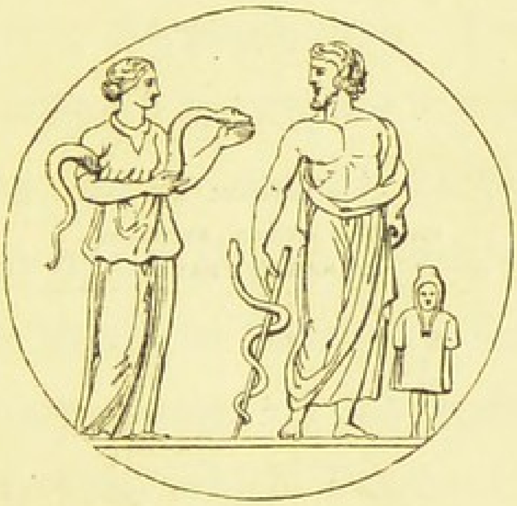
THE

NERVOUS SYSTEM

AND

ITS FUNCTIONS.



BY HERBERT MAYO, F.R.S.

SENIOR SURGEON OF THE MIDDLESEX HOSPITAL,
FORMERLY ONE OF THE PROFESSORS OF ANATOMY AND SURGERY
TO THE ROYAL COLLEGE OF SURGEONS.

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ADVERTISEMENT.

The present volume owes its existence to the following circumstances. I was applied to in the autumn to prepare some additional letter-press for a second edition of my Engravings of the Brain; and it occurred to me that it would be suitable to introduce in it a summary account of the functions of the nervous system, which I accordingly drew up, something in the following form. This publication, however, was for the time abandoned; and I likewise have altered my mind about it, and think it better to accompany the plates with a succinct anatomical explanation only, which will be the plan adopted. But in the mean time the form in which I had cast my survey of the nervous system, and the reflections to which it gave rise, appeared to me, if not to have elicited much that is absolutely new, yet to display what had been before discovered with new distinctness and force, and to give to several points, which I had before only half seen, certainty and importance. I therefore again went over the subject carefully, and rewrote what I now submit to the judgment of my Profession, and of the few who take an interest in physiology out of it.

2, *St. James's Place,*
May 2, 1842.

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ERRATA.

Page 32, line 25, *for* inner or left, *read* inner or right.
— 45, — 13, *for* ganglionic, *read* ganglionless.
— 90, — 25, *for* tubes, *read* filaments.
— 102, — 5, *after* back, *insert* and lower part.

"Increase of knowledge, instead of exhausting, multiplies the subjects of human inquiry."

"Knowledge is like a clearing in the forest; the larger the area, the more extensive the boundary challenging renewed labour."

"The sciences may be compared to so many detached clearings, which originally branched and diverged from, and again lead back to, that central and primal one, which consists in the knowledge of the ends and duties of human life."—*American Review.*

"We may lose ourselves among the briers and thickets for a little; but from the end of each avenue we see the old gray steeple, and the graves of our forefathers. I would I were to travel that road to-morrow!"—*Kenilworth.*

THE NERVOUS SYSTEM

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INTRODUCTORY REMARKS.

The Nervous System has a two-fold office. On the one hand it forms the immediate organ of consciousness, on the other it exerts a control over the bodily functions. The first is its most important and primary office. For life may exist without a nervous system: although no sooner is a nervous system part of the vital economy, than every function feels its influence. The relation of a definite corporeal structure to the mind will therefore constitute our principal inquiry. But there is an antecedent question which deserves our notice,—What relation does Vitality bear to Mind?

In the widest scope of nature, which our faculties can apprehend, Mind and Vitality are not visibly or conceivably united. Nay, Life drops wholly out of view. And the physical world presents to our contemplation masses of inert matter alone, distributed at enormous distances through space, all in motion, yet nowhere clashing or inharmonious,—the whole stupendous system bearing the impress of order, uniformity, and stability. Our thoughts elevate themselves thence to the conception of one all-pervading Intelligence, which framed and which sustains the world.

To discern Life, we have to look upon the surface of our planet, where, scattered in creative profusion, its varieties form the two great classes of plants and animals. In the former, Vitality is displayed alone and unmixed; and all its features are found to be comprised in growth and reproduction. Or plants manifest the power of imbibing foreign matter; and of assimilating it, or arranging its elements in new chemical compounds exhibiting new properties; and of so distributing the new products as to determine the proper shape, and bulk, and structure, of each, after its kind; and of moulding germs of the same materials, each capable of the same progression of changes as the parent plant: so that although the power of supporting growth ceases after a brief period in the individual, the species is preserved and at the same time multiplied by the transmission of this force, which is thereby nowise weakened. This power or force in plants we term their life; ignorant whether it is a separate force in nature, or whether the Creator of living things had but to compel the chemical combinations and bring about the exact material conditions, which are concentrated in a living being, and it would live; as a human mechanist has but to frame, and temper, and put together the parts of a watch, and it goes.

And animal life is essentially the same with vegetable life. But the vital movements and functions are now made subordinate to consciousness. So that when sense and volition are extinguished, the animal body immediately dies,—not to cumber the earth with the continued growth in plant-like existence, of beings that once partook of intelligence.

And animals and plants are made of the same ultimate elements; and after death are resolved into, as their essential constituents, carbon, oxygen, hydrogen, nitrogen. But these again either are constituents of the atmosphere, or are, under different forms, suspended in it; and it is from the atmosphere that the plant immediately borrows the materials which it assimilates; while it is from vegetable matter again, that directly or indirectly all animals derive their sustenance. So the materials of both are, to a great extent, taken from the atmosphere; and to that extent is there truth in Dumas' striking assertion,—that plants and animals are, chemically considered, but a portion of the atmosphere, temporarily withdrawn and set apart for the maintenance of life.

The same materials, likewise, are in constant circulation from one kingdom to the other. The animal, that lives upon the plant, eliminates the ammonia and carbon necessary for the growth of other plants. The carbonic acid, which he gives out in breathing, when imbibed by the plant, being reduced, yields to the latter its carbon; while its constituent of oxygen is liberated anew, to maintain the purity of the atmosphere and to render it fit for respiration.

The latest views in organic chemistry go yet further. And there are grounds in the researches of Liebig for anticipating, that the vegetable economy will be found, not only to produce a preliminary change in matter combining it into proximate vegetable principles, afterwards to be converted by the animal economy into animal substance; but, a more comprehensive function, to elaborate all the organic elements of either kingdom, and to form every constituent even of the animal frame. If this view prove correct, the chemical agencies of the vegetable and animal economy will display a singular contrast. The plant will be shown to provide and prepare, what the animal body only consumes.

Then the essential purpose of vegetable existence may be held to be the sustenance of beings endued with consciousness.

For in the lowest animal a glimmering of sensibility is traced; and, as is nature's wont, by many steps of infinite gradation, manifesting the fertility of her resources, and wonderfully combining variety with uniformity, an uninterrupted progression of improving organization, joined to an enlarging scope of sensibility, instinct, and subordinate bodily powers, extends thence upwards to man. And great as may be the final interval between brute intelligence and human reason, yet so much greater is the affinity than the distance, that no disparate modification of organs is required to be made for man; but all that exists in full development in the human brain is found typified and to a great degree already unfolded in the animals that come nearest to man.

The true purpose and aim of vitality are thus apparent. Life is a force so contrived and used, as to qualify the materials of the inert world for a temporary union with consciousness;—a means how mind may enter into such relations with matter, that it may have its being and part in physical nature, and its faculties developed, and its capabilities and tendencies drawn out and proved (for whatever ulterior purpose) in subjection to and in harmony with her laws.

As we imagine the Supreme Mind to be ubiquitous, infinite, controlling but uncontrolled by matter, so in contrast with these attributes we conceive the finite mind to be bound down to place, and to be dependent on a certain arrangement of matter for its manifestation, each power displayed as the property of a tissue, each agency as the function of an organ.

These views do not lead to materialism. For one cannot disjoin the physiology of the nervous system from mental philosophy, nor investigate the play of its organs without attending to the mind itself. And if equal consideration is given to the two classes of phenomena, it is impossible (so at least it appears to myself) to avoid the conviction, that they are essentially independent the one of the other, and belong to distinct essences; and that Ipseity, the consciousness of personal being, is not a mode of material existence, nor physical impenetrability an attribute of that which feels and thinks.

Few subjects of speculative inquiry have more interest than the relation of the mind to the body. Nor, considering the subtle nature of both the elements concerned, is it wonderful that our progress here has been slow; and that considerable labour has hitherto enabled physiologists fully to elucidate the simplest portion only of the subject, namely, the functions of the organs, which are common to every nervous system. So much, however, has been positively determined in these easier problems, as to enable me to lay down the results obtained in the form of laws of the nervous system. These will be found synthetically arranged in the first chapter of the present volume. Of the connexion between the higher mental operations and the parts of the brain little of a positive character has yet been made out. But many necessary preliminary questions have been solved, among which not the least is the determination of the structural relations of the different parts of the enkephalon; and the investigation of their functions, the discovery of which cannot be beyond our reach, has at all events been actively commenced, however opinions may differ as to the quantity of real knowledge hitherto acquired through it.

The reader must not expect to find that I have entered into much minuteness of detail. The individual facts brought forward are those alone necessary to establish the general conclusions which have appeared to me attainable. To this stock of facts I have myself been a part contributor, as well as to the inferences immediately deducible from them, and to the broader results to which they lead. These collectively constitute the modern discoveries in the physiology of the nervous system, of which in the following pages I have endeavoured to give a just exposition. To the admirable writings of Whytt, I would refer the reader for a discriminating survey at a former period. What I propose now to offer is an account of the level next beyond, a description of the table-land we have now reached with what it commands, from whence the next body of inquirers will have to start in their ascent to higher elevations and more comprehensive views.

"We have also parks and inclosures of all sorts of beasts and birds; which we use, not only for view or rareness, but likewise for dissections and trials, THAT THEREBY WE MAY TAKE LIGHT WHAT MAY BE WROUGHT UPON THE BODY OF MAN; wherein we find many strange effects: as continuing life in them, though divers parts, which you account vital, be perished and taken forth; resuscitating some that seem dead in appearance; and the like."—BACON'S *New Atlantis.*

Chapter I.

LAWS OF THE NERVOUS SYSTEM RELATING TO SENSATION AND VOLUNTARY MOTION.

I.

The nervous system is formed of two dissimilar textures, which are, for the most part, distinguishable by their colour; one being gray, ashen, or cineritious, the other of an opaque white, of the tint termed orange white. The first is principally composed of minute corpuscles. The second, of tubes containing either a gelatinous liquid or a definite filamentous structure. When portions of the nervous system, comprising the two textures, have acquired consistence through maceration in alcohol, the gray is found to have a granular fracture, the white to tear into threads, which are bundles of nerve-tubes.

In mammalia, birds, and reptiles, and in the enkephalon of fish, the distinction of colour in the two textures is strictly observed. In the spinal cord of fish it is very faintly discernible. In the larger invertebral animals, the difference of colour is again distinct. The successive observations which authorize the above general assertions as to the structure of the two textures, are those of Ehrenberg, and after him of Valentin. In the fresh brain of a small bird the general corpuscular texture of the gray matter, and the tubular structure of the white, are readily apparent. Fontana had anticipated, to a considerable degree, the discovery of the tubular structure of white nervous matter; but his observations, and the recent researches of Dr. Martin Barry, would go to render the tubular character subordinate, and to attach greater importance to the interior filamentous structure.

II.

The gray and white textures have determinably different functions: the white that of transmitting or communicating, the gray that of receiving impressions and originating impulses.

The disposition of the two textures is decisively affirmative of this conclusion. The gray matter forms isolated organs. These are united together by tracts of white matter, the filaments or tubes composing which tend directly towards or from masses of gray matter. Where the nervous system has the most ample organic developement, as in the brain, the superficies, or expanded terminal part, consists of the gray texture. It may be added that gray nervous matter is considerably more vascular than white,—a fact of itself indicating a higher function.

III.

The lowest manifestation of consciousness in animal life involves two elements,—sensation, and the origination thereupon of an effort towards motion.

In the humblest forms of animal life there is no evidence of the possession of further mental endowments. Perception follows later; and variety of impulse, with choice determined by instinct or reason.

No feature in nature's works is more remarkable than the avoidance of abruptness of transition. In the mimosa pudica I discovered the existence of surfaces endued with what may be called acute organic sensibility, on the slightest excitement of which *other* parts acted to throw down the leaf and close the leaflets; so there exist in this mimosa parts comparable to sentient organs,—parts that originate motion,—and something intermediate to connect the two;—so far veiling the transition to consciousness, that the earliest phenomena outwardly resulting from thence are here manifested without its presence.

IV.

Every nervous system consists of two parts,—of a central organ, in the structure of which gray matter predominates,—and of fasciculated cords of white matter, or nerves, which extend therefrom to the organs of the senses and of motion.

The form most affected in the central organs is nodular or spherical;—so one might take a small bead and attach to its side, transversely to its perforated axis, a few filaments of thread to image the rudimentary central organ and the nerves it originates. On examining a single ray in a star-fish, a few filaments are thus seen diverging from a minute nodule at the root of the ray. The filaments are nerves which have their origin in the nodule.

V.

A single minute organ, originating nerves, such as is found at the base of each ray in the star-fish, may be appropriately termed a sensorial nodule or nucleus. Hitherto a being has not been met with of so simple a type as to admit of its whole organization being supplied from a single sensorial nodule. The type of construction of the radiata and lower articulata is the compound or multiple type. Each being consists of two or more organizations, each capable of surviving and of living independently of the other, when the animal is divided into two or more pieces. For such a compound animal a compound nervous system is requisite. Instead of one sensorial nodule with its nerves, there must be several. These are united to form one organ, by means of fasciculi of white nervous matter, which extend one from each sensorial nucleus to the next.

The disposition of the parts of the nervous system in a compound animal may, then, be thus modelled. Take as many small beads with filaments of thread attached, as there are repetitions of the organization; so for the nervous system of a star-fish with five rays, five beads would be necessary. Then pass a thick silk through the five beads, and having so strung them, fasten them at regular intervals, and tie together the ends of the string. The compound central nerve-organ would be represented by the silk and beads: the beads would represent the sensorial nuclei; the lateral tufts of threads would represent the nerves. It is evident that such a chaplet of beads might be laid either in a circle or drawn out in two parallel lines. The former disposition would give the type followed in radiated animals. The latter, supposing the beads to form an even number, and to be adjusted in pairs, might represent the nervous system of the articulata.

VI.

The type originally set in the multiple animal is maintained in the nervous system of the higher articulata, although the being has become strictly individualized, and its frame consists of a series of segments dissimilarly organized. The nervous system remains a double chain, with pairs of sensorial nodules; but the latter vary in size with the importance of the functions enjoyed by the segment; as the sensorial nodules in the head have to originate nerves to the antennæ and eyes they are proportionately larger.

The disposition of the chain of sensorial nodules in a circle, or in two contiguous parallel lines, is a perfectly indifferent matter; that disposition appears to be adopted which agrees with the external shape of the animal.

In the lobster the whole of the chain is doubled on two parallel lines. In the crab the greater part is thrown into an oval ring.

VII.

In mollusca the number of the sensorial nuclei is reduced to its minimum. In the snail there exist but two pairs.

The sensorial nuclei of mollusca are, proportionately to the connecting fasciculi, very large; which arises from their being distributed to improved internal organs. Their fewness arises from the absence of a complicated locomotive apparatus.

In all animals the central organ of the nervous system is lodged in the most protected region. In vertebral animals its place is in the head and vertebral canal; in the articulata, upon the strong inferior tegument.

In invertebral animals a curious relation exists between the œsophagus and the double chain of sensorial nodules. The latter is either disposed as a chain encircling the œsophagus, as in the star-fish, and even in the snail; or, as it is more common, the first pair of nodules is situated above the œsophagus, which passes between, or is immediately embraced by, the two fasciculi, which are tending to the adjacent first inferior pair of nuclei.

VIII.

The central organs of the nervous system in vertebral animals consist of similar parts to those which exist in the invertebrata, and of something more;—of a double cord giving off nerves in pairs to the successive segments of the frame, corresponding with the chain of sensorial nuclei of invertebral animals;—and of new organs superimposed upon its anterior, or upper, or cranial extremity. The double cord may be termed the cranio-spinal cord; the succession of parts in it originating pairs of nerves, segments or nuclei; the superimposed organs are the cerebellum and cerebrum.

The spinal cord is the part of the double cord which is lodged in the spinal canal. Its evenness and flatness are unlike the nodular character of the double chain of invertebral animals: but sometimes, as in the upper cervical portion of the spinal cord in the gurnet, the true nodular form re-appears. In the cranial portion the same feature is always present to a greater or less extent. The cranial portion of the cord is subdivided by anatomists into the medulla oblongata, from which the ninth, eighth, seventh, sixth, and fifth cerebral nerves rise; the crura cerebri, whence the fourth and third take their origin; and the optic and olfactory nodules or tubercles, for the origin of the second and first nerves. The spinal nerves rise each by two distinct sets of fasciculi or roots; one from the anterior, the other from the posterior, lateral furrows.

The term segments, applied to the regions of the cranio-spinal cord which originate separate sets of nerves, is so far appropriate, that the cord might easily be cut into so many portions. The term nodule would be inappropriate, for, except in a very few instances, the segments have not the shape that word denotes.

IX.

The spinal cord, with the nerves thence arising, is not alone sufficient to maintain consciousness.

It is important, in reference to what is to follow, to establish this negative proposition beyond a doubt. Its proof rests upon experiments made on living animals,—a source through which so many important truths have been brought to light, as in some degree to atone for the infliction of pain and deprivation of life that attend it. Cold-blooded animals, reptiles especially, from their tenacity of life, furnish the surest results in inquiries like the present. In frogs, the functions of the nervous system continue for a time but little impaired by loss of blood, or the cessation of the circulation. Accordingly, the phenomena exhibited by the trunk of a decapitated frog, or by one from which the contents of the cranium have been entirely removed, may be confidently expected to show, whether the remaining part of the nervous system is enough to allow the persistence of feeling and voluntary motion. Now, after decapitation, the carcase of a frog lies relaxed, motionless, and to all appearance insensible. Nevertheless, if a toe is pinched, the limb is drawn up; and pricking the skin produces some general muscular action. How, then, is it certain that sensation is entirely extinguished? Let the mutilation be carried further, and the dead trunk divided transversely across the back. It will be found that the same partial movements as before can still be excited by the same means, and that equally in both halves. Do both halves then feel? The hind legs as well as the fore legs? We know from cases in which the spinal cord of human beings has been accidentally divided in the back, that the parts supplied with nerves from the separated inferior portion have retained no feeling. It is probable, therefore, that in the frog it is the same; and that the motions obtained in its legs in the experiment do not depend upon sensation. But these motions were the only evidence that the anterior extremities, or the entire trunk, previously felt: and at the same time they are totally unlike the maintained and co-ordinate movements which are observed where feeling is certainly present. We may presume, then, that the movements in question are merely organic, and so far resemble those of a recently amputated limb when its nerves are injured. Their precise nature will, however, be explained presently. It may be added, that the same may be produced by irritating the skin in the legs of human beings, in whom the lower half of the body has been palsied by lesion of the spinal cord; they are of course unfelt by the patient, and may be excited unknown to him, or in opposition even to his voluntary efforts to refrain from them.

X.

The spinal cord and medulla oblongata, with the nerves arising from them, are together sufficient to maintain consciousness.

The following instance from a communication by Mr. Lawrence, published in the fifth volume of the *Medico-Chirurgical Transactions*, is decisive of the truth of this proposition. It is the history of an infant, in whom the parts of the enkephalon beyond those specified had never been developed, and which survived its birth a brief period.

An acephalous infant was born, which lived four days. "The brain and cranium were deficient, and the basis of the latter was covered by the common integument, except over the foramen magnum, where there existed a soft tumour about equal in size to the end of the thumb. The smooth membrane covering this was connected at its circumference to the skin. The child, as is generally the case in such instances, was perfectly formed in all its other parts, and had attained its full size. It moved briskly at first, but remained quiet afterwards, except when the tumour was pressed, which occasioned general convulsions. It breathed naturally, and was not observed to be deficient in warmth till its powers declined. From a fear of alarming the mother, no attempt was made to see if it would take the breast; a little food was given it by the hand. It voided urine twice in the first day, and once a day afterwards. It had three dark-coloured evacuations. The medulla spinalis was found to be continued for about an inch above the foramen magnum, swelling out into a small bulb (obviously the medulla oblongata), which formed the soft tumour upon the basis of the skull. All the nerves from the fifth to the ninth were connected with this."

The following experimental details to the same purpose are given by Magendie:—"If you remove, by successive slices, in an animal with the cranium opened, all the parts of the cerebrum, then the optic thalami, then the entire cerebellum, in such a manner that the last section shall be anterior to the fifth nerve, the animal continues to feel all the sensations which have their seat in the face, except vision. It continues to be as vividly affected by sounds, smells, tastes, punctures of the face, as if it had experienced no further injury than the loss of blood attending the opening of the cranium. If, for example, you pluck a hair of the whisker, or apply a pungent acid to the nose, it tries with its fore feet to disembarrass itself of the cause of its pain, as if it were unmutilated. Respiration and circulation take place; the movements of the body are not more interfered with, than if the cerebellum alone had been removed. The sensibility of the trunk and limbs has besides suffered no alteration. The animal cries and agitates itself, endeavours to withdraw and to defend itself, when a toe or the sole of the foot is pinched, equally as when the lips or the nose are injured."

XI.

The superiority of the vital powers of the spinal cord and nerves *plus* the medulla oblongata and nerves, over those of the spinal cord and nerves alone, does not result from the difference in the mere quantity of nervous matter left in the two cases.

If in an animal mutilated to the extent last described, the spinal cord is divided at the upper part of the back, the only consequence which ensues is, that the hinder part of the frame is thereby deprived of sense and motion. Vitality and consciousness continue to be exhibited in the anterior part of the animal as perfectly as before; notwithstanding that the portion of the nervous system separated and rendered useless by the last mutilation is of many times the bulk of the whole medulla oblongata.

XII.

The competency of the acephalous infant to manifest feeling and voluntary motion when the spinal cord and medulla oblongata are entire, and the parallel preservation of consciousness in animals mutilated as above described, arise from the preservation in the two cases of that segment of the medulla oblongata in which the fifth nerves take their origin.

In an animal mutilated to the extent of removing the cerebrum, optic tubercles, crura cerebri, and cerebellum, it has been shown that consciousness may temporarily remain. But if the mutilation is carried a quarter to half an inch lower, so that the segment in which the fifth nerves take their rise is destroyed, every indication of animal life is instantaneously extinguished.

From this most curious fact, M. Magendie, who discovered it, drew the inference that, in vertebral animals, the perception of all sensations, except those of sight, takes place in the medulla oblongata. This inference appears to me unsound in two points. It ascribes, by implication, smelling to the fifth nerve, whereas real olfaction belongs to the first. And, which is the important error, it asserts the seat of perception generally to be the medulla oblongata; whereas the facts prove only that sensation does not take place, unless the nerves of the senses and their nuclei of origin preserve continuity with a certain portion of the medulla oblongata.

XIII.

Continuity with the segment of the medulla oblongata, in which the fifth nerves rise, is equally necessary to the maintenance of the functions of parts of the nervous system which are situated above or anteriorly to that segment.

In other words, if the medulla oblongata is divided transversely above or anteriorly to the origin of the fifth nerves, the functions of the cerebrum and cerebellum, and of the first, second, third, and fourth pairs of nerves, are extinguished. I cannot, indeed, advance experimental proof in support of this proposition, beyond the seeming total death which instantaneously results from the laceration of the segment of origin of the fifth in an animal otherwise unmutilated. More exact observations on the motions of the iris and of the eyeball under these circumstances, than I profess to have made, are necessary to determine the question experimentally supposing it to admit of proof in this manner. The truth of the above proposition, however, is so probable, that I will venture coupling it with the XIIth. to affirm the following, which comprehends and expresses both.

XIV.

The part of the medulla oblongata in which the fifth nerves rise constitutes the dynamic centre of the nervous system. No part of the nervous system severed from this segment participates in consciousness; but its function is thereupon immediately suspended, and, except in the instance of such nerves as admit of complete reunion after division, permanently extinguished.

I dwell upon this proposition to familiarise the reader with the view alone justly deducible from Magendie's experiments above related. The cessation of a function on the separation of a part of the nervous system from this segment, taken alternatively with the suppression of every function on the separate mutilation of that segment alone, does not prove that that segment was the seat of the first. The integrity of the segment of origin of the fifth may be necessary to the preservation of sensibility in the whole trunk, without its being the seat of sensation. The action of the heart in another way may be necessary to secretion, without the heart being the secerning organ.

It is natural perhaps to suspect that the importance of the segment of the medulla oblongata, where the fifth rises, may be here overrated; and to surmise that its seeming importance results from its central situation, which renders any considerable mutilation of it impracticable without disturbing in a great degree the communication between the anterior and posterior halves of the nervous system, as well as the origins of the seventh and eighth, which have so much to do with the common manifestations of vitality. But the reader may easily get rid of this doubt by observing the difference between a decapitated frog, where the head has been severed at the anterior part of the medulla oblongata, and the same animal when the next minute portion of the medulla is removed: in the first instance, the animal sits collected on its limbs in an attitude prepared for exertion, and if it is hurt, its body and limbs are prompt to consentaneous motion with the full expression of vitality and consciousness. In the second instance, the animal lies at once, extended, relaxed, nerveless, motionless.

XV.

Each lateral half of a vertebral animal is separately vitalized. Or the preservation of consciousness in one half is independent of its preservation in the other. Or the continuance of the functions of either lateral half of the cerebro-spinal system depends upon the integrity of the half of the segment of origin of the fifth nerve proper to it.

That is to say, all the modifications of the phenomena of consciousness, which Magendie produced in the preceding experiments upon the whole frame of the vertebral animal, he discovered, may be produced on one side alone, by limiting the mutilation to that side. So destroying the right half of the segment of origin of the fifth, appears to extinguish consciousness on the right side entirely, without in any degree affecting the left. Is it then possible, that by exactly severing in the median plane the two halves of the vitalizing segment, a vertebral animal might be made, temporarily, two separately conscious beings?

XVI.

The nerves derived from either lateral half of the cranio-spinal cord are distributed to the same side of the frame.

I state this proposition formally, to make occasion for explaining the single exception to it. That exception is found in the distribution of the optic nerves.

Most vertebral animals have lateral or divergent vision alone. Their optic axes lie either in the same right line, or diverge. They cannot be simultaneously directed towards the same object.

Man, with several of the mammalia, and some birds, and some reptiles (?) is capable of convergent vision.

Now, in all animals with divergent vision, there is reason to believe that the optic nerves supply exclusively the opposite eyes. But this is only certainly known of osseous fishes, in which the optic nerves cross without mingling their fibres, and the whole of the right nerve is seen to go to the left eye, and of the left, to the right. In all other vertebral animals there is more or less union of the nerves, which has not been anatomically unravelled except in man. But in birds with divergent vision, and in such of the mammalia as the experiment has been tried in, an injury of one optic tubercle is followed by loss of sight of the opposite eye. And the general rule as to all animals with divergent sight, is inferred to be what I have stated, from the visible structure in osseous fishes, and the experimental facts last mentioned.

In man, for the type of convergent vision, the principle of distribution is different; each optic nerve distributes fasciculi to both eyes.

Thus the general law of the distribution of nerves to the same side of the frame, is doubly violated in the instance of the optic. In animals with divergent vision, the optic nerves supply the opposite eyes: in animals with convergent vision, each nerve supplies both eyes. Perhaps the following suggestions may be found sufficient to reconcile these anomalies.

Convergent vision is the more perfect function. Now the most sensible spot in the human retina is situated at the optic axis. But this point is situated a little to the outside of the entrance of the optic nerve. Accordingly, it is probable that it is supplied by the fibres which form the outer portion of the optic nerve. But these fasciculi may be traced distinctly backwards, along the outside of the optic tract, to the optic thalamus and corpora geniculata of the same side. The part of the right retina in man, which has the acutest vision, is therefore probably supplied from the right optic tract; the corresponding point in the left retina from the left. And accordingly, so far as the part of the retina situated at the optic axis is concerned, the general law asserted of the distribution of nerves appears to be observed in man in the distribution of the optic.

But if the centre of the right retina, which lies to the right of the entrance of the right optic nerve, is supplied from its right fasciculi, it is probable that the rest of the right portion of the retina is supplied from the same source likewise: and so with the left. And nothing has been ascertained, anatomically, in contravention of this supposition. Then, the greater part of either retina in man probably is supplied by the optic nerve of the same side.

But the general direction of this portion of the right retina is towards the left, or towards the left of the common visual axis of both eyes. Now there is a part of the retina of the left eye, which is turned in the same direction. It is, of course, its inner portion. Are we at liberty to surmise, that that portion of the left retina derives its supply of nervous filaments from the inner fasciculi of the left optic nerve, which, at all events, enter the eyeball contiguously to it? If this should be proved to be the case, it would follow that the right optic tract supplies the inner portion of the left retina, as well as the outer portion of the right; for from that tract are derived those decussating fasciculi, which form the inner or left fasciculi of the left optic nerve. Then another, and compensating uniformity, in exchange for that obviously disregarded, would be obtained, and those surfaces of both retinæ, which are directed towards one side, or towards one side of the common visual axis, would prove to be supplied from one optic tract alone.

But, further, it would thus happen that the right optic tract would distribute all its fasciculi to retinal surfaces turned towards one side, and that side the left, or more correctly, the left of the common visual axis. Then suppose a transitional series, in which the same principle should be observed, from animals with perfect convergent vision, to others in which a very small part only of either retina admits of being so employed, it would follow that fewer and fewer of the fasciculi of the right optic tract would continue to go to the right eye. As many only would be so distributed as would supply that lessening portion of the right retina which could be turned towards the left of the common visual axis, the greater portion would cross over to the larger portion of the left retina, now looking towards the left. And finally, when in the completion of the series convergent vision should become wholly lost, the whole of the fasciculi of the right nerve would cross over, maintaining the same principle of uniformity, to be distributed to the left eyeball: the left to the right.

The preceding explanation assumes one or two anatomical facts, which are certainly not proved; but everything known renders them extremely probable. If it is just, the apparent breach of uniformity is only introduced to make room for a more important observance of the same principle; or to allow of the greatest possible uniformity in the anatomical arrangements for two functions so dissimilar as divergent and convergent vision; and even for the occasional partial introduction of the second more perfect function in the ascending series without any external alteration to betray the sudden step in advance, and the subsequent retreat from it.

The ideas commonly entertained respecting the purport and end of the decussation of the optic tracts in man are at variance with the above.

By some it is supposed that the object therein contemplated is the supply of the corresponding points of the two retinæ with filaments from both optic nerves, in order to provide for single vision with two eyes. But such an hypothesis is not needed. There exists another arrangement to which the phenomenon in question is more reasonably attributable. The fasciculi, which form the anterior part of the optic commissure, have no direct communication with the cranio-spinal cord; they are commissural to the two retinæ; and, extending from one retina directly to the other, afford obvious means of enabling the parts they unite to blend their functions.

Dr. Wollaston supposed that the object of the decussation was the distribution of filaments from the same optic nerve to the corresponding parts of both retinæ. On this hypothesis the anatomical arrangement would come near to that which I have supposed, but with one important difference. Dr. Wollaston would have divided the retinal surface at the optic axis into two, each half being supplied by a different nerve; whereas I suppose the whole of that sensible region to be supplied by one nerve only. But the observation, it will be recollected, which led Dr. Wollaston to this hypothesis, was a pathological phenomenon which he himself experienced,—temporary simultaneous loss of sight in the corresponding halves of both eyes; the simplest explanation of which, he suggested, was to assume the anatomical arrangement mentioned; when disorder of *one* optic thalamus would serve to account for the palsy of both organs. But the explanation, however ingenious, may be shown to be unsound, by taking into consideration other phenomena of the same class. When threatened with gout, before it declared itself, I experienced the semi-blindness described by Dr. Wollaston; it recurred three or four times, lasting about a quarter of an hour; but alternatively with it I experienced the following different affections of both eyes:

one, temporary blindness at the visual axis; the other, temporary blindness of all but the visual axis. It is presumable that these three alternative phenomena had a common origin; but two of them certainly arose from an affection of both optic thalami; and it is therefore probable that in the first both were likewise equally involved.

XVII.

The nerves in reference to the phenomena of consciousness are divisible into two classes, and into two classes only; they minister either to sensation, or to voluntary motion, alone; they are either exclusively sentient, or exclusively voluntary. Two or more nerves, however, having different endowments, may be bound up in the same sheath, so as superficially to appear but one.

This discovery was elicited by the following steps:—

Sir Charles Bell, as early as 1811, had pushed his speculations beyond the views then commonly received; which amounted, indeed, but to a conviction that the first nerve, the second nerve, and the soft portion of the seventh, were appropriated each to a special sense; and that the third, the fourth, the sixth, and the ninth cerebral nerves were for motion; beyond this nothing definite was taught as to the appropriation of particular nerves to sensation or to voluntary motion exclusively. In 1811 Sir Charles Bell suggested, supporting his views by original experiments upon the roots of the spinal nerves, that the cerebrum and the anterior portion of the spinal cord, and the fasciculi of the spinal nerves thence arising, have alone to do with sensation and volition; that the office of the cerebellum, of the posterior portion of the spinal marrow, and of the fasciculi of the spinal nerves thereto attached, is the control of the organic functions. He at the same time expressed his conception that nerves having different offices might be bound up in one sheath, and that nerves take different offices according to the place of their origin.

It was a step of eminent service to science then, and again later in his career of investigation, to set on foot new inquiries into the functions of the nerves, and to show that they might be elucidated by new experiments. With the researches of Sir Charles Bell, made in this his first essay, and *up to this point*, I had the advantage of being familiar, having been his pupil in the years 1812, 1813, 1814, and 1815. After this I was not in the way of knowing, nor did I know, anything whatever of the nature of Sir Charles Bell's researches, except through his published writings.

The most remarkable of these, and the first of the series, was a paper published in the *Philosophical Transactions* for 1821. In this elaborate essay it is evident that Sir Charles Bell had as yet made no advance towards the conception of different nerves being appropriated to sense and motion. The object of the paper is to shew, that in addition to the nerves of sensation and voluntary motion, (both which functions he together attributed to the same nerves,) there exists a peculiar system, the superadded or respiratory, which ministers to breathing, and to the expression of emotion. To the nerves of this supposed class he afterwards hypothetically attributed a special origin in what he termed the respiratory tract of the medulla oblongata and spinal cord. The nerves of this class he supposed to comprise the hard portion of the seventh, the eighth, the spinal accessory, the phrenic, and the branch of the axillary plexus, which supplies the serratus major. Of these he more especially dwelt upon the hard portion of the seventh as having furnished experimental proof of the reality of his special system of superadded or respiratory nerves, and he described the experiments which he considered to have made his discovery good.

The announcement of these new views was very favourably received by physiologists; and M. Magendie published a full account of them in two papers, one in his *Journal of Experimental Physiology* for October, 1821; the other in the number for January following. In commenting on the facts and views noticed in the first of these papers, M. Magendie says,—"We repeated these experiments at the Veterinary School at Alfort, with Mr. Shaw and M. Dupuy; and the result which we have obtained agrees perfectly with what we have just narrated, with the exception always of the influence of the section of the infraorbital nerve on mastication," (tom. i., p. 387). In a note to the second of these papers, M. Magendie says,—"We have repeated the experiment [of dividing the hard portion of the seventh]; but the animal at the moment of dividing the nerve, showed by its efforts and its cries that it felt acutely; nevertheless, we do not doubt the [contrary] fact, stated by Sir C. Bell: but this shows how careful one ought to be in representing a result as general," (tom. ii., p. 87).

I quote these passages, as they contain the only expressions of dissent in M. Magendie's comment on Sir C. Bell's paper; the general tenor of M. Magendie's observations being thoroughly favourable to Sir C. Bell's new system and views.

I became acquainted with Sir C. Bell's views on reading his published paper, and not being satisfied of their soundness, commenced a new investigation of the subject which led me to different conclusions. In August, 1822, was published the first Part of my *Anatomical and Physiological Commentaries.* The last essay in that volume is devoted to the examination of Sir C. Bell's theory. It is there shown by reasonings and experiments, which have not been controverted, that a respiratory or superadded system of nerves has no existence; that the experiments which Sir C. Bell advanced, to show that the facial branches of the fifth nerve are for sensation and voluntary motion jointly, and those of the seventh for respiration and expression, admit of another explanation, and are incomplete; that their true explanation is to be sought in the principle, that voluntary motion requires sensation to guide and maintain it; and that by modifying the experiment on the portio dura, so as to render it conclusive, the inference is deducible from it, "that the portio dura is a simple nerve of voluntary motion; and that the frontal, infraorbital, and inferior maxillary (facial branches of the fifth) are nerves of sensation only, to which office that branch of the fifth which joins the portio dura probably contributes;" and that it followed from anatomical facts referred to, "that other branches of the third division of the fifth are voluntary nerves to the pterygoïd, the masseter, the temporal, and buccinator muscles."

This paper was followed in October, 1822, by the publication of experiments by Magendie, on the double roots of the spinal nerves, in a paper in his *Journal of Physiology*. By these experiments he incontrovertibly established that the anterior roots of the spinal nerves minister to voluntary motion exclusively, the posterior to sensation.

The consecutive discoveries of the uses of the facial nerves, and of the separate functions of the anterior and posterior roots of the spinal nerves having been made, and the exact and striking parallel between the two roots of the fifth cerebral nerve and the two roots of the spinal nerves being familiar to anatomists, the discovery of the law above announced was virtually achieved; the true theory of the nerves was obviously struck out, though its details required one or two points of further and subordinate labour, not worth here discussing.

XVIII.

The sentient nerves belong to two classes; one, the common cranio-spinal sentient nerves;

the other, the special cranial sentient nerves. The first have ganglia near their roots, are distributed to all parts indiscriminately, and minister to several kinds of sensation. The second are distributed to the nose, eye, ear, one to each organ and one sense alone. Those organs, therefore, have two sentient nerves; one from each of the two classes.

The ganglionic fasciculi of the fifth and of the spinal nerves and of the glossopharyngeal and pneumogastric, constitute the common cranio-spinal sentient nerves. The sensations to which they minister are,—

1. The tactile sense upon the skin and some surfaces continuous with it.
2. The sense of temperature upon the skin and on several inward parts.
3. The sense of resistance, of which the seat is the voluntary muscles.
4. The inward sensations attending the appetites, and the sense of pain on bodily lesion.

These powers are common to all the nerves above specified; but the sensibility of the glossopharyngeal and pneumogastric as to touch is more vague than that of the fifth and spinal nerves.

5. The ganglionic fasciculi of the fifth likewise minister to taste; branches of the

second division serving this office on the soft palate; from the third, on the tongue.

XIX.

It has been proved of some, and may be anticipated of all the nerves, that their terminations consist in loops; a nerve-tube having never probably a terminal end, but at the distal point of its distribution bending to return upon itself, or to be continuous with another nerve-tube. It may be anticipated, likewise, that their origins will present the same feature.

The distal arrangement of the muscular filaments of nerves in muscles was seen by Messrs. Prevost and Dumas to be such as I have here described.

Upon the face and on the tongue union of larger filaments by apparent anastomosis repeatedly occurs. In these instances the union seems to be always between sentient nerves and voluntary nerves.

In the organs of the special external senses, and in the gray matter of the brain, there is probably a special nervous organization for receiving impressions, in which nerve-tubes probably terminate either in a network or single loops,—a compound or simple provision for *currents*.

XX.

"The nerves of sensation and motion, which supply any given region in the body, are derived from the same part in the nervous centre."

I might, on the present occasion, have better expressed this law, but I have preferred adhering to the form, in which it was originally given in my *Anatomical and Physiological Commentaries*, (Part ii., p. 135, Aug. 1823). Afterwards, in my Lectures, I used to state the law thus: "Nerves of sensation take their rise near those nerves of motion, the impulses transmitted along which they habitually excite or guide." Both expressions occurred to me, in attempting to reconcile the seeming confusion existing at the origins of the nerves of the medulla oblongata with the remarkable order and regularity observed in the origins of the spinal nerves.

Or, in detail, the facts justifying these expressions may stand thus.

Each spinal nerve distributes sentient and voluntary nerves to one region, and its two roots rise from the same segment of the spinal cord.

The ganglionic part of the fifth nerve bears the same relation to the ganglionless part of the fifth, to the hard portion of the seventh, and to the sixth nerve, collectively, which the posterior roots of a spinal nerve bear to its anterior root. The two are distributed to the same parts, one for sensation, the other for voluntary motion.

But the auditory nerve must be brought to rise near the hard portion of the seventh, because the latter is voluntary nerve to the muscles of the organ of hearing.

The ganglionic fasciculi of the glossopharyngeal are required for a parallel reason to rise with its ganglionic fasciculi; and of the pneumogastric nerve the same.

The ninth has to rise near the origins of the fifth and eighth, as it ministers to mastication and to speech.

The third and fourth have to rise near the second, as they govern the motions of the eyeball and iris in connexion with vision.

The first, or olfactory nerve, rises near no motor nerve. But it may be remarked that, in animals in which it is developed, it evidently less excites single actions than conduct; it governs their instinctive choice, and, accordingly, it actually spreads itself at its origin into the brain. Respecting the spinal accessory I can advance nothing that satisfies me.

XXI.

"In connexion with the preceding anatomical law, [it is to be remarked that] an influence may be propagated from the sentient nerves of a part to their correspondent nerves of motion, through the intervention of that part alone of the nervous centre, to which they are mutually attached. Thus, in vertebral animals, in which alone the fact is questionable, when the spinal cord has been divided in two places, an injury of the skin of either region is followed by a distinct muscular action of that part. Again, if the brain be quickly removed from a decapitated pigeon, excepting only the fore part of the crura cerebri, together with the tubercles and the second and third nerves, on pinching the second nerve the iris contracts."

This law I have likewise here enunciated in the same terms as in my *Anatomical and Physiological Commentaries*, published in 1823.

About the same time, I gave greater precision to the experiment above described on the head of the decapitated pigeon, thus. Repeating it, I further divided the optic nerves. So that nothing was left as a means of communication with the eyeballs but the third nerves; and, as before, no part of the enkephalon remained, but the optic tubercles and adjacent portions of the crura cerebri. On pricking the distal stump of the optic nerve adhering to the eyeball, no change took place in the iris. But on pricking the portion of the nerve in continuity with its origin, the iris acted just as before. This experiment requires to be performed quickly, and with some dexterity; if any degree of mechanical violence is used, or much time is lost, the powers of the isolated segment are found to have ceased.

Here it is obvious the primitive idea of a nervous system reappears with singular distinctness;—a sentient nerve, a motor nerve, and an intervening part or sensorial nucleus originating impulses.

XXII.

Likewise between both adjacent and remote segments of the spinal cord means of communication exist, adequate to enable them to co-operate independently of the medulla oblongata and brain.

"The cords which unite the nodules in the nervous systems of invertebral animals, we may presume are intended to transmit, reciprocally, the influence of the different segments of the nervous system one to another. The white fibrous strings, which form the outside of the spinal cord in man and vertebral animals, have probably the same office. In the experiment upon a rabbit above described, the division of the spinal cord in two places produced three independent centres in the nervous system. If in a snake, the head alone is removed, upon wounding the middle of the body, the neck is raised, and bent towards the point at which the injury is inflicted." (*Outlines of Physiology*, by the Author, second edition, 1829.) The fact last mentioned had been remarked by Dr. Whytt. It was, however, communicated to me by the Reverend Blanco White, when attending my lectures in 1825, from his personal observation.

The next step is to apply to the theory of the living economy the facts thus ascertained by observations made upon animals, which have been deprived of life and consciousness, —but so recently, that the footsteps and worn paths of living function have not yet had time to be effaced.

In the same way I had shown that for a short time after death it is possible to discriminate all the voluntary nerves of a part from nerves of every other class, by observing which, when pricked, or otherwise *mechanically* injured, excite muscular contraction.

XXIII.

In the entire and living frame, each segment of the cranio-spinal cord with its nerves (singly or in combination) is sufficient to originate those actions of muscles and of other contractile parts, which are directly consequent upon sensation and occur independently of the will.

The following are instances of these actions:

Contraction of the pupil from light impinging on the retina.

The play of the respiratory muscles in common inspiration, and in sighing, sobbing, and hiccough; in common expiration, and in coughing and sneezing.

Æsophageal deglutition.

Spasmodic action of muscles depending upon increased sensibility of the mucous passages, as in hydrophobia, stricture, &c.

Contraction of the flexor muscles about diseased joints.

These actions may be supposed to involve no further mechanism than that above specified upon the following simple reasoning. It has just been shown experimentally, that *that* mechanism may possibly be sufficient. Why, then, gratuitously look for more?

Dr. Marshall Hall has given the good name of reflex function to this circle of impression and action, and has added one or two interesting facts in additional illustration of the principle.

XXIV.

In the entire and living frame, the apparatus for sensation is complete in the sentient organ, the sentient nerve, and the segment of the cranio-spinal cord in which the latter rises, taken conjointly.

Vision, for example, is completed in the retina, optic nerve, and optic tubercle.

The following argument appears to me to establish the above proposition.

That the brain is not necessary for sensation in parts supplied with nerves from the medulla oblongata and spinal marrow, is shown by the case of the acephalous infant above cited and the corresponding experiments of Magendie.

Then two questions remain. Are the proper cerebral organs (the cerebrum and cerebellum) necessary for smell and vision? and is the medulla oblongata necessary for touch and the muscular sense?

That the proper cerebral organs are not necessary for vision, may be inferred from the want of any correspondence of development in fish and birds, between those organs and the optic tubercles and nerves; while the magnitudes of the optic nerves and tubercles are strictly proportionate.

That the medulla oblongata, again, is not the seat of the sensations of the trunk and limbs (as Magendie concluded it to be), may be deduced from the same consideration.

In birds there is much tactile sensibility in the feet, and the muscular sense is required to be well developed in their legs for maintaining their equilibrium. Now in birds the region of the spinal cord which originates the nerves of the inferior extremities is of great size; and the gray matter of the posterior portion which originates the sentient fasciculi, is so large in quantity, as to appear uncovered, forming the floor of a kind of ventricle opened between the posterior columns of white nervous matter. Here then again the sentient organs, the sentient nerves, and their segments of origin, are in size proportionate to each other. But in the medulla oblongata there is no corresponding amplitude.

XXV.

In the entire and living frame, the segments of origin of the motor nerves, with those nerves, are the whole apparatus requisite for originating and transmitting the voluntary impulse.

The argument in proof of this position is essentially the same as in the preceding instance. The size of the segments of origin is proportionate to the size of the voluntary nerves therein arising; while the size of the medulla oblongata and of the cerebral organs observes no such proportion.

This disparity is most conspicuous in some of the larger birds. The size of the medulla oblongata and of the brain is in these totally incommensurate with that of the segments of the spinal cord originating the nerves of the legs.

The difficulty of admitting this view to be correct arises from our habitually conceiving volition to be in the brain, through our confounding the will, used synonymously for intention, determination, resolution, with the voluntary effort to move the limbs. A little reflection will show that there is no reason for adhering to that notion.

The first act in deglutition is certainly voluntary,—that of forcing the food into the pharynx. But the acephalous infant, when food was placed upon its tongue, swallowed it. Why in a perfect infant should more nervous agency be used in swallowing the first morsel than sufficed in the acephalous infant? and why afterwards in an adult is more needed than in an infant?

Then voluntary action is to so great an extent suggested and guided by sensation, that we should naturally look for the place of its origination near the point where sensation is felt. Or let any one recollect how he learnt to skait; how strictly the effort was directed by his sensations, and how slowly each more difficult movement was acquired. At length, indeed, the action became as easy as walking. But walking, running, every complicated voluntary act is, in fact, learnt by the same slow process. Till at last, when we are perfect in each, the conception of going through it is no sooner introduced into the brain and approved and adopted, than with hardly the consciousness of willing it, it is performed. By the facility acquired through use we are led to overlook the interval there was originally between determining upon any corporeal action and its voluntary performance.

When the ostrich hears or sees its pursuer, the instinctive fear and the impulse to flight we may suppose to be in its brain. But the subordinate voluntary efforts, why should they be anywhere but in the great organ which sends off the nerves of its legs? Or let us, allowing the bird more reflection than it probably possesses, suppose it when pursued to deliberate between flight and hiding its head in a bush, the preference of either course, the deliberate determination to run away, for instance, would be a separate mental affection from the consequent voluntary effort to do so. The instinctive impulse towards flight, or the deliberate adoption of it, would be, not the voluntary effort, but its motive.

XXVI.

In the entire and living frame, each segment of the cranio-spinal cord, with its nerves, constitutes the whole apparatus requisite and sufficient for sensation being felt, and the impulses to muscular action, both reflex and conscious, originated.

The elaborate mechanism for these purposes is best seen in the spinal cord; it is displayed by making transverse sections of the cord at different parts. The gray matter in either lateral half of the cord is seen to expand into an anterior and posterior portion, which are continuous, so that the channel of functional communication between the two is manifest; and each at the same time, as I have specially shown, is seen to be developed exactly in proportion as muscular force or delicacy of sensation predominates, or both are equal, in the parts supplied from the region examined.

The impulses sent to the voluntary muscles are then, some directly excited by sensation, others mediately through a conscious exertion of will. Now there are instances where it is in our power to watch the alternation of the two phenomena and the transition from one to the other. Ordinary breathing is of the first kind. But we may, as it were, take breathing into our own hands, and make each inspiration a separate voluntary effort; and afterwards relinquish it to nature again. The facile transition is like a variation in the play of one and the same mechanism.

The springs of voluntary action are reflection, passion, habit, imitation, sympathy, instinct; now, (setting habit aside, to which the remark would not apply,) if the voluntary effort were not a simple faculty in its own organ, each muscle that acts through the influence of all these motives would require separate nervous filaments from the organs of each.

XXVII.

The nerves are media of communication or transmission; and sensation is felt, and the voluntary effort completed, in the segments of the cranio-spinal cord.

When a limb has been amputated, the patient appears to feel his toes with the former tactile precision.

When a limb is gradually smitten with palsy from cerebral lesion, the numbness and weakness begin at the hand, and gradually make their way towards the body,—a fact which contrasts most remarkably with the opposite feature in the seizure of the arm and leg, each taken as a whole. But the force of this, and of a former argument, will be better explained in the series of pathological corollaries which I proceed to adjoin to the present chapter.

XXVIII.

The fasciculi of white nervous matter, and the productions of gray matter and of gray and white matter blended, which are superfluous to the organization of the cranio-spinal cord taken alone, and which are prepared to extend as media of communication to the brain, have different destinations; one passes on to the cerebral organs of the same side, the other crosses over to the cerebral organs of the opposite. The latter are formed of the white fasciculi termed the anterior pyramids; the former comprehend all the other fasciculi which stretch towards the brain.

It is a remarkable characteristic of the cranio-spinal cord, as distinguished from the cerebral organs, that there is little union of the two lateral halves. In the spinal cord there is a small central part alone, a tenth of an inch in thickness, at which continuity exists. The fasciculi before and behind this are only laid in apposition. This circumstance is consistent with Magendie's experiment of extinguishing vitality in either half of the trunk and face alone.

XXIX.

The office of the anterior pyramids is probably that of transmitting impressions from the brain to the segments of the cranio-spinal cord, not from the cord to the brain.

I draw this inference from the fact that the size of the anterior pyramids is not proportionate to that of the spinal cord, but to that of the brain. The other parts of the medulla oblongata have a contrary ratio, and are proportionately likely to contain the upward channels of communication. It will be afterwards seen that the phenomenon of hemiplegia of the opposite side from cerebral lesion, greatly favours the hypothesis above expressed as to the direction of the current of influence in the anterior pyramids.

XXX.

Groups of adjacent segments of the cord are liable to have their functions temporarily or permanently suspended through lesions immediately affecting them, the segments above and below being unaffected.

No cases exemplify this proposition better, than cases of concussion of the back. Of these, which are very common, most terminate favourably. They may be referred to three classes, in reference to the parts of the cranio-spinal cord which may have been the immediate seat of injury.

1. A violent blow on the middle of the back,—as in the case of a labourer falling through the poles of a scaffolding, and striking the back obliquely against one, his fall being broken, and the principal lesion determined, by this casuality—will cause immediate numbness and paralysis of the legs, in other words, in the parts which derive their supply of

nerves from the segments of the cord which have suffered concussion. If the injury of the spinal cord has not exceeded mere concussion, it is usual, by means of appropriate treatment, to obtain sensible daily improvement, and in the course of a few weeks the patient is well, liable only for some time to inflammation of the part that has been thus mechanically disturbed.

2. A parallel injury often happens at the junction of the neck and back. A person pitches head-foremost into a cellar, for example, and the occiput first striking the ground, and obliquely, the head is driven forwards upon the chest, and the strain or mechanical stretching, with the attendant jar or concussion, tells upon the lowest part of the cervical portion of the spinal cord. When the patient comes to himself, he can use neither his arms nor legs. But, in a day or two, feeling and voluntary motion are completely restored in the legs, while, as yet, the arms and hands have experienced no improvement. Then, in favourable cases, in the course of a few weeks, the sensibility and muscular use of the upper extremities likewise come back. In cases of severer injury, the hands and arms never entirely recover, but remain permanently numb and weak, the hands being generally contracted.

It is obvious that the speedy and complete recovery of the legs in these cases, while the nervous power of the upper extremities remains long or permanently impaired, is owing to the essential independence of the lower segments of the cord of the upper. Coupling this class of cases with the preceding, we find in them a complete illustration of the principle, that as long as the vitalizing segment is entire, any of the other segments of the cranio-spinal cord, which remain unimpaired and in sufficient continuity with it, preserve their function.

3. A very interesting case was under my care, resulting from a blow upon the lower and back part of the head, producing concussion of the medulla oblongata. The boy was at first insensible; as he recovered consciousness, his arms and legs were seen to be paralyzed. Improving daily, before long he re-acquired the use of his arms and legs and their feeling was restored; at the same time his intelligence returned, which his looks expressed, but he could not speak, though he evidently made great efforts to do so. A pencil was given to him, when he expressed by writing his feelings and his wants. Gradually, the medulla oblongata recovering from the shock, his speech returned, and he was perfectly restored. It is obvious that the temporary continuance of palsy of the vocal

organs, after the use of the limbs had returned, belongs to the same class of phenomena with those of the preceding cases.

In partial disease of a middle portion of the spinal cord, the same phenomena have been observed. The feeling and motion of the legs have continued undisturbed, when the arms have been without motion from contraction or entirely paralyzed.

It has not yet been determined, how much, or what elements of the healthy structure must be left in the intervening diseased or injured segments, to allow of the part of the cord below retaining its functions. I remember an occasion on which it was tried to destroy an ass by pithing it between the atlas and occiput, and the cord appeared to be divided, but the animal went on breathing, and its head continued alive: on closer examination, a small fasciculus, which appeared not thicker than a packing-needle, and had formed the extreme edge of one side of the cord, was found undivided. When it was cut through, the respiratory motions stopped at once.

Disease is still more deceptive. Where there is change of colour and consistence in a part of the brain or spinal cord, pathologists are not entitled to infer that the portion so altered has necessarily lost its functions. In Mr. Stanley's case (*Med.-Chir. Trans.*, vol.

xxiii.), it was found that a very considerable change in colour and consistence of the posterior half of the spinal cord had existed without sensibly interfering with its known functions. The sensibility which Magendie observed to belong to its superficial fasciculi might, indeed, or might not have been here extinguished. The features of the case do not touch that point.

In cases of paraplegia, there is sometimes a doubt whether the loss of sense and motion in the legs depends upon the interruption of communication with the vitalizing segment of the medulla oblongata, or upon direct affection of the lower part of the spinal marrow. Some light may be thrown upon this doubt by rubbing and pinching the skin of the senseless feet; when, if the segments of the lower portion of the spinal cord are sound, some unconscious action of the muscles of the leg and foot will follow.

XXXI.

Isolated groups of segments are liable to be the seat of irritation, causing pain or spasmodic action, or both, with or without muscular weakness in the parts thence supplied with nerves.

Cases of this description, and their successful treatment, are too familiar to need illustration. The principle involved in the above proposition explains their nature, and legitimates the treatment, which has often proved successful.

Dr. Marshall Hall has satisfactorily proved that, in tetanus, the source of the continued spasm is in the same system of organs. Having produced tetanus artificially by strychnia, he divided the spinal cord of the animal, when the spasm nevertheless still persisted in the hind legs.

XXXII.

The cranio-spinal segments are liable to have their powers exalted, or their excitability increased through influences transmitted from the brain.

This is the explanation of the increased strength attending passion or a paroxysm of insanity.

It elucidates, likewise, the phenomena of chorea. Chorea is often produced in children by a sudden fright. But the effect of a sudden fright one may notice in passing is to produce a sudden general action of the muscles, a *start* of surprise. Then this cause, or whatever other may have brought on the disorder, is to be supposed to have rendered the motor halves of the cranio-spinal nuclei easily excitable, nervously irritable. The consequence of such a state would be, constant fidgetty action of the muscles. The ordinary sensations transmitted to the cranio-spinal segments would now be enough to determine in the irritable corresponding motor organ impulses to a twitch or catch. But it is a feature in chorea that the attempt to go through any trivial action heightens the twitching and catching movements. This is highly consistent with the above. A mandate comes from the brain to execute a particular gesture; it falls upon an irritable organ, and forthwith, besides the effort suggested, there fly off a thousand irregular uncontrollable impulses.

XXXIII.

The segments of the cranio-spinal cord are liable to have their powers depressed through an influence transmitted from the brain.

The phenomena here adverted to are those of hemiplegia from cerebral lesion. They are of such frequent occurrence, have such various shades, and are so important, that I shall repeat their explanation here.

It will be evident to every one, on reflection, that the influence which produces palsy in lesions of the brain, must be not a negative, but a positive influence. For palsy does not ensue in an animal from which one of the cerebral hemispheres has been abstracted; but it ensues constantly upon trifling, as well as serious, lesions of the brain,—from partial disorganization of, or any matters compressing, one hemisphere. If palsy resulted from the withholding of some accustomed and necessary stimulus furnished by the brain, the effects would be the converse. Removal of a cerebral hemisphere would then always produce palsy; disease and lesion might occasionally.

This positive influence, which travels downwards from the brain towards the palsied parts, is certainly transmitted by the anterior pyramids. For the palsy (*in unmixed cases*) always occurs in the opposite side of the frame to the cerebral lesion; and the anterior pyramid is the only part of the enkephalon in which fasciculi are reciprocally thrown across from the opposite halves of the brain or cord.

Further, the point at which the anterior pyramid plunges into, or is continuous with the centre and axis of the opposite half of the cranio-spinal cord, is the point of junction of the spinal cord and medulla oblongata. Here it implicates itself with the granular and filamentous texture that is continued in the axis of that half of the cord towards the brain in one direction, in the other down the spine.

Now, if in the hemiplegia from cerebral

lesion the cause is a deleterious influence propagated downwards along the anterior pyramid, and thence thrown upon the opposite chain of cranio-spinal segments, its strongest effect will consistently be manifested in those which first receive the shock; and the nuclei placed at the extremities of the chain will suffer proportionately less. But this is exactly what is observed in hemiplegia from cerebral lesion. If the case is moderately severe, the arm and face of the opposite side are alone palsied, either both, or singly. The facts, as stated, are of daily recurrence; but their frequency was not seen, nor their nature understood, nor that of the following, which lay ungrouped, without law or order, and in seeming inconsistency, till I proposed the explanation which I now repeat. The additional facts to which I refer are the following:—

In a severe attack of hemiplegia from disease of one hemisphere, the opposite leg, and sometimes the opposite eye, are palsied, as well as the opposite arm and side of the face.

When the opposite leg is thus palsied, the numbness and weakness are not so great in it as in the arm.

If the attack is gradual, the arm is not only more severely attacked, but it is the part first attacked, the leg, not till some days afterwards.

If the patient recovers, the leg mends much faster, and is restored much earlier and more completely, than the arm.

Such is the customary routine and order of these phenomena, which the reader will see tally exactly with the view above explained as to their mode of production. In the exceptions, which are comparatively few, the operation of additional and disturbing forces may be generally traced or reasonably surmised.

But to complete the elucidation of this subject, it may be pointed out that the very same system, and disease even, lead to exactly opposite features in the parts, where the operation of the palsy tells immediately through a negative or obstructive or withholding influence.

We have, with this point in view, to consider the subordinate phenomena occurring in a single limb affected by hemiplegia; the arm, for instance. Then it is evident that the wrist, the elbow, the shoulder, are parts less and less remote from the group of segments, whence their nerves are derived. Now, by my hypothesis, that group of segments has been struck by a positive influence, temporarily withering and depressing its power; and that influence again may have been sudden but transient, or it may have been gradual, slight at first, and augmenting. The segments so smitten are, it may fairly be presumed, able to throw an impulse proportionately less vigorous along the nerves to the muscles of the limb; there is here then a diminution or withholding of part of the customary stimulus; the influence *in the limb* is a negative or abstractive one; and the features observed are, that the hand is taken sooner and more severely than the fore arm, the fore arm than the arm;—in the gradual invasion of the disease, the hand is numb and feeble before the fore arm, the fore arm before the upper arm;—in recovery, the shoulder first gets strength, then the elbow, then the wrist.

Or the affection of the segments of the cord in hemiplegia is through a positive agency smiting deleteriously one part of the chain; so its intensity diminishes in each portion of the cord as the distance from the point directly smitten increases. But the affection of the parts of one limb arises from negative agency, from the withholding of the usual influence in consequence of the smitten state of the supplying segments; so its features are most developed at the remotest part of the limb.

Chapter II.

OF THE FUNCTIONS OF THE BRAIN.

XXXIV.

The brain, to be framed in correspondence with the popular idea of a sensorium, should comprise a terminal or central part, towards which lines of communication from all the other parts should tend. But no such structure is found in the brain, which, on the contrary, is composed of dissimilar organs, disposed in pairs symmetrically.

It may be suggested that a modification of Magendie's view of the functions of the segment of the medulla oblongata containing the roots of the fifth pair might be conveniently adopted, to reconcile the popular impression with the known structure and the observed experimental facts; and that this vitalizing segment may be the true centre of all, the real *sensorium commune*. But not to mention that the proof already given of the independent powers of the separate segments of the cranio-spinal cord, in contravention of Magendie's view, stands in the way of this likewise, the following consideration alone would render any such hypothesis inadmissible.

XXXV.

The junction of the cerebral organs with the cranio-spinal cord is effected by three pairs of tracts of white, or of white and gray, matter. Of these, one joins the cranio-spinal cord anteriorly to the segment of the fifth, and therefore might find a point of origin and departure in it; and the fasciculi of the second pair certainly tend in part towards the same point. But the greater number of these seem to pass by it to descend along the outer and posterior surface of the spinal cord; while the third pair of tracts of communication, the anterior pyramids namely, after keeping themselves strictly apart from the segment of the fifth nerves, plunge in a direction obliquely downwards and inwards to the centre of the opposite halves of the spinal cord, at a considerable distance below it.

In other words, the segment of origin of the fifth nerves is not the common terminus of all the tracts of communication, which come downwards from the brain, nor of the same if viewed as stretching upwards towards the enkephalon.

XXXVI.

The cerebral organs and cranio-spinal cord form, therefore, one system, all the parts of which are united indeed by very elaborate and complicated arrangements, but not in such a manner as to make any one part central. But the mental operations which are manifested in these organs, the seat of many of which has been already shown to be positively determinable, are characterized, not only by their variety and rapidity of combination, but by a principle of unity manifested in their constant reference to the sense of personal individuality, in their subject. And as that singleness of the mind, or personal ipseity, has no correlative in the structure of the brain, the mind, of which it forms so prominent a feature, must be something apart from the brain. And the mind, it may be presumed, is directly and equally connected with the entire nervous system, operating one function in this, another in that organ, capable, at its choice, of bending its attention to and of energizing in each singly.

It is extremely difficult to express ideas such as the above in unexceptionable language, or in words which do not convey the idea that the mind is material. This difficulty arises from the metaphysical assumption, that mind has no relation to space. Be mind, however, what it will, the simple fact that we *carry* it about with us, shows that *our* mental principle has, (as indeed everything must have,) a definite locality.

XXXVII.

The relation of the cerebral organs to the cranio-spinal cord is not analogous to that between the organs of sense and the cranio-spinal cord, to which it has sometimes been compared. The office of the cranio-spinal cord is not to refer to the organs of sensation for sensible phenomena, to the cerebral organs for reflection and feeling. But the following steps are observed. Impressions made upon the organs of sense are followed by the appropriate sensations being felt in the segments of origin. The office of the cerebral organs is to operate on and elicit more from, or further involve, whatever product the cranio-spinal cord has already obtained as factor to sensible impressions.

XXXVIII.

The cerebral organs may be conveniently divided into three parts. The cerebellum; parts added to the anterior segments of the cranio-spinal cord, or expansions of the latter in a determinate relation to the cerebrum; the cerebrum. Of these organs the cerebellum and cerebrum have a close correspondence in their internal formation, which, though complicated, looks intelligible; the mechanical relations of the structure admitting of being satisfactorily made out. The whole resembles a great building for some public office, in which we see the localities where business is to be transacted, and the means of communication between each, and in which, to pursue the metaphor, we know what the entire circle of operation comprises. What we have to learn is, into how many departments the office is divided, and where each is located.

We are indebted to Messrs. Gall and Spurzheim for the correct general conception of the anatomy of the enkephalon. But it is through the exact and patient investigations of Professor Reil, that we know with certainty the structure of each of its component regions. The researches of Professor Reil were made on the brain, when rendered firm by prolonged maceration in alcohol. The white nervous matter may be then torn into threads, the course and connexions of which admit of being displayed with the utmost precision. Nor is there room to suppose that the filaments, the course of which is thus easily traced, are other than fasciculi of primitive nerve-tubes, the distribution at once and course of function of which are thus rendered apparent. In Reil's original essays published in his *Archiven für die Physiologie*, in a condensed translation of the same with copies of Reil's plates lithographed in my *Anatomical and Physiological Commentaries*, and in my own plates of the Brain from drawings after dissections made according to the method of Reil, the reader may see the structure of the human brain delineated, of which the following is the outline.

1. The cerebellum consists externally of what would form, if it admitted of being spread out, a large thin sheet of cineritious matter, which is folded upon a plan not very complicated, the general disposition being in parallel concentric laminæ. Each of the folds, to the smallest, contains white matter, which,

collected in the middle of each hemisphere, forms a short column or stem of some thickness. The white matter tears into several orders of filaments, which extend from the superficial gray matter in different directions, establishing the following communications. A great series of filaments has a direction parallel to the foldings of the gray matter, and extends between near and remote laminæ of the same hemisphere. A second series converges from the gray matter of one hemisphere, and issuing at its side and forepart, (the middle peduncle of the cerebellum), crosses in a broad band (the pons Varolii), to coalesce with a corresponding series from the opposite side and bring into communication the two hemispheres. A third, converging from the upper part of one hemisphere, descends within the preceding to form the inferior peduncle, or crus cerebelli, for communicating with the medulla oblongata. A fourth, derived principally from the under and the inner part of the circumference of the hemisphere, converges to form the upper or cerebral peduncle of the cerebellum, and stretches forwards to communicate with the optic thalamus of the same side and the cerebrum: the gray capsule in the arbor vitæ is filled with white matter from this, the filaments extending to the capsule itself, piercing it, or being replaced on its outside by others which proceed onwards towards the circumference.

2. Having detached the strong band of fasciculi, called the crus cerebelli, to that organ, the rest of the medulla oblongata, consisting inwardly and above of cineritious and white matter mixed, below of white matter alone, stretches towards the cerebrum; the anterior pyramid passing through the pons Varolii, the rest of the medulla crossing over it. The striking feature now presented is the increment of white matter, which springs out of masses of cineritious matter, that occur in crowded succession. The pyramid, in passing through the pons, divides into coarse fasciculi: the intervals between these and the transverse fasciculi of the pons are filled with grey matter, which originates new white filaments: these reinforce the fasciculi of the pyramid, which issues of many times its former size forming the under and outer layer, or crust, of the crus cerebri. Above, the tubercula quadrigemina furnish a new supply. The mass of ascending filaments, now of some depth, passes through the optic thalamus, which has the form of an egg, pointed forwards, with a deep wedge-shaped part cut out in front, making a space in which the ascending white fasciculi are lodged. The structure of either thalamus is of white and cineritious matter intermingled,

tearing in concentric layers disposed around the ascending fasciculi: a vast increment of ascending white filaments is derived from it. The fasciculi, which have now passed through the thalamus, have finally to traverse the corpus striatum, which has a horse-shoe shape open behind, with cross bars or processes uniting the two sides; through these the white fasciculi ascend, having further additions made to them from this source. So various are the sources, and so numerous the fasciculi derived from them, of which the whole series of divergent fasciculi of either hemisphere of the cerebrum is to be constituted.

3. The structure of the cerebrum follows the same type with that of the cerebellum. But the exterior of either hemisphere is formed of a double sheet of cineritious matter, with a fine layer of white interposed between the two. This triple exterior sheet is thrown into folds or convolutions, larger and of a less regular disposition than the laminæ of the cerebellum. The mass of white matter, which forms the bulk of each hemisphere, and processes of which fill the hollows of the convolutions, is resolvable into three orders of filaments. First, into filaments placed parallel to the surface, which unite neighbouring convolutions of the same hemisphere, below them others which unite the more remote.

Secondly, of fasciculi, which, derived seemingly from the whole cineritious surface of one hemisphere, converge to coalesce with corresponding fasciculi from the opposite. These form two very unequal bands of communication. The upper, or commissura magna, consumes nearly the whole. The anterior commissure unites together the inferior and anterior convolutions of the middle lobes of each hemisphere only. The fornix is partly a commissure of the same description, but principally a means of junction between the optic thalamus and the posterior and middle lobes of the same side. Finally, to unite the hemispheres thus constituted with the parts below, the collected force of ascending filaments derived from the numerous sources recently described diverges in either hemisphere to its entire circumference; every part of this structure is easily unravelled, except where the divergent and convergent fasciculi meet and decussate each other in the hemispheres.

XXXIX.

The sources which throw light on the functions of this complicated apparatus, are vivisection, pathological records, comparative anatomy, comparative observation. The results obtained through the first channel are in the highest degree curious and valuable; the more so, that they are quite unlike what was looked for. They elucidate, indeed, the relations and working of the mechanism, not the functions performed in each part.

These results may be wholly attributed to M. Magendie, whose talent for experimental physiology transcends that of any other physiologist living or dead. In boldness and variety of conception he has gone before all; and where others in their own field have been able only to obtain ambiguous or erroneous results, as in the present instance, he has more than once elicited a consistent body of discovery by his skill in conducting experiments on living animals and in distinguishing true from false phenomena.

The following are the principal experimental results obtained by Magendie as to the relative agencies of different parts of enkephalon.

1. " Upon the removal of the middle and upper portion of the cerebellum in rabbits, the animals are observed to hold the head drawn backwards, their hind feet are moved apart, their fore legs become stretched and stiffened. In a short time the fore feet, with the legs kept rigidly extended, strike the ground; and the hind feet remaining motionless, the

animal moves retrogradely. The same injury carried deeper causes the animal to fall on its side; the head is drawn further backwards, and the feet, especially the fore feet, the rigidity of the limbs being preserved, are agitated more violently. But these movements are not uniform and regular. If the injury is confined to one side of the cerebellum, the only result is weakness of that side, and even palsy if the wound penetrates the base of the peduncle. The flight and walk of pigeons are not altered by the removal of the superior part of the cerebellum. Upon a deeper incision the animal totters, falls forward, raises itself, does not cease to agitate itself: a still deeper wound causes it to walk and fly backwards. After the entire destruction of the cerebellum, the animal, excited to move, walks almost in its usual manner; thrown into the air, it moves its wings regularly, and comes down gently upon its feet. After a quarter of an hour it can no longer stand; its legs become extended and rigid, but it walks with them if held up by the ends of its wings: if thrown or tossed into the air, it moves its wings with regularity. The legs remain rigid, and the head drawn back till death. M. Fodéra saw all these phenomena succeed each other in one bird; but each can be produced at once by making an incision at the requisite depth."

2. "On cutting one of the lateral peduncles of the cerebellum in a cat, rabbit, dog, squirrel, &c., the animal betakes itself to rolling over and over on its axis towards the side wounded, with a rapidity that may exceed sixty revolutions in a minute. The same effect is produced by any section of one-half of the cerebellum parallel to the median plane, with this difference, that the rotations are more rapid the nearer the injury is to the peduncle. A superficial injury even of the peduncle will cause this movement. It may be arrested by a similar section of the opposite side: if two sections at different distances are made, the animal turns to the side wounded nearest the peduncle."

"If the section is made in the median plane exactly, there is no rotation. The animal totters from right to left, and cannot preserve its equilibrium. If in this tottering he falls and rolls over once or twice towards one side, he immediately rolls as many times over towards the opposite."

3. "When the enkephalon is entire, wounding the optic lobe, especially at its base, irresistibly forces the animal to run, or to fly, or to walk in a circle towards the side on which it is wounded. In frogs and serpents the phenomenon is reversed; these animals turn towards the opposite side. After the destruc-

tion of both eyes, these movements continue as before. Upon similarly mutilating the opposite side, the phenomenon is at an end."

4. "If in any of the mammalia the upper part of the cerebral hemisphere and the striated body is removed, immediately the animal precipitates itself forward, and runs forward till stopped by some obstacle. If it should stop spontaneously, it preserves the attitude of advancing; and when it moves again, it is again forwards. These phenomena are manifested only if the white bands which ascend through the corpus striatum are destroyed. The destruction of the gray matter alone does not produce them. Upon then removing the optic thalami, the attitude of running forward disappears, the animal falls upon its side, the body bent, and the fore feet are moved with great rapidity. These results are uniform in dogs, cats, rabbits, guinea-pigs, hedgehogs, and squirrels. Only the last, in advancing forward, cross their fore-legs as if in climbing a branch, and if a stick is held to them, they actually do so."

XL.

It has thus been experimentally established that there exist in the enkephalon at least four series of currents or forces, intended to maintain a constant state of equilibrium, and giving rise to sensible disorder whenever that equilibrium is disturbed.

This discovery is immediately available in explaining several curious phenomena in pathology.

The equilibrium of these forces is liable to be disturbed by functional derangement or structural lesion in human beings. The following are examples.

M. Magendie mentions that a young woman, exhibited at the Royal Academy of Medicine, is affected with a nervous malady, the attacks of which oblige her to move backwards precipitately with no power of avoiding the obstacles against which she is urged by it.

M. Fodéra saw a young woman, who, after having struck the occiput through a fall, was attacked with convulsive paroxysms, consisting in irregular movements of the limbs with retraction of the head, as observed in rabbits in the experiments mentioned. Upon her death in one of these paroxysms, an abscess was found in the cerebellum.

M. Serres describes the case of a patient, who had a seizure that before many hours terminated his life, in which he evinced a strong disposition to rotation like the rabbits with lateral injury of the cerebellum. After death one crus cerebri was found to have been severed by an abscess.

Ordinary giddiness consists in the disturbance of equilibrium of the counter-forces of the two optic thalami. This is evident from the sensation, which is thence termed vertigo; likewise from the motion of one seized as he is walking with vertigo; before he is stopped, or drops, or recovers himself, he has described a segment of a circle. Likewise this giddiness can be brought on by turning round without closing the eyes; and can sometimes, when it has come on through cerebral or bilious disorder, be stopped by strongly fixing the vision on some stable point.

XLI.

The principal facts of the progression of improvement in the enkephalon of the successive classes of vertebral arimals, which are shown by comparative anatomy, are the following.

1. In fish, the cerebral organs are rudimentary, and inferior in magnitude to the cranial segments of the cranio-spinal cord, which are vastly developed. The latter form three great symmetrical organs. The posterior being the medulla oblongata; the middle, the

optic tubercles; the anterior, the olfactory tubercles.

It is in the torpedo, where it has to originate the great nerves of the electric organs, that the medulla oblongata exhibits its greatest development; but in the common skait the amplitude of the field of gray matter, and the size of the curved and indented columns of white matter flanking it, are sufficiently striking. In the skait, again, in which the optic tubercles are likewise large, the olfactory segments form a prodigious rounded double organ of cineritious matter.

The cerebellum, the pituitary gland, and the corpora albicantia exist, however, in the skait; and in osseous fishes the rudiment of a cerebrum.

The cerebellum is at first a small oval plate of gray matter, supported on a thin layer of white, which springs by two fasciculi, one on each side, from the lateral and back part of the medulla oblongata. In one species of ray there is no junction between the two halves of the cerebellum, which only meet, membrane being interposed. Elsewhere they coalesce in one organ; and in the common skait there are two slight transverse flutings, the rudiments of laminæ.

In osseous fish, one pair of small flattened rudimentary oval masses, situated above and before the optic tubercles, and in some a second smaller pair anterior to the first, represent the cerebral hemispheres.

The pituitary gland and corpora albicantia are of great size; they do not increase afterwards, and seem, therefore, to have to do with completing the cranial portion of the cord. The care with which the pituitary gland is protected has not perhaps attracted due attention.

2. In batrachian and in ophidian reptiles, the cerebellum most singularly shrinks to a narrow band stretched transversely over the medulla oblongata. In the lizard and tortoise tribe it makes a step of recovery, acquiring an increase of volume. The cerebral hemispheres continue to enlarge in each of these succeeding groups.

3. In birds the cerebellum, now regularly laminated, and increased in volume, yet wants lateral parts or hemispheres. The cerebrum enlarged is still but a double mass of gray substance, which gray substance is confounded anteriorly with the olfactory tubercles, although penetrated likewise by fasciculi, produced from the cord behind to radiate in it.

In vertebral animals first appear the lateral parts or hemispheres of the cerebellum, with their commissure, the pons Varolii; but, with three remarkable exceptions, they are uniformly of inferior development to the central part. Now, too, first appear true cerebral hemispheres, corresponding in principle with those of the human brain already described, and joined by a great commissure.

XLII.

The features manifested in this progression are definable complication of structure, and increase in general volume, in the cerebral organs. These, therefore, may be received as physical conditions of mental improvement.

It is, indeed, extremely difficult to measure the faculties and ideas of animals. But there must be grounds in actual observation for the general impression, that a canary bird has more intelligence than a fish, a warm-blooded quadruped than a bird. It is true that a canary bird or a parrot will show wonderful educability, discriminating personal attachment, pleasure at being noticed, jealousy of other favourites, sympathies, in short, with man. Yet there is evidently much more of human feeling expressed in the eye and gestures of the dog, and in its capacity a nearer approach to understanding and reason.

XLIII.

It may be asserted of the conformation of the cerebral organs in mammalia, that it possesses an intelligible superiority over that of the inferior vertebral animals.

In cartilaginous fish, the system of a double cranio-spinal cord, consisting of a chain of segments capable, each, according to its importance, of enlargement and development, is perfected, and there is but the rudiment of a cerebellum. The brain of mammalia displays some of the first organs enlarged; and superimposed upon them a new set. It presents the optic tubercles of the skait, swelled into the optic thalami and four pair of dependent tubercles. It presents the olfactory segment amplified into striated bodies. Above these, the cerebral hemispheres, consisting ultimately of a pair of great organs placed in correlation with the whole of the cord below, with the optic tubercles, and the striated bodies. One may fancifully illustrate the operation of a sentient organ, its nerve, and a cranio-spinal segment by the arithmetical operation, 1×10, or 10^1; superadd the cerebral organs, and the result is $1 \times 10 \times 10$, or 10^2.

The brains of osseous fish, of reptiles, and birds, are transitional from the inferior system to the higher.

XLIV.

The value of difference in volume, of absolute and relative magnitude, is the other element to be estimated.

We set off with the impression that volume and power in these organs, to a certain extent, go together.

1. But superior size of the cerebral organs is not alone a proof of mental superiority. The brains of the elephant and of the whale are larger than the human brain.

2. Neither is the relative size of the enkephalon to the whole organization such an index. The weight of the human brain is $\frac{1}{35}$th of the whole weight of the frame. The weight of a canary bird's brain is $\frac{1}{14}$th.

3. Nor even is the relative size of the enkephalon to the whole organization a measure of its power, when the comparison is confined to animals of the same class with brains exactly of the same mould and type. The weight of the brain of a canary bird is $\frac{1}{14}$th of its entire weight; that of an eagle's brain, $\frac{1}{200}$th. In the ostrich the disproportion is still more enormous.

Thus the supposed ratio between magnitude and power seems utterly confounded, or superseded by other relations. And it becomes necessary to examine more strictly what grounds there are for attaching importance to the magnitude of parts of the nervous system, and with what limitations the prevailing notions on the subject must be received.

We have adopted the general impression that volume and power go together in the nervous system, from observing that this holds in the organs of sensation and motion. The value of difference in magnitude in these organs admits of being very satisfactorily explained. If the leg of an ostrich requires large motor nerves and a proportionate cranio-spinal segment, it is only because its muscular fasciculi are more numerous, and require, therefore, a greater number of nervous filaments to supply them. If the optic tubercles and nerves in birds are large in proportion to the size of the eye, which, however, is of great magnitude, the quantity of retina in the eye of birds with the acutest vision is very large, and requires, therefore, a proportionate number of nervous tubes to carry its impressions, a proportionate organ to receive them.

Now it will be evident that the same grounds do not exist for increase of magnitude in the brain. For quantity of power required in the former case, we have to substitute the conception of variety of power or mental compass in this. This substitution being made, we may, however, anticipate that there will be found an increment of volume in the brain proportionate to the enlargement of its office.

Then we may inquire, what are the mental affections located in the brain of birds? they may consist of a greater or less disposition to gregariousness, more or less wariness or boldness, the instinct of choice of abode and migration, of nest-building and incubation, &c. But, of whatever they consist, it is probable that the number of ideas, or the number of changes that can be rung on those ideas, is much the same in different kinds of birds. Accordingly for the cerebral functions of all birds, no other relation being considered than the number of impulses and ideas they have, the actual size of the brain should not be very materially different;—a conclusion which removes what seemed anomalous in the apparent diminutiveness of the brain in large birds. The brain has to bear reference to the mental compass of the animal, not to the magnitude of its organs of sensation and voluntary motion.

The tables are indeed turned; and the difficulty is now to account for the superior magnitude of the eagle's brain over that of the canary bird, when there is no reason to suppose a corresponding superiority in mental compass or in number of ideas and instincts. We must, however, here, as always, be satisfied with observing nature. There *is* a certain ratio observed between the brains of animals of the same kind, dependent on their difference of bulk alone. Whether this has to do with their general corporeal organization, or whether it is necessary to enable the cerebral organs to manage, or counterpoise as it were, the larger cranio-spinal system, is a subject for after consideration. But either or both suppositions together are reasonable; and they consist with the facts observed.

XLV.

Then it appears, that the volume of the cerebral organs is proportionate to the place of the animal in the scale of organization, if considered in joint reference to the compass of the organs or the number of ideas and relations they deal with, and to the size of the animal relatively to the rest of the group framed on the same type.

XLVI.

Agreeably with the value which has thus been shown to belong to the development of cerebral organization and to volume, the human enkephalon is found,—first, to be specially enlarged and amplified in those parts, which are themselves characteristic of the brain of mammalia, namely, the hemispheres of the cerebrum and cerebellum; secondly, to possess these parts of much greater relative size than the animals which come nearest to man, as the dog or the oran-otang; thirdly, to have the same of so great absolute size that they are actually much more voluminous in man than in the horse or cow, which so much exceed man in weight; but, fourthly, to have cerebral organs less in volume than those of the elephant and whale in agreement with the immense disparity of general size,—the brain and cerebellum of the elephant and whale meanwhile not manifesting with their increased size the human proportions of the parts of the enkephalon, but retaining the lower type.

XLVII.

Having thus determined the principles which give organic superiority to the human brain, we may next inquire what difference in office is to be attributed to its separate great divisions.

One very striking difference of relation between the cerebrum and cerebellum immediately presents itself. The former is directly connected with the apparatus of smell and vision, [being, indeed, likewise connected through continuity with the medulla oblongata, with all the rest of the cranio-spinal segments and their nerves.] The cerebellum, on the contrary, has no direct connexion with the olfactory and visual apparatus; it lies, however, in the way of communication with all of the cranio-spinal segments but the optic and olfactory.

I see no other clue of a promising character. The cerebellum is large, indeed, in fish, many of which want a cerebrum. And in the cetaceous mammalia it is so highly developed that the lateral parts are, as in man, much larger than the middle part: but the cerebrum in these animals is proportionately developed. In anthropomorphous animals the lateral parts of the cerebellum have a parallel increase; while in frogs and serpents the whole organ has nearly disappeared.

XLVIII.

In following out this idea in reference to the cerebellum, it may be observed that the inferior peduncle, or crus cerebelli, on either side attaches itself to the lateral and posterior surface of the medulla oblongata, whereby the fasciculi which descend from it are brought into continuity with those of the spinal cord, which contain the posterior or sentient roots of the spinal nerves. Now the class of common sentient cranio-spinal nerves [see XVIII.,] has as one of its peculiar functions to minister to the inward or bodily sensations. Is it probable that some of the functions of the cerebellum may be to develope instincts connected with that class of sensations?

This idea is consistent with the belief, which so much prevails among phrenologists, that the cerebellum has to do with the sexual impulse. It appears to me, indeed, most probable that the cerebellum does not originate that impulse. That impulse is a sensational appetite, like hunger, and depends for its existence upon the state of the bodily organs and organs of mere sensation. The argument commonly deduced by phrenologists from pathological phenomena is certainly unsound. As Muller remarks, "The coincidence of disease of the spinal cord with affection of the genital organs is much more frequent than of disease of the cerebellum." And Cruveilhier even mentions the striking instance of a girl, in whom after death the complete absence of the cerebellum was ascertained, yet who had manifested a strong tendency to a practice growing out of the appetite referred to. "In place of the cerebellum there was merely a membranous band passing transversely over the medulla oblongata, and connected on each side with a swelling of the size of a hazel-nut; the pons Varolii was entirely absent; the olivary bodies were indistinct; the head presented the features of want of intelligence and indistinct articulation; for some years her legs had been extremely weak, that she could scarcely move them, but *their sensibility was perfect.*"

XLIX.

We may, however, certainly conclude with reference to the functions of the cerebrum that they include the ministering to those instincts and impulses that are more immediately connected with smell and with sight. The following facts may hereafter find an application in connexion with the above,—the olfactory apparatus is most connected with the anterior half of the brain, the optic with the posterior.

L.

Passing over the consideration of the uses of the individual cerebral organs, we may still inquire whether there exists any general index of their power. Agreeably with what has been before advanced, relative magnitude in individuals of the same species might be expected to be commensurate with a capacity for more numerous ideas. But this indication may be obscured, if different parts of the brain have different functions, by the inferior or hostile development of one neutralizing the action of another; and even completely masked, if, as it is probable, the force of brains outwardly the same should differ in intensity.

The facts collected by Tiedemann have shown that the average brain of the Caucasian race exceeds in magnitude that of the other families of mankind.

He gives tables of the internal area of the skull in Europeans, Americans, Malays, and Negroes. Of the first he adduces seventy-seven examples; of the second, twenty-four; of the third, thirty-eight; of the fourth, forty-eight. The method of gauging each which he employed was to ascertain the weight of millet-seed required to fill it. I find by averaging his tables, that the European or Caucasian cranium contains forty ounces; the American and Malay, thirty-nine; the Negro cranium, thirty-seven only. In other tables in the same paper the length and breadth of the European cranium are shown to exceed those of the Negro cranium. And a very curious fact is added respecting the brain of the Bosjes-woman, who was called the Hottentot Venus. The convolutions of the hemispheres in this specimen [the dimensions of which are likewise of the smallest,] are more strictly symmetrical than is the case in European brains. This feature [absent, I may take occasion to mention, in the brain of a New Zealander which I examined,] is an approach towards the type of the cerebral organization of animals as distinguished from that of human beings. From the oran-otang downwards the two cerebral hemispheres of animals exhibit in their superficial markings great closeness of resemblance; whereas in European brains the resemblance of the gyri of the two sides is general only, and the details of their disposition vary remarkably.

LI.

Another question, however, arises upon this. Is there any shape especially human, any proportion of subordinate parts, which distinguishes the brain of man from that of animals, and the relative increase of or recession from which in man may mark superiority or inferiority?

In the domestic animals, the horse, ass, dog, in sheep and cattle, the posterior lobes of the cerebrum are relatively smaller than in man, and the lateral parts of the cerebellum on a smaller scale. But this difference disappears on making the juster comparison of the brain of man with that of anthropomorphous animals. In some species of monkeys the proportions of the different regions of the cerebral organs to each other are strictly human, however greatly inferior the parts are each and all in development to those of man.

LII.

Are there grounds for adopting the phrenological chart of the cerebral organs?

If there are not sufficient grounds for adopting it, there are, at all events, for examining it. For it cannot be doubted that the vast extent of the layer of cineritious matter, which forms the cortical part of the brain, has some strict physical relation to the conceptions and emotions of the mind; and the probability is very great, that different regions of this stratum are concerned with different classes of conceptions or emotions; and no insurmountable obstacle is apparent to the detection of such relations by measurements even upon the living. And if the primary object of the inquiry should fail, still some new truths will certainly be brought to light in its progress. But there are reasons to hope that the inquiry will prove in the end more or less successful as to its direct object. Accordingly, most of those who have diligently studied the craniological map will be found to believe, that its general features, or some of its leading indications, are correct.

The circumstance of a large portion of the cerebral surface being withdrawn from observation, forms the principal difficulty in the inquiry. And there is a circumstance in one of the parts so hidden which necessarily raises some misgivings. The convolutions situated on the inner aspect of the cerebral hemispheres always present a plane superficies. Yet there can be no doubt, that these parts of the cerebral organization must vary in power like the rest; accordingly, *prominence of a part* is but an accident, at all events, in its dynamic development. But if that criterion is lost, what is there to guide one in deciding on a given extent of superficies, which organ is developed, which deficient?

However, these are perhaps not unconquerable difficulties. An intimate acquaintance with the anatomy of the brain, a familiar knowledge of the leading arrangements of its surface, of the uniform principal divisions among the convolutions, and of the varieties in the subdivisions, and a search after their concomitants, if such there are, in the external shape of the skull, may in the end enable an observer to interpret this most obscure page. And one would suppose the obstacles specified must be partly already overcome, when there are those who declare that their reading of the indications of character in the form of the head generally proves correct. Yet one must not build a too confident expectation on such occasional success when it is real. So much is there in physiognomy, and in general extraneous indications of character, to help, without his being aware of it, the guess of the craniologist.

However, for my own part, I profess that I have not sufficiently compared the craniological chart with nature to make my opinion of value as to its correctness. Nevertheless, I have not entirely neglected what opportunities of observation have come in my way. But I certainly am not satisfied that even the principle of distribution of the mental elements which is adopted by phrenologists is just;—that the intellects lie in the front, the moral impulses in the middle, the inferior impulses at the back of the head. Indeed, I have arrived at no more than a few general impressions, rather of a physiognomical than physiological character, which are perhaps hardly worth stating.

I think, *as an artist*, that persons of good capacities and of well-ordered moral impulses, have heads of a certain size or figure, or both.

1. Of the two elements, shape appears to me of more consequence than size.

2. In a small head the forehead should not recede, but should be broad or high; both together give most promise; and the upper part of the head must be round and full, not narrowing towards the vertex, nor the upper part of the sides of the head cut away. Length of head appears immaterial. The late Professor Coleman, whom I had the pleasure of knowing, a man of a social and most amiable disposition, quick of observation, with considerable reflective powers, of a right heart and a strong head, had a cranium, of which the posterior fifth appeared to have been obliquely sliced off. Shortness, indeed, but without so much abruptness, is almost necessarily a feature in well-formed small heads.

3. If the head is altogether large and ample, a receding forehead does not seem to be at variance with the possession of high intellectual and moral qualities.

4. The head, in addition to being large, very lofty at the middle of the vertex, the forehead sloping, is a mould which has gone with the highest intellect. In this mould was cast the head of Sir Walter Scott. The head of Shakspeare appears to have been similarly shaped.

5. A head of ordinary dimensions, the forehead vertical, but neither high nor broad, the vertex well rounded and of a good height, frequently accompanies great parts. Such was the shape of the heads of Pitt and of Chatham. The forehead of Chatham was something broader than that of his illustrious son.

6. A large eye with long eyelids often accompanies eminent talent; and whether connected with the size of the orbit or with development of the anterior and inferior convolutions of the brain, fullness and squareness of the superciliary region generally go with this feature. In the forehead of Newton, else nowise remarkable, this prominence and largeness of the lower part of the forehead are strikingly pronounced.

7. The head of Napoleon was characterized by its size and squareness, the forehead broad

and vertical, and at the same time higher than ordinary: the eyes remarkably large, and the eyelids long. The largeness of the superciliary region was balanced by an equal mass above it.

When large heads are met with in combination with dull capacity, their shape is commonly ungainly, and projections of bone, having no relation to cerebral development, catch the eye.

The worst physical character is great lateral narrowing of the upper part of the head, with a coarse breadth at the lower and middle part. Add to this a mean forehead, and want of symmetry of the two sides, and the portrait is yet deteriorated.

The heads of the ablest and the best, whether large or small, generally look more carefully shaped and better finished than those of commoner persons. The shape, too, in which they are fashioned, seems better filled out; so that the bony boundaries are lost sight of, and the roundness or fullness of the contained organs is the predominant characteristic.

Chapter III.

INFLUENCE OF THE NERVOUS SYSTEM OVER THE BODILY FUNCTIONS.

LIII.

Besides the cranio-spinal system and its nerves and the cerebral organs, the nervous system comprises another part, known under the name of the sympathetic or ganglionic system, which, common to all vertebral animals, has been identified in many of the invertebrata likewise.

LIV.

The textures employed in forming this system bear a close resemblance in part, a strict analogy always, to those used in the construction of the organs of consciousness. They are two; one a corpuscular texture, the other composed of filaments.

The corpuscular bodies in the first do not appear to be any ways distinguishable in shape or colour from the corpuscles of the gray matter of the brain. The filaments, however, have the peculiarity of being gray in colour; and they are smaller than the nerve-tubes or white filaments of the cranio-spinal system.

LV.

The disposition of the system, which is framed of these textures, bears, again, a close resemblance to that of the cranio-spinal system. The sympathetic system comprises a central organ analogous to the cranio-spinal cord, and nerves proceeding from it to be distributed universally through the frame.

LVI.

The central organ of the sympathetic system is composed of a double chain of flattened gray nodules or ganglia, united by fasciculi of gray filaments. The chain descends parallel to, and to the front and side of the vertebræ, from the carotid canal to the os coccygis, one half on either side.

In human beings, the number of nodules amounts to two or three pairs in the neck, twelve in the back, five in the loins, five on the sacrum; a single nodule on the front of the os coccygis, where the two chains coalesce. Upwards the system terminates in plexiform branches, which form a network round the internal carotid artery, and have a terminal ganglion near the cavernous sinus.

LVII.

The nerves derived from these nodules are of two orders, one verging outwards to unite with the trunks of the adjacent cranio-spinal nerves; the other tending inwards and forwards for immediate distribution through the body.

The first constitutes the reflected branches of the sympathetic nerve; the second its distributed branches.

LVIII.

The reflected branches are of a complicated nature; they consist in part of gray filaments, in part of white.

The common cranio-spinal sentient nerves, it has been already remarked, have each near its root a large reddish-gray ganglion; this organ consists of corpuscular bodies, between and among which the white opake filaments proper to the cranio-spinal nerves are seen to pass. From these ganglia there emanate fasciculi of gray filaments, which are distributed along with the white. Probably the gray filaments in the reflected branches of the sympathetic tend to coalesce or be distributed with the gray filaments derived from the ganglia in the nerves of touch. The white filaments of the reflected branches of the sympathetic may be supposed to be derived from the cranio-spinal nerves, and to be introduced to minister to the sensations and sensational motions of the viscera.

LIX.

The distributed branches of the sympathetic bend forwards and inwards upon the spine, and are characterized by collecting in plexuses and ganglia.

Of these the most remarkable are the semilunar ganglia and the solar plexus. It is presumable that a small plexus from the sympathetic accompanies every artery in the body. The principal visceral distribution of the branches of the sympathetic is to the heart, the bowels below the stomach, the pelvic viscera. But all the viscera receive some filaments from this source.

LX.

Thus there exist three sources in the nervous system, from which influences may be propagated to control the corporeal functions;—the cerebral organs, the cranio-spinal cord, the ganglionic system. And three channels through which these influences may be conducted;—the motor nerves, the sentient nerves, the branches of the sympathetic.

LXI.

The limits of the influence exerted by the cerebral organs are unknown. Its great extent is apparent from the variety of functional disturbance excited by affections of the mind; as well as from the symptoms attending lesions of the brain and spinal cord; and through experiments on animals.

LXII.

Affections of the mind are capable of altering the rate of the circulation instantaneously, and of the secretions, and of the blood; and of disturbing digestion, and even growth.

Fear will cause the heart to beat feebly, even to stop; grief will depress its action.

Fear, rage, passion, will produce paleness; shame and indignation, flushing.

The influence of fear on the kidneys and on the bowels is well known.

The imagination will cause the saliva to flow; and it is said in animals will maintain the secretion of milk.

Shame on sudden detection has produced jaundice in the course of a few minutes.

A loathsome idea will cause vomiting; strong mental excitement will stop digestion.

Fear and anxiety are said to have turned the hair gray in a single night.

LXIII.

Mechanical injury of the brain is capable of disturbing the circulation and the stomach.

Violent concussion of the brain produces immediate death. The patient is insensible, has no pulse, is pale, and does not breathe; and life does not return, If the injury has been less considerable, the action of the heart gradually re-establishes itself, and the present danger is at an end. Death from concussion of the brain is thus death from protracted syncope.

Dr. Wilson Philip discovered that crushing a large portion of the brain or of the upper part of the spinal marrow, in rabbits, immediately after they have been killed, stops the heart's action. In living frogs the heart stops, then beats feebly, then recovers itself, if a like injury is inflicted. Crushing the lower part of the spinal cord has little influence on the heart's action. The application of alcohol to the rabbit's brain was found to stimulate the heart.

In a series of important counter-experiments to these, Dr. Wilson Philip found that if the brain or spinal marrow are removed with gentleness from the slain animal, the heart continues to beat with the same force and frequency, and as long, as in animals destroyed by the same means in which the brain and spinal cord were left undisturbed.

LXIV.

It is thus established that the brain interferes to control the bodily functions on many occasions, both in health and the natural course of existence, or under bodily lesion. But is there reason to suppose that the nervous system is constantly exerting such an influence?

The valuable experiments of Dr. Wilson Philip just mentioned tend to the conclusion that, as far as the action of the heart is concerned, no influence from the brain or spinal cord is necessary to maintain that one organic function. But the same rule may not hold for every function; and the heart is remarkable for the persistence of its irritability, even when taken out of the body.

LXV.

The phenomena of growth are independent of the cerebrum and cerebellum.

The numerous instances of well-grown acephalous infants, which have reached fœtal maturity, sufficiently establish that uterine growth at all events is as efficiently performed without as with those organs. And in the instance which I have quoted, in which life continued in such a being between three and four days after birth, no bodily function was manifestly out of order.

Cases of idiotcy tend to confirm the same conclusion. The cerebral organs have been incomplete, reason has not had space for development, but the bodily functions have been perfectly performed.

In the progressive scale of organization, there are no facts that point distinctly either way. But it is a singular characteristic of fish, in which the cerebral organs are specially rudimentary, that their increase of size seems comparatively indeterminate.

LXVI.

The healthy nutrition of some parts is disturbed by inflammation when the nerves supplying them are divided.

The cases instancing this proposition are the following:—

When the pneumogastric nerves have been divided in the neck, inflammation of the stomach supervenes.

Upon division of the fifth nerve within the cranial cavity close to the brain in rabbits, M. Magendie found that partial inflammation and opacity of the cornea uniformly supervene.

Upon injury of the cauda equina or of the spinal cord sufficient to produce paraplegia, the patient surviving, in the course of some days inflammation of the mucous membrane of the bladder follows, characterized by secretion of tenacious mucus, and the urine becoming ammoniacal.

LXVII.

The immediate cause of these phenomena is obscure. They certainly arise from the influence of the cranio-spinal cord being cut off; nevertheless it would appear that they may be much heightened by the additional interception of an influence emanating from the ganglionic system.

M. Magendie found that on dividing the fifth nerve in rabbits within the cranial cavity, not close to the brain but near its exit, in such a manner as to destroy at the same time the ganglion of Gasser, there ensued not merely opacity of the cornea, but deep-seated inflammation of the eye-ball and suppuration, and the eye ulcerated and was lost.

LXVIII.

The regulation of animal heat appears in some degree dependent on the nervous system.

In a patient under Sir Benjamin Brodie's care, who died of laceration of the spinal cord in the upper part of the back, the temperature of the body rose before death to 111°.

LXIX.

We have seen that the secretions are liable to be influenced by the mind. But it is presumable that their regular course is independent of the cerebral organs.

The case of the acephalous infant already referred to seems to establish this conclusion. It took food, which it probably digested, or vomiting would have ensued; it voided urine.

LXX.

But at the same time it seems probable that nervous influence from some source is always requisite for this function.

There may be a difference in different organs. The secretion of tears must be under the dominion of the fifth pair and of the brain; and the salivary secretion one would suppose to be measured and determined by sensation.

The secretion of urine I found sensibly unaltered by dividing the nerves of the kidney. But those who have repeated this experiment and used chemical tests of the condition of the urine, have found it altered. Much must here depend on the violence done to the parts in the experiment.

The influence of the nerves on the digestive secretion of the stomach can hardly be viewed as yet determined. Sir Benjamin Brodie found digestion take place after the pneumogastric nerves had been divided in the cardia. Magendie obtained the same result after their division on the œsophagus. But division of the same nerves in the neck appears on the contrary always to interrupt the process. Less, indeed, Dr. Wilson Philip most singularly discovered, when the nerves are divided and their ends left in opposition, than when a part has been removed or the ends turned aside. The late Mr. Broughton, an excellent witness, assured me that he had observed this difference to be marked and constant.

Chapter IV.

OF PERCEPTION.

LXXI.

Our knowledge of the external world is not immediate and intuitive, but obtained by gradual steps.

Accordingly the reality of the external world admits of being hypothetically disputed, and of being proved by argument. Circumstances even occur under which men, *for an instant*, seriously question it. Thus in unforeseen calamity the sufferer finds momentary relief in asking, "May not this be but a dream, cannot I wake from it?"

LXXII.

We know, however, that our sensations are real; and we rely implicitly on the evidence of memory as to things of recent or frequent occurrence.

We believe our sensations to be real, just as we believe in the reality of every other mental affection when it is present. We are immediately conscious of them. To question their existence, is impossible. Experience and reflection neither lessen nor strengthen our belief in it. With respect to memory, the effect of experience is to teach us that it has limits, and the occasions in which we must relinquish absolute faith in it.

LXXIII.

Our knowledge of the external world is derived from our sensations and certain ideas immediately suggested by them.

As the mind can attend to one sensation only at a time, and as our knowledge of the external world depends upon the comparison of many sensations, it is through remembered sensations that our notions are really formed.

The education of our senses by comparison and use becomes so complete, that we find great difficulty afterwards, upon attempting to analyze any sensation, to determine what of the impressions it communicates are primary, what associated.

We feel, or are conscious of, sensations, we do not perceive them. We perceive by means of them.

As we are led, it will appear, to refer our sensations to something without us, the phenomena connected with mere sensation have to be viewed in two aspects, which have been distinguished by the terms objective and subjective. We feel heat for instance. Then the nature of heat,—whether it be a motion or a substance,—is an objective inquiry; the question, on the other hand, why the same degree of temperature strikes warm in winter and cold in summer, refers to a subjective difference.

LXXIV.

Our sensations are of two kinds, internal and external. Those are called inward which refer to our bodily feelings; those outward, which give us information respecting what is without us.

LXXV.

The inward sensations comprise those which go with the appetites and their gratification, the wants of the body and their relief, the general condition of the corporeal frame.

LXXVI.

The inward sensations are vaguely suggestive of one concomitant idea, namely, locality.

Thus one feels that hunger is not in the foot, that the uneasiness of protracted and strained thought is in the head. When the ordinary course of inward sensation is much disturbed, and positive pain is produced, the concomitant idea of its place becomes precise.

LXXVII.

The outward sensations are seven in number: they are those of smell, taste, heat and cold, contact, of the muscular sense, sight, hearing.

Of these, smell, sight, hearing, have each a separate pair of nerves appropriated to them. The rest are ministered to from a common source, namely, the ganglionic roots of the spinal and of the fifth cerebral nerves.

Whether the same filaments of these nerves minister to more than one of these sensations is unknown.

LXXVIII.

Sensations of smell, taste, and heat and cold, suggest one concomitant idea only, like the inward sensations; and the idea suggested is the same in both instances, namely, locality.

The suggested notion of locality is here again extremely vague. However, one certainly feels that one smells and tastes in the cavities of the head, not in the knee: and one does not confound cold feet with cold hands.

LXXIX.

The remaining sensations, those of touch, those of the muscular sense, sight, and hearing, concur in suggesting, but in very different degrees of distinctness, besides locality, the notion of outness or externality.

The general impression of outness is an intuitive concomitant of these sensations. Its reality is, therefore, not a subject of argument, but of consciousness and immediate apprehension. The impression either exists, or it does not. The inquirer has to satisfy himself on the point by close attention to what he feels on the exercise of each sense. Of the four kinds of sensations specified, hearing communicates this idea the least distinctly.

The intuitive idea of outness is the source of our positive belief in an external world. We cannot divest certain sensations of this adjunct, which is thus forced upon us continually in a succession of impressions, which otherwise varied, agree in this. We build up our notions of each sensible object upon this as a base, superadding to the impression of outness or externality, the other sensations excited on the same occasion, and their concomitant ideas.

LXXX.

The sensations communicated by the muscular sense, and by sight and hearing, suggest, besides, the idea of direction.

The briefest duration of either of the sensations specified excites this idea. Contact, however, or the tactual sense alone, does not give rise to it. We cannot, by repeated trials, discriminate through that sense the angle at which a point touches the skin.

LXXXI.

Definite ideas of figure, magnitude, distance, motion, are inseparable from the continued exercise of the senses, either of touch, or vision, or resistance.

The notions, which we use and act upon, are of course compounded of the impressions conveyed to us by all the outward senses. The result of their combination is not, however, to change the character of the impression, or to produce a mean resultant, but only to increase the range and definiteness of perception.

LXXXII.

The sensations, which are comprised in touch or the tactual sense, refer to varieties in the character of surfaces as to roughness and smoothness. The ideas of locality and outness attending this sense are extremely vivid and definite. The sense of touch has its organ in the skin and the mucous surfaces continuous with it. The condition necessary to the sensation, is the contact of bodies with the sentient organ.

Roughness and smoothness of surfaces are very imperfectly felt, if the skin is not moved over the surface to be examined, or the surface moved upon the skin.

Hardness and softness are, to a certain degree, appreciated by touch. The yielding of any soft surface, when the hand is pressed against it, appears to excite a definite tactual impression. Properly, however, in this and similar instances, the impression is compounded of touch and muscular sensation.

The idea of distance, or of an interval between two points, may be suggested by this sense; and, as Weber has curiously shown, with very different degrees of precision at different parts of the body. The following is a table of the tactual sensibility of different parts, measured by the contact of the two points of a pair of compasses. The numbers show the distance in lines at which the two points must be separated, to be distinguished to be more than one.

The tip of the tongue . .	$\frac{1}{2}$
The tip of the finger . .	1
The red surface of the lips . .	2
The tip of the nose . .	3
The middle of the palm . .	5
The forehead . . .	10
The back of the hand . .	14
The middle of the thigh .	30

As dimension is but distance between given points, the shape and magnitude of a small surface, nearly plane, applied to the skin, may be vaguely perceived.

Again, as motion is but change of place, or the traversing the interval between two given points, motion may be perceived through touch, by moving a point in contact with the skin.

The sense of touch is much employed in guiding muscular action; it keeps our attention to the effort we might else forget to maintain. This is seen in cases of anæsthesia of the hands, in which it is observed, that the patient holding anything in the hand is liable to drop it, unless he keeps his eye fixed on it. The muscular sense, and the senses of vision and hearing, are equally employed in regulating different muscular actions.

LXXXIII.

The muscular sense immediately feels resistance and motion: and is attended with the idea of force exerted, as an inward sensation; and with distinct conceptions of outness, locality, and direction. The sentient organ of the muscular sense is the voluntary muscles. The nerves, which minister to it, are derived from the ganglionic fasciculi of the fifth cerebral and of the spinal nerves.

The sensations, which suggest to us hardness, softness, weight, lightness, pressure, yielding, support, want of support, are evidently modifications of the feeling of resistance: but they are so mixed up with the impression of something without as their cause, that the terms convey notions of the qualities of bodies rather than the sensations they excite, or bring to our minds objective rather than subjective conceptions.

Sensations of touch often combine with those of the muscular sense. The sensations we have of aëriform, liquid, or solid resistance, for example, are united with and perfected through the tactual feelings excited by these different contacts.

Our notions of elasticity, and of the impenetrability of matter, are ulterior conceptions founded on the sense of resistance.

Our abstract conception of motion is rendered as if it were sensible to us through this channel.

Our abstract notion of force, in the same way, is realized to the mind through this sense, and is indeed exclusively derived from it.—So important are the relations of the muscular sense.

I originally supposed that the ganglionless fasciculi of the fifth and spinal nerves ministered to this sense, being led to form that opinion by observing that the nerves of the eyeball receive but a few minute filaments from the ganglionic fasciculi. And the anatomical fact is still a very puzzling one. Nevertheless, I think its true interpretation is this; that the muscles of the eye do not need a muscular sense: for their exclusive use is to govern the motions of the eyeball; and for that purpose they may be sufficiently instructed by the acute tactual sensibility of the conjunctiva, and by the sense of vision. Then the argument from uniformity will be in favour of the muscular sense belonging to the same class of nerves with the other senses.

But it may be asked, is the sense of resistance in which all the varieties of muscular sensation merge, is this seeming sensation of resistance really *a sensation?* is it indeed more than the mere consciousness of effort? may it not, then, more probably have its seat in the voluntary nerves and their origins, which are the seat of effort? This question may be thus answered. The consciousness of effort is not the same thing with the sense of effort exerted. For example, a person recovering from an attack of palsy has regained the power of moving his foot, but not that of moving his hand. Both efforts he now makes daily with different results. When he tries to move his hand, there is present only the consciousness of the effort. When he tries and succeeds in moving his foot, there is present, besides, the sensation of effort exerted, or of resistance overcome. However, it might be replied, the consciousness of effort, in the first case, is only the consciousness of trying to make an effort: and the argument proves too much, for, in the case advanced, the anterior fasciculi of the nerves are paralyzed as well as the posterior.

A better answer is found in the phenomena of anæsthesia already adverted to. Considering which phenomena, as well as the remarkable observations of M. Longé and M. Magendie, that the anterior roots of the spinal nerves, and the anterior fasciculi of the spinal marrow even, receive common sensibility through branches of the ganglionic fasciculi, I am disposed to believe that the sensations of different degrees of resistance felt through the muscles must have their communicating medium in the latter class.

In general, the muscular sense is excited by muscular exertion, and goes with it, as its measure. But there are certain sensations which are felt when no muscular exertion is being made, which yet seem to belong to the same source. I allude to the sensations experienced on being lifted, or allowed to sink; for instance, on board ship, when you are lying on the back making no muscular effort, the difference to your sensations is most distinct, produced by the vessel rising or sinking on the water. This sense of support and want of support, what is its seat? I am disposed to think it is still in the muscles. For when we lie perfectly still, we yet have a general sensation of the weight of our body and limbs. I conjecture that feeling to be dependent on the degree of muscular contraction called tone. The sensation of want of support, however, combines further elements.

The sense of resistance gives us, as it has been said, the most definite ideas of motion; we feel and measure each degree of motion by this sense. Now, in the instances just referred to, this sense of motion is obviously disturbed. To the combined muscular sense of resistance and motion, we may then probably attribute the feelings which go with support and want of support.

If the feeling of passive bodily support depends upon this sense, much more so does the feeling of equilibrium, when we stand and walk self-supported.

If we stand or walk in the dark, we rely nearly entirely on the muscular sense to inform us what exertion is necessary to maintain the erect posture; but the sense of touch in our feet contributes a little. In the light, the sense of vision materially aids us. We habitually lean upon our eyesight, in fact, as upon crutches. Accordingly, when a person unaccustomed to do so, looks down a height, and that under circumstances not calculated to disturb his nerves, when he is resting, for instance, against the balustrade round the area at the top of a column, he feels disagreeably the want of visual support, and has an impression that he may topple over. Even the sense of hearing helps us; and its disturbance by unusual noises will increase any existing difficulty in maintaining our equilibrium.

LXXXIV.

The sensations included in vision are those of colour and its differences, and of visual form, and magnitude, and place. The retinæ and optic nerves are the apparatus for receiving and conveying the visual impressions. The impingement of the rays of light on the retina is the immediate physical condition of vision.

The connexion of the idea of outness with vision is well exemplified in Cheselden's celebrated case of restored sight. The lad, on opening his eyes after being couched, shrank back with an impression that every thing he saw touched his eye.

The wonderful extent of information which we receive through vision, is derived through definite conceptions of direction, distance, and locality, which flow immediately from primary endowments of the retina, or which are as inherent in it, as sensibility to colour. The full interpretation of these conceptions, and the final knowledge of external objects derivable from them, is obtained by comparing and combining visual impressions with those of the muscular sense and of touch.

It is obvious that for vision of figure there must be difference of colour or shade. If the rays of light assembled on the retina were objectively alike, colour alone would be seen. Sensible differences of shade or colour are necessary to bring the following functional contrivances into play.

The eyeball is an optical instrument containing refractive media, through which the rays of light proceeding from an object are arranged on the retina as in a camera obscura; that is to say, in an inverted picture; the angular breadth and height of which may be easily shown to be one-half of those of the object so represented on it. The surface of the retina used in ordinary vision is, therefore, of very moderate extent.

For distinct vision, it is necessary that the focal adaptation of the eye to the distance of the object should be perfect. For correct vision, that the images of objects should be reversed. Many persons still erroneously suppose, that the inversion of the picture is either an imperfection requiring some compensating means, or else a matter of indifference.

Of the Law of Visual Direction.

If, having perfect eyesight, you look with one eye, the other being closed, at a strongly illuminated point, situated within the range of distinct vision, as, for instance, at six feet from you, it is optically certain that the cone of rays thence proceeding which enters the pupil is brought to a focus on the centre of the retina.

Now if (to repeat the original experiment of Scheiner, who discovered the law we are approaching), you look at the object through a very minute pinhole in a card held close to the cornea, the object is seen just as before. And if, carefully keeping the eye in the same direction, you now shift the place of the pinhole from the axis of vision, to different points immediately around it, the visual appearance, and place and direction of the object, remain unaltered: that is to say, looking at it by the upper or lower, or right or left set, alone, of the cone of rays by the whole of which you saw it before, makes no difference in its apparent direction. In other words, the difference in the angles at which the rays of light are made to fall upon the centre of the retina in this experiment does not change the apparent direction of the object. The object is in each case equally conceived to be in a line vertical to the centre of the retina. Or vision excited in the centre of the retina appears necessarily to suggest the idea of that direction, of an immediate oppositeness in the object.

It is easy to show that the same holds of every other part of the retina. If you shut your eyes, and look upwards and to the left, you bring the right side of the retina so forward, that you can easily compress any point of a considerable region of it by the point of a pencil pressed against the eyelids. Upon so doing, a little circle of light is seen; the place of which is always exactly opposite to, or in a line vertical to the point of the retina thus mechanically excited to sensation.

Again, if you adopt a second of Scheiner's experiments, and hold the head of a pin three inches only from the eye, you cannot see it distinctly; the image is large and confused. The object is too near the eye for the cones of rays proceeding from it to be brought to focal points on the retina; they still cover considerable circles. Now, if you interpose a card with a minute pinhole, the object is at once seen distinctly; for you see it by means of a single pencil of rays, which occupies a point only on the retina. But now, if you move the card as in the former experiment, a different result ensues. With the motion of the card the object, always seen distinctly, appears to shift its place or direction. But it is obvious that in shifting the place of the pinhole, you have caused different pencils of rays to reach the retina; which different pencils have reached different points of the retina; and each different point of the retina has seen the object in a different direction.

If you now vary the experiment by making two other minute pinholes, one just above, the other just below the first, on looking at the same object through the three simultaneously, three distinct objects are seen. And, if you close the lowest of the three holes, it is the uppermost of the three objects which disappears, and *vice versâ*. Whence it follows, consistently with the experiment of making pressure on the retina, that visual sensation excited in any point of the retina is accompanied with a definite idea as to direction; and that the supposed direction of the object seen by each point is always that opposite to the point of the retina which sees it. Or, which is the best expression of the law, that

Each point of the retina, when so excited as to experience a sensation of colour, refers the colour to some point in a line vertical to it.

The reason is then obvious, why objects are painted reversed on the retina. It is in order that each point of an object may be seen in the direction in which it truly lies. And it is thus evident that the inversion of the picture on the retina directly and essentially contributes to truth of vision.

But although the direction, in which each point of an object will appear to lie, is thus visually determined, its place, or, in other words, its distance in the line of visual direction, is not. Or we have yet to account for our visual judgment of distance at all, and especially why in looking at objects to one side of the visual axis, they are seen in so definite, and as it proves so true a relative position to each other.

The conceptions which we form upon this point are so much more sure and positive, when we employ both eyes, that it will make the exposition of the matter easier to begin with examining the phenomena of binocular vision.

By this function it will appear that we obtain immediate visual notions of the distance of objects, determined by laws of vision of the same force with that of visual direction already explained. It is convenient to separate the phenomena which have to be examined into two classes, those of vision at the optic axis, and by the lateral parts of the retina.

Of Binocular Axial Vision,

Or of single vision through impressions made on the centres of both retinæ simultaneously.

Then suppose the experiment made of looking at the head of a pin held at a foot before you, through two tubes, one for each eye. It is obvious that the lines of visual direction of the centres of the retinæ meet and cross at that point. Then have placed anywhere further on in the lines of direction after their crossing, two shillings, one exactly in each. So long as you keep the eyes steadily fixed on the head of the pin, the two shillings will appear but one. A similar result ensues, if the two objects are placed in the lines of direction before they cross. The singleness of vision and the conception of distance are the same, as when a single object is placed at the point of intentional convergence of the optic axes.

Hence the following law expresses the leading phenomenon of binocular axial vision. When the optic axes are intentionally directed towards one point, impressions made upon the centres of the two retinæ appear to be one and the same; and the object seen as single is referred to a definite distance, namely, the point of meeting of the optic axes.

Of Binocular Circumferential Vision.

We know by experience that the lateral parts of the two retinæ are capable of conveying to us similar impressions of the singleness of objects and of their place and distance, with the centres of the retinæ.

To obtain the law by which this singleness of impression is produced the following scheme is necessary.

Both optic axes being turned to one point, imagine a circle passing through that point and the centres of both eyes. Let us call this circle THE BINOCULAR CIRCLE. It is evident that it will enlarge or diminish as the point to which the opic axes is directed is more remote or nearer.

The law of binocular circumferential vision is found by observation to be, that all the pairs of points in the lateral parts of the two retinæ, the lines of visual direction from which converge to a point in the binocular circle, see single, or convey the same impression of singleness, place, and direction, which is obtained by the centres of the two retinæ at the point of convergence of the optic axes.

That it is not the mere meeting of the lines of visual direction from any two points of the two retinæ on which the same object is delineated, which will give single vision, may be thus shown.

Suppose that from a distance of four or five feet you look at a circular piece of white paper fixed to the wall, having its vertical diameter traced in a strong black line; and that you then hold a pencil perpendicularly before you in such a manner that it shall really cover the black line on the paper. Now, if you look at the black line, the pencil does not visually cover it, nor does the pencil appear single; there are two seen, one on each side of and parallel to the black line. Then advance the pencil so far that the middle points of the two seen shall coincide exactly with the ends of the transverse diameter of the paper. It is optically certain that the middle of the pencil now covers the point at which the lines of visual direction from two lateral points of the two retinæ cross, and that it is painted on those two points of the retinæ; nevertheless it is seen double.

The following then is the expression of the entire

Law of Binocular Vision.

In binocular vision, those objects are seen single, which are pictured on points of the two retinæ, the lines of visual direction from which converge to one point in the binocular circle.

I entertained the supposition that the binocular circle might be considered the equator of a sphere, to be called the binocular sphere, which might give the law for every plane of the eyeball. But Mr. Wheatstone assures me that the law does not hold much above or below the plane of the two optic axes.

But now another principle requires to be introduced to notice. In looking at near objects, the points delineated upon these corresponding points of the two retinæ, which seem single, are often not the same; indeed, unless the surface looked upon is a perfectly plane surface, they cannot be. If for instance you look at a prism turned edgewise to you, at the distance of one or two feet, the projection for each eye must be very different. Here the following law steps in to modify the preceding. It may be called,

Law of the Binocular Mean.

When bodies seen under the preceding conditions present to each eye dissimilar appearances, the mind has within certain limits a power of combining the two in one, and taking a resultant impression. So in the case supposed, the prism we seem to see is neither in outline or shading the same which is projected on either eye, but a resultant.

So, likewise, if we hold a shilling much to one side, at a short distance from the head, but within the range of binocular vision, we do not see two shillings of dissimilar size, as they are really painted on the retina, but a single one. This principle had not been investigated by philosophers, till Mr. Wheatstone took it up; his paper containing a series of experiments to elucidate it, is in the *Phil. Trans.* for 1838.

The term, binocular *mean*, is not indeed a very good one; it is correct only when taken figuratively; but it is intelligible.

Mr. Wheatstone's views are very lucidly exhibited by means of the stereoscope, an instrument which he invented to explain and illustrate them.

One of the most interesting experiments given, is the following. Mr. Wheatstone caused the images of two short black lines to be thrown one on each retina, one vertical, the other slightly inclined from the perpendicular, and the optic axes of the two eyes to be so directed that the centres of the two lines should be referred to the same point. Then, by the law of the binocular mean, the dissimilar parts of the two images were so combined as to appear but one, and to represent to the mind a line inclined away from the eye, that is to say, with its extremities at seemingly different distances. But now he complicated the experiment by drawing a faint vertical line crossing the strong black oblique line at its centre, when the faint line was seen at the intersection of the planes of visual direction of the two eyes above, in addition to the compound visual impression. Or the first operation of the law of the binocular mean was not disturbed; but the faint line was seen in its true place for the combined action of the two eyes, although the mind did not ally with it the conception of the vertical line seen by the other eye, which it had already combined with the oblique one.

It is evident, from the preceding laws, that our reference of objects to a special point in space, is connected with a special inclination of the optic axes towards each other. But that inclination is attended with a corresponding feeling in the eyeballs. Or we experience a tactual sensation corresponding with the action of adjustment, which averts us of what is taking place.

Further, our conception of distance or locality obtained through binocular vision is explained to us, and rendered complete and perfect, by comparing and combining it with the impressions suggested upon measuring the same distance by the sense attending voluntary motion.

The first combination adverted to, gives us definite knowledge of the visual change; the second informs us of its full meaning.

But there is a further lesson still to be learnt. Having obtained these definite impressions as to the distance of points in space by the laws already explained, we have yet to consider how it is that we so promptly interpret the visual picture into reality, and from the visual shape and magnitude educe the real shape and magnitude. This knowledge is gained by the same process of comparison. We so learn the ratio in which difference of distance diminishes the size of the picture, and to associate different ideas of the character of surfaces with their colouring.

But this associated knowledge is liable to mislead us. For example, one of the elements we rely on is brightness of colour, because colour fades with distance. Then of two objects of the same kind and visual size but differing in brightness, we are disposed to think, and seem to see, the dimmer to be the larger. Accordingly we think the dull red moon near the horizon larger than the same bright disk at the zenith. But the most remarkable consequence of this habitual reliance on collateral impressions is one displayed through Mr. Wheatstone's stereoscope. When you are looking at an object in it with both eyes, it can be contrived to cause your optic axes to diverge, the object remaining at the same distance, and retaining therefore really the same visual magnitude. Your mental idea of its magnitude, however, changes, owing to the habitual association of proximity with greater convergence of the eyes. When they are made to diverge, the object appears to grow larger.

We have now to return to our judgment of distance through vision with a single eye.

When we close one eye we are aware at once how much we have profited by the laws recently explained. We are now totally unable to guess the distance of objects held near to us, and require the comparison of other adjacent objects with them to decide the doubt.

Now there is a condition of the organs intermediate between binocular and monocular vision, which presents some interesting phenomena; when, the optic axes not exactly corresponding, and the impressions upon one eye alone being habitually attended to in vision, the laws above explained are nevertheless available; and the sight, though really single, has most of the advantages of double sight, with some privileges of its own. My own sight is of this kind. My left eye is near-sighted, my right eye not so. My left eye is besides turned a degree outwards, so as never to converge exactly with the right eye, and I am in the habit of using the two separately. I read and write with my left eye, and look at remoter objects with my right. But I find no difficulty in telling at once the distance of any near object. This, however, arises from no accidental supplementary process; for if I close either eye, I have no more power of doing so than others. But it arises in the following way. If I look at a star, I see two: one a bright point, the other a nebulous disk with the first situated in it to the right of its centre. If I look at a crow flying at a distance on a bright day, I see one well defined with my right eye, another larger, less black, and less defined immediately above it, and so much to the left that a fifth of the large crow is clear of the well defined one. I see two objects, then, habitually: one displaced a little to the left, but attend to the impression alone made by one; and the objects seen are of course not painted on corresponding parts of the retina. But the parts they occupy are near parts; and it is evident to me that I use both, either indifferently, as the elements of two binocular schemes; so that I can see with either eye the object at the point where it would be seen by both, if the optic axis of the other corresponded with the axis of the first.

When a single eye is used alone in vision, as when the sight of one is lost, or in all animals with divergent vision, we may suppose that various elements combine in assisting the law of visual direction so as to determine visual distance. For near objects the sensation in the eye-ball which attends the focal adjustment of the eye may be one of the sources of information. At greater distances the motion of the head, by furnishing comparative estimates of the visual place of objects, may contribute to the information required.

But some further principle is possibly in operation, analogous perhaps to the binocular limitation of distance.

It is unnecessary to advert to our visual perception of motion. Motion is change of place; and its visual phenomena resolve themselves into the vision of the same object in so many successive places.

LXXXV.

Hearing communicates to us the sensation of sound and its differences; its loudness, its quality, its pitch, and rhythmical and harmonic relations. The seat of hearing is the internal ear. The nerve the auditory.

The sense of hearing is gradually trained to convey tolerably definite ideas of direction. But it is by practice only that we develope this suggestion of audible impressions. The primary ideas of outness and direction excited by the sense of hearing seem to be extremely faint and vague.

LXXXVI.

The sense of taste estimates the sapid qualities of bodies, their sourness, sweetness, bitterness, saltness, and the like. Its seat is the lips, and the edges and fore part of the upper surface of the tongue; likewise the middle of the anterior surface of the soft palate. In both situations it is ministered to by branches of the ganglionic portion of the fifth.

To be tasted, a substance must be applied, either completely or partly dissolved or mixed in water, to the sentient surface.

No concomitant idea beyond a vague impression of locality goes with this sense.

LXXXVII.

The sense of smell appreciates scent and flavour. Its seat is on the surfaces of the mucous lining of the upper parts of the nasal passages. It is supplied by the first or olfactory nerve.

Like the sense of taste this sense communicates no other secondary impression than a vague one of locality.

Scent and flavour are the same impressions on the same nerve in the same parts. To excite either, particles of matter floating in the air must impinge upon the sentient surfaces. The difference between smell and flavour lies in this:—that which is snuffed up the nose is scented;—the fumes which rise from the fauces, and enter the nasal cavities from behind, are flavoured. Therefore the bouquet of wine or the fragrance of new bread are the same whether smelt or flavoured. What seeming difference in the sensations there may be arises from flavour being commonly joined with some taste; not to mention that the remains of some other flavour remaining in the fauces may modify the new one. The cetacea want this sense and its organ and nerve. In fish, the organ of smell is adapted to the water. In the skait, where it is very ample, the two lie before the mouth, so that the animal can flavour its food before and while it eats, by the effluvia dissolved in the water.

LXXXVIII.

Such are the leading phenomena of our senses. We distinguish in them sensation, and suggested ideas. Perception is the result. Or perception is the knowledge of the outward world which we obtain through sensation. Or it is the spontaneous interpretation of our sensations and the ideas they suggest. By use we become perfect in it, and its rapidity and precision are equally admirable. Its education is the unconscious labour of infancy.

The term perception is often misused for sensation. But this is to confound things essentially separate. It is one thing to experience certain familiar sensations, of touch and colour, and fragrance, and another thing to perceive a rose. Least of all do we perceive sensations. We do not perceive red, or green, or blue, or violet, or acid sensations; but we perceive something that is red, or green, or blue, or fragrant or sapid.

LXXXIX.

It is evident both from their organization and their habits that animals have similar perceptions to our own. Nay, it is evident from the greater acuteness of vision in birds, and of scent in mammalia, and from other parallel instances, that their perceptive faculties transcend our own. A like superiority belongs to man in his savage condition.

Here properly I should stop, having reached the limits of the physiological part of these inquiries; but the next step made by the human understanding is too great to be passed without notice.

XC.

In the infant, sensation leads to perception. Perception to another step. Upon perceptive knowledge conceptions of a higher order are developed through abstract reflection. These, as we learn in the history of human knowledge, were at first vaguely seen, and gradually shaped themselves into distinctness, through the progress of discoveries which are now synthetically based upon them. The conceptions to which I refer, though emerging thus slowly, wear all the characters of intuitive Truth. The mind, when once they have been presented to it, cannot dispute or shake them off. So they become more real and certain than all other truths, and other knowledge obtains its surest footing when brought within their dominion. Yet these conceptions may be fancifully described as no more than ideas awakened within us, [to use the expression figuratively, where Aristotle would have employed it in its direct sense,] by analyzing the simple interrogatives, where, when, why.

Locality, distance, remoter distance, and what beyond ? lead us to the abstract conception of space, which we finally recognise, free from all subjectiveness, to be of necessary and eternal existence, and without limits. The measure of space is extension, the development of its relations geometry.

To-day, to-morrow, yesterday, expand into the present, the future, the past,—Time, which could have had no commencement, and of which an end never can be,—Eternity, the figurative diameter of Space. And the measure of time is number, and numerical and symbolic calculation have their origin.

The first impulse of curiosity gradually expands into philosophic inquiry. The interrogative, Why? into the distinction of causes into physical and efficient; the conception of physical causes into the study of laws collected from observation and the institution of inductive science. The conception of efficient causation illuminates another intuition,—No change can occur without a cause adequate to its production. Therefore the Supreme Cause must be eternal.

Nothing, perhaps, more strikingly exemplifies the freedom and boldness and subtlety of human thought, than the different views which metaphysicians have taken of the subjects which have been thus briefly touched on. Berkeley, discerning that we are immediately conscious of sensation alone, was willing to annihilate matter altogether; Boscovich proposed to substitute for it a system of dynamic excitants of sensation; while Kant, more daring still, regarded even space, and time, and causation, as figments of our reason. But to what do the doubts thus raised amount? To the proposition, that our notions of matter, force, motion, and our intuitive conceptions of space and the rest,—being only suggestions of the understanding,—have *possibly* no counterparts out of the understanding. And what is their solution?—That many possibilities exist which contain no portion of probability, and that these are of them.

For, why should Nature have designed to mislead us? Why, when an elaborate mechanism was planned to convey to us ideas of existences beyond our own minds, should that mechanism have been perverted to give us incorrect ideas? Why, when for perception alone so many different avenues of knowledge are opened, should their issues have led each to a different deception, the whole treacherously combining to produce one vast coherent falsehood? Was this easier to Nature than speaking truth, or more for our advantage than discerning truth? The magnificent system of the universe, of which Newton unveiled the laws, the constantly increasing wonders of the microscopic world, each so far from us, and with such difficulty brought within the ken of science, why should Nature have framed such remote and august lies? Why not rather believe that her aim has been always to impart truth to us, and that our understandings have the noble power when carefully trained and diligently exerted, of contemplating her immediate workings, "*veramque patentem Deam?*"

XCI.

It is to deviate still further from my province, but let me be allowed in two or three sentences discursively to advert to the developmen of the second part of our nature. As we have sensations and perception and abstract conceptions of physical truth, so have we impulses and moral perceptions, and upon these slowly developed by reflection, conceptions of moral duty, which we recognise and accept as equally intuitive with the former.

The savage, to every other tribe treacherous and ruthless, in his own observes faith and is humane, and eminently displays patience under privation, and fortitude in suffering. Such are the virtues of the Red Indian, who in his long career has made no further advance. Nor will he now. Whether capable or not of more, his race is fast disappearing, as after him will perish the Australian, and every other wild inhabitant of climates in which either Europeans or the inferior grades of improvable man can live.

But let us look at the progress of those families of mankind which have manifested the capability of moral and intellectual development.

In countries by the eastern shores of the Mediterranean civilization began. Between 2000 and 1500 years before the Christian era all its elements were there already put forth. In Egypt, science and the arts, though coupled with degrading superstitions; near, for a while within it, the people who preserved the knowledge of the true God; and Phœnicia could boast her commerce and letters, and Asia Minor sent her colonies to Greece and Italy. It was the dawn of the first* day of the world, which with the night that followed lasted 3000 years.

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* To do justice to the metaphor, it was the third.

The first Milton sang; its night fell with the fall of man. The second closed with that cataclysm, the memory of which haunts the traditions of every nation. The third, long and slow in breaking,

"It seemed that mist of dawning gray
Would never dapple into day;
How heavily it rolled away—

As that day went on, to string exertion to its utmost tension, war, hitherto uninfluential on the general destinies of mankind, broke forth in invasion and conquest; and the Persian, of a middle race unable wholly to emerge from barbarism, overran and subdued Egypt, and Asia Minor, and threatened Greece, whose energies and loftier nature stayed and repelled his myriads.

Then shone the triumphs of that wonderful people; and heroism and valour, the noblest literature, the perfection of imaginative art, the subtlest philosophy,—but not these alone, —the truest conception of morals, formed their chaplet. Let me quote the golden words of the greatest of their sages, to show how admirable was their wisdom.

"God is one, perfect in himself, giving the being and well-being of every creature; what he is I know not, what he is not I know."—PLAT. *Phæd.*

"That God, not chance, made the world and all creatures, is demonstrable from the

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Before the Eastern flame
Rose crimson, and deposed the stars,
And dashed the radiance from their cars,
And filled the earth from his high throne
With lonely lustre, all his own."

Then the light touched Memnon's statue, and the issuing music chimed the third sunrise.

reasonable disposition of their parts for use and defence. * * He is such and so great as that he at once sees all, hears all, is everywhere, and orders all."—XEN. *Mem.*

"The best way of worshipping God is to do what he commands."—XEN. *Mem.*

"Justice and every other virtue is wisdom." —XEN. *Mem.*

"A just man and a happy man are one. He who, in opinion, divided honesty and profit (which are coherent by nature) did an impious act."

"To be employed is good and beneficial; to be idle hurtful and evil. They that do good are employed; they that spend their time in vain recreations are idle."—XEN. *Mem.*

"The body, being compounded, is dissolved by death; the soul, being simple, passeth into another life, incapable of corruption."—PLAT. *Phæd.*

"The souls of the good after death are in a happy estate united to God; the bad suffer condign punishment."—PLAT. *Phæd.*

"I have not reigned to-day," if the day had passed that he had not conferred a benefit, was the saying of the illustrious pupil of Aristotle, whose military genius rolled back, after two hundred years, the tide of war over Syria, Egypt, (whose strange fate it has been to have fallen the successive prey of every conqueror from Cambyses to Napoleon,—of the Greek, the Roman, the Arab, the Turk,) over Persia and India; and war found then an office which seemed to legitimate it,—the diffusion of civilization; war, now her foe, and fostered by one civilized country alone, which, keeping the front rank in intellectual progress, labours under a strange retardation of moral development.

But, in ruder times, war advanced the progress of mankind; and by war came Roman greatness. Rome, whose virtues were patriotism and courage, her genius conquest, who made her own the arts and letters of Greece, and the religions of all the world she subjugated; whose function it was to impart civilization, directly or indirectly, to the entire white race of men,—as provincials, as allies, or as the hostile neighbours, who in time were to rend and share her empire. But not civilization alone, but with it true religion, that, where Rome stood, there was left Christendom.

Then fell comparative darkness,—the figurative night of the middle ages,—when rapine and violence lorded it over the world; till nature reclaimed her order, and the arts of peace undermined feudal tower and donjon wall, and the foundations of a higher civilization were cemented.

But in that night of barbarism, there had been the stars, and Alfred had reigned, and justice had sometimes been seen on earth, and the lamp of science and learning had not been extinguished, and there had been watchers for the dawn; and in that night had been the lofty dream of chivalry, which left on the waking world the impress of Honor.

Then began the second day. Towards fifteen centuries of the Christian era, and the same elements reappear in freshened activity, as at the same time before it. For Phœnician adventure, Columbus; for European colonization, that of the New World; for Cadmus, printing; for Moses, Luther.

But what is the promise of this second day? In the first, three words were expounded,—where, when, why. Another interrogative remains,—how. Its exposition is already manifest, in the triumphs of physical science, whose great prophet declared, "Knowledge is power." But in morals.—Alas! the example of the same eminent person shows that to be wiser is not necessarily to be better, and the experience of centuries has proved how little may result from the soundest ethical views, and from the positive denunciations of religion.

But yet one need not despair;—

One thing certainly contemplated in the

scheme of creation is the development of the faculties of mankind, and a progression from barbarism to civilization. Now it is written in our hearts, and declared by revelation, that moral excellence is the noblest attainment. Is nature so powerless for good, or Providence so inconsistent a cause, as to have given man the means of indefinite improvement in that which is secondary and inferior, and to have condemned him to remain stationary and unimproved in that which has the highest worth?

Again, the enlargement of knowledge, and that in a continually-increasing ratio, and its diffusion, are things certain. Is it possible that this cause should fail to make men individually better, by furnishing to many new mental resources and occupation, by habituating increasing numbers to the investigation of truth, and by bringing home to general conviction that temporal prosperity and happiness depend upon self restraint and moral conduct?

Again, the application of enlarging knowledge to government, the efforts of legislation to prevent one class spreading immorality through another, the increased repression of crime resulting from just views of the object and operation of punishments, the provision of education for every class and wholesom encouragement given to resort to it, and, if, for long to come, the extreme circumference of society must be ground down by iron penury, yet judicious attempts to mitigate that awful allotment, joined above all things with the attainable good of elevating the condition of the class immediately above the lowest, and the influence on every other class resulting from such efforts,—as they are things certain to follow, can they fail to lead to a gradual progression of moral improvement? and may one not add, that, in proportion as men are drawn towards the practice of morality, the influence of religion will be more powerful, which, if it fail to make bad men good, yet never fails to make good men better?

And these our hopes, do they not find encouragement even in the visionary interest which men take in the future progress of their race, and in the allied infirmity of wishing to live in its remembrance?

APPENDIX.

APPENDIX.

A. (Page 55.)

Of the different occasions on which Voluntary Muscles are excited to Contract through the Stimulus conveyed by the Voluntary Nerves.

The actions of voluntary muscles excited through the voluntary nerves are referable to four heads, which may be distinguished as the reflex, the emotional, the irritative, the voluntary.

1. *Reflex action. The action of voluntary muscles immediately determined by sensation, without the intervention of the will.* The reader is referred for the exemplification of this principle to Axiom XXIII. The iris (a part contractile but not muscular,) moves by this law, and in human beings is subject to no other. But if you watch the eye of a hawk or cat, when its attention is excited by any near object, the alternations of dilatation and contraction of the pupil which it exhibits look like voluntary action, enabling the animal at its pleasure

to consider the object under different conditions as to light.

2. *Emotional action. The action of a voluntary muscle immediately determined by mental emotion, without the intervention of the will.* To this principle are attributable the play of the muscles which produces expression of countenance, and those bodily gestures and inarticulate cries which further minister to the unintentional outward expression of feeling. The essential difference between reflex and emotional actions is that in the former no parts are involved beyond the cranio-spinal cord and nerve, and sensation is the constant excitant; while in the latter the impulse originally proceeds from the brain, and the sentient nerves are indirectly only concerned with it. Or in the former case the sentient nerve, the intermediate segment of origin, and the voluntary nerve, are implicated; in the latter, the brain, the place of origin of the voluntary nerve, the voluntary nerve, form the chain of organs engaged. The features unbending into a smile at some humorous thought exemplify pure emotional action; the brow contracted in anger combines voluntary action with the direct emotional impulse. The anguished look of acute pain and the cry of agony combine, perhaps, reflex action with the emotional; the expression of patient suffering and resignation is purely emotional.

3. *Irritative action. Spasmodic action from pri-*

mary irritation of the cranio-spinal segments or brain. Tetanus and wry-neck exemplify the operation of this principle.

3. *Voluntary actions. Muscular actions directly caused by voluntary efforts.*

The voluntary effort may flow from either reflection, passion, habit, imitation, sympathy, instinct.

a. The whole of active life exemplifies the first variety.

b. An angry word, a hasty blow, the second.

c. Habit deserves to be specified as a source of voluntary action. For actions that have been habitually indulged in, such as personal tricks, the habit of biting the nails, for example, seem to be so little voluntary, that they are actually repeated against the determination to refrain from them. But it is evident that in the latter case the determination is forgotten when the actions are repeated; and that in all cases habitual actions are really governed by a feeble interference of inclination suggested by the associating principle.

d. The imitative principle is best exemplified in the instance of certain singing birds, which, if at the time they acquire their song they are secluded from hearing the song of their own kind and put in the way of hearing the song of another species, learn the latter and not their own. In human beings the superficial uniformity of manners and tone of conversation in the same rank of life arises in a degree from the same principle.

e. When a carriage-wheel passes so close the carriage one is in as to make one fear their collision, one draws up the leg of that side. If one sees a person in a dangerous position, and as we think nearly losing his balance, one inclines one's body the other way. Taking these as examples, sympathetic actions mean voluntary actions appropriate to observed or imagined situations, adopted because we temporarily suppose ourselves placed in the latter.

The laws of mental sympathy, the analysis of the conditions under which our feelings may be excited or heightened, our judgments even determined or quickened, through the known or conjectured, or even most faintly-indicated participation of others in them, form an interesting theme of inquiry.

f. Instinctive actions and instinct.

When different kinds of food are put to the nose of a calf or puppy a few hours old, its preference of one to the other is not an instinct, but arises from the smell of one being more agreeable than that of others. When an epicure eats of a well-imagined dish, his prehension of food, its treatment in his fauces, its eventual deglutition, are anything but instinctive: they are actions pregnant with observation and comparison, and most deliberately performed. But when the newly-dropped calf, attracted by the grateful smell of milk, drinks it, *that action* is instinctive.

The fondness of an animal for its offspring is not an instinct but an affection. The means to decoy an enemy from its nest a bird will try, which will utter cries, fly low and awkwardly, and drop and run to lure away the dog, are not instinct but reason. But the choice, when, where, and how to build its nest, and its conduct in incubation, are purely instinctive.

The faculty displayed by some animals of finding their way home from immense distances by new routes is not instinctive. It must be a wonderful combination of memory and observation of direction. But the tendency to migrate at particular seasons of the year is an instinct.

What then is instinct? The conception and simultaneous execution of a succession of voluntary actions leading to a definite result in the economy of the animal world; the conception and the actions not being prompted by recollection, imitation, or sympathy, but springing up directly under the appropriate circumstances.

We naturally suppose that when an animal has gone through the round of instinctive promptings once or oftener, on the occasion recurring it may go through the same actions more or less intelligently. That, for instance, after the migration of one season, a bird may anticipate an object in its flight on the same impulse recurring the next. But the first time, was the animal blind to its own course of action? When the comb is injured, and the young working bees repair their work, altering it to suit the exigency from the first type, are they as insensate *towards it*, as Mr. Weekes' steel tarantula? Or have they intuitive ideas to work by?

B. (Page 109.)

Of the Varieties of Sensible Motion occurring in Animal Bodies.

To prevent ambiguity in any of the preceding passages, it may be as well to examine the entire list of the sensible bodily motions. Yet I shall leave out expressly the ciliary motions, the motions of the spermatozoa, and those of a merely chemical or physical nature; limiting myself to the consideration of those which are referable to the principle of vital contractility of tissue or irritability, and its modifications.

Certain textures in the animal body evince a power during life of existing in alternating conditions, the one of tension, with a disposition to shorten in the length of the fibre, the other of relaxation, with a disposition to yield or become elongated in the same direction.

They may be examined in reference to the modifications of this power they display, in the following order. The voluntary muscles; the iris; the muscular coats of the stomach and bowels, and bladder; the womb; the heart; the capillaries;

the arteries; the veins; the absorbents; the excretory ducts; the skin.

1. The fibre of voluntary muscle is disposed to remain permanently at a minimum of action, just enough to preserve its fasciculi in a straight line, unless a stimulus to contract is conveyed to it. The proper stimulus for this purpose is conveyed along the voluntary nerves, under the laws explained in note A. It requires to be incessantly renewed. The instant it ceases to be furnished, the action is at an end.

Any mechanical or chemical irritant, directly applied to a muscle, or to its voluntary nerve, will excite a sudden action in it. A characteristic of muscular parts of this class is that they have a nerve distributed to them, upon pinching which with forceps, or otherwise mechanically exciting it, in an animal recently dead, and after that nerve, with all the other nerves distributed to the part, has been severed from the cranio-spinal cord, or after the part itself has been severed from the body, a single sudden and immediate action of the fibres supplied by that nerve takes place. The nerve, through which this phenomenon is brought about is the voluntary nerve. When the same nerve is divided during life, the muscle it supplies is paralyzed.

2. The action of the inner circle of the iris is in

some animals closely parallel to the above. I found that in pigeons and young cats, irritating the third nerve, when all the nerves of the eyeball had been cut through, is followed by a sudden action of the iris. When the third nerve is divided in these animals during life the pupil immediately dilates to the utmost and remains dilated. The same effect of course indirectly results if the nerve of vision is divided.

In rabbits the iris obeys a different law. Pinching no nerve of the eyeball will in the rabbit excite a sudden contraction of the pupil. But if the fifth is slightly tapped, the pupil is, after a second or two, slowly drawn together, and then it slowly expands again. If the fifth is divided, the pupil in a few seconds contracts to a minute aperture, and does not again expand.

In pigeons and cats, death is marked by broad dilatation of the pupil; in rabbits, by its extreme contraction.

3. On pinching the pneumogastric and the sympathetic nerves in dogs and rabbits immediately after death, I obtained no motion in the muscular coats of the stomach, intestines, or bladder.

On pinching the intestines themselves, no sudden action ensued, as on irritating a voluntary muscle. But slowly the fibres irritated got into action, and the action did not stop there; but gradually spread itself over the adjacent portion of intestine.

All that one conjectures of the principle of motion in the fibres of the stomach, intestines, and bladder, is that their contraction depends upon the stimulation of the mucous membrane which lines them by the quantity or quality of its contents. Accordingly, if we would make the intestines or bladder act, what we do is to compress those viscera against their contents by the voluntary exertion of the diaphragm and abdominal and pelvic muscles, when the intended visceral contraction supervenes. On the other hand, when the mucous membrane has become highly irritable, uncontrollable action of the same parts ensues.

Whether the stimulus to action is that which I have supposed, or of a more complicated nature; and in the former case, through what channel the exciting influence is conveyed from the mucous lining to the muscular coat, are points unknown. The sympathetic probably interferes in some way; and as soon as sensation goes with the muscular action, the branches derived to the sympathetic from the cranio-spinal nerves evidently come into play.

4. The fibres of the impregnated uterus act probably under exactly the same law with the muscular coat of the intestines and bladder. The state of the contents of the organ is evidently one determining cause of its contraction. Pressure

artificially made upon the inner surface is known to be capable of exciting its renewal.

5. The heart exhibits the highest form of irritability as the substantive endowment of a tissue.

The heart is so constituted, that as long as its chemical and physical condition can be presumed to be entire, it continues to act, or alternately to contract and dilate, independently of any stimulus, either from the nerves or from its contents. The heart of a warm blooded animal even, as of a dog, when taken from the body immediately after death by hanging, if placed in warm water, continues to beat regularly for some little time. Even, if the auricular part and vessels are closely cut away (so as to eliminate the influence of any hypothetical special system of cardial nerves), the ventricular portion continues to act with force and equal rhythm. I availed myself of this circumstance to determine experimentally that muscular fibre, upon contracting, gains exactly in breadth, what it loses in length. I had a glass vessel made, which would open below by means of a large stopper, and above, terminated in a long, open, narrow tube, about one sixth of an inch in diameter. This apparatus was filled with coloured warm water to half way up the neck; when the ventricular portion of a large heart, beating strongly, being immersed in it, the fluid in the narrow neck did not alternately rise and fall, but kept one undisturbed level.

The extent to which the heart's action is liable to be altered, to be either depressed or heightened, its power almost or quite extinguished, or its beating rendered hurried and violent, through the influence of the nervous system, has been adverted to in the text.

6. The irritability of the capillaries differs from that of the heart in this respect; the capillaries commonly exhibit little alternation from relaxation to action, but maintain a very uniform tension or resistance to the distending force of the blood. They agree with the heart in the suddenness and extent to which their tone may be lowered or heightened through impressions on the nervous system.

In evidence of the first assertion, one may adduce the uniform appearance, maintained for hours by the capillaries when observed in the web of the frog's foot with a microscope.

On the other hand, one affection of the mind instantly produces an increase of tone in the cutaneous capilliaries of the face. This is the mechanism of sudden paleness.

Or another emotion will produce sudden relaxation of their tone, and they yield to the pressure of the blood, and suffusion of the countenance supervenes.

There are two other occasions which throw light on the irritability of the capillaries.

When a part has the impulse of growth in it, the womb for instance, at the commencement of uterogestation, its capillaries become relaxed; so that, as Cruikshank pointed out in the rabbit, even when hot only, the whole uterine system, examined after death, appears black with congestion.

We are in the habit of overlooking the importance of the irritability of the capillaries in cases of trifling wounds. They naturally contract and close in a minute, in virtue of their irritability, when a part is torn or cut through, and well it is they do so. If they did not, the patient would die of the most trivial injury. There are some persons who actually exist in this continual peril. Their capillaries are constitutionally less irritable than they should be, and when opened do not close. I think I have seen nothing in surgery so appalling, as capillary hemorrhage from a gum but a little torn in the extraction of a tooth, the blood actually pouring irrepressibly from the whole surface till the patient became faint. The patient, whose case I have present to my mind in writing this, was eventually saved; after many days, during which his life was in constant peril, the hemorrhage gradually stopped. Snow and Ruspini's styptic were the most effectual temporary applications. This weakness of the capillaries is very rare: it is transmitted hereditarily in families.

7. The arteries have the same kind of irritability

with the capillaries, but their magnitude brings it better under examination.

Accordingly, John Hunter showed that an artery exposed to the air, visibly contracts. Through this contraction, the hemorrhage from a small artery may be seen gradually to cease. However, the retraction of the vessel, and blood clotting round its end, generally have to do with the cessation of arterial hemorrhage. Cold and styptics promote the contraction of the arterial tissue.

On the other hand, I ascertained that the tone of the arterial tissue may be artificially lowered. If you roll between the finger and thumb, compressing it slightly for about a minute, a large artery, like the carotid in an ass, it becomes ampullated or evenly expanded at the part. If the wound is closed, the artery recovers its tone and shape in a quarter of an hour. If the part of the artery, while so ampullated, is removed and examined, the increased external dimension is found to have resulted from dilatation, not from thickening.

The irritability of the arteries finds continual employment in the animal economy.

If more blood is to be transmitted to a part, the arteries of the part yield and give it passage. If the increased supply is to last some time, the arteries having first yielded, *grow up* to their increased and increasing external dimension.

There is one feature in arteries, which are thus yielding a freer passage to the blood, of which I showed the explanation, though I doubt if it has been generally understood. I allude to the tortuous form of arteries in parts where local action either is going on, or frequently goes on. The change in external form is the direct result of the tone of the arterial tissue being lowered. This I proved in the following way. The carotid of an ass being exposed, the animal was disturbed by holding its nostrils, when the heart acted violently; whereupon the artery, instead of lying like a rigid tube as before, leaped up, being elongated and rendered tortuous. But this was the consequence of more strain being made upon it through the increased action of the heart, its tone remaining unaltered. But it is obvious that if the relation between the two forces were altered in another way,—if, the heart's action remaining the same, the tone of the artery were lowered,—the same result would follow. But in parts in which the arteries are yielding to admit more blood, their tone *is* lowered; and accordingly, and necessarily, they therefore become larger and tortuous.

The arteries of the face and temples are remarkable for becoming tortuous as life advances. The cause of this is in the excitement the individual has gone through, and the number of times his countenance has flushed and burned, and his temples have throbbed. The arteries gradually grow to the length they have been frequently stretched to.

Here they do not much enlarge otherwise; but they do become larger, and that in proportion to their increased length. The arteries only become materially larger, where, as in the growing womb, there is occasion for much material being abstracted from the circulation, or when a large current of blood for other purposes is required in the part; the principle then is pushed to its highest power. However, sometimes most curiously upon the head, the arteries over a small spaee go beyond the normal limits for increased cutaneous action, and actually dilate and grow to a vast size. So, which I and others have instanced, a strong pulsatory tumour sometimes arises on the forehead or temple, formed entirely of a large tortuous artery and its vein.

Physiologists have sometimes confounded the primitive and unchanging curves of the cerebral arteries at their entrance into the skull with the tortuosity of the temporal arteries. But the former congenital arrangement is of a totally different character. The cerebral arteries are twice abruptly bent on entering the cranium, in order to diminish the impulse on the brain resulting from the aortic systole. The brain requires a tranquil circulation: it is gained through these means; and the momentum of the blood being so lessened, Nature, in her economy, immediately reduces the thickness of the coats of the cerebral arteries by one-half what they present elsewhere.

But what is the cause which determines the lowering of the tone of arteries?

It is natural to consider it an extension of the influence which is simultaneously relaxing the capillaries; and to suppose that in flushing of the countenance the same emotion directly lowers the arterial tone; and that in increased growth the demand for more material, which is felt through the escape of their contents from the capillaries, organically influences the arteries leading to the part. And to a certain extent this supposition may be true; but it is always satisfactory, when a constant and demonstrable physical cause can be substituted for these hypothetical ones; and such a cause I think I can show in operation here.

I believe it to be a law of arterial relaxation (with subsequent growth), that it necessarily follows continued diminution of resistance on the distal or capillary extreme of the circulation. It is obvious that this condition is present in the preceding cases given of diminished arterial tone. But where is the proof of its agency?

As soon as the main artery of a limb is tied, the collateral anastomosing vessels yield and enlarge. But what has happened to make them do this? the distal pressure on the circulation in the limb has become lessened.

But the following instance is more conclusive. Suppose the artery of the elbow punctured through a vein, and the external wound to be healed, but a permanent communication left between the vein and artery. The case has often happened, and the consequence is called aneurismal varix. Then half the blood brought by the brachial artery into the limb finds an easy direct channel back through the new aperture. It is obvious that the distal pressure on the brachial artery of this arm is then much diminished. Here is the physical cause present which I have announced: Does it operate? if it does not, the proper consequence, at all events, follows;—the brachial artery above the aneurismal varix becomes enlarged and tortuous. And one sees nothing else to which to attribute the effect; except a positive interference of the *vis medicatrix Naturæ* to remedy a lesion; which is a less likely event than that she should avail herself of a general and pre-established law of the organization.

Then the phenomena of determination of blood to a part, or of local action, as it is termed, really begin with the tone of the capillaries and arteries being lowered, or on their tissue being relaxed.

I should caution the reader against confounding this local action with inflammation.

Inflammation involves local action, indeed, but other changes besides. Inflammation is local action and something more. What is commonly called irritation,—such a state as follows when any small particle is blown into the eye, such a state as the womb often falls into in disordered health,—involves something short of this, disturbance of the nerves only, with local action. If the source of irritation is allowed to remain long enough, then the further transition is made to inflammation.

8. The veins have a very low degree of irritability; but they have it: the alterations in their tone are certainly more than any supposable force of elasticity would account for.

9. The sympathetic and lacteal vessels are eminently irritable. Filled by a force of imbibition at their commencement, that portion of the tube remains for a time relaxed; till being distended it contracts; and its valves prevent the retrograde course of its contents. In some animals pulsating parts even have been found on this system.

The lymphatics and lacteals are sadly gone out of fashion. They had their turn after the blood and blood vessels had been exhausted by John Hunter. Cruikshank and Mascagni took them up where Dr. Hunter had left them; and I remember when they formed the principal theme of physiological inquiry. Then came the experiments of Magendie and his school, which docked half their interest. He robbed them of the power of indiscriminate imbibition; and proved that deleterious agents introduced into wounds or into the intestines find their way into the system directly through the coats of the blood vessels. So he restricted the office of the lacteals to the absorption of chyle. And the lymphatics he dismissed to the class of useless parts, such as the spleen, the thyreoïd gland, the renal capsules, and the like.

But the functions of the lymphatics are well worth renewed study. There can be no doubt, from the transference of the carbonaceous matter detained by the lungs to the bronchial lymphatic glands, and from the irritation which supervenes in the lymphatic glands during ulceration of a part tainted with a morbid poison, that the lymphatics are the exclusive agents in the important functions of molecular, or nutritive, or modelling absorption.

10. The skin has the lowest degree of irritability, if we perhaps except that of the veins. Cold increases its tension, warmth relaxes it. But these are phenomena of life. Likewise certain bodily conditions (as rigor in fever with sensible heat of skin), and the direct influence of the mind will sometimes contract its tissue.

C.

Of the Brain of Marsupial Animals.

In the few sentences in which I adverted to the conformation of the brain in the different classes of vertebral animals, I specified the characteristic features, which find their commencement and development in mammalia. But I must not appear ignorant of the modifications of cerebral structure, which Professor Owen's valuable researches have brought to light in the anatomy of the marsupiata. Professor Owen has shown that the marsupial brain corresponds with that of birds in the absence of the whole or greater part of the great commissure, and points out the most interesting association of this fact with "the absence of a placental connexion between the mother and the fœtus," or with the brief uterine period of the life of the marsupial embryo, coupled, as it further is, with "traces of the oviparous type of structure in the circulatory and absorbent systems." [*Philosophical Transactions*, 1837.]

The facts and the relation brought to light by Professor Owen have the highest interest. Yet I venture to express a doubt, whether "an inferiority of intelligence and a low development of the cerebral organs" are justly attributable to this class of animals. In the figures, which Professor Owen gives of the brains of the beaver and wombat, but for the difference of type, the brain of the wombat from its convolutions (which Professor Owen notices), appears anatomically the better organ; so, too, the cerebellum, setting aside the predominance of its middle portion. So expecting rather that the mental compass of marsupial animals will turn out to be as good as that of their unmarsupiated congeners, a great source of interest in Mr. Owen's facts appears to me to lie in the observation of the development of an inferior type of brain to an equal perfection with the better type, and the detection in it of the requisite organic equivalents, such as the enlarged anterior commissure for the bulk of the commissura magna.

D. (Page 146.)

Of Perception.

I have endeavoured to explain the strict and proper meaning of the term, perception.

We do not perceive objects directly. We are immediately conscious of sensations only. We intuitively refer our sensations to something external as their cause. We recognise the presence of this cause by sensation. Or we perceive external objects through sensation.

I may, however, give yet further distinctness to the idea conveyed by this term by adopting and following out a very bold supposition.

There are on record several cases of catalepsy, in which the patients are said to have exhibited extraordinary perceptive powers. I am not going to inquire whether there is any truth in these narratives, but am willing to grant that they are at present false.

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