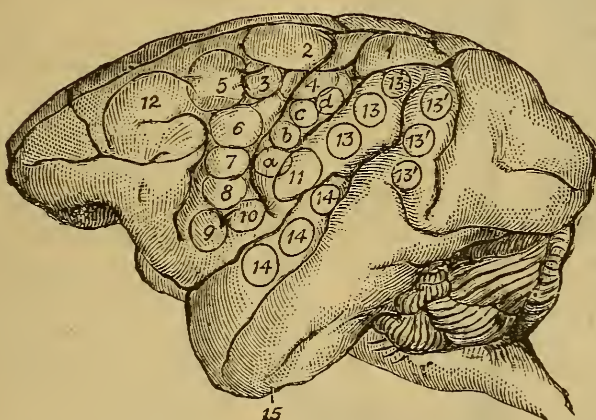


FIG. 182.—Lateral aspect of Monkey's Brain, showing the relative positions of the so-called 'Motor Centres' in the left Cerebral Hemisphere. (Ferrier.) For references see Text, and also Fig. 172.

in which, as a result of his investigations, the seats of the different supposed 'centres' for special Movements are indicated. They are as follows:—

(1.) Centres for movements of the opposite leg and foot, such as are concerned in locomotion—in *postero-parietal lobule.*

(2, 3, 4.) Centres for various complex movements of the arms and legs, such as are concerned in climbing, swimming, &c.—in the *convolutions bounding the upper extremity of the fissure of Rolando.*

(5.) Centres for the extension forwards of the arm and hand, as in putting forth the hand to touch something in front—in *posterior extremity of superior frontal convolution.*

(6.) Centre for the movements of the hand and forearm in which the biceps is particularly engaged (viz., supination of the hand and flexion of the forearm)—*near middle of ascending frontal, opposite posterior extremity of middle frontal convolution.*

(7 and 8.) Centres for the elevators and depressors of the angle of the mouth—*in lower end of ascending frontal convolution.*

(9 and 10), included together in one, is said to be the centre for the movements of the lips and tongue, as in articulation—*in posterior extremity of the lower or third frontal convolution* ('Broca's convolution').

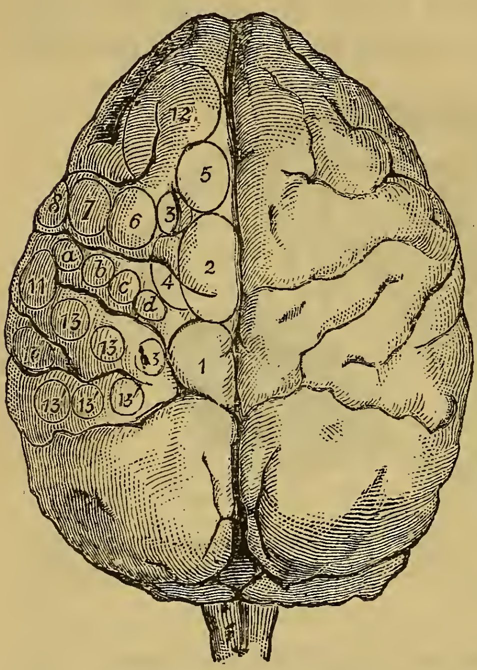


FIG. 183.—Upper aspect of Monkey's Brain, showing the relative positions of some of the so-called 'Motor Centres,' in the left Cerebral Hemisphere. (Ferrier.) For references see Text, and also Fig. 172.

(11.) Centre for retraction of angle of mouth—*in supra-marginal convolution, near lower end of ascending parietal.*

(12.) Centre for lateral movements of the head and eyes, with elevation of the eyelids and dilatation of the pupil (attitude of 'attention')—*in posterior parts of upper and middle frontal convolutions.*

(*a, b, c, d.*) Centres for movements of the hand and wrist—*in the ascending parietal convolution.*

The relative position of these supposed 'motor centres' in regard to two of the most important alleged 'sensory centres' is also shown in Fig. 182, in which the circles 13 and 13′ indicate what is regarded by Ferrier as the Visual Centre (*in the supra-marginal lobule and the angular gyrus*), whilst the circles 14, 14 indicate the situation of the Auditory Centre (*in the upper temporal convolution*). The centres of Touch, Smell, and Taste are, as we have previously mentioned (pp. 535–540), believed to be located in convolutions on the inner aspect and tip of the Temporal Lobe.

As an example of the kind of evidence upon which the above-mentioned localizations in regard to Special Movements have been made, one of Ferrier's experimental observations bearing upon this point may be quoted.

"The left hemisphere of a monkey was exposed in the region of the ascending frontal convolution sufficiently to display the centre of bicipital action [fig. 182, 6] or supination and flexion of the forearm. The exact spot being determined by the application of the electrodes, it was then accurately cauterised, just sufficiently to destroy the cortical grey matter. This operation immediately manifested itself in paralysis of the power of flexing the right forearm. All the other movements of the limbs were retained, but when the right arm was placed in an extended position the animal was utterly powerless to flex it, and the limb hung in a state of flaccid extension when the animal was lifted . . . . . It raised things to its mouth with the left hand, the movements of the leg were intact, there was no facial paralysis, and cutaneous and other forms of sensation were unimpaired."

Whether or not the various details, of which brief indications only have been given, are destined to be confirmed by other investigations, it seems pretty clear (notwithstanding all which has been said in an adverse sense) that experimental observations on Monkeys, as well as clinico-pathological data gathered from the study of the effects of disease in Man alike support the notion that certain 'excitable regions' of the Cerebral Cortex exist in each Hemisphere, the irritation of which produces Choreic or Convulsive Movements of the opposite side of the body, and the destruction of which gives rise to Paralysis of corresponding parts of the body. This 'excitable area' (figs. 172, 182) comprises the convolutions which border on or are adjacent to the 'fissure of Rolando,' viz., the ascending frontal and parietal convolutions, the postero-parietal lobule, and the posterior portions of the three tiers of frontal convolutions.

It seems safe to infer, therefore, that these portions of the Brain are *in some way* related to the production of Movements. The evidence pointing to such a conclusion is, indeed, precisely similar in kind to that which leads to the inference that the Corpora Striata are concerned with the production of Movements.

It is important, moreover, to mention that Burdon Sanderson* and others have shown that the same special Movements which follow irritation of special limited portions of the Cortex may also be evoked, after removal of this cortex, on stimulating corresponding regions of the subjacent white substance, or even by stimulating portions of the surface of the Corpora Striata themselves.

It may therefore be regarded as fairly well-established that the great majority of stimuli for the incitation of Movements of the Voluntary and Ideo-motor types pass off from the regions above specified of the parieto-frontal Grey Matter; that they traverse the intervening 'white substance' to reach the Corpus Striatum of the same side, thence to pursue the course already indicated through the Cerebral Peduncle, the half of the Pons and Medulla, to the opposite half of the Spinal Cord—from whose anterior horns of Grey Matter the continuations of such cerebral stimuli pass away by the 'anterior roots' and 'motor nerves' to appropriate groups of Muscles.

So that if, since David Hume's time, we still have not learned, in any full sense of the term, "the means" by which "the motion of our bodies follows upon the command of our Will," we have at least learned something as to the parts chiefly concerned, and thus as to the paths traversed by Volitional Stimuli. And this constitutes an important advance in our knowledge of the mode of action of the Brain as an Organ of Mind.

* "Proceed of Royal Society," June, 1874.

The next question that arises is as to the most correct interpretation of the newly discovered facts. What are the functions or modes of activity of these portions of the Cerebral Cortex whence the stimuli emanate which are to excite special Voluntary Movements?

Various answers have been given in reply to this question. We have (*a*) the hypothesis of Ferrier, that the results depend upon the existence of 'motor centres' for Volitional Movements in the cerebral convolutions; (*b*) the hypothesis of Schiff, that the Movements of the limbs resulting from stimulation of the cortical 'centres' are of a 'reflex' nature, and that the affection of Motility dependent upon the destruction of the same parts is essentially an 'ataxy' resulting from loss of Tactile Sensibility; and (*c*) the hypothesis of Hitzig and Nothnagel, that the convolutional areas in question are either the 'muscular sense' centres, or parts traversed by 'muscular sense' impressions.

(*a*.) The hypothesis of Ferrier is so important in itself, has been so ably advocated by him, and already numbers so many adherents, as to make it desirable that we should examine his views pretty closely.

The following passages have seemed to the writer to embody the most important statements and views adduced by Ferrier in his work on "The Functions of the Brain," in support of his position that 'motor centres' exist in the Cerebral Convolutions.*

(1.) "The entire removal of the [cerebral] hemispheres operates differently in different classes. In the fish, the frog, and the pigeon the removal of the hemispheres exercises little or no appreciable effect on the faculties of station and locomotion. Under the influence of stimulation from without, these animals swim, jump,

* The passages have been arranged in paragraphs and numbered, merely for the purpose of facilitating reference to the various statements contained therein.

or fly with as much vigour and precision as before. In the rabbit the removal of the hemispheres, while decidedly impairing the motility of the fore limbs, does not quite destroy the power of station, or of co-ordinated progression in answer to external stimuli. . . . . . In the dog, however, the removal of the hemispheres exercises a much more marked influence on these powers, rendering station and locomotion absolutely impossible" (p. 207).

(2.) "In proportion, however, as movements at first requiring volitional education tend to become organized or rendered automatic, the less are they affected by injury to the cortical centres. Hence in the dog, in which the acquisition of the control of the limbs is speedy, the destruction of the cortical centres produces a much less marked effect; the movements having become in a great measure independent of these, through organization in the subordinate centres" (p. 213). "In the optic thalamus and the corpus striatum the association between certain impressions and certain actions becomes so mechanical or organized that if we were to remove from the dog all the centres above the basal ganglia, these would of themselves, on the application of external stimuli, be sufficient to carry out all the co-ordinated movements of locomotion" (p. 214).

(3.) "The more the control of the limbs depends in the first instance, and continues to be dependent on voluntary acquisition, the more does destruction of the cortical motor centres cause paralysis of movement. Hence in man and the monkey, in whom volition is predominant and automaticity plays only a subordinate part in the motor activities, destruction of the motor centres of the cortex causes paralysis of a very marked character" (p. 213).

The facts cited in paragraph (1) are important, unquestionably true, and in part well known. They merely tend to show, that in higher forms of life the Cerebral Hemispheres with the Corpora Striata gradually take on some of the functions which in lower animals have been discharged through the intermediation of Medullary and Spinal Centres. The Cerebral Hemispheres in higher animals come to exercise, therefore, a larger proportionate share of influence in the execution even of the common movements needed for Locomotion.

The statements made in paragraphs (2) and (3), though they may be perfectly true, lend no special support to the doctrine of Hughlings Jackson and of Ferrier. They are equally or even more in accord with the views expressed in this chapter. The damage or removal of parts of the Brain concerned to a large extent with the Intellectual direction of Movements, of parts which are accustomed in the most direct manner to call into activity the Corpora Striata (the great motor ganglia of the Hemispheres), would necessarily interfere with the performance of each of such Movements precisely in proportion to the need for intellectual guidance in order to ensure its execution. The destruction of such cortical areas, in fact, puts the Corpora Striata themselves out of court, for the execution of all Movements except those which are at once simple and 'automatic.' Hence it is that the facts above cited lend no exclusive support whatever to the notion that 'motor centres' exist in the Cerebral Convolutions.

In the following paragraphs Ferrier sets forth certain developments or corollaries from his doctrine.

(4.) "The dog from which the cortical motor centres alone have been removed is, however, in a very different position. It retains its sensory centres, and is a conscious sentient animal, and is capable of ideation and emotion. It is not merely a mechanism, the activity of which is dependent purely on external stimulation, but has within itself the springs of action in the mediate form of revived or ideal impressions, and is thus capable of spontaneous action. As, however, the revived impressions occupy the same place, or coincide with the physiological activity of the same parts as are engaged in the consciousness of present impressions, the revived impressions can throw the automatic apparatus of movement into action just as well as immediate or present impressions" (p. 214).

(5.) "In the dog deprived of its cortical centres the path from impression to action is not, as in the ordinary course of volition, through the cortical motor centres to the Corpus Striatum, and thence downwards to the motor nuclei and motor nerves, but through the basal ganglia directly" (p. 215).

The suggestion here made that the 'way out' from the cerebral cortex is different in the case of Voluntary from what it is in Ideo-motor Movements has never been proved, and is directly contra-indicated by all that we know concerning Speech and its defects. The few difficult phenomena to be explained in reference to Emotion as an instigator, in cases where Speech is otherwise lost, does not warrant the statement above made that in Ideo-motor and Emotional Acts generally the 'way out' is "through the basal ganglia directly." This statement is, to say the least, hypothetical and vague; nor is it correct to say that revived impressions "can throw the automatic apparatus of movement into action *just as well as* immediate or present impressions." They are proverbially weaker, and, therefore, less potent incitors of Movement. And, unless the supposition that there is a distinct way out for Ideo-motor and Emotional Stimuli is better founded than it appears to be, they could not act at all in the case supposed. Dr. Ferrier must either make all these points much clearer, or else he must give up the attempt to explain a fact so damaging to his hypothesis as that of the recovery of motor power in the dog after the removal of what he regards as its "voluntary motor centres." The close relationship existing between the Voluntary and Ideo-motor modes of stimulation to Movement, does not seem to have been adequately appreciated by Ferrier.

Again, he says :—

(6.) "A dog, therefore, deprived of its cortical motor centres may yet be capable of spontaneous action and co-ordinated locomotion, under the influence of present or past impressions, or of emotional states. Only such movements, however, will be excited as have been automatically organized in the corpora striata. The movements of locomotion having become automatic may thus be easily effected, and the dog may be able to walk with as much apparent steadiness as before."

(7.) "The Corpus Striatum is the centre in which movements primarily dependent on Volition proper tend to become organized" (p. 214).

(8.) "It may be confidently asserted, and perhaps it may be one day resolved by experiment, that any special tricks of movement which a dog may have learnt would be as effectually paralyzed by removal of the cortical centres as the varied and complex movements of the arm and hand of the monkey by the same lesion.' Such forms of activity "as are not habitual, and have not become automatic, would be rendered impossible" (p. 215).

There are good reasons for believing, that no such definite distinctions exist between Voluntary and Automatic Movements as are postulated by Ferrier. It seems not only unnecessary but altogether unphilosophical to look for the nervous 'organizations' pertaining to Voluntary Movements in centres altogether apart from those in which Automatic Movements are 'organized.' The Voluntary Movements of one set of generations tend to become the Automatic Movements of remote progeny in subsequent generations. In the intervening periods less and less will depend upon higher Cerebral Influence—or, in other words, upon Intellectual guidance.

Ferrier* seems to us to start with a fundamental misconception in supposing, in reference to Cortical Centres, that those "immediately concerned in effecting volitional movements" are "as such truly motor"; or that because Voluntary Movements are paralyzed after the destruction of these parts, we have in this fact evidence to show that they are "motor centres." If 'Will' or Volitional Stimuli are not altogether independent and self-begotten entities—and this Dr. Ferrier is far from believing—they can only

* Loc. cit. p. 260.

be regarded as taking origin from the organic seats of Perceptive and Intellectual Actions. As Spinoza pointed out over two centuries ago, "The Will and the Intelligence are one and the same thing"—viewed, however, from a slightly different aspect.

(*b.*) According to Schiff and others, the parts deemed 'motor centres' by Ferrier are rather to be regarded as centres of Touch. The movements of the limbs which result from stimulation of these centres, they consider as of a 'reflex' nature; whilst the affection of Motility resulting from their destruction is supposed to be of an 'ataxic' order and occasioned by loss of Tactile Sensibility.

Against this explanation, there is the fact that injury to such regions of the surface of the Brain do not appear to cause, either in the lower animals or in Man, any distinct impairment of the sense of Touch; neither does it appear to be true, as was formerly believed, that mere loss of Tactile Sensibility, even if it did exist, would of itself cause either ataxic or paralytic symptoms. The evidence furnished by persons suffering from complete Hemi-anæsthesia, as well as that occasionally supplied by persons suffering from some forms of 'locomotor ataxy,' seems to show that loss of Tactile Sensibility alone causes no appreciable interference with the Movements of the affected parts. This is the opinion of Charcot, of Broadbent, and others, and it is entirely confirmed by the writer's own examination of the celebrated Hemi-anæsthetics of 'la Salpêtrière' when visiting Prof. Charcot's wards last autumn.* The evidence that formerly seemed to support the opposite opinion, and with which Ferrier appears to have been still

* For an account of these patients see "Brit. Med. Journal," Oct. 12, 1878. *See* also Ziemssen's "Cyclopædia," vol. xiii. p. 88.

impressed at the time of the publication of his work, is unquestionably defective, and stands in need of revision.

(*c.*) According to Hitzig, and also to Nothnagel, the affection of Motility resulting from the destruction of the cortical regions in question is due to a paralysis of the animal's 'muscular sense.' Nothnagel thinks the fact of the recovery of Movement after a time in dogs proves that the centre of the 'muscular sense' is not itself destroyed, but that the destruction of the particular regions of the cortex has sufficed to interrupt, for a time, and not far from their termini, the paths for such ingoing impressions. Hitzig, on the other hand, seems more inclined to believe that the centre itself ('End-station') for impressions of the 'muscular sense' or 'muscle-consciousness' is destroyed by the experimental lesions. Or, if this be not the case, he, like Nothnagel, is disposed to believe that the afferent path from muscle to 'mind' is in some way interrupted. Both these investigators, in further support of their notion, say that the condition of the animal, in regard to Motility, is somewhat similar to that of a Man who is suffering from the disease known as 'locomotor ataxy.'

Ferrier, in opposition to this view, contends that "loss of the muscular sense without any affection of the other forms of common or tactile sensibility is a condition the existence of which is purely hypothetical." He further considers that no investigations bearing upon the subject have furnished the slightest evidence of impairment or loss of Touch or Common Sensibility when his so-called 'motor centres' have been destroyed: hence he infers that the 'muscular sense' has also remained unimpaired (*see* p. 69). The affection of motility met with after destruction of the so-called 'motor centres,' he says,—" only resembles ataxia in the case of the cat, dog, &c.; but in man and the monkey the resemblance fails, for in these there is complete motor paralysis, with distinct retention of the pristine sensibility to the various forms of cutaneous stimulations. The argument from mere resemblance is thus seen to fail when a wider comparison of instances is made. But, further, it has been shown that the condition which may with truth be described as loss of muscular sense or of muscle-consciousness is dependent on lesion of a totally different part of the brain, *viz.*, the hippocampal region, or centre of tactile consciousness."*

These objections of Ferrier to the views of Nothnagel and Hitzig do not seem to us to have nearly as much cogency as he supposes. Our knowledge in regard to several of the points touched upon by him is far from complete, but the evidence at present in our possession may be interpreted quite differently. Thus, the observations of Landry, as well as the case of Demaux † when contrasted with that of ordinary hemi-anæsthetic patients, make it probable that unconscious 'muscular sense' impressions, in the restricted sense of that term, have a distinct existence, and probably a cerebral 'locus' of their own, quite apart from Tactile Impressions, whatever may be the region of the Cortex to which the latter are specially distributed. The paths for these two classes of Impressions, *viz.*, those from Muscles and those from Skin, seem to be topographically distinct in the Spinal Cord; they are probably more or less contiguous in the Cerebral Peduncles; whilst they may subsequently diverge again and go to different, though functionally related, Cerebral Convolutions, rather than to the same cerebral region as Ferrier seems to suppose (*see* p. 544).

The Cerebral Cortex is, in our view, to be regarded as a continuous aggregation of interlaced 'centres,' towards which

* Loc. cit. p. 218. † See Appendix, p. 700.

ingoing Impressions of all kinds converge from various parts of the body: here they come into relation with one another in various ways, and conjointly give rise to nerve actions, which have for their subjective correlatives all the Sensations and Perceptions, all the Intellectual, and all the Emotional Processes which the individual is capable of experiencing. From these terminal and complexly related 'end-stations' for ingoing currents, and from certain annexes in connection therewith, outgoing currents issue, which rouse in definite ways the activity of the highest 'motor centres' (the Corpora Striata and Cerebellum), and through them evoke the properly adjusted activity of lower motor combinations, so as to give rise to any Movements that are 'desired,' or which are accustomed to appear in response to particular Sensations or Ideas.

The plan on which Nerve Centres generally are constructed, of whatsoever grade, makes it essential that the stimulus which awakens the activity of a 'motor' ganglion or centre shall come to it through connecting fibres from a 'sensory' ganglion, centre, or knot of cells—that is, from cells which stand in immediate relation with ingoing fibres (see p. 26).

If we turn to the very simple nervous system of a Slug (fig. 27) we find two upper Sensory Ganglia, connected by distinct 'commissures' with two conjoined Motor Ganglia. It can scarcely be doubted that stimuli (as sequences of the nervous processes concerned with Sensations) are accustomed to pass from these Sensory Ganglia along the 'commissural' fibres uniting them with the Motor Ganglia, and that, in accordance with their different origins or starting-points, these stimuli may cause the latter Ganglia to evoke distinctive muscular contractions in various parts of the body. Could we galvanize separately the several sensory ends of these 'internuncial' fibres we should doubtless evoke similar Movements. But would such facts entitle us to infer that these Sensory Ganglia contain 'motor' Centres? Assuredly not: no more than we should be entitled to call the 'sensory cells' on the ingoing side of a simple mechanism for some Reflex Action 'motor cells,' simply because a stimulus issues from them which ultimately evokes the Movement—that is, after it has passed through other nerve elements which, by common consent, are regarded as 'motor cells.'

The nervous fibres that extend from the Cerebral Cortex, in higher animals and in Man, down to the Corpora Striata are, in their nature, strictly comparable with the fibres connecting the 'sensory' and the 'motor' Cells in an ordinary nervous mechanism for Reflex Action. Such currents from 'sensory' cells may pass in the same horizontal plane, they may have to ascend, or, as frequently happens, they may descend to 'motor' cells situated at a lower level.*

The Corpora Striata, conjointly with the Cerebellum, are doubtless specially called into activity by the Cerebral Cortex, in ways which are most important though they cannot be precisely defined. These organs, as we

* On account of the variability of this relation, therefore, such nerve fibres cannot be considered to be invariably in relation either with 'ingoing' or with 'outgoing' currents. We may distinguish them by the name of 'internuncial fibres,' with the understanding that in different parts of the Nervous System currents are transmitted along them in an ascending, a horizontal, or in a descending direction. Still, as the stimuli emanating from the Sensory Centres and their annexes in the Cerebral Cortex, at once take a downward direction to the Corpora Striata, it will be most convenient in this case, to speak of the origin of 'outgoing' currents as being from the Cerebral Cortex itself, and to regard certain of its Centres as occupying what has been aptly termed the 'bend of the stream'—that is the regions where 'ingoing' currents end or give place to 'outgoing' currents.

contend, are the great motor ganglia through which cortical stimuli resulting from so-called 'Volitional' or Intellectual guidance operate. If, indeed, what has been set forth in this chapter gives anything like a true account of the relations existing between Voluntary and Automatic Movements, not another word need here be said against the general point of view upon which Hughlings Jackson and Ferrier rest their hypothesis as to the existence of 'motor centres' in the Cerebral Cortex, nor against the view that the mechanisms for Voluntary Movements are 'organized' in regions altogether apart from those concerned with the execution of Automatic Movements.

What has been said in the earlier parts of this chapter in reference to the origin and nature of 'Volitional' stimuli, together with what has been stated above, make it possible to explain the results of irritation and destruction of certain fronto-parietal areas of Grey Matter and of the white matter intervening between them and the Corpora Striata, without in the least countenancing the supposition that 'motor centres' exist in the Cerebral Convolutions.*

The Centres in question are rather 'sensory' in nature, and are probably intimately concerned with certain groups of Kinæsthetic Impressions—whatever other functions they may subserve, or with whatever other centres they may be in intimate relation. We have, indeed, seen

* We have here, in fact, to do with a misconception very similar in kind to that which previously led Foville and others to regard the Cerebellum as a Sensory Organ (p. 504) simply because 'internuncial fibres' enter it from various sensory nuclei or ganglia. To argue that groups of cells have motor functions, merely because stimuli issuing from them evoke movements when they impinge upon motor ganglia, is quite on a par with the argument that an organ has sensory functions because fibres come to it from sensory cells.

reason for believing that the Kinæsthetic must be in the closest functional relationship both with the Visual and with the Auditory Centres. From one or more (but perhaps more especially from the first) of these inter-related Perceptive Centres or their annexes, 'internuncial fibres' issue, by which they are brought into functional relations with the great underlying motor ganglia—the Corpora Striata.

Stimulation of certain sets of such 'internuncial fibres' should produce special Choreic or Convulsive Movements; destruction of them should produce Paralysis; and, looking to the direction in which they transmit their stimuli, analogy would lead us to infer that the severance of their connections with cortical nerve-cells might lead to small bands or tracts of 'descending degenerations' between the seats of such severance and the corresponding Corpus Striatum—yet these are the results the occurrence of which is so confidently relied on by some in support of the 'motor' functions of such portions of the Cerebral Cortex.

CHAPTER XXVII.

CEREBRAL MENTAL SUBSTRATA.

After the first ' Sensation ' nothing strictly answering to this term exists. We only consciously realize any impression, as of such and such a nature, by automatic comparison of it with other impressions which have gone before it. A simple ' Sensation ' can, in fact, scarcely exist in consciousness, nor can it be imagined by us in our present phase of mental evolution. Our so-called ' Sensations ' are really Perceptions. In one and the same act or state each of them embodies Feeling and Intelligence in indissoluble connection.

A seat of ' simple ' or ' brute ' Sensation is, therefore, not to be looked for. The seats of conscious sensibility in the only intelligible phase in which such states can exist for us are centres for Perception*.

As the act of Perception involves the automatic comparison of present impressions with revived past impressions of the same kind, as well as of some or all other kinds of impressions capable of being yielded by the Object perceived, it happens that even in the simplest so-called ' Sensation ' the conjoint activity is necessitated of no one limited tract of convolutional grey matter—but rather of widely extended cell-and-fibre mechanisms corresponding, it may be, with many more or less diffused and complexly related Perceptive Centres (p. 522).

Seeing that each Perceptive Centre forms the basis or starting point of different processes of Ideation, and,

* See pp. 176, 524, and " Nature," Jan. 20, 1870, p. 309.

therefore, of Thought, and that the several centres must have the same kind of relation to Emotion, we may find therein additional reason for the belief that the different Perceptive Centres are diffuse in seat, and that widely separated parts of the Cerebral Hemispheres are probably knitted together for simultaneous action even in the simplest sensory Perception—containing, as this process does, the germs of Thought and Emotion, to say nothing of 'Volition'.* And although these diffuse, but functionally unified, nervous networks may differ much from ordinary 'Centres' (owing to their assumed lack of topographical distinctness and exclusiveness), it is still convenient to be able to refer to such networks as 'Centres.'

But in addition to the complex perceptive mechanisms in relation with the 'five senses,' there are also other Cerebral Centres for ingoing impressions, some of which are, when in action, habitually attended by more or less of Consciousness, whilst others are as constantly devoid of any such accompaniment. Yet all these 'Centres'—quite irrespective of the degree of vividness of the subjective accompaniments dependent upon their activity—are probably situated in some portions of the Cerebral Cortex.†

* See Dr. Lombard, "On the effect of Intellectual and Emotional Activity on the Temperature of the Head," in "Proceed. of Royal Society," 1878, p. 462.

† Among these a 'sense of Space' Centre ought, perhaps, to be included, the activity of which would, however, be of less importance for Man than for many of the lower animals (pp. 214–219). The instinctive and untaught migrations of young Birds may depend much upon the automatic activity of this Centre, and are phenomena of the same order as the instinctive fear of the young Turkey on hearing the cry of the Hawk (p. 189), or the instinctive appreciation of food and distance which enables the young Chick to snap at and capture a Bee (p. 188). In all these cases we have to do with automatic Perceptions, as well as with Automatic Movements.

There are, in the first place, termini for the important class of Visceral Impressions which, so far as they are connected with the animal's 'life of relation,' are divisible into two main categories—the Alimentary and the Genital. The parts of the Visceral Centre appertaining to these sets of impressions are the cerebral foci in relation with two all-powerful 'appetites'. They must, each of them, be in intimate connection with the special Perceptive Centres, whose activity is conjointly roused during the times of recurrence and active manifestation of the various Instincts of lower animals, as well as during the various phases of human passion and action which are immediately or remotely connected with such Visceral Impressions.

Differing altogether from the foregoing Impressions, both 'special' and 'visceral' (though their related physical mechanisms may be inextricably intermixed), we have another great class of Impressions—viz., those of **Kinæsthesis.** Here we are not concerned, except indirectly, with impressions made upon the external or internal surfaces of the Organism. Such impressions evoke Movements, and these in their turn occasion various ingoing impressions. Some of these latter Kinæsthetic Impressions (such as those occasioned by the contractions of the Heart and of the Alimentary Canal) give rise in the healthy human being to no recognizable phase of Consciousness: it is even doubtful whether some of them ever reach the Cerebrum. Other of these impressions, however—especially in cases where Muscles are called into play voluntarily in unaccustomed actions, and where the Movements produced affect large Joints or tracts of Skin—give rise to more or less distinct states of Consciousness, and thus place it beyond all reasonable doubt that such impressions reach the Kinæsthetic Centres in the cortex of the Hemispheres.

It is of importance to remember, concerning this last Sense-endowment, that part of its impressions are distinctly Tactile in nature, and as such are probably realizable, or have their organic seats, in portions of the Tactile Centre; and that those of them which are least attended by Consciousness are probably the impressions emanating from the Muscles themselves. These last components of the many-sided Kinæsthetic Sense correspond, in the main, with what has been erroneously termed 'muscular consciousness,' or with the 'muscular sense' in the most limited acceptation in which this latter term has been used.

The occurrence of Movement is for the Kinæsthetic Sense, what the presentation of an object is to the Visual Sense; and the inability to cognize the impressions occasioned by Movement (either those that are conscious, those that are unconscious, or both) which is sometimes produced by certain morbid conditions, is a defect of the Kinæsthetic Sense altogether analogous to 'blindness' in relation to the Sense of Vision. To speak therefore, as Ferrier does,* of this sequence of Movement and the Sensations thereby induced, as a "sensori-motor association," is altogether to miss and invert the real significance of the phenomena to which he refers.

The impressions coming from every one of the 'special' Sense Organs are, in part, dependent for their various combinations upon the Movements of such organs, and for this, as well as for other reasons subsequently to be referred to, the connections existing between the several 'perceptive centres' for such impressions (especially those of Touch and Sight), and the Kinæsthetic Centre must be peculiarly intimate and complex.

Each 'special' Perceptive Centre and also the 'visceral'

* Loc. cit. p. 268.

Centre may, at times, and according to the nature of the stimulus, form the starting point both in '**sensori-motor**' and in '**ideo-motor**' **Acts**, whence outgoing stimuli issue to rouse the Motor Centres. But whether these impulses pass off from such 'special' or 'visceral' Centres directly, or whether (without our consciousness) they pass from them to, and then off from, some parts of the Kinæsthetic Centres must be considered to remain, for the present, very uncertain.

On other occasions, either of the 'special' Perceptive Centres may receive impressions which form the initial starting points of currents ending in **Voluntary Acts**; though the immediate execution of the Movement thus prompted may, in the case of the majority of limb-movements, be dependent upon the secondarily excited guidance of co-active Visual and Kinæsthetic Centres—just as in the case of the complex movements concerned in Articulate Speech, the immediate execution of such movements is dependent upon the regulative activity of the combined Auditory and Kinæsthetic Centres.*

Owing to the great preponderance of movements of the right arm and hand, as compared with those on the left side, the Kinæsthetic Centre of the left Cerebral Hemisphere would be much better developed, in the great majority of persons, than that of the right Hemisphere. The impressions of the Kinæsthetic Sense are, in this respect, precisely like those of Touch—and these two kinds of sensory endowments, as we have seen, merge into one another so imperceptibly as to make it, in part, impossible to separate their Cerebral Centres from one another.

This preponderating activity of the left Cerebral Hemisphere in regard to Tactile and Kinæsthetic Impressions (about which there is no room for doubt) may have some-

* See p. 555, and Chap. xxix.

thing to do with another fact, viz., that the left Hemisphere is the most potent, and seems to take the lead in giving rise to the Voluntary Impulsions which determine the muscular acts involved in Articulate Speech.*

In regard to our 'ideas' of Words—the symbols with which our Thoughts are inextricably interwoven—these are, for the most part, complex, the components (as in the case of simple Perceptions) being dependent upon the activity of different Centres—which need not always act together—and in their order of importance are probably to be enumerated as the Auditory, the Visual, and the Kinæsthetic.

Of these modes of 'ideal' recall of Words, the two former are distinct and easily recoverable, while the latter is characteristically vague and difficult of conscious realization. Let any one contrast his idea of the sound of the word 'London,' or his idea of the appearance of the word when printed or written, with his idea of the muscular and other feelings associated with the articulation of the same word, and the inferiority in definiteness and recoverability of the latter will at once become obvious. There is nothing surprising in this, however, since we know that the tendency of Kinæsthetic Impressions generally is that they should, like Visceral Impressions, soon come to affect the motor machinery of our bodies without arousing our Consciousness. In such animals as are born with their motor acquirements already well-nigh complete (pp. 188, 229), Kinæsthetic Impressions probably enter as little into their conscious Mental Life as multitudes of Visceral Impressions enter into our own.

Speech has already become, for the human race, a

* See p. 403, and also Dr. Lombard in "Proceed. of the Royal Society," 1878, pp. 463, 464.

much more 'instinctive' act than Writing, so that it is merely a result of the tendency above alluded to that the Kinæsthetic Impressions, pertaining to the more deeply ingrained motor acts, have become proportionately more vague and irrecoverable. Be this explanation correct or not, the fact itself is obvious. Let any one shut his eyes, place his fingers in the position for writing, and make in the air such movements as would be needed for writing the word 'London;' immediately afterwards let him articulate the same word and compare, in regard to relative distinctness, the two sets of Kinæsthetic Impressions. The difference appears to the writer to be most marked.

The fact that Thought in a child, or in an 'absent-minded' person, is apt to be accompanied with muttered Articulations may be easily understood when we consider to what an extent Speech soon becomes a mere reflex or 'ideo-motor' act, and that the phenomenon in question occurs especially in those persons, or under those conditions, in which Volitional Control is in abeyance and reflex actions are most prone to manifest themselves. Again, that Articulation should (where it is not intended) so frequently accompany the attempt to read made by an illiterate person or by a child, is simply due to the fact that during the process of learning to read (from which they have not yet emerged), their attempts are always accompanied by vocal articulations—as in the process of reading aloud to a teacher. To stop at the mere realization of the Visual Impression, and thus undo their previous habit, is an accomplishment to which these persons and many children have not yet attained.

To speak, therefore, of the 'ideas' of Words as 'motor processes,' or to say that, "a *suppressed articulation* is, in fact, the material of our recollection, the intellectual manifestation, the *idea* of Speech," is, in the writer's opinion, both misleading and erroneous—though the latter is a view which has been put forth and advocated by no less an authority on psychological subjects than Professor Bain.* That mental representative of a Word which is least distinct and most difficult to revive (whatever may be the view entertained as to its precise nature and origin), is here declared to be of most importance in regard to Thought and Speech processes—as of so much importance that it is spoken of by Prof. Bain as constituting the "material of our recollection" in the use and production of Words, whilst no mention is in this place made of other (auditory and visual) modes of revival.

Again, relying much upon the above and allied doctrines, Dr. Hughlings Jackson† has repeatedly and in the most forcible manner, urged his own view that "*mental operations in the last analysis must be merely the subjective side of sensory and motor substrata.*" For those who hold, as Hughlings Jackson does, the view of Bain, Wundt, and others, to the effect that our Consciousness of 'muscular activity' is in great part initial, centric and realizable in the Motor Centres—this mode of expression is legitimate enough: it is, in fact, its logical outcome. But for those who wholly disbelieve this general doctrine, as Dr. Ferrier does, and who regard all sensations or impressions connected with Movement as derivable from peripheral 'ingoing' impressions emanating from the moving parts themselves, and not going back to the Cerebrum along motor nerves, such an opinion and such modes of expression would be altogether inadmissible.

* "The Senses and the Intellect," 3rd Ed., p. 336. It is true that in other parts of the same work (*e.g.*, on p. 436) Prof. Bain, in a contradictory manner, refers to sensory elements of the auditory type as the most important components of our memory of spoken language; but this in no way diminishes his responsibility for the emphasised statement above quoted. (See "Fortnightly Review," Ap. 1869, p. 493.)

† "Clin. and Physiolog. Research on the Nervous System," (Reprint), 1876, pp. xx–xxxvii.

Yet, strangely enough, this latter able writer and experimenter, whose views are likely to exercise considerable influence, seems to have been betrayed into such an inconsistency.*

If the various impressions which go to make up the Kinæsthetic Sense are all of them (as we suppose) real 'ingoing' impressions that traverse different kinds of sensory nerves, the mere difference of the mode or occasion on which they are excited, should not lead to their being spoken of as though they were radically different in nature from other sensory impressions. So that in accordance with this view, the dictum '*nihil est in intellectu quod non fuerit prius in sensu*' loses none of its old force—it is a formula broad enough to include the Kinæsthetic and Visceral as well as the Special Senses—and if incorrect, would be so as much in the one as in the other direction.

Ferrier truly says†:—"By the movements of the head and eyes we greatly extend the scope and complicate the facts of visual sensation, and by the movements of the limbs the range of tactile experience is increased a thousandfold." But he conveys (from his own previous point of view) a contradictory and erroneous implication when he adds:—"There are few objects of cognition known to us only by sensory characters or impressions. The vast majority involve the activity both of our sensory and motor faculties, and our ideas are a mixed revival both of ideal movements and ideal sensations in their respective coherent associations. This is exemplified in the acquisition and constitution of ideas of form, shape, weight, resistance and the like."

A view of this kind (viz., that 'ideal movements' have a basis other than, and wholly opposed to, that usually known as 'sensory') is one now commonly held, and is altogether similar to that taught in this country by Prof. Bain. He, for instance, when speaking of Sight, has said‡ it "is now generally considered as a mixed sense, and that the visual sensations are partly muscular feelings and partly optical feelings." He adds:—"In all that

* This may be seen by comparing Ferrier's examination of the 'muscular sense' question ("Functions of the Brain," pp. 215–227), with his views and modes of expression in Chap. xi., some statements in which are now about to be referred to.

† Loc. cit. p. 267. ‡ "Fortnightly Review," April, 1869, p. 498.

regards visible movements and visible form, the muscular consciousness, it is now contended, is the indispensable element; the optical sensations merely guiding the movements. Naked outlines, as the diagrams of Euclid and the alphabetical characters are, to say the least, three parts muscular and one part optical, their retention is supposed to depend upon the adhesive property of the ocular muscles and their nerve centres, and not upon purely optical circles. The memory of a visible form, as a rainbow, contains the consciousness of a muscular sweep; the windings of a river which, in the actual view, have to be followed by movements of the eye, are remembered as ideal movements."

Without questioning the undoubted fact, that the movements of a sensory organ must greatly increase the variety of impressions derivable therefrom, or that they may contribute notably to generate in the mind of the individual the fundamental notion of modes of existence known as 'space,' 'time,' and 'resistance,' it is nevertheless open for each one of us to form his own opinion as to the extent to which 'muscular consciousness' reveals itself to us as interwoven with our ordinary sight impressions, and many may perhaps be inclined to think they can detect far less of it than Prof. Bain. It is also open to each one of us to take a different view as to the meaning and nature of what Prof. Bain here speaks of as 'muscular consciousness.' He, we know, regards it as a 'concomitant of the outgoing current,' and upon this basis considers it to be radically opposed to all other modes of sensibility—though this is a view which others have just as decidedly rejected.

For those, however, who entertain this disbelief in the existence of a 'muscular sense' or 'muscular consciousness' as a concomitant of the 'outgoing' current, and who consider that the knowledge attributed to such an endowment has, in reality, been acquired by means of 'ingoing' impressions emanating from the moving parts themselves, the revival in idea of such knowledge must be as purely dependent upon the activity of Sensory Centres as are the processes concerned with the revival in idea of particular Odours.

The seats of revival in idea of Movements of parts of the body which are not seen (*e.g.*, those of the larynx or of the eyes), are the Kinæsthetic Centres alone; whilst in the case of Movements of parts of the body that are habitually seen—Movements which have perhaps been learned under additional guidance from Vision—

a double or mixed ideal recall occurs, partly having its organic basis in the Kinæsthetic and partly in the Visual Centres.

It seems, therefore, not a little inconsistent to find Ferrier (who rejects the doctrine of Bain and Wundt) writing as follows:—"In the same manner as the sensory centres form the organic basis of the memory of sensory impressions, and the seat of their representation or revival in idea, so the motor centres of the hemispheres, besides being the centres of differentiated movements, are also the organic basis of the memory of the corresponding movements, and *the seat of their re-execution or ideal reproduction.** We have thus a sensory memory and a motor memory, sensory ideas and *motor ideas;* sensory ideas being revived sensations, *motor ideas being revived or ideal movements. Ideal movements form no less an important element in our mental processes than ideally revived sensations.*"

There is here an obvious confusion between two totally distinct centres and processes. Ferrier, in fact, by rejecting the doctrine of Bain and Wundt in reference to the 'muscular sense,' or 'muscle consciousness,' rejected the natural basis upon which Hughlings Jackson originally founded his hypothesis, as to the existence of 'motor centres' in the Cerebral Convolutions. Yet on coming to his Chap. xi., "The Hemispheres considered Psychologically," Ferrier writes as though he had forgotten this previous rejection, and the whole discussion to which he had devoted pp. 215-227 of his work. He has, therefore, on the one hand, striven to localize 'motor centres' in the Cerebral Convolutions, and, on the other hand, he has deliberately rejected that interpretation of the philosophical and physiological evidence upon which the existence of any such centres must rest.

Motor centres, wherever they may be situated, are parts whose activity appears to be wholly free from subjective concomitants. No 'ideal' reproductions seem ever to take place in such centres; they are roused into activity by outgoing currents, and, so far as we have any evidence, the induction in them of molecular movements which, immediately afterwards, issue through cranial and spinal Motor Nerves to Muscles are simply physical phenomena.

* Italics not in the original (loc. cit. p. 266).

These processes are apparently as free from subjective accompaniments as are the actual molecular processes thereby incited in the Muscle itself. It is the altered condition of the Muscle thus induced, and of contiguous parts as occasioned by the Movement, which together engender a body of ingoing impressions, the terminus for which is the Kinæsthetic Centre. This, therefore, is a true Sensory Centre, and in it 'ideal movements' may be revived, either alone or conjointly, with related Visual Impressions.

The Kinæsthetic Centre is, indeed, one of great importance. Its impressions enter inextricably into a large majority of our mental processes—as widely and inextricably, in fact, as the assumed 'muscular consciousness' of Bain is supposed by him and others to be intertwined with what they would distinguish as 'passive' sensibilities. But it can only produce an extreme amount of confusion, if the activity of this Sensory Centre is attributed to and confounded with that of Motor Centres, the processes of which seem to lie even more truly outside the sphere of Mind than the molecular processes comprised in the actual contraction of a Muscle: these latter processes are at least immediately followed by 'ingoing' impressions, whilst so far as we know—that is so far as any evidence exists—the former are not.

The Cerebral substrata of Mind, therefore, in no way include, as the writer believes, the processes taking place in the Motor Centres of the Cerebrum, wheresoever they may be situated. Mental operations, in other words, can no longer be legitimately postulated as being, in part, immediately due to the activity of Motor Centres. Nor can 'ideal' Words be rightly described as 'motor processes.' This is a point so fundamental that in regard to it there should be no misunderstandings or ambiguities, other than those which may be inherent in the subject itself.

CHAPTER XXVIII.

SPEAKING, READING, AND WRITING: AS MENTAL AND AS PHYSIOLOGICAL PROCESSES.

The views arrived at in the last chapter will be found to harmonize well with what is known as to the mode in which the faculty of Articulate Speech, together with the superadded accomplishments of Reading and Writing, are acquired. A preliminary consideration of these subjects will, moreover, facilitate our comprehension of the various defects in the power of Intellectual Expression (whether by Speech or Writing) liable to be produced by different kinds of Brain-disease: and the study of the latter subject is most important for the psychologist. Its investigation has already revealed some very interesting facts as to the order and precise relations of various mental processes, as well as concerning their relationship to the functional activity of particular tracts of Brain-tissue. We are, indeed, in this manner afforded the nearest approach that is possible to an experimental investigation of such subjects. A close scrutiny of the necessary details will, whilst furthering our knowledge, serve also (as a result of this knowledge) to increase our chance of being able to bring amelioration to the sufferers themselves.

That Thought in all its higher modes cannot be carried on without the aid of Language is a proposition which will be almost universally admitted if we use the latter term in its broadest sense. For, as Thomson says,*

* "Laws of Thought," 1860, p. 27.

"Language, in its most general acceptation, might be described as a mode of expressing our thoughts by means of motions of the body; it would thus include spoken words, cries, involuntary gestures that indicate the feelings, even painting and sculpture, together with those contrivances which replace speech in situations where it cannot be employed." Articulate Speech, in one or other of its modes, is, however, the process which (for ordinary human beings) is found to be inseparably related with their Thinking processes. Speech is, indeed, nothing else than "a system of articulate words adopted by convention to represent outwardly the internal process of Thinking."

Taking the Human Race at the present stage of its history, when most elaborate Languages have long ago been acquired by different sections of it, we may now briefly set forth the principal steps by which individual children learn to understand one of these languages; how afterwards they learn to Speak, to Read, and to Write; and to what extent the symbols involved in these various processes recur to the Mind as the framework of Thought.

A brief sketch of the nature of the processes involved in these acquisitions was attempted by the writer in 1869, in an article* entitled the "Physiology of Thinking," and from this a few quotations may now be made.

"The young infant first begins to distinguish natural objects from one another by differences in shape, colour, touch, odour, etc., which these may present to its different senses; it is then taught (slowly and with difficulty) to associate some object possessing certain combined attributes by which it is remembered, with a certain articulate *sound* which has been often repeated whilst the object is pointed at, till by dint of continual repetition this sound (or word)

* "Fortnightly Review," January, 1869.

becomes so identified with the various attributes of the object that, when heard, it invariably recalls to memory the object of which it may now be said to form a kind of additional attribute, just as the sight or touch of the object will in turn call up the memory of the *sound* which has been employed as its designation. At first these articulate sounds (or spoken words) are only connected with external objects, though soon certain adjectives, signifying approval or disapproval, are added as qualifying sounds. By degrees the number of nouns and of adjectives in use increases, and also other parts of speech are added. . . . . . the process of learning is the same in all cases, whether the spoken sound is to be associated with an external object, with an emotional condition, or with a conception of the mind: first, it is necessary that we should be able to recollect and identify, when again presented to consciousness, either the set of attributes belonging to the object, the peculiarities of the emotional state, or of the intellectual conception; and, secondly, that we should be able to recollect the particular vocal sounds which have been associated with these several modifications of consciousness when previously existing. . . . . . This is the first stage passed through in the acquirement of a language—it is the mere learning to associate particular *sounds* with particular mental impressions, which association at last becomes so strong as to be almost inseparable, the thing unfailingly recalling to memory the sound, and the articulate sound as surely conjuring up a more or less vivid *idea* of the thing. In the process of Naming, therefore, there is involved not only a simple act of memory, but also, as Herbert Spencer has pointed out, the germ of a reasoning process in the form of a simple act of inference . . . . . it would seem pretty obvious that so far as the infant thinks by means of language, it does so by means of the *remembered sounds* of words—these are its linguistic symbols of thought, which must, however, be mixed up inextricably in its mind with other sense-impressions, and more especially with those of sight. For it may fairly be said that the great majority of children can remember the names given to many external objects when they are four or five months old; their memory in this respect continually increasing through succeeding months, even whilst they still make no very distinct effort at articulating words for themselves."

The next step is the development or acquirement by the individual child of the power of articulating for himself the sounds which have hitherto been increasingly employed as mental symbols. The potentiality of attaining to such a power the child receives, in the main, as an inheritance from so many antecedent generations of men, that its actual manifestation—the acquisition, that is, of the power of Speaking—can only be regarded as a motor achievement of an order similar to some of those which may be included among the Instinctive Acts of lower animals: the similarity being not so much with the Instinctive Acts that animals are born with the capacity of performing, but rather with those which manifest themselves a little later in life, and which (from their more gradual acquirement) might be thought not to be Instinctive Acts at all (p. 561).

A process of 'learning' to Speak intervenes in part in the former case, but it is whilst the inherited structures are undergoing development in the child's Nervous System.

"A certain order of development is always observed in the various parts of the human body, and this holds good also with regard to the several parts of the nervous system . . . . . . Even though the child acquires the power of uttering articulate sounds slowly, still when we think of the delicacy of the muscular combinations necessary, and of the almost instinctive way in which they are brought about, we shall rather be impressed with the notion that this could not have been accomplished at all had not the infant been born with a nervous system tending to develop itself in certain special directions, and thus making the performance of the highly complex muscular acts necessary for articulate speech a possibility. Slowly elaborated developments of the parts of the Medulla and of the Brain concerned in the acts of speech, we may presume had taken place in remote individuals of the parent race, as they acquired additional powers in this respect ; and the power of developing similar structural connections between nerve cells and nerve fibres, thus established, having been handed down and gradually rendered more perfect by hereditary transmission through countless succeeding generations, the infant of to-day is born, perchance, with the potentiality of developing a nervous system as complex and as perfect in this respect as any which may have preceded it in its own ancestral line." A slowly growing mechanism of this kind becomes perfected under the influence of suitable stimuli of a volitional order, which here, as in the case of the acquirement of new motor powers by an adult, have an unquestionable though an unexplained influence in bringing about the development of nerve-tissues in the Centres to which they are directed (see p. 563). "This impetus, we may presume, is given by the passage of nerve-currents downwards from those superficial portions of the cerebral hemispheres concerned in the acts of intellectual perception and of memory, to those parts which are the motor centres concerned in articulate speech."

"At first the child's articulatory capacity is confined to mimicking—that is to say, it repeats such words only as have just been spoken to it; but after a time, when the act of emitting this sound has become perfectly easy by constant repetition, the child gives utterance to it of its own accord, on the mere sight of the object with which the sound was originally associated in its mind. This then is the second stage in the acquirement of language; and the child only slowly attains to a more perfect performance of the mental and motor processes involved." After a time, however, Thought and Language become inseparably associated, so that words are voluntarily recalled by the renewal of previous nerve actions in the Auditory Perceptive Centres, and such nerve processes are followed by the complex combination of muscular actions concerned in the articulation of the several words as they arise in Thought.

Since the foregoing views were expressed and published, the writer has met with an altogether unexpected confirmation of their truth. In the year 1877 he was consulted concerning the health of a boy, the son of a leading barrister, who was then twelve years old, and had been subject to 'fits' at intervals. The first fits occurred in infancy, when the patient was about nine months old. Towards the end of the second year these fits seemed to have ceased, and the child appeared sufficiently intelligent—to be well, in fact, in all respects except that he did not talk. When nearly five years old the little fellow still had not spoken a single word, and about this time two eminent physicians were consulted in regard to his 'dumbness.' But before the expiration of another twelve months, as his mother reports, on the occasion of an accident happening to one of his favourite toys, he suddenly exclaimed, "What a pity!" though he had never previously spoken a single word. The same words could not be repeated, nor were others spoken, notwithstanding all entreaties, for a period of two weeks.* Thereafter the boy progressed rapidly, and speedily became most talkative. When seen by the writer he spoke in an ordinary manner, without the least sign of impediment or defect.†

No explanation of such facts seems possible, except on the supposition that Speech has now become a truly automatic act for human beings, and that if children do not speak at birth this is in the main due to the fact that their nervous systems are still too immature. But when, in the natural course of development, the parts concerned have become properly elaborated, the highly complex move-

* An emotional is much stronger than a volitional stimulus—a thing of higher tension—so that it may occasionally force its way along channels and against resistance which the volitional stimulus alone has been unable to overcome. Illustrations of this are frequently to be met with among persons who, from the effects of disease, have temporarily lost the power of speaking. Such individuals occasionally utter some word or short phrase under the influence of Emotion which they are afterwards quite unable to repeat.

† Although there seemed no room for doubt as to the credibility of the above narrative, still, on account of the extraordinary nature of the facts, it may be well to remark that it was completely confirmed by the governess who had previously had the care of the child, and who was present on the occasion of this first and untaught act of Articulate Speech. A proof of this sheet has also been submitted to the father, who, in reply to my enquiry as to whether anything required to be altered in the account above given, writes (Jan. 9th, 1880):—"The statement as to my boy A—— is perfectly correct." On mentioning this case to a distinguished physician, he informed me of a closely related fact. His eldest daughter up to the age of two years had not walked a step, or even tried to walk, when one day he put her down in the standing position, and to his great surprise as well as to that of the nurse, she walked from one side of the room to the other. This also was an untaught act, as there had been no previous trials and failures (see p. 562).

ments concerned in Speech may, under certain circumstances, be at once called into play, independently of previous trials and failures—just as the nervous mechanism concerned with the act of sucking may be called into play in the human infant at the time of birth, on the presentation of its proper stimulus. No such untaught acts of Speech would however be possible, unless development had been taking place in the normal manner, and unless the Auditory Sense and Intelligence were unaffected. The manifestation of attempts at Speech are supposed in this case to have been merely retarded by some slight and quasi-accidental conditions, such as are occasionally operative in childhood—especially in those who suffer from epileptic or other convulsions.

Without an instance of this sort coming almost under one's own cognizance, neither the writer nor any one else might have been inclined to bestow much credence upon two very similar cases, the records of which have come down to us from writers of antiquity.*

The son of Crœsus who, according to Herodotus,† had never been known to speak, and whose cure had been in vain attempted, was, at the siege of Sardis, so overcome with astonishment and terror at seeing the king—his father—in danger of being killed by a Persian soldier, that he exclaimed aloud—*Αηθρωπε μὴ κτέινε Κρôισον*—"Oh, man, do not kill Crœsus!" This was the first time

* The real import of these latter cases does not seem to have been apprehended, either by those originally recording them or by a modern writer who has lately referred to them (Bateman, "On Aphasia," p. 138). It need scarcely be pointed out that the sudden beginning to speak for the first time without previous prolonged trials and failures, is a matter vastly transcending in importance the sudden resumption of Speech, when it has been for a while suspended in consequence of Brain-disease.

† "Herod.," Hist. I. 85.

he had ever articulated, though he is said thereafter to have retained the faculty of Speech as long as he lived. Again, it appears that Aulus Gellius,* after repeating the above story from Herodotus, relates a similar fact in the following terms:—"Sed et quispiam Samius athleta, nomen illi fuit Αἴγλης, quum antea non loquens fuisset, ob similem dicitur causam loqui cœpisse. Nam quum in sacro certamine sortitio inter ipsos et adversarios non bona fide fieret, et sortem nominis falsam subjici animadvertisset, repente in eum, qui id faciebat, sese videre, quid faceret, magnum inclamavit. Atque in oris vinculo solutus, per omne inde vitæ tempus, non turbidè neque adhæsè locutus est."

The powers of Reading and of Writing are accomplishments superadded to that of Articulate Speech.

The child has already learned to associate certain objects, or particular states of consciousness, with definite Sounds (or Names); he has further gained the power of articulating these names for himself: so that when he begins to learn to Read, he gradually builds up a still further 'association,' by which certain written or printed hieroglyphics, representing letters in definite combinations, are linked to the already known states of consciousness (Perceptions, Ideas, &c.) and their sound representatives. The previous combinations are therefore supplemented by being correlated with new visual symbols; and it seems certain that in the act of Reading the words which are primarily perceived in the Visual Centre would almost simultaneously recall the corresponding sounds in the Auditory Centre, as part of the perceptive process involved in this act.† From the Auditory Centre

* "Noctes Atticæ," lib. v. cap. ix.

† Where this cannot occur it must be more difficult for the person to understand what is read, and, as may be seen from what follows (p. 641), it may be impossible for him to read aloud.

the stimuli inciting to the articulation of the corresponding words would then pass to the Motor Centres in precisely the same manner as in the case of ordinary Speech—whatever the precise course pursued by these stimuli may be, and howsoever they may, on their route, come into relation with those portions of the Kinæsthetic Centres that are concerned with Speech-movements.

"With reference to the process of Writing, it almost invariably happens that this accomplishment is acquired after the individual has been taught to Speak and to Read more or less perfectly. During this course of instruction the pupil learns to associate the visual perceptions of the separate letters of words with certain muscular movements of the hands and fingers necessary to enable him to produce the written letters for himself, and afterwards to join them together so as to represent words. This involves a long and tedious process of education, and the muscular movements which are ultimately learned are in all probability more intimately associated with sight-perceptions than with sound-perceptions; though of course the Word as a revived sound-perception may be said to exist also during the act of Writing. The muscles of the upper extremity being also to the fullest extent voluntary muscles, and therefore very different from those concerned in the acts of Speech, the whole process of learning to write is one which comes much more within the ken of our consciousness than does the otherwise parallel process of learning to articulate words."

We ought therefore to have much more power of recalling 'in idea', either (a) the 'volitional efforts' that were needed to enable us to Write words, or (b) that 'muscular consciousness' spoken of by Professor Bain as representing the particular states of tension of the individual muscles employed, than we could ever expect to have of the volitional efforts needed, and of the states of tension of individual muscles of the larynx and other parts involved in Articulate Speech.

But the objections to these two modifications of the view promulgated by Hughlings Jackson and others, that Words are revived in thought as 'motor processes', have been already considered (pp. 594, 691) and shown to be insuperable. We found good reasons for believing that the impressions referred to (as well for spoken and for written words as for all other muscular movements) are neither anterior to, nor concomitants of 'outgoing currents', but distinctly sequential to the passage of such currents—that they are, in fact, due to 'ingoing currents' derived from the moving parts themselves.

Looked at from this newer point of view, we may first consider the question of the degree of definiteness and recoverability of the Kinæsthetic Impressions derived from Writing-movements.

How almost impossible is any such recall to consciousness, and how vague and blank a feeling is associated with the attempt, as compared with the recall of a Visual or of an Auditory Impression, any one may easily convince himself who will make the following simple experiment. Let him close his eyes, and with pen in hand make movements in the air as though he were writing the word 'London.' He may thus assure himself that he has a set of sensations accompanying these movements. After an interval, say the next day, let him again close his eyes, and, without making any movement, attempt to recall 'in idea' the muscular and other sensations he previously experienced when writing the above-mentioned word. Let him then contrast his comparative powerlessness in this direction, with his ability to recall in idea the visual appearance of this word when written or its corresponding sound.

From this stand-point we may, in the second place, look to the relative definiteness and recoverability of the Kinæsthetic Impressions consequent upon Speech-movements. We may find then, that the Impressions which accompany actual Speech-movements for different words can only vaguely be realized as distinct from one another, and that they are certainly far less distinctive than the Kinæsthetic Impressions derived from the acts involved in Writing different words. The general rule, that the vaguer the Sensation the lower is its degree of recoverability in Idea, certainly holds good here also—as any one may discover who will make the necessary comparative trials.

Thus, slight as may be the power of recalling the Kinæsthetic Impressions derived from Writing, the ability to recall those occasioned by Speech is even less. But that there should be such a difference is no other than might have been expected, since a precisely similar difference obtains in regard to impressions from 'automatic' movements generally as compared with those of a more 'voluntary' order.

CHAPTER XXIX.

THE CEREBRAL RELATIONS OF SPEECH AND THOUGHT.

OUR powers of Perception or Apprehension, of Thinking or Reasoning, of Speaking, Naming, Writing—even of expressing Thoughts by Gestures or the simplest Signs—are all dependent upon cerebral processes very complexly interrelated, as may have been gathered from what has already been said. Much attention has of late years been given by physicians and pathologists to the investigation of disturbances of the normal relations existing between these several processes, brought about by limited lesions or injuries of different portions of the Brain. An analysis of some of the typical conditions thus revealed will throw more light than could otherwise be done upon the manner in which Cerebro-mental processes are correlated with one another. It will serve to convey some faint outline of the mode in which the higher processes of Sensory Apprehension, Thought, and Intellectual Expression (and consequently of 'Volition') are dependent upon one another, and also of the mode in which these processes are related to the activity of some imperfectly defined areas in the cortex of the Cerebral Hemispheres.

What is now to be set forth by means of illustrations selected from some of the abnormal mental conditions produced by Cerebral Disease, whilst it will suffice to test and illustrate the accuracy of the views expounded in the last chapter, may also be regarded as the continuation of what has been said in Chapters xxiv. and xxv. We

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there sought, with the light afforded by experiments upon lower animals supplemented by clinical and pathological investigation, to trace 'ingoing' impressions from their seats of origination to certain portions of the Cerebral Cortex: the regions whence Volitional and other 'outgoing' stimuli from the Cerebral Cortex were given off, were also indicated—so far as they are at present known. Our object now will be to throw some little light upon the extremely complex processes which have been superadded, or that have grown out of, the processes immediately excited in the Cerebral Cortex by the incidence of ingoing impressions—and as a result of which outgoing stimuli pass over to motor centres, for the performance of Voluntary Acts and for Intellectual Expression generally.

We shall make a faint attempt, therefore, to begin to unravel the order of the incalculably complex intermediate processes taking place in the highest nerve centre of the highest animal between the incidence of 'ingoing' and the exit of 'outgoing' currents. Such actions are to be regarded as elaborations of one median part or stage of the typical 'reflex process,' as it occurs in lower organisms or in the lower nerve centres of higher organisms.

Any attempt to gauge and understand the Mental-processes of lower animals was found to be necessarily dependent upon the study of their Actions under particular conditions. Similarly, our attempts to gauge and understand the Thought-processes of our fellow-men, must rest ultimately upon a study of their Actions, or of the results of their actions, as embodied in Speech, Writing, or other products of the movements which they have evoked for purposes of Intellectual Expression. In place of the mere emotional signs and gestures of lower animals, the accumulated results of the movements employed in Speech and Writing for generation after generation, have been available in the case of man for the building up of that great department of human knowledge known as Objective Psychology.

Our aims now, however, are different from what they were in the earlier chapters, when considering the mental processes of lower animals. We were then principally concerned with the endeavour to ascertain something as to the nature of these mental processes, in order to learn whether, or to what extent, they were similar to those of Man. It was necessary to ascertain, in fact, whether the general similarity in structure of their Nervous System, carried with it a general similarity in mode of action. But now we are not concerned so much with the estimation of the nature and extent of Man's mental powers, as with (*a*) the nature and order of the processes involved in Thought and Intellectual Expression; and (*b*) with the endeavour to refer some of these processes to the activity of definite parts of the Brain. These, in fact, are the final questions needing consideration, in order to complete our necessarily imperfect sketch of what is at present known concerning 'the Brain as an organ of Mind.'

In the first of these analytical studies we have briefly to consider some of the more typical of the various defects in Perception, Verbal Memory, Thought, and Intellectual Expression (either by Speech or Writing), which have been observed as results of disease or injury in different parts of the Cerebral Hemispheres.

The great importance of the due activity of the Auditory and Visual Preceptive Centres, and the absolute dependence of the great bulk of our intellectual perceptions, of our memory of words, and of our powers of thought, as well as of intellectual expression, upon the functional integrity and proper inter-action of these parts may have been gathered by the reader as probabilities from what has already been said (see also p. 637, footnote). These conclusions will now, however, be confirmed by illustrations drawn from the histories of certain carefully selected examples of Brain-disease.

It must continually be borne in mind by those who study these examples, that each Perceptive Centre is capable of being called into activity in three modes:—(1) By means of external Impressions; (2) by 'Association'—that is, by impulses communicated from another Centre, during some act of Perception or during some Thought-process; and (3) by 'Voluntary' recall of past impressions, as in an act of Recollection.*

The excitability of the Centres—that is, the molecular mobility of their constituent tissue-elements, may vary much with age, state of health, or different morbid conditions. Their mobility may be so much *lowered*, that they are only capable of responding to powerful stimuli; so that whilst 'Volitional' recall or Recollection may be impossible or difficult within their province, they may still be capable of acting in 'Association' with other centres (that is in an automatic manner during an ordinary process of Thought), and still more easily under the 'sensory' stimulus or external impression which is the forerunner of a Perceptive-process. At other times, the excitability of Perceptive Centres may be unduly *exalted*, so as to lead to hallucinations, illusions, and a wholly different class of defects often met with among Insane persons, but which will not here be considered.

Again, the Auditory Word-Centres, the Visual Word-Centres, and the double Kinæsthetic Word-Centres (viz.,

* These second and third modes of activity are probably closely related to one another, though we have no definite knowledge concerning the processes involved in the latter.

those in relation with the movements for Speech and for Writing) are, of course, only parts, though probably distinct and extensive parts of the respective cerebral Centres for Audition, Vision, and Kinæsthesis generally. Hence spoken words may not be comprehended though other sounds are; and again, written or printed signs may not be understood, though ordinary objects may be easily recognized through sight-impressions.

Concerning the precise functional relations of the Kinæsthetic Word-Centres with the corresponding parts of the Visual and Auditory Centres nothing is at present known—the writer, however, believes that they play little or no part in Thought. One section of them is probably called into activity principally at the instigation of stimuli emanating from the Auditory Centre for the bringing about of Articulate Speech, whilst the other section is probably called into activity principally at the instigation of stimuli issuing from the Visual Centre preliminary to the production of the movements concerned in Writing.

From this point of view the Kinæsthetic Centres would be concerned more with the expression of Thought than with the Thinking-process: their activity would only be roused as Thought is about to translate itself into Action. Thus, they may, perhaps, form the last outposts on the side of 'ingoing' currents, and be at the same time the starting-points for 'outgoing' currents. This view is quite harmonious with the fact that the processes taking place therein are almost as devoid of conscious accompaniment, and almost as irrecoverable in idea, as are the molecular processes occurring in the Motor Centres upon which the initial 'outgoing' currents act.

An attentive study of the mental defects resulting from Cerebral Disease will, we think, be found to yield results quite in accordance with the views above expressed.

The principal defects which the following cases are destined to illustrate, may with advantage be first tabulated, so as to show their mutual relations both as Mental and as Neurological Processes.

I. DEFECTS OF VERBAL MEMORY, THAT IS DEFECTS IN THE ASSOCIATIONS OF IDEAL THINGS OR OF CONCEPTIONS WITH IDEAL WORDS.

A. Amnesia Verbale.

(*a.* Paralytic Variety; *b.* Incoördinate Variety.)

1. *Diminished Excitability of the Auditory Word-Centres.*
2. *Defective Action in the Visual Word-Centres.*
3. *Damage to Visual Word-Centres and of Afferent Fibres to Auditory Centres; together with certain defects producing Incoördinate Amnesia.*
4. *Damage to Commissures between Auditory and Visual Word-Centres.*

II. DEFECTS IN THE ASSOCIATION OF IDEAL WORDS WITH VERBAL MOVEMENTS FOR SPEECH AND WRITING, OR FOR EITHER OF THEM SINGLY.

B. Aphasia.

5. *Damage to first parts of outgoing tracks leading from Cerebral Word-Centres to left Corpus Striatum.*

C. Agraphia.

6. *Damage to first parts of outgoing tracks leading from the left Visual Word-Centre.*

D. Aphemia.

7. *Damage* (a) *to first parts of outgoing track leading from the left Auditory Word-Centre, or* (b) *to some lower parts of the same track, or* (c) *to the actual Motor Centres for Articulation.*

A. Amnesia Verbale.*

In the acquirement of Speech there gradually arises, as we have seen, an 'association' between the impressions produced by external objects, as well as between the cerebral processes involved in ideas and other mental states on the one side, and the actual or revived sounds or sights of certain Words on the other. A similarly close 'association' also springs up between these latter processes taking place in the Auditory and Visual Perceptive Centres, and other processes in Motor Centres causative of Articulatory Movements for the production of Sounds corresponding to the Names of the objects or mental states thought of. Thus in the process of Thinking, so long as the brain acts in a healthy manner, Words become nascent in consciousness primarily, and perhaps principally, as revived Auditory Impressions. These revived impressions, either without or with voluntary efforts (that is, by Ideo-Motor or by Voluntary Action) bring about, in a manner the details of which are extremely obscure, those multiple combinations of muscular action necessary for the Articulation of the corresponding Words. If this primary memorial association between the impressions produced by things and their names, or between the ideas of things and other mental states and their corresponding words, prove defective (so that the one does not follow the

* The views expressed in this Chapter were contained in embryo in a paper (published in 1869, in the "Brit. and For. Med. Chir. Review") entitled, "On the Various Forms of Loss of Speech in Cerebral Disease." The present Chapter was written in the autumn of 1878, and therefore contains no reference to recent communications. The author has since read Kussmaul's elaborate article (Ziemssen's "Cyclopædia," vol. xiv.) where many of the views expressed in his earlier papers are endorsed.

other immediately) it seems evident that, in proportion to the degree of these particular defects, there must be a diminution in the power of Speaking, and a hinderance, though to a less extent, in the process of Thinking.

Two kinds of defective Verbal Memory require to be distinguished.* One of them is dependent upon a *diminished activity* in one or other of the parts of the Brain concerned with the verbal associations above referred to. Such diminution may amount to a more or less complete arrest of action or paralysis, hence this variety may be named **Paralytic Amnesia.** The other kind of defect is related to an *irregular or perverted activity* of the parts in question. They act, but they act wrongly. It is not that words cannot be revived, but rather that wrong words are revived, just as an 'ataxic' man produces wrong movements of his limbs. This second variety may, therefore, fitly enough be distinguished as **Incoördinate Amnesia.** Though the two conditions may exist separately, they are often combined in different proportions.

a. Paralytic Amnesia.

Under this head may be included a momentary forgetfulness and confusion about proper Names and Nouns, with power of recovery after a time; or there may be a more permanent and habitual forgetfulness of Names of objects, persons, or places, with attempts to remedy this forgetfulness by employing a periphrasis in place of the Noun, which cannot be recalled.

Different degrees and special varieties of this kind of defect are recorded in the following sections.

* In reference to Memory generally, some very suggestive and original views may be found in a paper by the late Dr. Laycock, in "Edin. Med. Jrnl.," April, 1874.

1.—*Diminished Excitability of the Auditory Word-Centres.*

According to the degree in which the proper vitality of the Auditory Word-Centres is affected, we may find evidence that they cease to respond, first to 'volitional' incitations, secondly to those coming to them by way of 'association,' and lastly to 'sensory' impressions coming from without.

A good example of an ordinary case of Amnesia is thus referred to by Trousseau in his "Lectures," in which the 'volitional' and 'associational' recall of names was impossible, though their 'sensory' recall was preserved.

"The patient does not speak, because he does not remember the words which express ideas. You recollect the experiment which I often repeated at Marcou's bed-side.* I placed his nightcap on his bed, and asked him what it was. But after looking at it attentively he could not say what it was called, and exclaimed, 'And yet I know well what it is, but I cannot recollect.' When told that it was a nightcap, he replied, 'Oh! yes, it is a nightcap.' The same scene was repeated when various other objects were shown to him. Some things, however, he named well, such as his pipe. He was, as you know, a navvy; and, therefore, worked chiefly with the shovel and the pickaxe, so that these are objects the names of which a navvy should not forget. But Marcou could never tell us what tools he worked with, and after he had been vainly trying to remember, when I told him it was with the shovel and the pickaxe, 'Oh! yes, it is,' he would reply, and two minutes afterwards he was as incapable of naming them as before."

In the slighter forms of Amnesia the efforts at Recollection of a person who is "at a loss for a word" tend also to call the Visual Word-Centres into an incipient or

* The earlier condition of this man will hereafter be referred to (p. 627), as at that time he manifested a distinct tendency to 'echo' words.

abortive amount of activity. Dr. Graves has placed on record what may be taken as an illustration of this fact, though he quotes the case merely as "a remarkably exaggerated degree of the common defect of memory observed in the diseases of old age, in which the names of persons and things are frequently forgotten, *although their initials are recollected.*"

"A farmer, fifty years ago, had suffered from a paralytic attack, from which he had not recovered at the time of observation. The attack was succeeded by a painful hesitation of speech. *His memory was good for all parts of speech except noun-substantives and proper names:* the latter he could not at all retain. This defect was accompanied by the following singular peculiarity:—*he perfectly recollected the initial letter of every substantive or proper name for which he had occasion in conversation, though he could not recall to his memory the word itself.* Experience had taught him the utility of having written on manuscript a list of the things he was in the habit of calling for or speaking about, including the proper names of his children, servants, and acquaintances; all these he arranged alphabetically in a little pocket dictionary, which he used as follows:—if he wished to ask anything about a cow, before he commenced the sentence he turned to the letter C, and looked out for the word 'cow,' and kept his finger and eye fixed on the word until he had finished the sentence. *He could pronounce the word 'cow' in its proper place so long as he had his eyes fixed upon the written letters; but the moment he shut his book it passed out of his memory and could not be recalled, although he recollected its initial, and could refer to it when necessary.* He could not even recollect his own name unless he looked out for it, nor the name of any person of his acquaintance; but he never was at a loss for the initial of the word he wished to employ."

In regard to this memory of the first letter alone of a Name or Word, the following passage from David Hartley is not without interest. He said,* whilst illustrating his celebrated doctrine of 'Association':—"When a variety

* "Observations on Man," 1748, Prop. xii., Cor. vii.

of ideas are associated together, the visible idea, being more glaring and distinct than the rest, performs the office of a symbol to all the rest, suggests them and connects them together. In this it somewhat resembles the first letter of a word, or first word of a sentence, which are often made use of to bring all the rest to mind." The fact, moreover, that in these cases—when we cannot 'get out' a particular word—we often seem to know something of its length, and can say that it consists of about so many letters, also seems to testify to an abortive or incipient revival of the Word in the Visual Centre.

The fact that this partial Visual revival is not associated with full consciousness of the word and does not enable it to be Written, is one of considerable significance, because it seems to show how all-important, in the majority of cases, is the primary revival in the Auditory Centres, not only for the accomplishment of Speech but also for that of Writing; and, further, that the more special Intellectual or Emotional Mechanisms, often cannot immediately rouse the Visual Word-Centres for the execution of Writing Movements, these being probably called into play, in Writing spontaneously as well as in Writing from dictation, for the most part through the intermediation of the Auditory Word-Centres.

A remarkable kind of defect, of an exceptional order and very difficult of explanation, has been recorded by Dr. Hertz, who says ("Psycholog. Mag.," vol. viii.) :—

"In August, 1785, I was called to an officer of artillery, a man about forty years old, who, as I was informed, was seized with a palsy. . . . . I found him so much recovered as to have the complete use of his feet; his hands also were stronger, but in regard to his speech the following very remarkable circumstance was to be observed: *he was able to articulate distinctly any words which* *either occurred to him spontaneously, or when they were slowly and loudly repeated to him.* He strenuously exerted himself to speak, but an unintelligible kind of murmur was all that could be heard. The effort he made was violent, and terminated in a deep sigh. On the other hand, *he could read aloud with facility.* If a book or any written paper were held before his eyes, he read so quickly and distinctly that it was impossible to observe that there was the slightest fault in his organs of speech. But if the book or paper were withdrawn he was then totally incapable of pronouncing one of the words which he had read the instant before. I tried this experiment with him repeatedly, not only in the presence of his wife, but of many other people: the effect was uniformly the same."

Here it would appear that Words could not properly be revived in the Auditory Centres by 'volitional' incitations, and, consequently, that 'outgoing' stimuli could not be made to pass over from them to the motor centres concerned in Speech. His difficulty in repeating words (implying sluggishness of response of the Auditory Word-Centre to direct 'sensory' impressions) makes this case hard to understand. The view that the molecular mobility of this Centre itself was lowered, or that its emissive fibres were damaged, is not in accord with the fact that it appeared still to respond well to strong impulses coming to it from the Visual Centre. And evidence will subsequently be given, tending to show that in 'reading aloud' the Auditory Word-Centre is called into play, so that it then acts as in ordinary Speech (p. 641). But there may be exceptions to this rule. Both this case and the one which follows would be more explicable if we might suppose that motor incitations could, in some well practised persons, pass over, in Reading, from the Visual Word-Centre to the portions of the Kinæsthetic Word-Centre in association with Speech-movements, without previously passing through the Auditory Word-Centre. By analogy it would seem quite possible that this may occur, just as the initially-guiding Visual Sense may after a time be dispensed with in the execution of ordinary movements (p. 556).

The next case* is rather more complicated, but it affords clearer evidence of a great diminution in the excitability of the Auditory Word-Centre.

Dr. Hun, of Albany, mentions the case of a blacksmith, æt. 35, who, before the present attack, could read and write with facility. He had been labouring for several years under disease of the heart. After a long walk in the sun he was seized one evening with symptoms of cerebral congestion, and remained in a state of stupor for several days. On recovering from this condition he understood what was said, but it was observed that he had great difficulty in expressing himself in words, and for the most part could only make his wants known by signs. There was no paralysis of the tongue, which he could move in all directions. *He knew the meaning of words spoken before him, but could not recall those needed to express himself, nor could he repeat words when he heard them pronounced;* he was conscious of the difficulty under which he was labouring, and seemed surprised and distressed at it. If Dr. Hun pronounced the word he needed, he seemed pleased, and would say, "Yes, that is it," but was unable to repeat the words after him. After fruitless attempts to repeat a word, Dr. Hun wrote it for him, and then he would begin to spell it letter by letter, and after a few trials was able to pronounce it; if the writing were now taken from him he could no longer pronounce the word; but after a long study of the written word, and frequent repetition, he would learn it so as to retain it, and afterwards use it. He kept a slate, on which the words he required most were written, and to this he referred when he wished to express himself. He gradually learned these words and extended his vocabulary, so that after a time he was able to dispense with his slate. *He could read tolerably well from a printed book, but hesitated about some words. When he was unable to pronounce a word he was also unable to write it till he had seen it written;* and then he could learn to write as he learned to pronounce, by repeated trials. At the end of six months by continually learning new words, he could make himself under-

* American "Jrnl. of Insanity," Ap. 1851; and given, as here, in abstract by Dr. Bateman in "Jrnl. of Ment. Sc.," Ap. 1868.

stood pretty well, often, however, employing circumlocution when he could not recall the proper word, somewhat as if he were speaking a foreign language imperfectly learned."

The fact that Words could not be articulated which had just been pronounced before him, though such Words were really heard and understood, seems to point to a very low degree of activity of the Auditory Word-Centre. The patient's ability to read aloud, however, as in the last case, appears to make it probable that this act may be performed, as previously explained, without necessarily involving the activity of the Auditory Word-Centres. The fact that this person had a difficulty not only in pronouncing certain words from sight, but in writing them, seemed to point to the existence of some small amount of functional impairment in the Visual Word-Centre.

In this relation it may be mentioned that in different kinds of Cerebral Disease it sometimes happens that the patients' Speech is entirely limited to a mere imitative repetition of words spoken in their hearing, whilst they are without the power of volunteering any statement—*i.e.* their Auditory Word-Centres respond only to direct 'sensory' incitations, and not at all to those of the 'associational' or 'volitional' types. In these cases, other causes of general mental impairment almost invariably co-exist.

A defect of this kind (occurring in a woman who was hemiplegic from cerebral hæmorrhage) has been recorded by Professor Béhier.* She was born in Italy, and had resided both in Spain and France; of the three languages she had thus acquired she had completely forgotten the Italian and Spanish, and had only retained a most limited use of French. In this latter language *she only repeated like an echo* the words pronounced in her presence, without, however, attaching any meaning to them. But in the case of a woman seen at the Salpêtrière by Bateman the mimetic tendency was much stronger. She even reproduced foreign words with which

* "Gaz. des Hôpitaux," May 16, 1867.

she had never been familiar. "In the words that she thus *echoed*, her articulation was distinct, although the foreign phrases were not repeated in quite so intelligible a manner as the French. . . . . Just as we were leaving her bedside, a patient in an adjoining bed coughed; the cough was instantly imitated by this human parrot! In fact, this singular old woman repeated everything that was said to her, whether in an interrogative form or not; and she imitated every act that was done before her, and that with the most extraordinary exactitude." In other cases there is a tendency to dwell upon and repeat some one word or phrase that has been uttered in reply to a first question, as an answer to those which follow—till at last something new may be said which is repeated in the same way. A good instance of this may be quoted from Trousseau. In a man suffering from left hemiplegia, his usual "stock of words was restricted to these two, 'My faith!'; and when he was pressed hard, he looked impatient, and uttered the oath, 'Cré nom d'un Cœur!' . . . . . I asked him what his name was, and his occupation; he looked at me and answered: 'My faith!' . . . . I insisted, but in spite of his efforts, he only shook his head with an impatient gesture, exclaiming: 'Cré nom d'un Cœur.' As I wished to find out how many words he had at command, I said to him: 'Are you from the Haute-Loire?' He repeated like an echo, 'Haute-Loire!' 'What's your name?'—'Haute-Loire.' 'Your profession?'—'Haute-Loire.' 'But your name is Marcou?'—'Yes, sir.' 'You are sure it is Marcou?'—'Yes.' 'What department do you come from?'—'Marcou.' 'No; that's your name.' But with an impatient gesture, he exclaimed, 'Cré nom d'un Cœur.'" *

2.—*Defective Action in the Visual Word-Centres.*

No very distinct illustration of this defect has been met with, but one which is in some respects the converse of those recorded by Drs. Hertz and Hun has been related by Dr. Hughlings Jackson.† In this example the

* The same kind of tendency to repeat the last impression made on the Visual Centre is shown by other patients, when Writing (see Trousseau's "Lectures," Eng. Trans., Pt. I. p. 228).

† "Brit. Med. Journ.," 1866.

power of Writing and of Spelling was very much impaired, whilst that of Speech was affected only to a more trifling extent.

The man had "performed the duties of an important government office, requiring good education and intelligence," and he had been subject to a series of epileptiform attacks, at first principally involving the left side of the body, but then, after an interval, affecting the right side instead. The defects in the patient's power of intellectual expression about to be noted occurred only after the second series of fits. Dr. Jackson says, "After these attacks, the patient could talk, but he made mistakes in talking." A few weeks afterwards, he met this patient in the street, and says,— "He was then, to superficial appearance, as well as ever. *I observed that he spoke quite well, and this throughout rather a long conversation.* The patient said, however, that he was often at a loss for a word; and his father told me that his son frequently made mistakes in names." His greatest trouble was in writing—he had no difficulty about the mere penmanship, this was excellent. "His trouble was that he could not readily find the proper words, and those he wrote he often spelled incorrectly." He was able to copy a paragraph from a printed book well, making only one or two trivial errors; but in attempting to write from dictation, he made very much worse mistakes in spelling than occur in a corrected letter which Dr. Jackson has reproduced. When asked to spell words, he also succeeded very badly; and *though he could repeat perfectly even the most difficult sentences, when he attempted to read aloud he could not succeed at all, pronouncing almost every word of two or more syllables wrongly.*

Here, again, as in the case recorded by Dr. Hun (p. 623), the ability to read aloud was commensurate rather with the power of writing than with that of speaking. Both reading aloud and writing necessarily require the integrity of the Visual Centre, and that this was more impaired than the Auditory Centre seems clearly indicated by the fact recorded above, that the patient could repeat even the most difficult sentences correctly—an operation in which the Auditory Word-Centres are called into play, but not the Visual—whilst he could not read aloud the simplest passage without making many mistakes. It will be interesting subsequently to compare these cases with those that will be given under the head of Agraphia (p. 657), especially the other case recorded by Dr. Jackson, which might perhaps with equal propriety be placed here.

*3.—Damage to Visual Word-Centre, and of Afferent Fibres to Auditory Centres; together with certain defects producing Incoördinate Amnesia.**

A case of great interest belonging to this category has been fully recorded by Dr. Banks,† but is given here only in abstract. The power of apprehending what was spoken by others was entirely lost, and the patient's ability to comprehend written or printed characters was almost lost. His powers of expression by Speech and Writing were correspondingly defective. He seemed to have lost all knowledge of the proper use of Words, and was unable to express himself in an intelligible manner.

A gentleman, aged about seventy-five, after having walked a considerable distance on the 28th of March, 1864, sat down to dinner, and proceeded with his meal as usual. After a time it was observed that some of the water he was drinking flowed from his mouth. He put down the glass, calling at the same time in a loud and excited voice for his wife and the servant who was in the habit of waiting upon him, although they were both present. The patient was in a very short time seen by Dr. Kidd, who found him sitting on the sofa, looking puzzled but evidently conscious, calling out loudly at intervals for the servant and others, but not taking the slightest notice of anything which was said to him. The excite-

* The consideration of the nature of the defects inducing this latter condition, will be better deferred till some examples of the condition itself have been given.

† "Dublin Quart. Jrnl. of Med. Science," Feb. 1865, p. 78.

ment under which he laboured after a time passed away. He endeavoured to speak, but unintelligibly. He walked upstairs unassisted, wound up his watch, went to bed, and slept well. The following morning it was discovered that he was *completely deaf, the loudest noises not being perceived.* His sight seemed good, and *there was no motor paralysis of any kind.* In speaking he used wrong words, so as to be utterly unintelligible. Dr. Banks says, "he certainly recognized me, and was glad to see me, but misnamed me; saying something, but using words without meaning. *We endeavoured to communicate with him by writing, but it was evident that he did not understand it.* 'Have you pain?' was written, and he looked at it and said, 'Good, good God;' appearing to read what was written." He attempted to write letters frequently, and his address was written two or three times at the head of the sheet of paper, some of the words being imperfect. 'My dear Sir,' was written correctly. *The sheet was filled with writing, but no word except 'wife' was legible, the rest being utterly meaningless; some letters were correctly formed, but no words until the end, where his name was signed with a steady hand and in his usual manner.* He varied, however, in his power of writing at different times; occasionally when wished to sign his name, he could not be induced to do so, and "only scribbled some unintelligible words." *It was impossible to get him to understand anything;* and his meaning could only be guessed at by his gestures, and by the very few words at his command, which were almost always misapplied.

At the beginning of April a remittance was due from his agent, and each morning he was much excited, asking frequently for something. At length it occurred to one of the family to show him his agent's letter, which seemed to please him; but he was not quite satisfied till the money was brought and counted before him. Some shillings were not shown to him at first, but when he saw them he appeared to know all was right, and, on the money being handed to his wife, he seemed content. His feelings of affection for his wife seemed to be intensified; but there was some amount of emotional weakness.

He occasionally for a time made use of some one word, applying it in the most varied ways. Wishing to inform Dr. Kidd that a liniment which he had been using was nearly finished, he said, pointing to the bottle, "Bring the cord." On another occasion, speaking of pills he had been taking, he said he had taken "potatoes." Very frequently there was some similarity in the word used to the right one; or it could be discerned that there was some association with the idea he wished to convey; for example, giving his waistcoat to be put aside, the watch being in his pocket, he said—"Take care of the break-fall." He seemed conscious of his deafness, and sometimes spoke of it. One day he said he could neither hear nor read—"*Only a little, could read the words, but could not take in the meaning.*" Every morning, notwithstanding, he spent some time as if busily engaged reading the Bible and the newspapers. This was, doubtless, from the mere force of habit; for on testing him, *he read after a fashion, but the words were unconnected and meaningless, and had not even the most remote connection with the text.* His powers, both of speaking and writing, were subject to variation at different times. (Lithographs of two letters are given by Dr. Banks which, though made up of properly written words, are almost unintelligible.) Occasionally it was difficult to manage him; as, if he wished to go somewhere, and it was found impossible to comprehend his wishes, he became very much excited. He continued in much the same condition till the 7th of October, when he had a distinct apoplectic seizure, and became completely hemiplegic on the right side of the body. He lived only a week after the onset of this more severe attack.

The great mental defects in this case were unassociated with paralysis. The Visual Centre was evidently much damaged, since the patient could not understand printed or written characters and could only write in an unintelligible manner. This same conclusion is strengthened by the fact that he read so badly—even worse than he spoke. His amnesic defects of speech, of the incoördinate type, were probably due to some lack of harmony between the higher Intellectual and the Auditory Centres, but this subject will presently be considered more at length. His total deafness, coupled with his ability to articulate fairly well, seemed incompatible with the existence of a grave lesion of the Auditory Centre itself. The fact, however, of the existence of this complete deafness is an exceptional feature, difficult to explain on the otherwise probable supposition that originally only one seat of disease existed in the Cerebral Cortex. If ordinary right-sided deafness had existed anterior to the date of this patient's sudden cerebral disease, his symptoms might be explained by one lesion of or near the Cortex of the left Hemisphere, seriously damaging the afferent fibres going to the Auditory Centre, as well as seriously deranging the functional activity of the corresponding Visual Centre.

Dr. Broadbent* has recorded a clinical history in many respects comparable with the foregoing.

A painter, æt. 42, had been subject to gout, and also to epileptiform attacks, for several years. During the night of October 14, 1871, while lying on the right side, he suddenly put out the left arm and began to jabber—his right arm being quite useless. There were no convulsions, and no loss of consciousness. He was found by Dr. Felce, who was called to him, completely hemiplegic and with greatly impaired sensibility of his right side, keeping up a meaningless gabble, in which m-sounds were predominant, and showing the paralyzed arm. The attack was followed by much cerebral excitement, shouting and violence. He soon regained power in the right limbs, but the speech was as imperfect as ever, and he was unable to write or copy. His general health became much deranged, and finally gangrene of the left foot came on. It was soon after this, on Dec. 14, that he was first seen by Dr. Broadbent, who says:—"He received us with a profusion of bows and smiles, with gestures expressive of welcome . . . . His speech was a mere jabber, in which 'Ma' and 'Mum' were prominent, and was accompanied with an excess of gesticulation, smiles, and facial expression. The gestures were very striking, and apparently appropriate when we had a key to their meaning . . . . It was stated that he said 'Yes' or 'No,' and 'Oh, my' at times; but he did not use even these simple words before us. He was unable to write his own name when his signature was before him. When urged to do so, he *scribbled off rapidly something in which letters of some sort were distinguishable at first, but then tailing off into a scrawl.*"

"*He obviously did not understand anything that was said to him;*

* "Medico-Chirug. Transact., 1872," p. 170.

did not squeeze my hand on repeated requests, but went on shaking it and smiling; put out his tongue repeatedly when told to close his eyes, but instantly imitated the act after Dr. Felce. *It was doubtful how far he recognized the state of his speech; he went on chattering as if he thought he was understood,* but he also made signs . . . . He remained in much the same state till his death, about Christmas; once startling some friends in conversation at his bedside by exclaiming 'Exactly' at a very appropriate moment, but not otherwise regaining speech."

In this case, whilst the damage to the left Visual Word-Centre was probably even greater than that recorded by Dr. Banks, the left Auditory Word-Centre seems to have been equally damaged, as was shown by the patient being unable to articulate distinct words, combined with his seeming inability to understand spoken language.* In another case, recorded by Dr. Broadbent, there was the same inability to understand what was said, although this patient was accustomed to speak not in mere inarticulate gibberish, but in distinct though irrelevant words.† Here, however, it is said that after the fit by which the lady's illness was initiated, "her naturally cheerful expression was exchanged for a dull stolid look, and she took no notice of anything." There was evidently a condition of partial dementia; but in a case very briefly recorded by Trousseau, in which there was a similar irrelevant use of words whose meaning was not realized by the speaker, the patient is said to have been in other respects

* As the right Hemisphere was open for the reception of auditory impressions, it seems strange that Speech should not have been comprehended better in this case. Correct and incorrect auditory impressions, simultaneously impinging on the two sides of the Brain, might, however, produce so much mental confusion as to prevent the correct impression being realised.

† A similar inability to understand what was said by himself occurred in a patient, whose case is referred to by Winslow ("Obscure Diseases of the Brain," 3rd. Ed., p. 328).

rational in her actions. She rose with an air of kindness to receive a visitor, and pointing to an arm-chair, said, "Cochon, animal, fichue bête!" whilst her son-in-law, who was present, and knew what she really meant, said, 'Madame vous invite à vous asseoir"—the lady all the time seeming quite unconscious of the insulting expressions she had used.

b. Incoördinate Amnesia.

The cases detailed in the foregoing section are so distinctly illustrative of the 'incoördinate' defects of Verbal Memory, that we are now naturally led on to a consideration of the mode in which these defects are to be explained. Such a wrong use of Words as was encountered in the case recorded by Dr. Banks, is to be met with in very various degrees, and constitutes, in fact, one of the most common defects of Speech from cerebral disease, sometimes showing itself more especially in Articulate Speech, sometimes more in Writing—or, in other cases, the power of Expression may be nearly equally bad in both.

Patients are mostly aware when they make use of wrong words in either of these modes of expressing themselves, though this is by no means always the case.

Luys* alludes to an instance where the person was continually in the habit of using one word for another without being conscious of his mistakes. One day he pronounced the word 'jardin,' wishing to say 'lit,' repeated it several times, and afterwards fell into a violent passion because his orders were not comprehended. He was then made to write the word he wished to make use of, and the *sight* of the proper written symbols soon convinced him that the word which he had actually uttered was not the one he had intended to utter.

* "Syst. Nerveux," 1865, p. 395.

Elsewhere* the writer has given a very good specimen of a letter written by a well-educated Amnesic patient, full of mistakes, and in some places even unintelligible, yet, judging from the lack of erasures, these mistakes were apparently not observed by the patient himself.

The range of these incoördinate defects of Verbal Memory is very various, both as to frequency of occurrence and as to extent. It may be that a wrong word is only occasionally used in Speech or Writing, or such errors may be much more frequent and more extensive. It may be so extensive as to make the person's Speech or Writing wholly irrelevant, and even quite incomprehensible—owing to the utterly confused collocation of actual words.

Winslow has recorded an instance of this extreme form of amnesic Speech, occurring in a gentleman who had partially recovered from an apoplectic attack.

"He could speak, but what he said, without a key to its interpretation, was quite unintelligible. He was able to pronounce words with great clearness, but they were sadly misplaced and transposed. What he said was written down, and the words placed in their proper order. By adopting this course his family were able clearly to comprehend his wishes. This state of brain, and impairment of speech, continued, with slight intermissions, for nearly a fortnight."

The letters written by Dr. Banks's patient afford an example of a similarly extreme defect in intellectual expression by Writing. Though made up of properly written words, the mode of collocation of the latter was such as to convey no intelligible propositions.

The explanation of the 'paralytic' defects of Verbal Memory is a problem presenting no particular difficulties; but the same cannot be said in regard to these 'incoördinate' affections. There is an obvious reason, how-

* "Paralysis from Brain Disease," 1875, p. 189.

ever, why both the kinds of Speech-defect should be most frequently met with in regard to Names of persons, places, and things. In the slighter cases, it is only these altogether special 'associations' which either cannot be recalled at all, or which are misapplied. It is rarer to find such defects extending to substantives generally and to other parts of speech. As Broadbent truly observes* "Words other than names, such as adjectives, verbs, etc., constituting the framework of a sentence or proposition, stand on a different footing; they are not associated with and tied down by visual, tactual, and other perceptions. Their use implies a previous knowledge of words as names, and mark a step beyond the act of naming. . . . . They are not substantive intellectual symbols, but intellectual agents, instruments and products of intellect in action, not presentations impressed upon it. It is with respect to this class of words that it may be strictly said that 'we think in words,' for we often think [in part] in revived visual impressions not reduced to words. The convolutions concerned in their employment, will be such as are the seat of the intellectual operations, the superadded convolutions."

Even though we do not quite agree with Broadbent, in supposing that Intellectual Action and its Centres can be so distinctly separated from Perceptive Action and its Centres;† or, in regard to the divisions which he seeks to

* "Med. Chirurg. Trans.," 1872, p. 192.

† H. Spencer says ("Principles of Psychology," vol. i. p. 163), "The proximate components of Mind are of two broadly contrasted kinds—Feelings and the Relations between Feelings." But a close examination of what is said in regard to 'Relations' makes it evident that they correspond with what has been spoken of generally in this work as the 'cognitive side of Feeling.' Though H. Spencer names two components of Mind and describes them apart, this is only for descriptive purposes, since he himself adds:—" Strictly speaking

establish between these modes of activity; or with his explanation of the process of Naming—still what he says above is very suggestive in regard to possible differences of seat in the organic substrata for Words according as they do or do not denote external objects.* It is reasonable to suppose that the latter might be in more immediate relation with Perceptive Centres, whilst those of other parts of Speech would be much more intimately associated with regions where Perceptive Processes become merged into more complex and more purely Intellectual Operations.

Roughly speaking, therefore, the inability to recall names, or the miscalling of persons, places, or things, would be defects going with injuries to or altered states of Perceptive Centres, and might exist with comparatively slight impairment of Intellectual Activity; whilst, on the other hand, the extreme forms of Amnesia, in which wholly irrelevant propositions, or a mere jumble of words are uttered, are more likely to be associated with marked im-

neither a Feeling nor a Relation is an independent element of Consciousness"—which is exactly what Aristotle and many succeeding philosophers have said, in effect if not in actual words, in regard to Feeling and Cognition (see p. 182). The discrimination of a Feeling as such and such necessarily comprehends its 'relations' of degree, kind, place, and time. And as H. Spencer says (loc. cit. p. 187):—"Mental actions, ordinarily so called, are nearly all carried on in terms of those tactual, auditory, and visual feelings, which exhibit cohesion and consequent ability to integrate in so conspicuous a manner. Our intellectual operations are indeed mostly confined to the auditory feelings (as integrated into words), and the visual feelings (as integrated into impressions and ideas of objects, their relations, and their motions)."

* Loc. cit., p. 181. See also Dr. Bristowe's Lectures "On the Pathological Relations of Voice and Speech" ("Brit. Med. Journal," May 10, 1879, p. 691), for a succinct statement of Broadbent's view.

pairment of Intellectual Power—to be dependent, in short, upon injuries or altered states of parts of the Brain more specially concerned with such modes of activity.

The process of Thought seems to be in a measure independent of the Words in which the Thought is expressed, so that perhaps we 'think in words' somewhat less than is generally supposed. Its partial independence appears indicated by the fact that we 'select' our expressions. Thus, according to the different shades of meaning sought to be conveyed in our propositions, we often deliberately weigh or 'select,' the substantives, adjectives, and verbs, that we may deem most expedient for the complete communication of our thoughts to others. This seems to indicate some separate process by which Thoughts or 'Relations' associate themselves with Words—one which is perhaps a little less automatic than that by which external objects, real or in 'idea,' associate themselves with Words.

In the 'incoördinate defects' of different grades, it is these particular verbal relations or associations, which are disturbed. How, we know not. The error may be in the mode of activity of the Perceptive or Thought-Centres, or perhaps in their related Word-Centres; the effect, in either case, being that erroneous associations become established, so that, as a consequence, incorrect or meaningless propositions are uttered.

In the very extreme forms of this incoördinate defect, in which Speech is reduced to a mere jabber of meaningless sounds, we probably have to do with some grave defect, either in the Auditory Word-Centres or in the Kinæsthetic Word-Centres. There are two types of such cases; one like that recorded by Broadbent, in which the person who jabbers, also does not understand what is said to him; and another like that of Dr. Osborne, about to be related, in which, whilst only able himself to talk gibberish, the affected person clearly understands everything that is said to him. These two types are perhaps best explicable by defects in the respective regions above indicated.

Similarly extreme defects exist in regard to Writing, and they may perhaps be similarly explained by some defect in the Visual Word-Centre, in cases where the power of Writing is reduced to a mere meaningless assemblage of letters with inability to comprehend written or printed words; whilst, where this latter disability does not exist, the incoördinate Writing may be a mere defect in execution, due to some derangement of the Kinæsthetic Word-Centre—and this seems a possible explanation, in part, of the case of the sailor recorded at p. 660.

Defects of this type, so slight as to belong to quite the other end of the scale, also exist, in which strange mistakes may, habitually or not, be made in the articulation of some words, or in the mode of writing them. Dr. Winslow mentioned the case of a man who, after an attack of paralysis, always transposed the letters of words in his mode of pronouncing them; thus, "endeavouring to say the word 'flute' he said *tufle*, *puc* for 'cup,' *gum* instead of 'mug.'" Again, there may be an almost invariable substitution of certain letters for others—such as a *z* for an *f* in every word which should have contained the latter letter.

Defects in pronunciation and defects of spelling of this kind are extremely common with patients who are slightly Amnesic, and to a very slight extent may indeed be met with occasionally in persons who are otherwise thoroughly healthy. Such persons when meaning to use one word actually employ another—being sometimes conscious of their error and sometimes not; and the same holds good for their mistakes in writing—these may be detected at once, or not till the occasion of some subsequent perusal of such writing. Persons who are liable to make such mistakes in expression, may occasionally altogether wrongly apprehend some word which they hear spoken or which they see in writing or in print, in a way quite surprising to themselves, when the mistake is recognized.

4.—*Damage to Commissures between the Auditory and the Visual Word-Centres.*

On reflection it will seem clear that there must be at least two sets of commissures between the Auditory and the Visual Word-Centres; the one (a) for transmitting stimuli from the Visual to the Auditory Centres (*visuo-auditory fibres*), as in the act of reading aloud, or naming at sight; the other (b) for conveying impressions in the opposite direction, *i.e.*, from the Auditory to the Visual Centre (*audito-visual fibres*), as in the act of writing from dictation.

Both sets of commissures may be simultaneously damaged, and this seems to have been the cause of the most notable defects met with in two of the writer's own patients, whose cases are subjoined. The first of them came under observation at the National Hospital for the Paralysed and Epileptic, in 1869,* but nothing similar was encountered until last summer, when the second example was seen. The writer is not aware that any other such cases are on record.

A middle-aged woman had an attack of right Hemiplegia with pretty complete Aphasia in the early part of the year 1868. In the course of some months she improved considerably, though she continued subject to 'fits' at intervals. After twelve months she was able to walk about with a little assistance, though she was still

* "Paralysis from Brain Disease, 1875," p. 201.

incapable of using the right hand and arm. She seemed thoroughly to understand everything that was said to her, and had in great measure regained her power of speaking. She could repeat almost any word uttered in her hearing, and this without hesitation, though she could not read even the simplest words in large type. Yet the same words could be uttered with ease immediately on hearing them pronounced. *She copied the written word 'London' fairly well with her left hand, but could not write 'cat' or 'dog,' after merely hearing them pronounced, though she could spell the same words quite well.* She could not even write the first letter of either of these words. . . . . Twelve months afterwards she was found to be in much the same condition. Could not read aloud even such simple words as 'and' and 'for'; *could point out any letters which were named with the greatest ease, but could not herself name the letters when they were pointed to.* She had improved in her power of walking, and was also able to talk rather better. She could read a letter silently so as to understand it, though she did not always seem to comprehend what she read in a newspaper or a book. When seen again, four years afterwards, this patient was found to be in much the same condition.

It is worthy of note that during the early stages of this woman's illness, she seemed to be suffering from ordinary Aphasia with right-sided paralysis; it was only after she recovered her power of Speaking that it was possible to obtain evidence of the more special defects above illustrated, which pointed, as may be seen, to a severance of functional relation between the left Auditory and Visual Word-Centres. Thus she could not read aloud, neither could she write from dictation—both of them being acts which require the conjoint activity of these two Centres.* But she could freely articulate words which she heard, and could copy writing easily with her left hand—because these were acts, one of which called the Auditory

* Especially in persons not very well educated, and therefore not thoroughly habituated to the performance of these processes. Exceptions, however, may occur to this rule (see p. 624).

and the other the Visual Centre into operation independently of the other. The act of copying was in this case performed, as a result of recent practice, with the left hand; so that the stimuli operating upon the motor centres (in the right corpus striatum) must have immediately emanated from the Visual Centre of the right side.

The details of the second case, which is even more interesting, are fuller.

Thos. A——, a tinplate worker, forty-two years of age, was admitted into University College Hospital, March 12, 1878. Three months previously he had become suddenly paralyzed in the right side of the body, without convulsion or loss of consciousness; but after the attack his speech was found to be almost lost. When admitted, he had become able to move his right leg and arm slightly; though there was still some diminution of sensibility on this side of the body. There was a slight amount of right facial paralysis, and some deviation of the tongue to the right. *Sight and hearing were good.* He continued to improve slowly, and on April 2 his condition is thus described:—He recognizes common objects, but cannot name them, repudiates a false name, and recognizes the real one at once when he hears it. Can never remember his own name till it is suggested to him. On being asked to repeat it (Andrews), after a few trials which vary each time he pronounces it 'Anstruthers' or 'Anstrews.' His first name (Thomas) seems to come more readily, and he can often attempt this without prompting. But either after it has been repeated to him, or when he says it spontaneously he pronounces it 'Towvers.' The letter 'L' is difficult for him to utter, sometimes he pronounces it like a 'D,' and at others like a 'V.' He has been taught to count, and *can fairly pronounce the numerals from one to twelve;* after twelve he is uncertain, the articulation and order becoming rapidly worse. He is conscious when he makes a mistake, but cannot correct himself, and ends in a hopeless muddle. *In reading from a book the words he pronounces have no relation to the print, either in length or sound—neither does he seem to understand written characters, as he will not attempt to answer a question written on a slate, though he will at once endeavour to respond when the same question is put to him orally.* He, however, *recognizes numerals from one to nine when written,* and is conscious when they are not placed in regular order. He cannot name any coins, but seems to have some idea of their relative value. He indicated on his fingers that sixpence was worth six pennies—not being able from sight to utter its name.

On April 16, the patient had two slight fits, which, judging from the symptoms, were apparently due to some further slight damage to the left side of the brain. After neither of these fits did his speech seem to be worse. The second, however, was followed by an aggravation of the right-sided paralysis, though there was no further impairment of sensibility. Three days afterwards this increase of paralysis had passed off, and the patient was again able to walk about the ward.

Two weeks afterwards, it was noted that his speech was as bad as ever; he could *name any numeral written down and pointed out to him*, and he could also correctly add small columns of three or four figures; but he *altogether failed to name individual letters of the alphabet*, however plain or large they might be. He could recognize common objects, such as a dog, a fowl, or a tree, in an engraving, and point out any one of them when asked to do so. But he could not volunteer the name even of the most familiar object to which he pointed.

May 8.—Asked successively to name large, separate, printed capitals O, K, and G from sight, on each occasion he said 'P,' and on D being pointed to, he called it 'M'—though he repeated the name of each of these letters without a moment's hesitation after hearing it pronounced. Although there is this inability to name letters from sight, the patient now seems to understand simple sentences written or printed; thus, when the sentence "Have you a wife?" was written on a slate, it seemed perfectly evident that he understood the writing. His condition, however, in this respect seems to vary from time to time. *In the sentences, the meaning of which he comprehends, he is still quite unable to pronounce the individual words from sight, though after hearing them uttered he can articulate them at once, more or less distinctly.*

Two days after, he was observed reading something in the newspaper, and on being asked if he understood it (the report of a case of poisoning in a police-court), he at once said he did, and unmistakeably indicated by his gestures that this was true. *With his left hand he could write his own name after a copy, but not easily without, and sometimes not at all. A less familiar word he did not even attempt to write from the sound, even when it had been distinctly heard and comprehended.*

It will be observed that this patient's state on April 2 was distinctly different from what it became towards the end of the month, after the two fits. At first he had no power of recalling the names of common objects—he could not name them at sight. Neither could he voluntarily recall his own name. And when, after prompting, he endeavoured to repeat words, his pronunciation showed distinct defects of the incoördinate type. In attempting to read aloud from a book these incoördinate defects were so marked, as to make what he read quite unintelligible; neither did he seem to comprehend any written characters except simple numerals. Towards the end of April, however, whilst the patient's utterance had become more distinct in repeating words which he had heard, he could not even emit an unintelligible jargon in attempting to read. At the same time he had become able to understand what he read, though he still could not name even a single letter at sight, nor could he write a single word from dictation—both these latter processes requiring for their performance the proper relation (and therefore the integrity of the commissures) between the Visual and the Auditory Word-Centres. That part of the commissure which conveys stimuli from the Visual to the Auditory Word-centres (as in reading aloud) seems to have been more extensively damaged after the two fits than it was before. The fact, however, that he could read and pronounce the names of numerals suggests the possibility that these more familiar units may have been articulated by means of stimuli passing direct from the Visual Word-Centre to the half of the Kinæsthetic Word-Centre concerned with Speech-Movements (see p. 624).

Dr. Broadbent has recorded an extremely rare and interesting result of cerebral disease, closely allied to that found in the two cases just related. His patient, however, had not lost the power of 'voluntary' or of 'associational' recall in the Auditory Word-Centre. He spoke, in fact, fluently, and with only an occasional hesitation; though he was unable to write at will.

The patient, a gas-inspector of remarkable energy and intelligence, after an acute cerebral attack had entirely lost the power of naming objects at sight and of reading. He talked fluently and intelligently, scarcely ever made a mistake in words, but was sometimes at a loss for a name, especially of a street, place, or person. He was, however, quite unable to read, or even to name a single letter; the only exception being that he recognized his own name, whether written or printed; though even here he did not know whether the Christian names or initials only were given. Whilst this was the case, *he wrote correctly from dictation, and took notes of my instructions, which he could not read a moment afterwards.** He explained that he was forgetful, and his wife would make them out. If a hand, or an article of clothing, or any familiar object were shown him, he was quite unable to name it; *while if the name came up in conversation he spoke it without hesitation.* Asked the colour of a card, he could not give it. "Is it blue?" "No." "Green?" "No." "Red?" "Well, that's more like it." "Orange?" "Yes, orange." A square and a circle were drawn, and he was asked to name either. He could not do it; but, when the circle was called a square, he said, "No, but that is," pointing to the proper figure.

The injury of a single set of commissural fibres (the visuo-auditory), with the addition of some slight defect in the Visual Word-Centre, would produce such a combination of symptoms as are above recorded. We

* In the more detailed account of this case it is said he could not read his own writing "an hour later." It seems that there was more than an inability to read aloud. He showed an inability to comprehend words (from defect in the Visual Word-Centre), such as did not exist in the previous cases, though there was no inability to recognize the nature of common objects or even of geometrical figures.—"Brit. Med. Jrnl.", April 8, 1876, p. 434, or with more details in "Med. Chir. Trans.," 1872 (Case viii.).

have supposed that impressions made on the Visual Centre usually pass from it to the Auditory Word-Centre, and thence through the Kinæsthetic to the Motor Centres if the Sight-impressions are to be named articulately. But if merely this set of commissural fibres were damaged, the individual would be left with his Sight intact, and with his ordinary powers of Speech intact—he would simply be unable to read or to name from sight, because of the block between the Visual and the Auditory Centres. In this particular case, however, the block seems to have been only partial, since the man could still write from dictation—a process usually necessitating the passage of stimuli from the Auditory to the Visual Word-Centres, before the excitation of those parts of the Kinæsthetic Word-Centres concerned with Writing-movements and whence issue the appropriate outgoing stimuli.

Still it is possible that both the sets of commissural fibres may have been destroyed, and that in this case of a better educated man, his more familiar Writing-movements may have been evoked by the passage of stimuli direct from the Auditory to the Kinæsthetic Word-Centre—rather than by way of the Visual Centre (see p. 644).

Dr. Broadbent interprets this case quite differently. His opinion, however, as to the separate existence of a single 'naming centre' altogether apart from the Perceptive Centres, is not here adopted. We have postulated instead the existence of three 'word-centres' as important and intimately correlated parts of the more general Auditory, Visual, and Kinæsthetic Centres.*

* It is difficult to get evidence of the existence and special activity of the last-named component of this triad, but since the above was written the author has seen in Von Ziemssen's "Cyclopædia," vol. xiv. p. 776, a short abstract of an exceedingly interesting case (recorded by Westphal) having some relations with that above

The three principal cases recorded in this section are particularly important from a psychological point of view. They enable us to trace Will or Volition to its sources —when we find persons unable to Will an act in response to a Visual Impression, though they can at once and without hesitation effectively Will the same act in response to a related Auditory Impression—or *vice versâ* (pp. 353, 355).

B. Aphasia.

5.—*Damage to the first parts of the outgoing tracks leading from the Cerebral Word-Centres to the left Corpus Striatum.*

Hitherto we have been considering defects resulting from abnormal conditions of the Auditory and Visual Word-Centres themselves, or from injuries to their 'afferent' or 'commissural' fibres; now we turn to the illustration of the results following upon injuries to the 'outgoing' fibres from these and from the Kinæsthetic Word-Centres—those which bring them into relation with

given, and affording also some information of the kind referred to. Of this patient it is said:—"He could write very well from dictation, but shortly after he was unable to read the words he had written, and he suffered in general from complete alexia [*i.e.* inability to comprehend written symbols]. By means of a stratagem, however, as he himself very clearly explained, he succeeded in reading the word he had written from dictation upon the tablet. He passed his finger over each letter of the written word as if he were writing it again and read it while so doing. He then made a sort of calculation and counted off the sum of the separate letters." Here apparently the Kinæsthetic Impressions from Writing-movements were capable of rousing related parts of the Auditory Word-Centre so as to enable them to act through the other portion of the Kinæsthetic Word-Centre, and thus evoke Speech-movements.

the Motor Centres, concerned with Speech-movements and with Writing-movements, in the Corpus Striatum.

The relation existing between the Auditory and Visual Word-Centres and the parts of the Kinæsthetic Word-Centres to which impressions derived from Speech-movements and Writing-movements respectively proceed, are confessedly uncertain. There is reason to believe, however, that the incitations which evoke Speech start primarily from the Auditory Word-Centre, and then pass through the corresponding Kinæsthetic Word-Centre, so as to rouse it into conjoint and practically simultaneous activity. Similarly, there is reason to believe that the incitations which evoke Writing-movements start primarily from the Visual Word-Centres, and thence pass through the related parts of the Kinæsthetic Word-Centres.

It is clear, therefore, that destruction of the Auditory and of the Visual Word-Centres would cause inability to Speak and inability to Write. These disabilities would, however, be associated with such defects as have been considered under the head of **Amnesia**—viz., inability to comprehend Speech and Writing, together with inability to revive Auditory and Visual ideas of Words.

What we are specially concerned with in the present section are the results that follow upon damage to the outgoing fibres leading from the left Auditory and Visual through the Kinæsthetic Word-Centres, to the great Motor Ganglion beneath—viz., the Corpus Striatum.

It would seem that these two sets of outgoing channels are, at all events in some parts of their course, situated moderately close together, so that they may be destroyed simultaneously by some small lesion, and that too without the implication of outgoing fibres for limb-movements—and consequently without the association of a right-sided paralysis. One of the two cases originally described by

Broca, in 1861*—that of Lelong—evidently conformed to this type, but as he did not come under observation till some time after the commencement of his malady, we select a fairly typical case recorded by Dr. Bateman.†

A waterman, fifty-one years of age, and previously healthy, after helping to unload a vessel at Yarmouth on December 9, 1864, went to a tavern with the intention of asking for some beer, when, to his astonishment, he found himself unable to speak. Only a few hours previously he had called at a merchant's office and arranged about a fresh cargo, so that at this time his aptitude for business was in no wise impaired. His loss of speech was accompanied by no ordinary paralytic condition, for although speechless, he, on the same evening, removed his vessel from one part of the river to another, and the next day he helped to reload it with a fresh cargo before starting for Norwich by rail. On reaching home his friends were alarmed at finding that his vocabulary was limited to the words, "Oh dear! Oh dear!" There was no marked improvement till the expiration of a fortnight: after this period he seems gradually to have become able to utter a few more words. When seen by Dr. Bateman about three months and a half from the commencement of his illness he looked well, seemed remarkably intelligent, and appeared to understand everything that was said to him. *He was still unable to give expression to his ideas by articulate language, except in a very imperfect manner, though he could move his tongue freely in all directions. He had been able to write fluently before the date of his illness, but he had almost lost this power, as well as that of speech. Although just able to write one or two words, he could not write a sentence. Yet there was no trace of paralysis of limbs, either on the right or on the left side.*

Later this man became subject to fits at short intervals. After nearly two years, he was again admitted to the Hospital, on January 12, 1867. He then seemed in the possession of his usual intelligence, and was still free from any signs of paralysis in limbs or face. He had regained the power of speaking to a considerable extent, and now suffered from a different kind of defect—he had become Amnesic rather than Aphasic. "He understands all that is

* "Bullet. de la Soc. Anatom.," Aug. and Nov. 1861.

† "On Aphasia," 1870, p. 65.

said, but is affected with an incapacity to employ substantives, having lost the memory of words as far as that part of speech is concerned, and he will make use of a periphrasis to avoid using the substantive required." A few months afterwards he became paralysed, and soon after that so demented as to necessitate his removal to the Borough Asylum.

This, in its first stage, seems to have been a case of Aphasia pure and simple. Trousseau records several instances in which such a condition lasted only a few days or perhaps only a few hours, owing to the existence of some temporary abnormal cerebral condition—induced occasionally without apparent cause, and at other times as a sequence of some great excitement conjoined with 'worry' or over-work. Such cases are not extremely rare; two or three of them have also fallen under the notice of the writer.

When however an actual lesion exists, of greater magnitude than that which may have been present in the first stage of Dr. Bateman's case, it often happens that the Aphasia co-exists with a paralysis of the right side of the body—or a right Hemiplegia, as it is termed.

The larger the lesion, too, the greater is the chance that the Visual or the Auditory Centres themselves, or some of their commissures may be seriously damaged: with the effect of producing an admixture of Amnesic symptoms with those of Aphasia. Such additional symptoms may reveal themselves either from the first, or only as the individual begins to recover from the Aphasic condition.

Three instances of complications of this sort will now be given. The first of them being a case recorded by Trousseau, in which Aphasia was produced by a lesion that, at the same time, caused right-sided paralysis together with inability to read—the latter disability being probably due to damage of the left Visual Word-Centre.

M. X—, æt. 57. One evening whilst rising from his chair to shake hands with the curate of the place, he suddenly staggered, stammered, and dropped into the arms of his visitor, who had rushed forward to support him. He remained in a most profound apoplectic stupor for more than ten hours with complete paralysis of the right side. For a few days he gave only obscure signs of intelligence; but from the time of this seizure he entirely lost the faculty of speech. A few months afterwards (summer of 1860), he almost completely recovered the power of moving his right leg, but the movements of his right arm have always been impeded.

In the spring of 1863, M. X— was seen by Trousseau, who gave the following account of him :—"His face was intelligent, cheerful, and full of benevolence. He seemed by his gestures, and especially by the expression of his face, pleased to see me. He could not speak, and only uttered in a faltering voice unintelligible words, in which the monosyllable '*Yes!*' returned frequently. When I questioned him he answered '*Yes!*' to everything, even when he shook his head in denial. 'How old are you?'—'*Yes!*' How far back do you date your illness?'—'*Yes,*' &c., &c. It could be easily seen, however, that he was not satisfied when the word 'Yes' was wrongly applied, for he then made an impatient gesture. He looked pleased, on the contrary, when the word was used appropriately. He sat to table with us at dinner, used his left hand, and ate with great propriety. He looked after his guests during dinner, and took part in some of the discussions carried on. When the delicate character of the lamb of the country was praised, he nodded assent; whilst on some of the guests saying that the kid of the country had a better flavour than the lamb, he shook his head in disapproval. He made signs to the servants to hand the wine, and when wine of an esteemed vintage was going round he made signs that it should be drunk in preference to the rest."

"He played every day at 'all-fours,' hiding his cards behind a pile of books, and using his left hand. He often won when playing with the curate, the doctor, or his son, without their allowing him to do so out of kindness. His son and Dr. Laffite declared to me that he played as well as he ever used to do. Sometimes his son sits by his side to advise him, and stops him when he takes a card which seems not to be the proper one, but he insists on playing as he likes, and by winning the game proves to his adviser that if he sacrificed a card it was because he could thus improve his game. Although his son manages all his affairs, he insists on being consulted about his leases, contracts, &c.; and his son stated to me that his father indicates perfectly well by gestures which are understood by those habitually around him, when certain portions of the deeds do not please him, and that he is not satisfied till alterations are made, which are, as a rule, useful and reasonable."

Although his sight was good he could not read, or at least understand the sense of what he read; he listened with pleasure, however, when he was read to. He could not put together loose letters of the alphabet, nor write with his left hand.

"After dinner," Trousseau says, "I tried to make out how far he could give proof of intelligence.* As he always answered '*Yes*,' I asked him whether he knew how that word was spelt, and on his nodding assent I took up a large quarto volume, with the following title on its back: 'History of the Two Americas,' and requested him to point out the letters in those words which formed the word '*Yes*.' Although the letters were more than one-third of an inch in size, he could not succeed in doing as I wished. By telling him to seek for each letter in turn, and by calling out its name, he managed after some hesitation to point out the first two, and was very long in finding the third. I then asked him to point out the same letters again, without my calling them out first, but after looking at the book attentively for some time, he threw it away with a look of annoyance, which showed that he felt his inability to do as I wished him."

It has often happened to him to say a word which he has not uttered for a very long time, as if an old impression were revived in his brain. Some time ago he dropped his handkerchief, and as a lady near him picked it up and gave it to him, he said to her, "*Thanks!*" in a loud and distinct voice. His friends were delighted at this, and thought that he had recovered his speech. He was asked, implored, to say the word again; it was repeated to him several times, but all was in vain, he never could succeed: and this was the general rule, *he could not even repeat the simplest sound which had been uttered before him.* He told his age correctly in a most remarkable way, with his fingers.

* What follows, however, is rather to be regarded as evidence bearing upon the functional activity of his Visual Word-Centre, which was very defective. It constitutes no measure of the degree of the patient's intelligence, since this (as shown by a previous paragraph) was well preserved.

In the case next selected, the Aphasia was also associated with right-sided paralysis, but it was accompanied by considerable mental impairment, and there was evidence of the existence of damage not only to the Visual but also to the Auditory Word-Centres. The patient could neither Speak nor Write. Moreover, she did not seem to be able to apprehend the meaning of spoken words, and she was equally at a loss to understand written or printed characters. This case was recorded by Dr. Bazire.*

"M. W—, æt. 24, a young woman of short stature, was admitted as an out-patient at the National Hospital for the Paralysed and Epileptic on January 10, 1865, suffering from imperfect right hemiplegia, and complete aphasia. To all my questions she invariably answered, 'Sapon, Sapon.' It was ascertained from a relative who accompanied the patient, that she had been seized with paralysis on the right side three months previously. The actual attack was sudden. She dropped down senseless, remained in a comatose condition for several days, and when she recovered her senses could not utter a single word beyond 'Sapon, Sapon,' which she has ever since kept repeating at every turn. The paralysis was not complete after the first few days."

"When I first saw her the patient had walked to the hospital, a distance of about two miles from her residence. Her face was full of expression, and her eyes beaming with intelligence; yet it was manifest that these appearances were deceptive, and that her intellect was very much impaired. *She could not be made to understand at once, by words alone, what was required of her; and could not always answer correctly by gestures the questions which she was asked. Her pantomime was not so clear as that of a deaf and dumb individual, and she seemed not to be able to understand the meaning of words. They had to be spoken very slowly, and repeated several times before she could catch their meaning, and she most frequently failed completely in this. Gestures she understood at once. Thus, when I asked her to show me her tongue, she did not always do so immediately; but on putting out my own*

* Trousseau's "Lectures," Trans. p. 224.

tongue, and then making signs to her to do the same, she instantly complied. She was prone to shed tears or to laugh immoderately for the least thing, as ordinary hemiplegics are well known to do, at a certain period of their complaint. *She could not write a single word with her left hand; she held her pen properly, but only made a meaningless scrawl. Although she kept constantly repeating 'Sapon, Sapon,' I could never make her say 'Sap' or 'pon' by itself, or repeat any syllable or word after me.* She knew her own name, and when I mentioned it she laughed and pointed to herself. According to her sister's statement she remembered localities and knew faces well."

A month after she came under observation, she had further acute cerebral symptoms which increased her paralysis, and also still further clouded her intellect for a time. But by slow degrees, and after an interval of many months, she improved remarkably, so that by the following October she was considerably better in many respects. Dr. Bazire continues :—"Her intellect was improved, but not in the same proportion as the paralysis. Her emotional excitability is much less than before, although it is still marked. Her vocabulary comprises now a few more words. She still says *Sapon, Sapon,* but she can now distinctly articulate *yes* and *no,* although she does not always use them appropriately, and she can count *one, two, three, four.* When under the influence of great excitement she sometimes exclaims, 'Oh, dear me,' according to her sister's account. *She cannot yet write a single word, nor even form a single letter, although she has often tried hard. She does not know the letters of the alphabet,* and when she is shown *a* and *o,* and asked to point out *a*, she cannot do it. *She has still great difficulty in understanding what is said to her in words, although she is not in the least hard of hearing; but she immediately understands gestures.* Her own pantomime still lacks clearness. She never reads, but is fond of looking at pictures."

The next case of Aphasia to be recorded, was one which came under the care of the writer. There was here, also, the association with right Hemiplegia, but both it and the mental impairment were much more marked than in the last case. There was the same loss of ability to Read; and some difficulty in apprehending Speech, whilst in addition there was an imperfect power of comprehending signs, and an inability to Will and execute even the simplest motor acts.

M. C—, æt. 24, had suffered much mental distress owing to the recent death of one of her children. On October 3rd she had a fit for the first time, whilst in the street, but was able to walk home, and during the two days which intervened before her admission into University College Hospital she had twelve other epileptiform attacks.

Soon after her admission, she had another series of convulsions, affecting both sides of the body, though principally the right. During the intervals between the separate attacks, it was found that her face was partially paralysed on the right side, the right arm was completely paralysed, and the leg to a less extent. She had six series of these convulsive attacks in the three days following her admission, and during this time remained in a dull, lethargic state. On October 13th she gradually began to regain a certain amount of intelligence in look and manner.

On the 19th, her attention could be at once arrested; she made decided efforts to speak after questions, and was able to say 'yes' and 'no' indistinctly, though not appropriately. When told to show her tongue she merely opened her mouth, not attempting to protrude the organ. Was able to swallow without difficulty, and took food eagerly. On the 26th, seemed still more intelligent. Did not protrude the tongue when told, but opened her mouth and took hold of the tip with her fingers, with the view of bringing it forwards. *Although unable to move it by an unaided volitional stimulus, on a sweet lozenge being applied to her lips she immediately put out her tongue with great readiness, and whilst eating it laughed and seemed much pleased.* On the 28th, looked much brighter, and took notice of what passed around her. Made signs when she wished to attract the attention of the nurse. When asked if she had pain in the head, she nodded assent; but did not move her hand when told to place it upon the painful part, or else moved it in quite a different direction. Paralysis of limbs and face continued much the same.

About ten days afterwards I examined her again carefully. She had continued to improve in the meantime, and could now say 'Nurse' distinctly, in addition to 'Yes' and 'No.' *She could not repeat the simplest vowel sounds, neither could she read single words in large print, either aloud or to herself, so as to comprehend them.*

She could not, in fact, point out individual capital letters of very large type. When asked to point out M, after a long time, and much pressing, she placed her finger upon W; and when told that she was not right, and asked to point out W, after a still longer interval, she laid her finger upon S. *She seemed to recognize familiar objects, and know when the right name was given to them. She could not be made to count by tapping with her forefinger, although she had been shown most carefully what she was to do. She could not even be induced to give a single tap, and only looked distressed.* She seemed to recollect her own name. And although she did not give any signs of recognition when the name of the street in which she lived was mentioned, she immediately nodded assent when she heard the remaining part of her address—viz., "Fitzroy-square," pronounced. She rarely laughed, but frequently had fits of crying. She uttered no additional exclamations when excited, and her vocabulary was confined to the three words above mentioned.

This is a good example of one of the severer forms of disease, in which, beyond the Aphasia, with defective activity of the Auditory, and especially of the Visual Word-Centres, there was a general impairment of mental power due, in all probability, to the extensive nature of the lesion in the left Cerebral Hemisphere.

As a connecting link between the slighter cases pertaining to this category and those of the next—Agraphia—a good example may be quoted from Trousseau. It is an instance in which there was greater damage to the outgoing fibres from the Visual than to those from the Auditory Centre—since when the individual had regained some of his lost ability to Speak, he still continued unable to express his thoughts by Writing.

"A young labourer, æt. 28, had, according to the statement of his friends, been seized, suddenly and without any assignable cause, with complete mutism.

"The affection for which he came to the Hospital consisted solely in *an utter inability to speak, although his intelligence seemed to be unimpaired*, and he could perfectly understand all the questions that were put to him. But to these questions he invariably answered '*No*,' even when he nodded his head to signify assent. One of the students, however, informed me that when left alone with him, he had succeeded in making him say the word '*cloak*,' after many repeated trials. I found only a marked deviation of the apex of the tongue to the right, but no other sign of paralysis; the face, the trunk, and limbs, could be moved with perfect freedom and force. . . . When I asked him to write his name down he did so correctly, but when I told him to write down what had happened to him, he only wrote '*was, was, was*.' He knew perfectly well that this was not what he wanted to write, and, annoyed at not being able to express his thoughts, he put down the pen. Two days after this, on my asking him to write down the name of his birth-place, he wrote '*alone, alone, alone*,' and did so again when I asked him to write 'good morning.' His impatient gestures, all the while, showed that he was perfectly conscious that he was not writing what he had in his mind. On the following day he wrote again words that had no sense, such as '*game*' for '*soup*,' but he could say '*Good morning, Sir*,' speaking, it is true, like a child who is learning to speak. A few days later he said very distinctly, '*I am pretty well*,' and then '*Good morning, Sir, I am getting on well*,' with a hesitating voice, however, like an habitual stammerer, who endeavours not to stutter. When the attempt was renewed to make him write, he only scribbled on the paper a series of syllables without any meaning, but he managed to write under dictation, '*I have eaten*.'"

C. Agraphia.

6.—*Damage to Emissive Channels between the left Visual Word-Centres and the Motor Centres in the corresponding Corpus Striatum.*

In the typical form of this defect there would be a severance of the connections between the Visual Word-Centre and the superior motor centres concerned with the act of Writing—so that this act alone would become impossible, whilst the mental powers, with ability to Read and ability to Speak, would remain intact. This is a perfectly possible condition, and that, too, from a small lesion in one or other of various situations. The lesion might implicate the fibres which conduct the stimulus from the Visual Word-Centre to the Kinæsthetic Word-Centre, or it might involve this latter Centre itself, or, lastly, it might destroy, in some parts of their course, the fibres passing from the Kinæsthetic Word-Centre to the related motor centres in the Corpus Striatum. In either of these ways it is conceivable that a person might lose his ability to Write, alone and without other defect.

Should the individual, however, be paralysed on the right side of the body any such special defect would be hidden by the more general loss of power occasioned by paralysis of the right arm. But if such a person were to attempt to learn to Write with the left hand, there is no reason why he might not succeed, provided the left Visual Word-Centre were itself uninjured and in free communication through callosal fibres with its fellow of the opposite Hemisphere.

A person affected with right Hemiplegia would, however, probably be incapable of re-acquiring the art of Writing, with the left hand, if the left Visual Word-Centre itself were damaged. But with the existence of such a lesion the patient would also be unable to comprehend written or printed language. This seems to have been the case, for instance, with Trousseau's patient—M. X—, who, notwithstanding all his intelligence, could not, after three years, write with his left hand (see p. 652).

The Agraphic defect is almost never met with alone. It is most frequently associated with some mental defects, or with defects of Articulate Speech.

Again, the same term, Agraphia, may be appropriately enough allowed to include 'incoördinate' as well as 'paralytic' defects in the power of mental expression by Writing. Even with this extension, however, the cases on record that can be included under this head are comparatively few. The first to be quoted is one of the 'incoördinate' type. It is one of the many cases illustrative of Speech-defects for which we are indebted to Dr. Hughlings Jackson.*

An elderly, healthy-looking woman suddenly became ill five weeks before admission. She lost the entire power of speech for a week, and was also paralysed on the right side. When seen there was no apparent hemiplegia, but she complained of weakness in the right side. She could then talk, but made mistakes. For instance, when I was trying her sense of smell, which was very defective since the paralysis, she said in answer to a question, "I can't *say* it so much," meaning she could not smell so well. She frequently made mistakes in speaking, and called her children by wrong names. *This was never very evident when she came to the hospital, and might easily have been overlooked,* but her friends complained much of it. She seemed to be very intelligent. *Her power of expression by writing, however, was very bad, although her penmanship was pretty good, considering that she wrote with the weakened right hand.* She wrote the following at the hospital. I first asked her to write her name—I do not like, for obvious reasons, to give her real name for comparison: it had not, however, the slightest resemblance to the following, in sound or spelling,—

"SUNNIL SICLAA SATRENI."

When I asked her to write her address, she wrote,—

"SUNESR NUT TS MER TINN— LAIN.'

Thinking she might have been nervous when she wrote at the hospital, Dr. Jackson asked her to bring something that she had written at home. She did so, but the specimen (a fac-simile of which he gives) was not in the least better than what she had previously written. It is a perfectly meaningless assemblage of letters, notable only for the frequent repetition of small groups of them, in a fashion which we shall also find repeated in the next case.

* Lond. Hosp. Reports, vol. i. p. 432.

Unfortunately it is not stated whether this woman was able thoroughly to comprehend written or printed characters, and without knowing her condition in this respect, no safe diagnosis can be made. There was in her case an ability to form letters, but an inability to group them into proper words—and thus a complete inability to express her thoughts by Writing, even though her errors in Articulate Speech were comparatively few.

The next case is one which came under the writer's own observation. It is by no means typical, but very peculiar in many respects. The man was a Criminal Lunatic—one who had been some years before absolved from the penalty otherwise attaching to a murderous act, on the ground that he was an irresponsible agent.*

The patient, originally a sailor, is now about 45 years of age, and partially demented; he was formerly violent and dangerous, but without obvious delusions, and was certified to be insane in 1855. It was not till about the year 1857, or later, that he began to write in an extraordinary manner; previous to this date his letters to his friends are stated to have been written in an intelligible style. The peculiarity manifested itself first in this way: he commenced the writing of each word correctly, and then in the place of some of the remaining letters he wrote *ffg*. Afterwards, the whole character of the word became altered, and duplication of many of the consonants, together with an almost invariable termination with the letters *ndendd*, or, at least, *endd*, became the most noteworthy features of writing which though produced voluminously was almost utterly unintelligible.† When I was in the habit

* The particulars are given nearly as they were recorded in the "Med. Chir. Rev." for Jan., 1869.

† Trousseau speaks of a case of Aphasia in which the person during recovery, when he became able to utter a few monosyllables, always ended them by *tif;* and if he wished to say a word of several syllables, he only pronounced the first syllable, and added *tif* to it, saying, for example, "montif" for "monsieur," "bontif" for "bonjour," etc. We have thus additional evidence of the similarities existing between the different kinds of defective Speech and defective Writing.

of seeing him, about three years ago, he gave me very many sheets of his peculiar writing at different times, and from what I have in my possession I have cut out the sixteen specimens that have been lithographed. These show, plainly, that he either wrote with a peculiar and continual iteration of certain sets of letters, the writing being partly intelligible, or else that it was a mere succession of letters or strokes to which no meaning whatever could be attached.

One of the principal peculiarities about this case is, that whilst the man writes in this fashion he speaks in the ordinary way.

At my request Dr. Orange very kindly submitted the patient to a careful re-examination, and the replies with which he has furnished me seem to show that the man has now become more demented, though his special defect is much less marked than it was. The principal peculiarities observed were as follows:—

1. He can speak fairly well for a short time, but his attention wanders, and his voice then becomes drawling and monotonous, when he often either mispronounces a word (generally by altering its termination) or he substitutes another word or mere sound having no meaning.

2. He can read the newspaper either to himself or aloud—but he does not seem to gather the full meaning without effort, and his power of continuous effort is small. When he reads aloud he stumbles over the difficult words, and he reads in a drawling tone, but the words which he utters, if not actually those before his eyes, are words of a somewhat similar sound, and do not appear to have any obvious relation to the peculiar style of his writing.

3. He spells a word, when asked to do so, in the way in which he would write it, and then he pronounces it correctly immediately afterwards.

It is interesting to find that this man's mode of Reading was in accordance with his mode of Speaking, rather than with his peculiar style of Writing.* Upon this, in part, we base our view as to the nature of his particular defect, viz.: that it was due not so much to disordered action in the Visual Word-Centre as to some defect in the emissive

* Though the reverse obtained in the case of the government clerk recorded by Dr. Jackson (p. 628).

channels beyond—perhaps in the part of the Kinæsthetic Centre concerned with Writing-Movements. It is also in harmony with the view previously enunciated, that in reading aloud usually Visual Impressions revive corresponding Auditory Impressions of words, and that the stimuli which occasion either form of Articulate Speech pass in the main from the Auditory to the Kinæsthetic Word-Centres, and thence to the Motor Centres.

It is worthy of note, however, that in this case, as well as in others in which there has been defective action of the Visual Word-Centre, the mode of spelling was almost entirely harmonious with the patient's mode of writing rather than with his mode of speaking. It was, however, very strange to hear a man when asked to spell 'cat' say deliberately 'candd,' and then immediately pronounce the word as though he had spelt it 'cat.'

In a case of Agraphia recorded by Dr. William Ogle,* there was a grave Amnesic condition as regards Speech, though this was associated with a greater inability to Write than existed in either of the other cases.

"James Simmonds, fifty-four years of age, after a heavy blow on the left side of the head, seven years ago, was obliged to give up his work. He spoke without difficulty or hesitation, but miscalled things strangely. He then had a fit one morning, whilst dressing, which left him speechless and hemiplegic on the right side. For a fortnight he could not speak at all, though he was quite sensible. He could not say so much as 'yes' and 'no.' From this he gradually recovered, but always, as before, miscalled things. . . . A month ago he had a second fit, which left him with less power than before in his right side, but made little or no change in his speech."

"There is now partial paralysis of the right side, which does not prevent his walking. The facial muscles on that side are slightly affected as well as the limbs. His speech is very hesitating and

* St. George's Hosp. Reports, 1867, p. 103. The convenient word 'Agraphia' was, in this article, first introduced by Dr. Wm. Ogle.

imperfect. He often stops suddenly, at a loss for a word, and then frequently uses a wrong one. As, for example, he substituted 'barber' for 'doctor,' 'two shilling piece' for 'spectacles,' 'winkles' for 'watercresses,' &c. *He can, however, pronounce any word perfectly when prompted.* He says that he generally knows when he has used a wrong word, but not always."

"Before his illness he wrote a good hand, and was above his lot as regards education. *Now he cannot form a single letter.* Even with a copy before him he makes only uncertain up and down strokes. I gave him some printed letters, and asked him to pick out his name. After a long time he arranged JICMNOS. Clearly he had some slight notion of the letters which composed his name. According to his wife, before his illness, he spelt well, and was very particular about the spelling of his own name, which is one admitting of many variations. *When a copy was before him he quickly picked out and arranged his name correctly. He can read;* but he says that reading makes him very giddy, and causes great pain in the head. His general understanding seems good, and up to the average of men in his class."

The conditions here recorded represent the remainders of an 'Aphasic' attack. Inability to spell, *i.e.*, inability spontaneously to recall the letters composing a word, probably depends in the main upon some defect in the Visual Word-Centre; but the patient's ability to put the letters of his name together with a copy, shows that this Centre could act to some extent. This is seen also by the statement that he was able to read a little—though his powers in this direction were probably very slight. We may conclude that in this case the most severe or durable lesions were, therefore, in the track of the emissive fibres from the left Visual Word-Centre—perhaps in the Kinæsthetic Word-Centre itself.

Marcé speaks of a man in regard to whom it was noticed that he was able to write numerals with much greater precision and ease than ordinary letters—a condition which is not so singular as he thought. It is, indeed, commonly the case, that Amnesic patients find less difficulty in recalling the names of simple numerals than of letters (see p. 643), which is not to be wondered at when we recollect that these in all are nine in number rather than twenty-six, and that the observation directed to individual numerals has always been of necessity much more intent than the observation of single letters. The degree of familiarity with a set of objects or a set of actions is always a matter of great importance in these cases of impaired cerebral power: the newly acquired or more complex acts are those which first become impossible, whilst those which are most familiar and most deeply ingrained are the last to be interfered with. Dr. Lasègue knew a musician completely aphasic, who, being unable to speak or write in the ordinary way, could, after hearing a passage of music, write such passage on paper with ease.

D. Aphemia.

7.—*Damage to Emissive Channels between the Auditory and the Motor Word-Centres.*

The conditions now to be referred to are related to defective communications between the Auditory and the Motor Word-Centres, in much the same way that those of the last section are related to defective communications between the Visual and the Motor Word-Centres. With the necessary changes, what is there said will also here hold good in reference to the situations in which lesions of the Brain may produce Aphemia, with the addition that this particular defect *may* also be produced by a small lesion implicating the lower or medullary centres for Articulation.

These cases, as isolated defects, are, like those of simple Agraphia, extremely rare; though one of a typical character has been recorded by Trousseau (see p. 669). Similarly they may or may not be associated with paralysis of limbs, and they are also almost invariably occasioned by lesions in the left rather than in the right Cerebral Hemisphere, if the seat of damage be above the pons Varolii: but when the lesion is in the latter situation, or in the Medulla, the question of the side affected becomes a matter of indifference.

The nearer the lesion is situated to the Auditory Word-Centre (and therefore to the Cortical Grey Matter), the greater is the likelihood that there will be complications, in the way of associated mental defects; whilst, on the other hand, in the cases in which the defective action, resulting in the production of Aphemia, is to be referred to a lesion in the Corpus Striatum or of the lower articulatory centres in the Medulla, we may expect to have to do with mere motor disabilities, as a result of which vocal Speech will be rendered indistinct or wholly abolished.

Some cases will now be given in illustration of these defects, beginning with those which are most complex, and thence passing on to others of great comparative simplicity. The first of them is an illustration of extreme incoördinate defects of Speech, in combination with other abnormal conditions. Though complicated and obscure, it is too interesting to be omitted.

This case was recorded long ago by Bouillaud.* The man did not, as a rule, speak in mere unintelligible jargon; he mostly made use of actual words, though they were of such a kind and so collocated, as to have no resemblance to what he ought to have said. When reading aloud, however, he often uttered nothing but mere jargon.

Lefèvre, æt. 54, after some extreme mental anxiety, became unable to read, write, or find words to express his thoughts. His sensibility and powers of movement were unimpaired, and his general health

* Traité de l'Encéphalite, 1825, p. 290

was pretty good. When he wished to reply to questions that were addressed to him, he made use of expressions either quite unintelligible, or else having a meaning quite different from that which he intended to convey. When questioned as to his health, he replied rightly in two or three words; then in order to say that he did not suffer at all from pain in the head, he said, "*Les douleurs ordonnent un avantage*," whilst in writing he replied to the same question in this way:—"*Je ne souffre pas de la tête*." When a word such as *tambour* was pronounced, and he was asked to repeat it, he said *fromage*; though he wrote it, on the contrary, quite correctly when asked to do so. He was requested to copy the words *feuille médicale*; he wrote them perfectly, but could never exactly read the words which he had just written; he pronounced instead, *féquicale*, *fénicale* and *fédocale*. Then, when made to read the word *féquical*, written by himself, he pronounced it *jardait*. He often wrote upon paper phrases which were unintelligible, either by the nature of the words employed, or by their lack of relation to one another. When he was shown different objects, he generally named them correctly; but then he was wrong at times, and during the same sitting he called "une plume, *un drap*; un crachoir, *une plume*; une main, *un tasse*; une corde, *une main*; une bague, *un crachoir*."

This case is complicated, and one in which there were very distinct mental defects. The Visual Centre seems to have been fairly healthy, hence the patient was able to copy correctly. From the fact, however, that instead of repeating the word 'tambour,' when asked, he said 'fromage,' though he wrote the word quite correctly; and from the fact that after he had also copied a written word properly, he could not rightly pronounce it, we may infer that impressions received in the Auditory Word-Centre, might pass on correctly to the Visual Word-Centre, so as to enable its equivalent to be correctly reproduced in writing; but that impressions striking at once upon the Auditory Word-Centres, or coming to them from the Visual Word-Centres, could not be correctly rendered into articulate speech. The conclusion, therefore, is warranted that there was in this case not so much a defect of the Auditory Word-Centre, but rather something wrong with a portion of the emissive channels leading from it, by way of the Kinæsthetic Centres, to the motor centres for Articulation—whereby the activities of the Auditory Word-Centre became (incoördinately) associated with Articulatory Movements of the wrong kind.

This defect was, therefore, in its relations to Speech, very comparable with those existing in relation to Writing, in the cases of Agraphia recorded by Dr. Jackson and the writer, as given in the last section. The case was, however, complicated by considerable Amnesic defects of the incoördinate type, showing themselves both in Speech and Writing, though more frequently in the former.

In another very remarkable case, carefully investigated and recorded by Dr. Osborn,* the patient was able to talk only in a meaningless jargon, and on attempting to read aloud gave utterance also to a series of articulate sounds having no intelligible meaning or resemblance to those which he should have uttered. Some of the principal particulars concerning this case are subjoined.

A scholar of Trinity College, Dublin, twenty-six years of age, of very considerable literary attainments, and well versed in French Italian, and German, whilst sitting at breakfast, after having bathed in a neighbouring lake, suddenly had an apoplectic fit. He was reported to have become "sensible in about a fortnight," but, although restored to the use of his intellect, he had the mortification of finding himself deprived of speech. He spoke, but what he said was quite unintelligible, although he laboured under no paralytic affliction, and uttered a variety of syllables with the greatest apparent ease. When he came to Dublin his extraordinary jargon led to his being treated as a foreigner in the hotel where he stopped; and when he went to the College to see a friend he was unable to

* "Dublin Journ. of Med. and Chemical Science," vol. iv. p. 157.

express his wish to the gate-porter, and succeeded only by pointing to the apartments which his friend had occupied.

Dr. Osborn, after frequent careful investigations, ascertained the following particulars concerning his patient:—

1. He perfectly comprehended every word said to him.

2. He perfectly comprehended printed language. He continued to read a newspaper every day; and when examined proved that he had a very clear recollection of all that he read. Having procured a copy of Andral's 'Pathology' in French, he read it with great diligence, having lately intended to embrace the medical profession.

3. He expressed his ideas in writing with considerable fluency; and when he failed it appeared to arise merely from confusion, and not from inability, the words being orthographically correct, but sometimes not in their proper places.

4. His general mental power seemed unimpaired. He wrote correctly answers to historical questions; he translated Latin sentences accurately; he added and subtracted numbers of different denominations with uncommon readiness; he also played well at the game of draughts.

5. *His power of repeating words after another person was almost confined to certain monosyllables;* and in repeating the letters of the alphabet he could never pronounce *k*, *q*, *u*, *v*, *w*, *x*, and *z*, although he often uttered these sounds in attempting to pronounce the other letters. The letter *i*, also, he was very seldom able to pronounce.

6. In order to ascertain and place on record the peculiar imperfection of language which he exhibited, Dr. Osborn selected and laid before him the following sentence from the bye-laws of the College of Physicians, viz., "*It shall be in the power of the College to examine or not examine any Licentiate previous to his admission to a Fellowship, as they shall think fit.*"

Having set him to read, he read as follows:—"*An the be what in the temother of the trothotodoo to majorum or that emidrate eni enikrastrai mestreit to ketra totombreidei to ra fromtreido as that kekritest.*" The same passage was presented to him a few days afterwards, and he then read it as follows:—"*Be mather be in the kondreit of the compestret to samtreis amtreit emtreido and temtreido mestreiterso to his eftreido tum bried rederiso of deid daf drit des trest.*"

He generally knew that he spoke incorrectly, although he was quite unable to remedy the defect. After the expiration of eight months, however, he was so far improved that he was able to repeat the same bye-law after Dr. Osborn as follows:—"*It may be in the power of the College to evhavine or not ariatin any licentiate seviously to his amission to a spolowship, as they shall think fit.*" Some little time after this Dr. Osborn says he "repeated the same bye-law after me perfectly well, with the exception of the word 'power,' which he constantly pronounced *prier*. He was also able to pronounce all the letters of the alphabet except *d*, *k*, and *c*." He progressed in this way under the directions of Dr. Osborn, who advised him to commence learning to speak again like a child, repeating first the *letters* of the alphabet, and subsequently words, after another person, on the ground that he had "lost, not the power, but the art of using the vocal organs."

In this strange but very interesting case there seems to have been no appreciable mental defect. It appears conceivable that a disordered relation between the Auditory and the Kinæsthetic Word-Centres, or else a disordered activity of the latter Centres themselves, may have sufficed to induce some such defect.

Trousseau records another interesting case, in which there was an absence of mental defect and a simple inability to Speak. He says:—

"I received one day in my consulting-room a carrier of the Paris Halles, very young, and having the appearance of a man enjoying excellent health. He made signs that he could not speak, and handed to me a note in which the history of his illness was detailed. *He had written the note himself, with a very steady hand, and had worded it well.* A few days previously he had suddenly lost his senses, and had been unconscious for nearly an hour. When he came round he exhibited no symptom of paralysis, but *could not articulate a single word.* He moved his tongue perfectly, he swallowed with ease, but, however much he tried, he could not utter a word. He was ineffectually galvanized for a fortnight, but without any special treatment he completely recovered his speech five or six weeks after the invasion of the complaint. It is very remarkable, however, that *during the whole course of this* *singular affection he could manage all his affairs by substituting writing for speech.*

Here, the man being unable to articulate at all, was also incapable of reading aloud in any fashion; although we may fairly presume that he could readily comprehend what he read silently. And if, as the writer thinks, the patient was suffering from a simple motor defect, it was not so strange, as Trousseau supposes, that he should have been perfectly well able to manage his own affairs.

This last case may, indeed, be pretty confidently interpreted through the reflected light thrown upon it by another, more recently recorded by Dr. Bristowe.*

"A steward of a steam packet, æt. 36, in the midst of previously uninterrupted good health, complained, on the morning of March 7, 1869, in the Straits of Malacca, of headache and feverishness. This condition was succeeded, in the course of a few hours, with a series of very severe epileptiform attacks following one another quickly. Four hours after their commencement he began to recover consciousness. When he recovered, he found himself lying on the floor of the cabin; and he soon discovered that, although he could see and understand everything that was going on, he was totally unable to move a limb, had entirely lost the faculty of speech, and was 'stone deaf.' He could not hear a pistol fired off close to his ear. He remained in this condition as nearly as possible up to the time of his arrival at Singapore on March 20." At that time his right leg and arm were still weak, his left leg and arm were numb and quite powerless. He had considerable difficulty in 'masticating' his food, and he was still perfectly deaf and speechless. He gradually improved in the Singapore Hospital. "In the first week he regained the complete use of his right side, and audition so far returned that he could hear when spoken to loudly. His hearing was completely restored by April 22. He also regained to a great extent the use of his left arm, and improved remarkably in general health." He left the Hospital in the middle of June, and was put on board a sailing vessel homeward bound.

* "Trans. of the Clinical Society," 1870, p. 92.

On November 1st he was admitted into St. Thomas's Hospital, still speechless, and dragging his left leg much in walking.

Dr. Bristowe says:—"Three days after admission I saw the patient for the first time, and examined him pretty carefully. I found that he was perfectly intelligent, that he understood everything that was said to him, that he could read well and comprehend everything that he read, and that he could maintain a conversation of any length, he writing on a slate and his interlocutor speaking. He wrote indeed with remarkable facility a very excellent and legible hand, expressing himself with perfect point and accuracy, except for an occasional error of spelling and construction, due evidently to defective education. But he could not speak, he could not utter a single articulate sound. I ascertained, however, that he could perform with his lips, tongue, and cheeks all possible forms of voluntary movement, and also that he was capable of vocal intonation, in other words, that he could produce musical laryngeal sounds."

This patient was afterwards taught with great care, and with complete success, to speak again, although "he had been nine months entirely speechless, and believed himself to be hopelessly dumb."

The bilateral paralysis which existed at first, together with complete deafness and other symptoms, make it almost certain that in this case the patient was suffering from a lesion situated somewhere on the confines between the upper part of the Medulla and the pons Varolii. A lesion here might cause the complete deafness, the double paralysis, and for a time functionally disable the lower articulatory centres. There was clearly a mere motor Speech defect; and a much slighter lesion about the same region, or a little higher, might have given rise to such minor symptoms as were met with in Trousseau's case. It is possible, however, that this latter group of symptoms might have been occasioned by a slight lesion higher up in the left motor track—perhaps in the Corpus Striatum, or, even higher, in the white substance intervening between these bodies and the Kinæsthetic Word-Centres.

It has long been known that lesions in these situations, especially in the pons Varolii, may cause great difficulties and indistinctness of articulation, if not actual loss of Speech. A briefly-related case of this kind, in which a considerable lesion was actually found in this situation, as recorded by Dr. Wilks, may suffice for the final elucidation of this section.

"A lady fell in a so-called fit during dinner. She was taken up speechless and put to bed. She lay with her mouth open and with the saliva running from it, and she was *unable to swallow or to speak.* There appeared to be no paralysis of her limbs, and from her gestures and expression there was every reason to believe that she was perfectly sensible. She was soon able to leave her bed, and recovered her usual health, but *she never lost the paralysis of the tongue and palate.* She wrote down all her wants on a slate. *She swallowed with difficulty,* and the saliva was continually flowing from her mouth; but she was able to walk three or four miles a day, and was accustomed to join in a game of cards. About two years after the first attack she had another apoplectic fit, in which she died. On post-mortem examination there was found to be a great amount of disease of the cerebral vessels; much blood, which had escaped from the pons, was effused at the base. Within the pons *there was an old brownish cyst.* The central ganglia were healthy."

If the foregoing interpretation of Aphemia should prove to be correct, it will afford a simple explanation of a class of cases which many have deemed to be as puzzling as they were in the estimation of Trousseau. What has been said on this subject will have sufficed to show their relationship with those cases in which there is unquestionably a mere difficulty in articulation either complicating an ordinary attack of Hemiplegia, or forming part of a degenerative disease of the Medulla, known as 'Glosso-laryngeal paralysis'. On the understanding that it may be 'complete' or 'incomplete,' Aphemia is a term broad enough to include all these varieties of mere loss of Speech or difficulty of Articulation.

CHAPTER XXX.

FURTHER PROBLEMS IN REGARD TO THE LOCALIZATION OF HIGHER CEREBRAL FUNCTIONS.

THE study of the various defects of Speech, and of Intellectual Expression in general, produced by Cerebral Disease is of great importance in many ways. An accumulation of instances more or less crudely observed must almost necessarily precede the attempt to analyze and classify these various defects. Thereafter observers will work better and with more chance of success in two directions. They will (1) have learned more fully how to observe such cases, that is, what is specially to be looked for in the way of ability or defect in persons so affected; and (2) they may, whenever the precise mental defects manifested during life have been clearly recognized and recorded, as the occasion arises, note with more hope of profitable scientific result the exact region of the Brain which has been damaged.

The error of massing together all the varieties of 'loss of speech' under one name, such as 'Aphasia,' and then altogether rejecting doctrines of Cerebral Localization, because the lesions in such dissimilar cases have not always been found in some one part of the Brain, is manifest and absurd, and yet it is one which has been too often repeated in recent years. Even such an accomplished physician as Trousseau spoke of a representative case of Amnesia as a typical instance of Aphasia, and based his explanation of the Aphasic condition a good deal upon the phenomena by which it was characterized. This massing together, under one name, of wholly dissimilar defects, and the confusion thus created, would of course, so long as it lasted, effectually defeat all attempts at Cerebral Localization.

It is, therefore, absolutely necessary if further advance is to be made in regard to the 'localization' of higher Cerebral Functions, first, that we should learn carefully to discriminate the different Speech-defects from one another during life; and, secondly, that where opportunities occur, the locality of lesions should be principally observed and recorded in typical and uncomplicated cases.

A few brief additional details (beyond those which it has been found convenient to mention in the last chapter) will now be given as to the extent of knowledge already garnered within this second sphere of observation and inference—which, though not at present co-extensive with the other, nevertheless includes some facts of a rather startling description.

In 1825, Bouillaud* affirmed that the Frontal Lobes of the Brain were the parts principally concerned with Speech, because, as he said, these were the organs "for the formation and recollection of words, or the principal signs which represent our ideas." He had collected 114 observations of disease of the Frontal Lobes accompanied by loss or defect of Speech, and upon these he based his views.

Andral, however, in 1833, recorded fourteen cases where Speech was abolished without any alteration in the Frontal Lobes, but in which a lesion existed in the Parietal or in the Occipital Lobes.

* "Traité de l'Encéphalite," p. 284.

In 1836 Dr. Marc Dax called attention to the great frequency of loss of Speech in association with right rather than with left-sided Paralysis. The title of his essay was this :—"Lesions of the left half of the Brain coinciding with the loss of memory of the Signs of Thought." * In support of this view that loss of Speech depended especially upon lesions of the left half of the Brain, Dr. Dax brought forward 140 observations.

But in 1861, Broca† went still further. Whilst affirming, with Dr. Marc Dax, that the left Hemisphere was the one principally concerned with articulate Speech, he precisely defined the seat of lesion in that condition which we now call Aphasia as *"the posterior part of the third frontal convolution of the left hemisphere."*

This view, originally based upon a very small number of cases, was received at first with the greatest surprise and scepticism. It was thought by many to be most improbable that such a faculty as Speech should depend upon the integrity of one small portion of only one of the two Cerebral Hemispheres. Yet by reason of the observations which have accumulated during the last eighteen years, it is now admitted by most of those who are best entitled to judge, that Broca's localization is in a certain sense correct, and that in the instances of real typical Aphasia the lesion is, in a large majority of cases, found to involve the posterior part of the third frontal gyrus on the left side, or else the immediately subjacent white substance intervening between this convolution and the Corpus Striatum. The reason why lesions in other parts may, according to their situation, either occasionally or invariably lead to a more or less similar Speechless condition, is a question upon which we shall hope to throw additional light in this chapter.

* Republished in the "Gaz. Hebdomad.," April 28, 1865.

† "Bulletin de la Soc. Anatom.," Aug. and Nov., 1861.

Many cases are on record in which a lesion of the posterior part of the third frontal gyrus of the right Hemisphere has existed, without producing any loss of Speech. So that we have both positive and negative evidence in favour of Broca's association of the power of Articulate Speech with the integrity of the third *left* frontal convolution, especially if we extend the depth of the region cited by him so as to make it include the outgoing fibres from this part of the third frontal gyrus.

Fig. 184.—Brain of a Woman who suffered from Aphasia, showing the traces of a lesion in the posterior part of the third frontal Convolution. (Prevost.)—*See* "Nature," March 16, 1876, p. 400.

It is, however, also true that in a certain small proportion of cases a similar condition of speechlessness has been induced where a lesion has been found in the corresponding parts of the right Hemisphere. In some of these exceptional cases the persons have been left-handed, though in others even this reason for the change of sides has been absent. The writer has himself met with a most typical instance of this. But it is of importance to note that even in these very exceptional cases, though the side affected has been different, Speech has equally been lost by a unilateral damage of the same definite and extremely limited region of the Hemisphere.

Thus it would follow, that the motor incitations sufficing to call the articulatory centres into activity during Speech, are accustomed, in the large majority of cases, to emerge from the third frontal gyrus of the left side: though in a small minority of persons it may happen that the effective motor stimuli are wont to pass off instead from the right third frontal gyrus. The halves of the bilateral Articulatory Centres in the Pons, Medulla, and upper part of the Spinal Cord are so welded together by commissures that each of them practically constitutes one double Centre. And these may (after the manner of such bilateral Centres) be incited to action by stimuli coming through the Corpus Striatum either from the left or from the right Cerebral Hemisphere—though, as a matter of fact, as above stated, such stimuli seem to reach it, in the large majority of persons, from the left side of the Brain.

But if bilaterally-acting muscles are always in association with closely welded bilateral Motor Centres, and if such Centres may generally be called into activity by stimuli reaching them from either side or from both sides simultaneously, then the habitual excitation of the Speech Centres and their related muscles from the left side, must be regarded as a remarkable peculiarity.

There is, however, some reason for believing that if the habitual outgoing channels of the left side are damaged (so that Speech has been lost), the route for stimuli from the *right* third frontal gyrus to the corresponding Corpus Striatum may, under certain circumstances, be more effectively opened up, so that the power of Speaking is after a time regained. In such a case the stimuli would, of course, impinge upon the right rather than upon the left side of the lower bilateral Articulatory Centres.

Broadbent indeed maintains that, as a rule, loss of Speech is only temporary with lesions of the left Corpus Striatum, or of those parts of the outgoing fibres from the third frontal gyrus which are contiguous to this body. And he ingeniously attempts to explain its supposed speedy restoration in these cases. If the left third frontal gyrus be itself undamaged, and if the fibres of the Corpus Callosum which extend from it to the right third frontal gyrus be intact, then the outgoing stimuli not being able to take their usual course may, he thinks, find their 'way round' from the left to the right third frontal and thence downwards to the Corpus Striatum of the right side.* In these cases loss of Speech would possibly only exist for a few weeks, till the new route and new mode of action could be thoroughly opened up and established.† It is difficult, however, to understand how the previous education and organization of this right Corpus Striatum can have been brought up to the stage necessary to enable it speedily to assume such functions, if, to take the most favourable supposition, only feeble and ineffective stimuli have previously been reaching it.

There are difficulties also in the way of the acceptance of some of the reasoning upon which this theory is based.

* Inability on the part of an Aphasic person to learn to Speak from the right side of the Brain would thus be found to depend upon conditions precisely analogous to those producing in a right-sided Hemiplegic an inability to learn to Write with the left hand (*i.e.*, from the right side of the Brain). Speech would be impossible if the Auditory Centre, and Writing would be impossible if the Visual Centre, in the left Hemisphere were destroyed; or, similar disabilities would exist if the fibres of the Corpus Callosum respectively connecting either of these left Centres with its corresponding Centre of the opposite Hemisphere were cut across by disease.

† "Brit. Med. Jrnl.," April 8, 1876, p. 435.

Broadbent says:—"In its first attempts to talk the child is influenced by imitation and guided by the ear; that is, as the grouping of the motor cells of the cord is effected through the sensory cells, by cell processes passing from the posterior to the anterior nerve nuclei, so the grouping of the cells in the corpus striatum will be effected through the cells of the auditory perceptive centre by means of the fibres connecting together the two. . . . And, as the motor nuclei of the cord can still be employed in reflex action through the sensory nuclei, as well as in voluntary motion by means of descending fibres from the corpus striatum, *so may the word groups in the corpus striatum be reached imitatively through the auditory perceptive centre, as well as through the third frontal gyrus.*" Consequently he assumes that there is a double action of a consensual character from both Auditory Centres, and that in the early 'imitative' Speech-processes these parts would both react upon their respective Corpora Striata. There is also, as he thinks, a higher or volitional unilateral action through the left third frontal gyrus—an action which is unilateral because, as he puts it, "The left hemisphere alone is educated for intellectual expression."

But, Sensori-motor and Ideo-motor acts of Speech are dependent upon processes occurring (in a slightly different manner) in identically the same cerebral regions—and these would correspond with Broadbent's 'imitative' modes of Speech. Yet, as the writer has previously endeavoured to show (pp. 550–557), no valid demarcation can be established between Ideo-motor and Voluntary acts of Speech, and the distinction conferred upon the latter by the addition of an 'emotion of desire' does not make it the less necessary for the outgoing stimulus primarily to pass off from the Auditory Centre; nor, on the other hand, is there any distinct evidence to show that the incitations in 'imitative' Speech do not, like those in Voluntary Speech, also find their 'way out' through the third frontal gyrus. In fact, we have every reason to believe that the route from the Auditory Perceptive Centre to the Corpus Striatum is one and the same for every kind of Speech, whether its mode of incitation may be strictly 'imitative,' Ideo-motor, or distinctly Volitional.

This latter conclusion is found to be in accordance with the evidence derived from disease. No fact has been more certainly established in regard to Aphasic patients, than that there is in them a loss not only of Voluntary, but of Ideo-motor, and, to just as marked an extent, a loss of 'imitative' Speech. A really Aphasic patient cannot copy the simplest word or vowel sound, which he has just heard, nor does he even do it unbidden and echo-like, in the most purely imitative reflex style.

Others again have assumed that a separate route exists by which Emotional stimuli may be transmitted to the lower centres for Articulation in the Pons and Medulla, without passing through the Corpus Striatum, simply because Aphasic patients occasionally utter new words of an interjectional order—as oaths, or such phrases as 'Oh dear!' 'Thanks!' and other simple exclamations, under the influence of a strong emotional stimulus. Even for this kind of connection, however, no independent evidence exists (see p. 580); and perhaps the facts can be equally well explained by the supposition that Emotional stimuli of greater energy, or which emanate from a wider area, may occasionally force their way through damaged tracks, the resistance in which could not be overcome by mere Volitional stimuli.

As to the causes which have determined the greater or almost exclusive influence of the left Hemisphere in inciting Speech-movements, only conjectures can be offered. It has been thought that a certain more forward condition of development of the left hemisphere —as a result of hereditary right-handedness recurring through generation after generation—might gradually become sufficient to cause the left Hemisphere to 'take the lead' in the production of Speech-movements. Some little evidence exists—though at present it is very small —to show that it is left-handed people more especially who may become Aphasic by a lesion of the *right* third frontal gyrus. It is practically certain, indeed, that the great preponderance of right-hand movements in ordinary individuals must tend to produce a more complex organization of the left than of the right Hemisphere, and this both in its sensory and its motor regions. We may confidently look for the existence in it of the organic basis of a vastly greater and more complex Tactile experience; and as movements of the right arm and hand are more frequent, both as associated factors of this experience and in other ways, we have also a right to expect that the Kinæsthetic Centres will be similarly developed to a notably greater degree in the left Hemisphere. And as a matter of course also the nervous mechanisms for the movements with which these sensory impressions are associated would be much more complex in the Motor Ganglion of the left than in that of the right Hemisphere.

Many years ago, moreover, the writer ascertained a fact which at the time seemed very difficult to understand— viz., that the specific gravity of the cortical Grey Matter of the Brain in left frontal, parietal, and occipital regions is often distinctly, though slightly, higher than that from corresponding regions of the right Hemisphere.* But such an increase in specific gravity might be produced by

* See a paper "On the Specific Gravity of the Human Brain," in "Jrnl. of Mental Science," 1866, pp. 28, 32.

the existence of the greater number of cells and commissural fibres which the extra sensory and derivative functions above referred to would probably entail.*

Having considered some of the questions of cerebral localization' relating to the production of Aphemia, Agraphia, and Aphasia, something must now be said in regard to the seat of lesions productive of the very varied conditions comprised under the term **Amnesia.**

Our knowledge on this point is at present rather vague and indefinite, since it is only quite recently that the necessity of not confounding such cases with Aphasia has been at all generally recognized. Moreover, no distinct attempt has hitherto been made to analyze and classify the various conditions comprised under this one term 'Amnesia.' Much more will doubtless soon be ascertained, in reference to this subject, by future workers, especially when the examination of cases is more thoroughly and systematically undertaken.†

Still the knowledge we possess of Amnesic conditions, as well as of the distribution of 'ingoing' fibres in their passage from the base of the Brain to the Convolutions, already enables us to point roughly to the neighbourhood in which lesions or injuries would be likely to produce defects of Speech and Writing of this type.

Lesions of the convolutions *about the posterior extremity*

* See also pp. 399–404.

† In all cases of Amnesia, or of mixed Aphasia and Amnesia, details should among other things always be given in reference to the following points:—(1) The patient's ability to understand spoken words (not being deaf); (2) to repeat sounds or words when requested; (3) to write from dictation; (4) to understand and therefore to point out printed letters and words (not being blind); (5) to copy written words, or printed words into written words; and (6) to name printed letters or objects, or read aloud.

of the Sylvian Fissure of the left Hemisphere will probably prove almost as instrumental in producing one or other variety of Amnesia, as lesions of or about the third left frontal are of inducing Aphasia. In Broadbent's case (p. 645) the lesion was found in this region, and in a fairly typical unpublished example of Amnesia the writer has also recently found a lesion in the same situation.

The reason for looking to this region will, moreover, be obvious if the reader will recollect that the posterior third of the peduncular fibres (that is of the so-called 'internal capsule') spread out from beneath the posterior part of the Thalamus; and that, stretching backward and outwards across the floor of the lateral ventricle from near the beginning of the descending cornu, they distribute themselves in the main to the Occipital and the Temporal Convolutions. And if the conclusions of Ferrier in regard to the important relations of the 'supra-marginal lobule' and the 'angular gyrus' with the Visual Centre, and of the posterior part of the 'upper temporal convolution' with the Auditory Centre should prove to be correct, there would be these still more precise reasons for expecting to find the lesions productive of Amnesia, with some frequency, in or about the situation indicated. Such a 'localization' may, therefore, be provisionally entertained, and no more promising means of ultimately ascertaining with tolerable certainty the situation of the most important parts of the Visual and Auditory Perceptive Centres in man would seem to present themselves, than the careful clinico-pathological study of typical Amnesic cases whenever the opportunities may occur.

Another question of great interest now arises, and that is, whether it will be found that lesions productive of Amnesia are also in the main limited to the left Hemisphere. Some eminent observers, such as Brown-Séquard and Hughlings Jackson, believe that a limitation of this kind does obtain. But whilst the writer freely admits that lesions of the left are more likely to be potential than those of the right Hemisphere in the production of such states, it seems to him that both facts and theory tend to negative the idea that similar defects would not be induced by lesions in certain parts of the right Hemisphere.

It will be found that many such cases are already on record—one of the most typical being that of Marcou, as given by Trousseau (see p. 621). And if we bear in mind that corresponding Perceptive Centres in the two Hemispheres are almost habitually called into simultaneous activity, and are in structural continuity with one another through the Corpus Callosum, it might be expected that irritative or destructive lesions of the Auditory or the Visual Word-Centres of the right side could scarcely occur without producing distinct derangement, at all events for a time, in the functional activity of the similar centres in the left Hemisphere—which, as one is bound to admit, seem to take the lead in the expression of Thought by Speech and Writing. On this very interesting subject much further information is needed, and we have previously (p. 493) had to refer to the doubt that exists as to the extent to which one Hemisphere alone may suffice for ordinary mental activity. It may fairly be expected, perhaps, that Amnesia produced by a lesion of the right side would have a tendency to be more temporary than such a condition when occasioned by similar lesions of the left Hemisphere.

Finally, another consideration of some importance in connection with 'cerebral localizations' now suggests itself. The condition of Amnesia may merge by insensible gradations into one of Aphasia—so that the latter state, with certain extra peculiarities, may at times result from a lesion altogether away from the third left frontal gyrus, if, as we at present suppose, the regions in which lesions have the greatest tendency to produce one or other of the forms of Amnesia should be situated around the posterior extremity of the left Sylvian Fissure.

This may be easily understood. Suppose a person to be suffering from a defective activity of the Auditory Word-Centre, so that Names cannot be recalled 'voluntarily' or by 'association.' There would already be great hesitations and difficulties in the expression of Thoughts, both in Speech and in Writing. But suppose this mere defective activity to be replaced by actual destruction of the left Auditory Word-Centre, so that its functional activity became entirely lost: words could then, of course, neither be recalled 'voluntarily' nor by 'association'; and still further, they could not be perceived and consequently could not be imitated. An individual thus affected would neither be able to Speak nor to Write, that is, he would be completely Aphasic—with the superadded peculiarity that he would not readily comprehend spoken and perhaps written Language. The latter ability might persist to some extent, because the molecular equilibrium of the Auditory Word-Centre and of the related Visual-Centre of the opposite Hemisphere might not be sufficiently disturbed to prevent all apprehension of spoken or of written symbols. We might, in fact, have in such a case, the production of a complex Aphasic condition almost precisely similar to that met with in the girl whose case was recorded by Bazire, (p. 653) or even one like that recorded by the writer at p. 655, and yet such an Aphasic condition might have been caused by a lesion far away from the left third frontal convolution. And if this were so, such cases might have been quoted with much apparent effect against existing doctrines in regard to 'cerebral localization.'

Similarly, it is possible that **Agraphia**, accompanied by 'word-blindness,' might result from a lesion of the left Visual Word-centre, and that the site of such lesion might be contiguous to the posterior extremity of the left Sylvian Fissure.

Aphemia (that is, mere loss of Speech) could not be produced by a lesion of this region of the Brain, because destruction of the Auditory Word-centre would destroy the revival of words for spontaneous Writing, as well as for Speech—so that the double condition **Aphasia** (or an approximate state in which 'imitative' Writing only is possible), would necessarily result, instead of the more special Aphemic state.

It is clear, also, that if important tracts of the Auditory and Visual Word-Centres are in reality situated somewhere about the end of the Sylvian Fissures, and if the Kinæsthetic Word-Centres, both for Speech and Writing, are situated in or somewhere in the neighbourhood of the third frontal convolutions, **Aphasia** might in addition be caused by lesions cutting across the commissural fibres in any part of their course between these pairs of centres.

Clearly, if stimuli caused by the mental revival of words do not (*a*) issue from the Auditory and Visual Word-Centres; if they (*b*) are stopped on their way therefrom to the corresponding Kinæsthetic Word-Centres; or (*c*) if they are stopped in or on the other side of these latter Centres, that is on their way to the left Corpus Striatum, the result would, in each case, be the production of **Aphasia**, although the situations of the lesions in these cases would be altogether different. In the first case, too, we should have Aphasia with much mental impairment; in the second case we should have Aphasia with trifling mental impairment; whilst in the third case we should have the typical Aphasia, in which little or no mental degradation is to be detected.

This being true, a general law may provisionally be formulated, as a future working hypothesis: that *the tendency to mental impairment with Aphasia, and the degree of such impairment, will, other things being equal, increase as lesions of the left Hemisphere recede in site from the 'third frontal convolution' and approach the Occipital Lobe.* The general doctrine of Marc Dax seems to be justified, whilst Broca's more special localization must be held to hold good only for one particular though very common form of Loss of Speech—or, to use the broader and more accurate phraseology, loss of the power of Intellectual Expression.

The conclusions above arrived at are found to afford a new and quite unlooked for confirmation of the view already announced as to the special frequency with which lesions of the Occipital Regions of the Hemisphere are apt to be associated with marked mental degradation; they will also tend to make us appreciate more fully the real validity of the objections raised by some against the doctrine that the posterior part of the left 'third frontal gyrus' is *the* region always damaged in cases of Aphasia; and they may pave the way for new and more exact differential observations, by means of which alone we can expect to make real progress in a task of extreme difficulty, in which we are now only breaking ground in a tentative manner—that is, in the endeavour to determine what kind of functions are principally carried on in different regions of the Cerebral Cortex.

If we have said nothing in regard to the 'localization' of certain higher Intellectual and Moral Powers, the reason for this will be obvious to all thoughtful readers. No step can be taken with any chance of success in this direction till the preliminary enquiries to which we have been devoting our attention have been reduced to a more settled condition. The foundations of the subject must clearly be laid before we can begin to rear a superstructure.

Yet that every higher Intellectual and Moral Process—just as much as every lower Sensorial or Perceptive Process—involves the activity of certain related cell-and-fibre networks in the Cerebral Cortex, and is absolutely dependent upon the functional activity of such networks, the writer firmly believes. He, however, as decidedly rejects the notion which some would associate with such a doctrine, viz., the supposition that Human Beings are mere 'Conscious Automata.'

It must be conceded that if Conscious States or Feelings have in reality no bond of kinship with the molecular movements taking place in certain Nerve Centres; if they are mysteriously appearing phenomena, differing absolutely from, and lying altogether outside, the closed 'circuit of motions' with which they coexist, no way seems open by which such Conscious States could be conceived to affect or alter the course of such Motions. The logic of this seems irresistible. The conclusion can, indeed, only be avoided by a repudiation of the premises: and this the writer does. He altogether rejects the doctrine that there is no kinship between States of Consciousness and Nerve Actions, and consequently would deny the view that the 'causes' of Conscious States lie altogether outside the circuits of Nerve Motions.

Consciousness or Feeling must be a phenomenon having a natural origin, or else it must be a non-natural, non-material entity. For reasons which have been set forth in various parts of the present volume the writer adopts the former of these views.

It is commonly believed that 'living matter' has now, or has had in past times, a natural origin; Nerve Tissues also have a natural origin in or from elemental forms of 'living matter'; and if Conscious States or Feelings are admitted to be an appanage only of Nerve Actions, so also (as far as we can ascertain) does their mode of appearance, their increase in intensity, their modifiability by agents modifying the nerve tissues, and the limitation by which they occur only in association with certain nerve actions taking place in the higher and most complex of an animal's Nerve Centres, harmonize with the notion that they are in some way an actual outcome of such Nerve Actions—no more capable of being dissevered from the physical conditions on which they depend, than is Heat to be dissevered from its physical conditions (see p. 142). To say that Heat is a 'mode of motion,' takes for granted the underlying fact that we cannot have motion except through a something which moves. Heat has no abstract and isolated existence as an entity. Consciousness also is a result of a something which moves. But just as it is the very material motions on which Heat depends which do the work ascribed to Heat, so do the very material motions on which Consciousness or Feeling depends, do the work which we ascribe to Feeling. These particular motions, be it remarked, enter as components into the 'circuit of motions' constituting Nerve Actions, and may, therefore, easily co-operate as real motors. Hence it is that States of Feeling may, in very truth, and in accordance with popular belief, react upon Nerve Tissues so as to alter the molecular motions taking place therein. Feelings, whether purely personal or of the moral order, thus have, as they seem to have, an indubitable effect in modifying our Intellectual Operations, our Volitions, or our Movements.

To show how these particular motions in Nerve Tissue arise which underlie Conscious States, and how they again subside into more ordinary nerve actions, must, from the very nature of the problem, ever remain impossible. But we certainly should not on this account allow ourselves to be mentally paralysed by a belief in the existence of a metaphysical gulf between what is termed the Subjective and the Objective—the 'Ego' and the 'Non-Ego.' Yet, even some believers in the philosophy of evolution have thus been led to deny the natural origin of Conscious States, and have as a consequence found themselves forced to hold a doctrine of thoroughgoing 'Automatism'—one in which all notions of Free Will, Duty, and Moral Obligation would seem from this theoretical basis to be alike consigned to a common grave, together with the underlying powers of self-education and self-control.

APPENDIX.

VIEWS CONCERNING THE EXISTENCE AND NATURE OF A MUSCULAR SENSE*.

According to Sir William Hamilton, the recognition of the Muscular Sense, as a medium of apprehension, was originally made, some three centuries ago, by two Italian physicians. It was recognized by Julius Cæsar Scaliger in 1557, and afterwards independently by Cæsalpinus of Arezzo in 1569, that the exercise of our power of movement is the means whereby we are enabled to estimate degrees of 'resistance,' and that by a faculty of "active apprehension" which was by them contrasted with touch as "a capacity of sensation or mere consciousness of passion."

After a very long interval, De Tracy (one of the most distinguished followers of Condillac) about the beginning of this century, more explicitly developed this conception and "established the distinction between *active* and *passive* touch." German physiologists and psychologists towards the close of the last and the beginning of this century had, however, made the same analysis, and "the active touch there first obtained the distinctive appellation of the Muscular Sense (Muskelsinn)." These views were soon after introduced into Scotland by Dr. Thomas Brown.

Subsequent variations of opinion in regard to the Muscular Sense are, to some extent, represented by the following quotations. J. Müller ("Physiologie," 1835) says:—"We have a very exact notion of the quantity of nerve force starting from the brain, which is necessary to produce a certain movement . . . . It would be very possible that the appreciation of the weight and pressure, in cases where we raise or resist, should be, in part at least, not a sensation in the muscle, but a notion of the quantity of nerve force which the brain is excited to call into action." Soon after this date, we find Sir William Hamilton (1846), in his 'Notes and Dissertations' on Reid,

* See p. 541.

maintaining that the notion of 'resistance' or 'weight' is apprehended "through the *locomotive faculty* and not the *muscular sense.*" His view was almost precisely similar to that of Müller; for whilst holding that resistance and weight are measured principally by what he terms the 'locomotive faculty,' he admits that the appreciation by this faculty of the greater or less force of our "mental motive energy" is always accompanied and aided "by sensations, of which the muscular nisus or quiescence, on the one hand, and the resisting, the pressing body, on the other, are the causes." He adds:—"Of these sensations, the former, to wit, the feelings connected with the states of tension and relaxation, lie wholly in the muscles, and belong to what has sometimes been distinguished as the muscular sense. The latter, to wit, the sensations determined by the foreign pressure, lie partly in the skin, and belong to the sense of touch proper and cutaneous feeling, partly in the flesh, and belonging to the muscular sense. These affections, sometimes pleasurable, sometimes painful, are, in either case, merely modifications of the sensitive nerves distributed to the muscles and to the skin."

This opinion that we appreciate 'weight' or 'resistance' principally by the so-called 'locomotive faculty' was, a little later, also favourably regarded by Ludwig, who says ('Lehrb. der Physiologie,' 1852):—"It is conceivable and not unlikely that all knowledge and discrimination arrived at through the exertion of the voluntary muscles are attained directly through the act of voluntary excitation, so that the effort of the will is at once proceeded on as a means of judgment." Prof. Bain, in the first edition of his work, "The Senses and the Intellect" (1855), seemed to incline to the same view, though his opinion was not quite adequately expressed. He demurs to what he calls Hamilton's assumption that "we have a feeling of the state of tension of a muscle, independently of our feeling of motive power put forth." "It may be quite true," he adds, "that sensitive nerve filaments are supplied to the muscles as well as motor filaments, and that through these we are affected by the organic condition of the tissue, as in the first class of feelings above described; but it does not follow that we obtain by the same filaments a distinctive feeling of the degree of the muscle's contraction." When, a few lines farther on, Bain speaks of "a sense of expended energy" as "the great characteristic of the muscular consciousness," his precise view becomes indistinct and somewhat confused.

Landry, a little later ('Traité des Paralysies,' 1859), relying upon pathological as well as psychological data, re-affirms the same kind of view as that of Hamilton (doubted by Bain) in reference to the existence of impressions yielding feelings of tension coming from the muscles by sensory nerves; only, instead of regarding (with Hamilton) these impressions as subsidiary, he deems them all-important, and denies that our notions of resistance, weight, &c., can be derived from any mere cerebral process, or, indeed, from any other source than the moving parts themselves. He says:—"The *ego* has a direct consciousness of the phenomena of volition; it knows immediately that there has been a voluntary stimulus, and to what part of the body it is directed; as to the effects produced it is only mediately informed of these and can disregard them . . . . . . The nervous action which incites the movement can only, therefore, furnish to consciousness an idea of the volition, and not that of its execution . . . . . . It is necessary that the effect of the central incitation (the contraction) should be produced in order that the brain may perceive, and then it perceives, at the same time, both the seat and the degree of contraction. *The movement itself is, therefore, the source whence we derive notions of this kind.*"

This latter part of the view of Landry, adverse to the notions of Müller, Hamilton, Ludwig and others, in regard to the 'locomotive faculty,' was about the same time independently affirmed by G. H. Lewes ('Physiol. of Common Life,' vol. ii. 1860), though in regard to the mode in which we derive our impressions from the moving members, Lewes, in part, introduced us to a new view—based however, upon very debatable grounds. He deemed it an error to regard the nerves of the anterior and of the posterior roots as essentially distinct in function: the fibres of each, he contended, are both sensory and motor—that is capable of transmitting ingoing impressions as well as outgoing stimulations, though they may minister to these functions in different proportions. The kind of sensibility to which motor nerves directly contribute (by conveying impressions backwards from muscle to motor centre) must, Lewes thought, "be that of what we call the Muscular Sense, by which we adjust the manifold niceties of contraction required in our movements." "The body is balanced," he added, "by an incessant shifting of the muscles, one group antagonizing the other. But this would be impossible, unless each muscle were adjusted and co-ordinated by sensation." Lewes admits, however, that such sensations do not much "emerge into that prominence which causes the mind to attend to them," and he cites Schiff as holding the view that "all the phenomena (*i.e.*, conscious impressions) attributed to the muscular sense are due to the foldings and stretchings of the skin when the muscles contract*." Trousseau's† view was very similar to that of Schiff.

Wundt ('Menschen-u. Thier-Seele,' I. p. 222, 1863), thinks it most probable that "the sensations accompanying the contraction of the muscles arise in the nerve fibres that transmit the motor impulse from the brain to the muscles." If it were due to sensory nerves in the muscles, he says, "the muscular sensation would constantly increase and decrease with the amount of internal or external work done by the muscle. But this is not the case; for the strength of the sensation is dependent only on the strength of the motive influence passing outwards from the centre, which sets on the innervation of the motor nerves." A statement similar to this was made by Hamilton, though it has now been shown to be completely erroneous. The contrary condition of things is, indeed, well illustrated by the cases of Demeaux, and Spaeth (pp. 698, 700).

Bain's statements in the second edition of his work (1864) become more explicit than they were in the first. He says:—"Our safest assumption is that the sensibility accompanying muscular movement coincides with the outgoing stream of nervous energy, and does not, as in the case of pure sensation, result from an influence passing inwards by ingoing or sensory nerves." This opinion is repeated and emphasized in the third edition (1868), in which he adds (p. 76), in regard to the characteristic feeling of exerted force, "we are bound to presume that this is the concomitant of the outgoing current by which the muscles are stimulated to act." He considers it to be of immense consequence, from a philosophical point of view, that such impressions should be associated with the outgoing current, and not dependent upon ordinary sensory nerves.‡

Bastian ('On the Muscular Sense,' Brit. Med. Journ., April, 1869) says:—"All the evidence we can obtain from disease, and also, as I think, the evidence which we can obtain from the most careful examination of our own sensations, goes rather to support, so far, the opinion of Landry—that these impressions do not depend upon our notions of the quantity of nerve-force liberated during a volitional effort, or, in other words, upon the mind's consciousness

* See his 'Muskel u. Nervenphysiol.,' pp. 156, ff.

† 'Clinical Medicine,' *art.* 'Locomotor ataxy'.

‡ The very existence of sensory nerves in Muscles was formerly held to be quite uncertain. This doubt, however, no longer exists. The investigations of Sachs ('Centralblatt für die Med. Wissensch.,' 1873, and 'Archiv für Anatomie,' 1874) have shown conclusively that sensory fibres are abundant within the Muscle itself, and that, having a course and distribution entirely distinct from the motor filaments, they enter the Spinal Cord by the posterior or sensory roots of the spinal nerves.

of its own outgoing energy." The feeling of 'expended energy' by which we obtain our ideas of resistance and of an external world is not contained in, or an appanage of, the volitional act, "but is derived through impressions emanating from the moving organs themselves." Our perceptions of 'resistance' and of 'weight' are, in fact, "partly made up of tactile impressions, partly of passive sensations emanating from our muscles and joints, and of inferences founded upon these . . . . . . We experience certain feelings of pressure, combined with certain sensations in the muscles and in the joints, and we gradually come to associate certain combinations of these with the sensations produced by handling certain standard weights." If the term 'muscular sense' is not to be applied to the passive sensibilities of muscle, then it must be restricted to mere 'unconscious' impressions, which may, perhaps, pass upwards from *spinal motor centres* to the brain by a special set of fibres (see p. 699, note). Such an endowment would, in that case, have to be regarded as "an unconscious organic guide in the performance of voluntary movements," and for the existence of some such guide, evidence is not altogether wanting. It would also, in all probability, supply the guiding sensations necessary during the continuance of automatic movements.

If we attempt to classify the views (which have been above set forth or referred to in mere order of time), as to the modes by which we apprehend different degrees of *resistance* and *weight*, they may be ranged as follows:—

Through Motor Centres.	1. Estimation of Will-force (through a so-called 'locomotive faculty') anterior to and independent of sensations from the moving members. *Scaliger* and *Wundt*. 2. By a "sense of expended energy" which is "a concomitant of the outgoing current"—that is, by a sensory revelation resulting from the activity of motor centres, nerves and muscles. (This view, which is allied to the last, differs from it by the added supposition, that the appreciation of weight or resistance requires more than the activity of the volitional centre, and can take place only on condition that the motor incitation is not stopped by paralyzing or other lesions, but goes on to evoke the activity of the motor nerves and muscles with which the volitional centre is in relation.) *Bain*. 3. By ingoing currents or impressions from the muscles, conveyed back to the volitional centres by the motor nerves themselves. (According to this view, motor centres and nerves would be coincidently or in immediately successive increments of time engaged with outgoing and with ingoing currents.) *Lewes*.

Through Motor and Sensory Centres.	4. Principally in the way specified by Scaliger (*i.e.*, through a 'locomotive faculty'), though this appreciation is aided by ordinary sensory impressions, traversing sensory nerves and coming from the moving members, *e.g.*, by feelings of tension and pressure from the muscles ('muscular sense'), and feelings of pressure emanating from the skin. *J. Müller* and *Hamilton*.
Through Sensory Centres.	5. Through impressions of tension and pressure transmitted by ordinary sensory nerves from the moving members, *e.g.*, from muscles, from joints and from skin; and possibly, in addition, through certain 'unconscious' impressions passing by special afferent nerves from the spinal motor centres. *Bastian*. 6. Through impressions of tension and pressure emanating from the contracting muscles, transmitted by ordinary sensory nerves of muscle to sensory centres. *Landry*. 7. Through cutaneous and articular impressions alone. *Schiff* and *Trousseau*.

On the other hand, in regard to the existence and nature of anything like a distinct 'muscular sense,' we meet with the following different views:—

1. That there is such an Endowment: though opposing notions are entertained as to the source of its impressions and as to its seat.

   a. Its impressions (becoming symbols of 'weight' or 'resistance') are derived from muscles through sensory nerves, and its seat is on the sensory side. *Hamilton*, *Landry*, &c.

   b. Its impressions are derived from muscles through motor nerves, and its seat is on the motor side. *Lewes*. (Allied to this, though each differing somewhat therefrom, are the views of *Wundt* and *Bain*.)

2. That there is no such Endowment.

   a. That impressions giving notions of 'weight' and 'resistance,' and knowledge of the position and movements of a limb, are not derived from muscles. *Schiff* and *Trousseau*.

   b. That the above impressions are only in part derived from muscles, and, as those having such an origin are for the most part of the 'unconscious' type, that there is no endowment worthy of the name of 'muscular sense.' *Bastian*.

Since 1869 the principal contributions to the subject have been made by Bernhardt ('Archiv für Psychiatrie', vol. iii., 1872), Weir Mitchell ('Injuries of Nerves', 1872), Ferrier ('Functions of the Brain', 1876), and G. H. Lewes ('Brain,' No. i., April, 1878).

Bernhardt supports the intermediate view that our notions of 'resistance' and 'weight' are derived principally from an apprehension of the degree of outgoing energy in the volitional centre, though in part, also, from ordinary centripetal impressions. Weir Mitchell also holds an intermediate doctrine: he admits the efficacy of ordinary centripetal impressions from skin, joints, and muscle, though he, in addition, relies upon an estimation of another kind, more distinctly connected with the volitional act, either in the manner suggested by Scaliger and Wundt, or else after the fashion suggested by the present writer in 1869. His words are (*loc. cit.* p. 358):—"Probably, then, a part of those ideas which we are presumed to obtain through the muscular sense are really coincident with, and necessitated by, the originative act of will, or else are *messages sent to the sensorium from the spinal ganglia which every act of motor volition excites*." Weir Mitchell adduces many extremely interesting facts in reference to the sensations in question, and the power of recalling feelings of movement referred to amputated limbs, which have a very interesting bearing upon this subject. He thinks, and his facts seem to show, that something more than mere ordinary centripetal impressions require to be postulated; but he admits that these facts may be explained just as well by impressions passing to the sensorium from spinal as from cerebral motor centres. So far, therefore, Weir Mitchell's views are closely in accord with those previously expressed by the writer in 1869—though this was apparently unknown to Mitchell at the time of the publication of his work.

The reasons cited by the present writer in 1869 seemed quite sufficient to entitle him absolutely to reject the notion that degrees of 'resistance' and 'weight' were apprehended through the cerebral motor centres, rather than from centripetal impressions. The grounds for this rejection have been, however, very decidedly strengthened by Ferrier. Experiments made by himself and Lauder-Brunton show that muscular discrimination of weight is independent of the volitional act, since it can be exercised when the muscles are made to contract artificially by means of the electric stimulus (*loc. cit.*, p. 228). The facts furnished by certain persons suffering from complete *Hemi-anæsthesia* also seem conclusively opposed to the notion of Wundt, Bain and Lewes, and to others who may hold that any part of our notions concerning degrees of 'resistance' are derived from the volitional or motor centres. A case of this kind was long ago recorded by Demeaux*, some details of which are well worthy of being cited. There was a complete loss of sensibility (both superficial and deep) in the moving member, and Demeaux says:—"She put her muscles in action under the influence of her will, but she had no consciousness of the movements which she executed; she knew not what was the position of her arm—it was impossible for her to say whether it was extended or flexed. If one told the patient to raise her hand to her ear, she executed the movement immediately; but when my hand was interposed between her own and the ear, she was not conscious of it; if I stopped her arm in the midst of its movement, she did not become aware of it. If I fixed, without allowing her to be aware of it, her arm upon the bed and told her to raise the hand to her head, she strove for an instant and then became quiet, believing that she had executed the movement. If I induced her to try again, showing her that her arm had remained in the same place, she attempted to do so with more energy, and as soon as she was compelled to call into play the muscles of the opposite side [of the body], she recognized that the movement was opposed."

In the recent contribution of G. H. Lewes to this subject, he brings forward no new arguments against the possible exclusive adequacy of passive sensibilities, and he now largely admits them as components of the complex group of impressions *resulting* from movements which go to make up what is known as the 'Muscular Sense.' And except that he holds to the doctrine that some active sensibilities enter into the same complex, his present views are almost entirely in accordance with those expressed by the writer, in the paper above referred to. The evidence which Lewes considers favourable to the existence of an 'active' element in the 'muscular sense' endowment, can, in the writer's opinion, be better explained by the supposition previously started, and still favoured by him, that a set of 'unfelt' impressions relating to states of tension of muscles exists—the components of which are more or less distinct from those that reveal themselves in consciousness.

The writer, for instance, pointed out in 1869 that in 'locomotor

* 'Des Hernies Crurales,' Thèse de Paris, 1843, p. 100, and quoted by Ferrier in his Functions of the Brain,' 'd 181.

ataxy' the amount of symptoms indicative of a diminution in the so-called 'muscular sense' was generally proportionate to the impairment of the different modes of common sensibility in the limb. Yet some more exceptional cases of this disease recorded by Bazire, Trousseau and others, as well as some remarkable cases referred to by Landry, in which, *without the existence of anæsthesia*, the patients were reduced to a condition very similar, as regards motility and the sensations resulting from movement, to that of Demeaux's patient, seemed to show pretty conclusively "that the brain is assisted in the execution of voluntary movements by guiding impressions of some kind, which, whilst they differ in mode of origin from the impressions derivable by means of the ordinary cutaneous and deep sensibility, may differ still further from these, owing to the fact of their not being revealed in consciousness* . . . . There is clearly a loss of something in these cases, of a something which serves as a guide in the execution of voluntary movements, but whose absence can be compensated by the supervision of the visual sense; and this is in great part the function which some physiologists attach to the 'muscular sense' . . . . . . my position is that these impressions of the muscular sense, whose existence we are thus obliged to postulate, are *unconscious* impressions, and that the conscious impressions that have usually been stated to fall within its province are really derivable through modes of ordinary cutaneous and deep sensibility."

The conclusions thus deduced in 1869, are fully borne out by what we now know concerning Hemi-anæsthesia of cerebral origin. The instance recorded by Demeaux is altogether exceptional, since in many of such cases complete superficial, and in some even deep

* The route of these afferent impressions at the commencement and towards the end of their course was then wholly unknown. And in face of difficulties presented by evidence adduced by Arnold, the writer hazarded the following conjecture: "Thus I assume it to be possible that when molecular changes are excited in certain spinal motor cells as a result of a volitional impulse, proportional recurrent impressions may be carried along certain fibres taking origin from the motor cells, and ascending in the posterior columns of the cord." In this way the brain might derive impressions referrible to the degree of activity of the various muscles, or sets of muscles, of a limb. But our present increased knowledge concerning the existence of 'sensory' nerves in muscle, no longer renders necessary any such hypothesis, especially as the writer is now inclined to agree with Ferrier in his interpretation ('Functions of the Brain,' p. 220) of Arnold's experiments. He thus no longer feels any difficulty in believing that some of the sensory fibres of muscles which enter the spinal cord by the posterior roots of the spinal nerves, may transmit to the brain those almost ever-present 'unconscious' impressions which so materially guide us in the execution of all our movements.

and superficial, anæsthesia, may exist without much if at all disturbing the co-ordination of movements on the same side of the body —a phenomenon several times seen by the writer, and which was also recently pointed out to him by Prof. Charcot on the occasion of an examination of some of his remarkable hemianæsthetic patients at la Salpêtrière. In Demeaux's case (in addition to cutaneous and deep sensibility) those peculiar 'unconscious' impressions may have been cut off, the loss of which alone in the patients of Landry produced an inco-ordination of movement in the absence of sight impressions. His case is, therefore, most instructive in its bearings upon the general question. There was in this woman a total disappearance of all that kind of knowledge which has, by one or other, been ascribed to, or supposed to be derived from, the 'muscular sense.' The woman was ignorant of the position of her limbs, and unconscious of any movements which she might execute. The volitional centres, the spinal motor centres, the motor nerves and the muscles were capable of being called into activity as before —yet all the information usually supposed to be derived through the 'muscular sense' had vanished.

A precisely similar condition of things also existed in a celebrated case of spinal-cord disease, associated with extreme anæsthesia, which was observed by Spaeth and Schueppel (see Ziemssen's "Cyclopædia," vol. xiii. p. 88). Concerning the state of this patient the following note may be quoted:—"Sense of pressure in the upper extremity, and the sense of force, entirely extinct. Sense of position of the upper extremity and of passive movements of the latter completely extinct. Movements of the upper extremities powerful and perfectly correct; the patient eats alone, dresses himself, etc., as far as he can direct his acts with his sight"

No clearer evidence than this, together with what has been previously mentioned, could be forthcoming to show that the knowledge of the position of our limbs, of their movements, and of the state and degrees of contraction of our muscles generally, does not depend, as Wundt, Bain, and others assume, upon impressions that are "concomitants of," or that coincide with, "the outgoing stream of nervous energy."

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