AN

ADDRESS

DELIVERED TO THE MEMBERS

OF THE

ROYAL MEDICAL SOCIETY,

DECEMBER 16TH 1836.

BY

JOHN H. BENNETT,

PRESIDENT OF THE ROYAL MEDICAL AND ROYAL PHYSICAL SOCIETIES; AND
VICE-PRESIDENT OF THE ANATOMICAL AND PHYSIOLOGICAL
SOCIETY OF EDINBURGH.

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J. Perry Esqr
from the Author –

PRINTED AT THE REQUEST OF MANY MEMBERS OF THE SOCIETY.

TO THE

MEMBERS

OF THE

ROYAL MEDICAL SOCIETY,

THE FOLLOWING PAGES

ARE RESPECTFULLY

DEDICATED.

ADDRESS.

Gentlemen,

To be placed in this chair has ever been considered the highest distinction which it is possible for a medical student in the University of Edinburgh to attain, and is one which some of the most eminent members of our profession have felt proud to acknowledge. Entertaining as I do a very exalted idea of its importance and value, I cannot but feel sentiments of the deepest gratitude towards you for the honour which has been conferred on me. Conscious also of the responsibility and arduous nature of the duties it imposes, I must crave your indulgence for any deficiencies that may arise in my method of discharging them, promising however that, with your assistance, and with the assistance of the talented colleagues you have associated with me, that I will use every endeavour to support the dignity of this chair, and perform the duties connected with it, so as to merit a continuance of your good opinion.

You may now, gentlemen, consider that I have said all that is strictly necessary; but on an occasion like this, in a session so important to the annals of the Society, I should consider myself deficient in duty did I not allude to some of those circumstances which led to the foundation and subsequent celebrity of this institution, and point out to the large assemblage I have the honour to address, a few of the many advantages of which it can justly boast.

There was a period in the history of society when knowledge was confined to a few, and when even these amassed the fruits of science not for the purpose of ameliorating the condition of man, or of benefiting their fellow-creatures, but for the unworthy motive of establishing an influence over the multitude, and of subjecting it to the yoke of tyrannous authority. It was in those days that discussion was deemed heresy,—that the mutual interchange of thought was considered one of the greatest crimes, and the contest of abilities which the improvement of science required, led only to the infliction of inquisitorial vengeance. A time however arrived, when the energies of men increased, when the intellect was no longer to be confined, and when, aided by the press and milder forms of government, it overcame the dogmas of old, cast aside the trammels of power, and launched into the ocean of scientific discovery. It now became apparent that mental as well as physical power gained strength by association; that the prejudices of different opinions were often corrected by their collision with each other; that the co-operation of various minds best tended to the enunciation of truth; and that knowledge was only to be increased by the united efforts of understandings directed to its prosecution. Such it appears to me must have been the general views which led to the institution of Societies; and the results which followed have more than realized the expectations of their founders. The establishment of the Royal Society of London, for instance, followed by others of a similar nature abroad, gave an impulse to science which is felt to this day, and dragged from obscurity crowds of illustrious men, to advance the knowledge of mankind, and extend the boundaries of civilization. Among other advantages, it led to the more successful cultivation of individual sciences; and none received greater benefit from the stimulus thus given to it than that of medicine.

This important science, almost coeval with the history of mankind, has been prosecuted by the learned in all ages with the utmost diligence and enthusiasm; and we can easily imagine how, with the first dawnings of intellect, man must have felt a natural instinct to alleviate the diseases to which he was subject, and experienced a restless curiosity to investigate into their causes. Hence we can trace in the mythological fables of the most ancient nations the existence of deities supposed to preside over health and disease, attended by priests who were the immediate agents for affording relief to suffering humanity. We can follow its progress, although enveloped in mysticism and the allegorical imagery of the Egyptians, to the time when it became mingled with the philosophy of the Greeks. We can pursue the various additions it received as a practical art from the Romans, and continue our observation of its successive improvements, until in common with the other branches of knowledge, it was overwhelmed by the inroads of barbarians, and subsequently fettered down by the bigotry and superstition of the middle ages. It was, however, the first to break through the clouds which enveloped it, and assist in dispelling the obscurity in which all the sciences were involved. It was now it received in common with these the stimulus imparted to them by learned associations; now it was that schools of instruction became established for its more zealous advancement, and that crowds of students, attracted by the beauty and utility of the study, prosecuted with an ardent enthusiasm all its various branches.

It was at this period in the history of our profession, that a few of these enthusiastic students, then humble and unknown, destined afterwards to acquire celebrity and renown, urged by their insatiable thirst after knowledge, and deeply impressed with the advantages it would afford, founded the Royal Medical Society of Edinburgh. On looking back to this event, now more than a hundred years ago, what important topics are presented to me for consideration. How interesting would it be to contrast the state of medicine as it existed then, with the position it at present occupies, or to point out the successive great improvements that have occurred within the past century, and endeavour to trace how far the production of these is connected with the existence of this Society. However conjectural it may appear, it seems more than likely, that by an idea, originating in some debate, Cullen perhaps was led to form those extensive views which caused him to revolutionize the state of medicine.

To the members of this Society probably, Black exhibited carbonic acid gas, pointed out its connexion with the animal economy, and explained his beautiful theory of latent heat. Here Beddoes, the early patron of Davy, might have been stimulated to commence his inquiries into pneumatic chemistry ; and not to single out further individual illustrations, to this Society, Fordyce, Fothergill, Blagden, Rutherford, the Monros, Duncan, Blane, Bateman, Gregory, Gordon, and a host of other illustrious men, living as well as dead, may have been indebted for that spark which kindled within them the desire of distinction, and lit the torch which guided them to renown.

To enter minutely, however, into these inquiries, would absorb too much time, and they are somewhat superseded by a topic, to us, if possible, still more interesting.

Gentlemen, it appears from authority which cannot be questioned,* that this society originated in the month of August 1734, although it was not firmly established till three years after. It was then that six students,† after spending a social evening together, determined to meet periodically, and discuss medical questions. This plan produced such beneficial effects, that the little society thus formed became extended by the admission of others, many of whom were then acquiring that knowledge which was afterwards to direct the energies of our profession, and advance the science to its present position. Favoured by

* See Life of Dr. J. Fothergill, prefixed to his works, by Lettsom, 4to, and Dr. Stroud's History of the Medical Society of Edinburgh.

† Dr. Cleghorn, Dr. Cuming, Dr. Russell, Dr. Hamilton, Mr. Archibald Taylor, and Dr. James Kennedy.

the then fluctuating state of medical opinion, and the facilities offered for free discussion, an association of young and ardent minds was admirably calculated to examine the false theories which had become consecrated by usage, and eradicate the errors that preceding ages had established. It has indeed been stated, that discussion perverts the understanding, depraves the temper, occasions personal hostility, and induces a spirit of idle wrangling; and circumstances certainly have not been wanting to give a colour to these charges. But if properly conducted, it has led, and continues to lead to far different, nay, very opposite results, while it has been the great agent by which all the dogmas that have shackled science from the days of Pythagoras to our own times have in turn been overthrown. It was by discussion that the sophists' doctrine of old was shaken to its foundation; it was by discussion that Descartes exposed the errors of the Aristotelian philosophy; it is to discussion we are indebted for the overthrow of those hypothetical and speculative doctrines promulgated by Galen, which so long delayed the advance of medicine; and it was by discussion that the members of this Society, shortly after its establishment, proved the fallacy of those principles taught by Boerhaave, introduced into this school the more enlightened views of Hoffman, and by the revolution in medical science thus brought about, first laid the foundation of that celebrity and fame which the University of Edinburgh has since maintained.

From the ranks of the Society, as it then existed, Cullen arose, who, it has been said, did for medicine what Newton did for astronomy. His works evince the greatness of his genius; the influence of his labours will be felt by future generations; and his name descends to posterity, not only in connection with the University, whose celebrity he caused to be extended over the world, but as the individual who, in the year 1775, laid the foundation-stone of this building, and contributed by his advice and exertions so much to the Society's reputation. Since then the institution has continued to advance in honour and usefulness; its property has been confirmed to it by a royal charter; freedom of discussion has ever been maintained within its walls; for in this very hall were fought those well known mental contests between the disciples of Brown and Cullen, the noise of which spread over Europe; and from that time it has weekly been the arena of intellectual battles, and never wanted combatants anxious to engage in them. Our library has gradually become one of the most select and valuable now extant; the extended education of modern times has introduced into our reading-room all the leading foreign, as well as domestic periodicals; our laws having undergone successive alterations, to meet the changes of the times, present a code excellently adapted for conducting its affairs; while, besides a floating capital more than sufficient to meet the annual expenditure, a sinking fund has been established which must ever guard the Society from the pecuniary distress which mutations of income are liable to occasion.

With these advantages, then, we enter upon a new century of existence. The present celebrity of the institution has been built up by the talents and labours of our predecessors; its future honour and prosperity must come from you. Let me therefore earnestly solicit your united endeavours in transmitting its reputation unsullied to our successors. Do not say that your object in entering here was to acquire rather than to communicate knowledge; for it is not only our duty to collect information, but it becomes us, as we value liberality of sentiment, to diffuse it for the good of others. If a proper sense of the advantages conferred by the founders of this institution have ever excited in you feelings of gratitude—if, among the number of illustrious names to be found in our list of members, there be any entitled to admiration; let the enthusiasm displayed by them for the benefit of the socity stimulate you to like exertions—let their busts and portraits which adorn this hall witness struggles on your part emulative of deeds performed by the originals—let their influence extend even from the tomb, so that centuries hence the transactions of this session may be pointed out as among the memorable eras in the Society's annals.

I need not, however, dwell only on the merits and abilities of those who have preceded us. I am surrounded, this evening, by members who combine among them a mass of learning, talent, and intelligence, which, if animated by the enthusiasm shewn by their predecessors, and brought to bear on our discussions, would render this year equal, if not superior to any of the past. I see many who have returned from various countries, laden with the experience and knowledge of foreign science. Many of you have listened to the prelections of the greatest luminaries of medicine abroad—have visited the numerous ~~and~~ scientific institutions of France, Holland, Germany, and Italy, and are come hither this session, I trust, to communicate the result of your observations, as different topics in the course of debate may recall them to your recollection. The younger members should reflect, that as they at once reap all these advantages which the industry of others has collected for them, and that as they have enrolled their names on the list of the Society, they are bound to support it. This is only to be done effectively by cultivating their talents, and seizing every opportunity for improvement: regular attendance on the Society's meetings will contribute in no small degree to the advancement of both; and by listening attentively for a short time to the discussions of their seniors, and thus exposing themselves as it were to the sparks which the heat of debate occasions, they themselves will at length be inflamed with the desire of contributing to its brilliancy.

I have spoken of the intense interest and enthusiasm which former members exhibited; but this session has produced a most gratifying proof that these feelings, so necessary for continuing the honour and fame of the institution, are still kept alive, and exist undebased and unalloyed in the bosoms of our most respected and active members. None but those who have engaged in such a task can in any way appreciate the enormous labour which the formation of our Catalogue Raisonné has occasioned. It must be remembered that this is not a work that could have been performed by a mere scrivener; it evinces literary, professional, and scientific knowledge in an eminent degree; while the judicious arrangement which characterises it throughout, stamps on it the feature of originality. Figure to yourselves the labour and toil of reviewing separately, the numerous works which compose our library—of even writing their names. Add to this the trouble of classifying them, and the necessity of perusing many, the ambiguity of whose titles was such as not to denote their nature. Reflect on these circumstances, gentlemen, and consider that all this was undertaken without the hope of reaping any of those rewards for which most men enter into literary composition,—without the satisfaction even of having their names attached to their own publication: yet was this herculean labour cheerfully performed for the good and advantage of that institution endeared to them by the remembrance of the benefits it had conferred, and at whose shrine they thus offered up the most disinterested and undoubted proofs of devotion. The records of history point out to us, that nations and states were most worthy renown, and that their honour and glory shone brightest at those times when the citizens evinced a pure patriotism, unmingled with the feelings of self-interest which debase our nature. We may judge of private associations by the same criterion; and how proud ought we to be that in the hundredth year of the Society's existence, at a period when most institutions are crumbling into dust, that we can thus triumphantly point to an unerring test of its usefulness and stability.

I am conscious that the humble eulogium thus paid for such disinterested conduct is far from adequate, and that in alluding to this event, I have offered a very insufficient tribute to the labours of those gentlemen by whom the catalogue was completed,* and more particularly to those who superintended its progress through the press.† The latter, with a laudable anxiety to present the work at the commencement of this session, have performed incredible exertions. I myself have had occasion to observe some of these, and know that the rising sun, and midnight lamp have often been witnesses to their toil. They have all received the unanimous thanks of the Society; and although this was the only reward for which their labours were undertaken, they now also possess the inward satisfaction of not only having benefited their fellow members, but of having conferred no inconsiderable boon on the profession at large.

In addition to this, everything evinces that the laurels formerly acquired are still preserved by the Society green and flourishing. I have never witnessed or heard of a session which bids fair to become more prosperous than the present; for, besides the excellent series of papers provided for us, the eagerness with which members have come forward, and the number of communications on various interesting topics that have already been announced, promise a fertile field of instruction, and hold out the expectation of reaping a rich harvest of improvement.

* Drs. Wood, Balfour, Maclagan, Dyer, A. Thomson, Imlach, G. Paterson, Ransford, Taylor, and Mr. Seaton.

† Drs. Wood, Balfour, and Maclagan.

Long then may the Society continue its career of honour and usefulness ; may the prudence and talent which have been its support and guide through the past century continue to uphold and direct its progress for centuries to come, so that ages hence, when the transactions of this session shall be reckoned among the things that were—when all who are now present shall have long mouldered in the " tomb of all the Capulets"—when arts and sciences, when knowledge and civilization shall have been introduced into countries yet unknown, this institution, I hope, will not merely serve " to point a moral or adorn a tale," but will then, as it has ever done, introduce into our profession some of its brightest ornaments, and perpetuate to succeeding years that thirst for improvement and persevering exertion which is the student's only certain path to scientific renown.

with the Author's kind regards

cXI

INAUGURAL DISSERTATION

ON THE

PHYSIOLOGY AND PATHOLOGY

OF THE

BRAIN:

BEING AN ATTEMPT TO ASCERTAIN WHAT PORTIONS OF THAT ORGAN ARE MORE IMMEDIATELY CONNECTED WITH MOTION, SENSATION, AND INTELLIGENCE,

SUBMITTED TO

The Medical Faculty of the University of Edinburgh,

IN CONFORMITY WITH THE RULES FOR GRADUATION,

BY AUTHORITY OF

THE VERY REV. PRINCIPAL BAIRD,

AND WITH THE SANCTION OF

THE SENATUS ACADEMICUS,

BY

JOHN HUGHES BENNETT,

PRESIDENT OF THE ROYAL MEDICAL AND ROYAL PHYSICAL SOCIETIES; VICE-PRESIDENT OF THE ANATOMICAL AND PHYSIOLOGICAL SOCIETY OF EDINBURGH,

AND CANDIDATE FOR THE

DEGREE OF DOCTOR IN MEDICINE.

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MDCCCXXXVII.

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TO

WILLIAM KINGDON, Esq.

OF LONDON,

MEMBER OF THE ROYAL COLLEGE OF SURGEONS, &c. &c.

THIS ESSAY

IS DEDICATED

AS A MARK OF RESPECT AND ESTEEM

FOR HIS PROFESSIONAL TALENTS

AND PRIVATE VIRTUES,

AND

AS A TRIFLING ACKNOWLEDGMENT

FOR THE NUMEROUS ACTS OF KINDNESS

HE HAS CONFERRED

ON HIS SINCERE FRIEND,

THE AUTHOR.

PREFACE.

The following Essay is divided into Two Parts :—The First, gives a short abstract of the more important physiological and pathological facts with which we are acquainted, and exhibits how opposed to each other are the different theories deduced from them.* The Second, contains the conclusions the author has derived from the whole, with such arguments as, in his opinion, appear sufficient to warrant their being entertained.

A short account of the opinions and discoveries of the older writers has been added in the form of Introduction. It has been compiled from the different histories of medicine, and biographical memoirs; where these, however, have been deficient, the originals were consulted. The author hopes that this portion of the Essay will, as a matter of reference, be useful to some of his readers.

John Hughes Bennett.

July, 1837.

* The first part of the Essay is founded on a paper read to the Royal Medical Society of Edinburgh, January 8, 1836.

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ESSAY.

HISTORICAL INTRODUCTION.

Pythagoras, who flourished about 600 years before Christ, was the first, as far as I can discover, who is recorded to have attributed any function to the brain. According to him, this organ was destined to be the seat of the soul. The soul he divided into two portions, the rational and the irrational; the former he placed in the brain, the latter in the heart: the first he considered immortal, the last perishable. The rational, he imagined, after death passed into the regions of the dead, where it remained till it was sent back to the world to be the inhabitant of some other body,—brutal or human; and that, after suffering successive purifications, it was received among the gods, and returned to the eternal source from whence it first proceeded.

Timæus Locras, a celebrated Pythagorean philosopher and contemporary, although he has treated in his work, "De Animâ Mundi," of the different functions of the body, with regard to the nervous system has little to say. He calls the brain "the seat of the soul," and says that it is "the origin and root of the medulla, and that a process extends from it through the vertebræ of the back."

Alcmæon, a disciple of Pythagoras, is said to have been the first who attempted the dissection of a dead body, but there are strong grounds for believing that his anatomy was confined to the lower animals. He discovered the cochlea, and said that hearing resulted from the concave form of the interior of the ear, all hollow places resounding when any noise entered them. He imagined the brain to be the seat of the soul, which is in perpetual motion and immortal. He supposed it to receive the odours inhaled in respiration, thus producing the sense of smell, while, by means of its humidity, moderate heat, and softness, the tongue was enabled to discriminate tastes.

The absurd opinions held by these philosophers regarding the structure and functions of the brain, were not destined to receive any material improvement, even from the acute mind of Hippocrates. The knowledge of this individual, although it threw light upon almost every subject connected with medicine, was necessarily limited by the prejudices of the time in which he lived, when the human body had hitherto never been dissected. His acquaintance with human structure could only be derived from accident, or by a comparison with that of other animals. Hence the whole of his physiological doctrines are unworthy of any serious regard. Concerning the brain, it does not appear that Hippocrates had the least suspicion of its connexion with sensibility and understanding; indeed, so far from considering it as the peculiar seat of the thinking faculty, he places it in the left ventricle of the heart. He speaks of it merely as a gland,* which he says it resembles in texture. According to him, it serves as a receptacle for the redundant moisture, which is afterwards discharged in a fluid state through the ears, eyes, nose—sometimes into the fauces, gullet, and medulla spinalis. To the retention or immoderate discharge of this fluid, he ascribes those diseases termed by us mental, the one causing apoplexy, the other, hallucinations of mind. He also considered the brain to be an organ of reproduction, for he states that the semen was eliminated and prepared in it, and conveyed by the spinal marrow to the vessels provided for its reception. Hippocrates knew nothing distinctly concerning the nature and uses of the nerves, though he seems to have had some confused notions respecting the nervous power, which however he places in the veins. If the spirit, he says,† which flows through the veins, be stopped or interrupted, the part in which it is stopped becomes impotent; thus in sitting or lying down, when the veins are compressed so that the spirit does not pass through them, a torpor is immediately induced.

Polybus, a disciple of Hippocrates, was the reputed author of many books that now appear under the name of that physician.

* Lib. de Glandulis. † De Locis in Homini.

It is probable that the book "De Glandulis" is one of these, as we know from Galen that Polybus wrote a work on the nature of the semen, in which he adopted the same views as Hippocrates.

Plato considered the brain as the seat of the governing principle,* but he has shewn himself ignorant of the proper distinction between nerves, tendons, and ligaments. In his Thætetus, however, he has treated of the philosophy of sensation with such precision, as proves that he had formed a distinct conception of its nature, although he was but imperfectly acquainted with the instruments which convey it to the mind. In the Phædo, Socrates says, "I gave myself up in the earlier part of my life to the study of nature with great ardour; and amongst other things, was anxious to know whether we have sense and intelligence by the blood, or by fire, or by air; or whether the senses of hearing, seeing, and smelling, depend upon the *brain*."

The celebrated philosopher, Aristotle, appears to have had very erroneous notions concerning the anatomy and physiology of the brain. He thought this organ was nothing but a mass of earth and water, void of blood, and destitute of sensation, whose only office was to balance and correct the heat of the heart. This he agreed with Hippocrates in considering the seat of sensation and all the intellectual faculties; though some, he says, are of opinion that the powers of perceiving and feeling are in the brain. He laid it down as a maxim, that man has the largest brain of all animals in proportion to the size of his body; and this, though now proved to be erroneous, has been almost universally received from his own time to the present day. He confounded the nerves with the tendons and ligaments, and ascribed the origin of them to the heart. His abstract ideas regarding the soul, however, are more philosophical:—"Some improperly call fire or some such principle the soul. It would be better to say that the soul exists *in* such a substance, because fire is the body most subservient to her operations. For, to nourish and move are the operations of the soul, and these she performs by the instrumentality of this principle. To say that the soul is fire, is as if one were to call a saw or a wimble the artificer, or his art, because his work is performed along with them. Hence it appears why animals stand in need of heat."†

Under the Ptolemies of Egypt flourished two celebrated ana-

* Plato, Tim. Loc. de Animâ Mundi.

† De Partibus Animalium, lib. ii. c. 7.

tomists, Herophilus and Erasistratus, who were the first, as far as authentic records go, who dissected the human subject. It is not to be supposed that so important an organ as the brain could escape their notice; and, accordingly, we find that they were the first also who properly investigated its nature, and attributed to it and the nerves their proper function. For these reasons, their opinions demand some consideration.

Herophilus looked upon the brain as the seat of the soul, which resided in one of its ventricles, and as the sensorium, or source of all the vital actions and sensations. The cavity of the fourth ventricle of the brain he compared to that of a pen. The point where all the sinuses meet he termed ληνος, or wine-press, which retains the denomination to this day, with the addition of his name, being now called torcular herophili. He also first named the tela choroidea. The discovery of the true nerves, which were unknown both to Hippocrates and Aristotle, is ascribed with much apparent plausibility to Herophilus, who arranged them in three divisions. The first consisted of those real nerves which originated in the substance of the cerebrum, cerebellum, or spinal marrow. These he considered the organs of motion and sensation throughout the system, having found that those which communicated sensation, and obeyed the commands of the will, could be traced either to the encephalon itself, or to the spinal marrow, which is but a continuation of it. What he arranged as nerves under the two remaining divisions, were evidently nothing more than the tendons and ligaments. He particularly described the optic nerves, or, as he called them, the optic pores, which had, he maintained, a perceptible cavity, not observable in any of the other nerves.

Erasistratus gave a very complete and clear account of the appearances presented by the cerebrum, cerebellum and nerves, upon dissection. "We examined," says he, "what the nature of the human brain was, and we found it divided into two parts, as in all other animals. Each had a ventricle or cavity of a longitudinal form; these ventricles had a communication with each other, and terminated in a common opening, according to the contiguity of their parts, reaching afterwards to the cerebellum, where there was also a small cavity; and the cerebellum in particular was wrapped up by itself, as well as the brain, which, by its various windings and turnings, resembled the intestinum jejunum. The cerebellum was in like manner folded and twisted different ways, so that it was easy to know by seeing it, that as in the legs of swift running animals, as in the deer, the horse, and some others, we observe the tendons and muscles well calculated for that purpose, so in man, who has a larger share of understanding than other animals, this great variety and multiplicity of foldings in the brain, was undoubtedly designed for some particular end. Besides, we observed all the apophyses, or productions of the nerves which come from the brain; so that to state all at once, the brain is visibly the principal of every thing that passes in the body; for the sense of smelling proceeds from the nostrils being pierced in order to have communication with the nerves; the sense of hearing is also produced by the like communication of the nerves with the ears; the tongue and the eyes receive also the productions of the nerves of the brain."

On reviewing the opinions of these eminent men, we must conclude that they had studied the anatomy of the brain with greater care than any of their predecessors, and had obtained a pretty general and accurate idea of its function and importance. We cannot therefore but admire the sagacity, that in an age so barbarous, and so prejudiced against anatomical inquiry, led to the generally correct results which distinguished their labours.

The records of the remaining Greek physicians do not appear to throw any new light on the anatomy or physiology of the brain. Nor do those appertaining to the Romans, until the time of Rufus of Ephesus, who lived under the emperor Trajan. He traced the nerves from their origin in the brain, and divided them into those of sensation and those of voluntary motion. He says,* "the upper part of the brain is called the varicose, the inferior and posterior the base; and the process arising from it the cerebellum. Two kinds of nerves arise from the brain, viz., the sensatory and the voluntary, by which sensation and voluntary motion are produced, and all the actions of the body are accomplished. Some of these nerves arise from the spinal marrow, and its investing membrane." Again, he says,† "The senses which proceed from the brain and spinal marrow are divided into the active, the sensatory, the voluntary, and the tensive." Rufus pointed out the decussation of the optic nerves at the infundibulum, distributed the nerves coming from the brain into seven pairs, first described the nervus palatinus, and discovered the par vagum, which he termed the sixth pair.

* De Part. Corp. Hum. lib. 1, c. 23. † Op. Cit. c. 35.

Aretæus paid much attention to anatomy, but his physiological opinions were rather extraordinary. He maintained with Erasistratus, that the nerves were not only the organs of sensation, but likewise the source of all the action and motion of the limbs. Instead of ascribing the faculties to the brain, he attributed them to the stomach, which he conceived to preside over pleasure and pain, and to affect the mind through its consent with the soul. He is the first writer who has remarked the influence which the mind exerts over the health of the body, and the reaction of the body upon the mind; a fact, he observes, which we content ourselves with admiring, without hoping to be able to detect its cause. In his work *De Morbis Chronicis,* he gives the following account of paralysis, which would seem to indicate that he was not unacquainted with the distribution of the nerves into sensatory and motory:—"Apoplexy, paraplegia, and paralysis are all diseases of the same kind, for they are all a defect of motion or touch, or both; sometimes of mind, or of some other sense. If the sense of touch alone be deficient, (but this is of rare occurrence), the disease is more properly called insensibility. Sometimes the nerves proceeding from the brain suffer, which generally occasions insensibility, but not readily loss of motion; and yet if they are affected sympathetically with the parts which are moved, they may even undergo a certain loss of motion, for they have naturally a certain power of motion, and sometimes the nerves which pass from muscle to muscle have this power of motion, and impart it to the nerves which arise from the head; for they have the greater part of their motion from the other class, but they have a certain share themselves. The others rather suffer loss of motion; sometimes, however, though very seldom, they undergo also loss of sense."*

Galen divided the faculties of the human body into the natural, the vital, and the animal.† The brain he held to be the seat of the animal powers; that is to say, he considered it to be the organ from which sensation and motion are derived; and these he maintained were the powers by which animals were distinguished from vegetables. The natural faculty he placed in the liver—the vital in the heart. These three faculties produced the three sorts of actions, according to Galen, which are designated by the same

* De Morbis Chronicis, lib. 1, c. 7.

† De Facultatibus Naturalibus.

epithets, and which he divided into internal and external. The internal animal actions are imagination, judgment, and memory; the external are the five senses, and muscular motion, which he reckoned, as did also Hippocrates, to be one of the senses. The internal vital actions are violent passions, as anger, &c.; the external are motion, the pulsation of the arteries, and distribution of the spirits through them, diffusing life and heat. The internal natural actions are sanguification, the digestion of food, and the actions connected with it; the external are the distribution of the blood by the veins, for the purpose of nourishing, enlarging, and preserving the body. Besides these, which are general, Galen admitted of particular faculties, residing in each organ of the body, and directing its movements; and if he were asked what was the prime mover of all these faculties, he answered, with Hippocrates,—Nature. Galen decidedly taught that the nerves of the senses are distinct from those which impart the power of motion, and that the former derived their origin from the anterior part of the brain, or cerebrum, and the latter from the posterior, called by the Greeks *encephalis*—(under this term he comprehended the cerebellum, tuber annulare, and medulla oblongata of modern anatomists)—or, from its process, the spinal cord. He maintained that the nerves of the five senses are formed of matter too soft to be the vehicle of muscular motion, and too hard to be susceptible of fine sensibility.*

Oribasius, Ætius, Alexander, Paulus, and others, adopted the physiological views of Galen concerning the brain, and brought forth nothing new respecting it. Alexander describes phrenitis accurately, and confutes the notion that it is an affection of the diaphragm, and not of the brain. Paulus also wrote at great length on the diseases of this organ.

Theophilus† was the first to trace the olfactory nerves from their origin in the brain, to their expansion upon the membrane lining the nostrils, so as to form the organ of smell.

Serapion, Rhazes, Avicenna, and the other Arabian physicians followed the opinions of Galen.

Haly Abbas agreed with Aristotle respecting the brain, namely, that it is the coldest viscus, and antagonizes the heat of the heart;

* De Usu Partium, lib. 8, 9, 10. De Placitis Hippocratis et Platonis, lib. 7; et Anatomicæ Administrationes.

† Wrote between the years 610 and 641.

for he says that those parts of the body which are vascular, and contain much blood, are naturally hot; whereas such as contain little blood, are comparatively cold. Of this latter class are the brain, nerves, and fat.*

Albucasis wrote a good chapter on operations on the head, particularly the manner of operating in dropsy of the brain, observing that water is effused not only on the surface, but into the ventricles of the brain, which he regarded as incurable, and a case in which no prudent surgeon would operate.

Notwithstanding the great encouragement the Arabians had from their princes, and advantages derived from the remains of the Alexandrian Library, little advance was made in the study of physiology, or even in anatomy. The fact is, that they were chiefly engaged in translating the works of the older writers, whose opinions they adopted.

William of Salicetum, born 1280, was the first after Galen, who made any original observations on the brain and nervous system. When speaking of wounds of the thorax, he makes some important remarks upon the nerves of the part, observing that those which proceed from the sixth or seventh pairs, derive their origin from the brain, and serve for the purposes of voluntary motion, while those arising from the cerebellum and spinal marrow, serve for the actual or vital functions, a circumstance which he illustrates by the symptoms of apoplexy. In these views, therefore, he somewhat approached the theory of Willis, who, four centuries after, pointed out the difference between the cerebrum and cerebellum, as consisting in the one presiding over the vital, or involuntary actions, the other over the animal or voluntary ones.

Guido de Chaulia, an English physician, who flourished in the year 1363, relates the case of a man who recovered after the removal of a considerable portion of the cerebrum, or anterior part of the brain, a circumstance the more worthy of remark, on account of its being perhaps the first case of the kind upon record in the annals of surgery,—for although Galen and others speak of injury of the brain, they are silent with respect to the removal of any portion.

Numerous anatomical works were now published, and among other subjects the brain received a considerable share of attention. Anatomists, however, were principally engaged in disputing

* Theor. lib. 1.

about the opinions of Galen, and the controversies which ensued (carried on by such men as Ingrassius, Vesalius, Fallopius, Eustachius, and others,) tended to increase the knowledge previously possessed.

Of all who entered into these disputes, perhaps Vesalius was the most eminent. He endeavoured to detract from the reputation of Galen, on whose opinion the medical world had relied for so many centuries. He calls in question his anatomical knowledge, affirming that Galen drew his descriptions from the bodies of apes, and other brute animals, and brought forward as discoveries things he imagined, and never saw. Yet in the account given by Vesalius of the nervous system, he has not been able to point out more than two or three errors of Galen, the greatest part of whose anatomy and physiology on this subject he is under the necessity of adopting. With Galen, he considers the brain as the seat of the rational soul, which acts on the sentient and moving parts by the animal spirit and nerves; and thinks with him also, that from the blood-vessels, in their winding course, the vital spirit is formed, from which with a portion of air insinuating itself into the brain, the animal spirit is first prepared. This is afterwards elaborated in the ventricles of the brain, whence a portion of it is carried into the ventricle of the cerebellum, and into the spinal marrow, and so to the nerves arising from it; the spirit passing from the other ventricles into those nerves which have their origin near to them, and by them to the organs of sense and voluntary motion. He admits with Galen that the nerves vary with respect to hardness and softness, the former being for the purposes of motion, the latter for sense.

This attack of Vesalius induced many anatomists to stand forth in the defence of Galen. Amongst others, Laurentius, who lived in the beginning of the seventeenth century, distinguished himself. He adopts the anatomy and doctrines of Galen, relative to the nervous system, and agrees with him also in respect to the nature, uses, and distribution of the nerves themselves. He says that the faculty of feeling and moving flows from the brain to the whole body of the nerves; but whether this faculty alone flows, or with it something corporeal, admits of dispute. He says that the nerves have no perceptible cavities, but that their substance is fistulous and spongy; yet he thinks it possible that the animal spirit, which is the most subtle of all things, may flow through cavities in nerves which we cannot discern. Laurentius does not agree with Galen in his opinion that the nerves of sensation arise from the brain, and those of motion from the spinal marrow; nor does he admit universally that the nerves for motion are hard, and those for sensation soft. He offers some ingenious conjectures in explanation of the circumstance, that feeling sometimes remains when the power of motion is lost, and the contrary.*

A host of anatomists and physiologists now followed, all of whom more or less studied the brain, and in a greater or less degree added something to our knowledge of its functions. It would be tedious to describe the labours of each, (though, for the most part they implicitly believed in the doctrines promulgated by Galen,) I shall therefore only mention cursorily, those who were most distinguished for their discoveries and opinions.

John Dryander, in 1537, published a work, in which he pointed out the distinctions, unnoticed before his time, between the cortical and medullary portions of the brain. He also saw the olfactory nerves, which he miscalled the optic.

Volchu Coitu, discovered that the brain derived its motion from the arteries. He also ascertained that this organ was not essential to life, as some animals survived its removal.†

Varolius described the transverse portion of the brain, which has been denominated in honour of him, the pons varolii. He also discovered the glands of the choroid plexus, and was the first who divided the brain into three portions, by adding the medulla oblongata, previously to its issuing from the skull, and giving birth to nerves whose origin had been supposed to be in the brain.

Malpighi, by his microscopical investigations, discovered the glandular structure of the cortical substance of the brain; he seems also to have had some idea of the fibrous nature of the medullary portion, for he states that this part of the brain in fishes resembles somewhat the pipes of an organ,—that he had observed the same fibrous structure in the brain of sheep, oxen, and other animals, but that it was best seen in the posterior part of the medulla oblongata.‡

William Briggs found that the expanded filaments of the optic nerve lie in the most regular order, and that they continue to retain this order, when afterwards united in the nerve, and preserve it unbroken until they reach the brain.

* Laurentius, lib. iii. quest. 11. † He published in 1566.

‡ Exercitatio Epistolica de Cerebri, 1664.

Vieussens wrote largely on the brain, and dissected the organ with extreme care. He was the first to trace the medullary fibres, and exhibit the connexion that existed between the crura of the cerebrum, and the corpora pyramidalia, by means of longitudinal fibres of white substance passing through the annular protuberance. He also pointed out that these fibres could be more readily traced after boiling the brain in oil.* In demonstrating, he first exposed the corpus callosum, from which he considered the fibres arose, and by slicing off the hemispheres, formed what has since been called from him the centrum ovale. He then exhibited the transparent partition, (or communication between the cerebellum and corpora quadrigemina) called after him the valvula vieussenii, and so proceeded to examine the fornix, &c.

In 1664, Willis published his Cerebri Anatome, followed in 1672 by a work entitled De Animâ Brutorum, &c., in which he considers the soul of brutes to be the same with the vital principle in man, corporeal in its nature, and perishing with the body. His reputation, however, principally depends upon his first book. In this he attributed a different action to the spinal cord, the cerebellum and the brain, and attempted to establish the cerebrum as the organ of voluntary motion, and the cerebellum that of involuntary motion. By the term cerebellum he also included the pons varolii, and medulla oblongata, and on these circulation, respiration, and digestion were dependent. He placed the vital property in the cerebellum, and the animal faculty in the cerebrum, imagination in the corpus callosum, perception in the corpora striata, and memory in the convolutions of the cerebrum. Willis, therefore, was the first who endeavoured to explain the phenomena of brain, by attributing to separate portions of its structure different functions.

Antonio Paccioni, a native of Rizzio, published, in 1721, his final disquisition on the supposed muscular nature and action of the dura mater. His opinions were maintained with considerable ingenuity, and the investigations to which the controversy led, contributed greatly to improve our acquaintance with the parts which were connected with the subject in dispute. During his dissections, he discovered the glands which bear his name.

The opinions of Haller, although of the utmost importance, it would be unnecessary to detail at length here. The example he

* Lib. i. c. 8 and 10.

held out of carefully abstaining from all opinions founded upon speculative grounds, and of deducing his general principles merely from experiment and observation, was of the utmost advantage. By these means he established his theory of irritability and sensibility, as specific properties attached to the two great systems of the animal frame, the muscular and the nervous, to which either separately or conjointly may be referred all the phenomena of the living body. He was opposed to the doctrine which places the various faculties of mind in different portions of the brain and cerebellum, and contrary to the opinion of Willis, concludes from numerous cases of the fatal effects of injuries, that sensation resides in the cerebrum, and volition in the cerebellum.

The opinions of Haller gave rise to much controversy, which assisted greatly in forwarding, among other subjects, the physiology of the brain. Whytt and Porterfield, particularly the former, opposed the Hallerian doctrine. He attributed vital motions to the operation of the sentient principle, which he supposed to be something distinct from the corporeal frame, at the same time that it was necessarily attached to it, and under the influence of physical causes.

The fibrous structure of the brain having been examined by Malpighi and Vieussens, was successfully prosecuted by Professor Reil, who in 1795, published a paper on this subject in Gren's Journal, followed by others, in which he gave a minute account of the fibrous structure of the cerebellum—traced the fibres from the pyramidal bodies through the pons varolii to the crura cerebri, and from thence through the corpora striata to the convolutions; he investigated the fibres of the corpus callosum, and anterior commissure, and traced them into the hemispheres. He also described accurately the structure of the convolutions, and remarks if one were to fix upon a point in the nervous system, such as the medulla oblongata, this system might be regarded as radiating from this point to the extremities of the nerves on the one hand, and to the extremities of the fibres of the cerebrum and cerebellum on the other; or that all these fibres might be considered as converging from their extremities towards the medulla oblongata.

The opinions of Bichat, owing to their ingenuity, and the eloquence with which they were maintained, excited the greatest sensation among physiologists. In 1805 he published his work, " Recherches Physiologiques sur la vie et la mort," in which he divided the nerves into two distinct systems, animal and organic, the one having for its centre the brain, and consisting of those nerves which received impressions, or were subservient to volition; the other had many centres, existing in the ganglia, each of which possessed a distinct source of nervous influence, although an intercommunication took place between them by means of nerves. The first, according to him, presided over sensation, voluntary motion, and intellectual power; the second governed those operations of the animal economy over which the mind had no control, together with the passions.

As we approach our own times, in which so much has been written on the structure and functions of the brain, it becomes obviously impossible to give even an outline of the various works produced. The anatomists of England, France, Germany, and Italy have with the greatest talent and diligence endeavoured to discover those laws which govern the operations of brain, and the connexion which exists between mind and matter. Great progress has latterly been made in the pursuit, and we may reasonably hope that our knowledge of the functions which the nervous system performs will at no very distant period equal our acquaintance with the physiology of other parts of the animal economy. The recent discoveries will be noticed in the following pages; and being now acquainted with the opinions of authors up to the time of Bichat, we shall be better prepared to enter on their consideration, and appreciate the important results to which they have led.

PART I.

ON THE FUNCTIONS OF THE BRAIN.

The brain, cerebellum, and spinal marrow, in a purely scientific point of view, cannot but be considered as one organ. The separation, however, although arbitrary, like the divisions in every branch of science, tends to facilitate the more minute study of each portion, and favours the acquisition of knowledge, when directed to it as a whole. In the following pages, when speaking of the brain, I shall therefore use it in the common acceptation of the term, as the contents of the cranium, divided into cerebrum, cerebellum, pons varolii, and medulla oblongata; but from the intimate connexion that exists between it and the spinal cord, the latter will necessarily receive some share of consideration.

The functions that physiology and pathology warrant us in ascribing to the brain, are those of sensation, motion, and intellectual power. The two former it possesses in common with the spinal marrow, the last is peculiar to itself.

That sensation and motion are somewhat dependent on the brain, is proved by the destruction of these functions on the removal by the experimentalist of certain portions of its substance—by the sudden effects of injury, or the more slow progress of disease. On the other hand, in some of the lower animals, sensation and motion appear to be carried on equally well without a brain, amphibia living for months after decapitation, and some of the warm-blooded animals, such as birds, continue to live and move some time after the separation of the head from the body. The brain has also suffered very extensive lesions, and been diseased to an enormous extent, without in any way affecting either of these functions. Facts confirmative of this opinion are so numerous, that we cannot hesitate in stating, that the brain is not the only source of sensation and motion.

That the manifestations of mind are attributable to the brain, is now generally acknowledged. With the metaphysical inquiry into this subject we have nothing to do, and shall leave the question of the dependence or non-dependence of mind on matter, to the speculations of theologians. But physiologically and pathologically considered, we cannot doubt that mind is inseparably connected with brain, and all our observations of the animal economy, in its healthy or morbid condition, tend to confirm this truth. In the infant, (as argued by Lawrence), like the body, it is weak and without vigour. As the brain acquires firmness, the intellect proportionally increases and advances in power in an equal ratio with the bodily strength, until in the adult it has assumed all the powers of which it is capable. As the body and general organization decline in strength, the mental powers diminish, until the one being decrepid, the other becomes fatuous. Original malformation of the brain is always accompanied by defective mind, whereas an enlarged healthy development of that organ is followed by an increase of the intellectual powers. Besides, on removing the cerebral lobes in animals, physiologists have uniformly found them become dull and stupid, observing that all control over their motions was lost. Pathology shews us that the various manifestations of mind, such as judgment, memory, &c. are often impaired when the brain is diseased either wholly or in part; that when the organ is compressed either by external or internal means, consciousness is destroyed, and on the removal of the compressing cause is again restored.

The labours of Tiedemann, besides establishing a general law of nervous development, have shewn that the appearance of the higher faculties and instincts in animals keeps pace with the development of brain. The zoophytes being destitute of nerves, possess no actions attributable to instinct or volition; and on examining the brains, in the different tribes of fishes, reptiles, birds, and mammalia, it has been proved that the brain receives various additions, according to the more perfect organization of the animal, and that these additions are accompanied by a more perfect state of the functions it performs.

These circumstances, therefore, fully warrant us in ascribing the functions of sensation, motion, and mental power to the brain. We shall now proceed to consider in detail what facts we possess in connexion with this subject from physiological and pathological researches.

SECTION I.

OF SENSATION AND MOTION.

Physiological Results.

HITHERTO no satisfactory explanation has been given of the means by which sensation and motion are produced. That through the intervention of nerves the one is conveyed from the surface of the body to the brain, and that volition proceeds from the brain to the surface, the simple experiment of dividing a nerve sufficiently proves to us. Sir Isaac Newton imagined that this influence, whatever it be, was conveyed by oscillations; yet Haller, after the most careful examination with a magnifying glass, of a nerve, which at the time was throwing a muscle into violent contractions, could not observe the least movement in the nerve itself. Darwin thought that nerves contracted; but if they did so, they would be observed elongating and shortening their fibres; yet this has never been seen. Dr. W. Philip is of opinion, that the nervous and galvanic power are the same, and performed several experiments, with a view of proving this. Among others he placed a shilling on the stomach of a rabbit, cut across the eighth pair of nerves, and bound some tin foil round their extremities, connecting the shilling with one pole, and the foil with another of the galvanic battery in action. Under these circumstances, although the influence of the brain was removed, the stomach performed its usual functions. Other experiments of a like nature tended to confirm Dr. Philip's belief. But the experiments of Sir B. Brodie and Magendie shew, that division of the eighth pair does not materially affect the function of the stomach, if made in such a manner as not to prevent or impede respiration ; and although some of Brachet's experiments are opposed to this conclusion, most physiologists have regarded these with considerable distrust. Besides, as advanced by Dr. Bostock, " before the electric hypothesis can be established, it will be requisite to prove that every function of the nervous system may be performed by electricity," an objection alone sufficient to refute it.

The seat of sensation had always demanded a large share of the attention of physiologists. Almost every portion of the brain has had this function ascribed to it. Descartes placed the seat of sensation in the pineal gland, which he considered also as the centre of mind ; Le Cas in the pia mater; Willis in the corpora striata ; Digby in the septum lucidum ; Sœmmering in the water of the ventricles ; La Peyronie in the corpus callosum. Haller states that it is in neither of these, but in the medulla of the cerebrum ; while Richerand imagines that it resides in the annular protuberance ; and Parfour Petit, Foville, and others, in the cerebellum.

Motion, in like manner, has been ascribed to different parts of the brain. By Willis, it was located in the cerebrum ; by Haller, Rolando, and others, in the cerebellum ; while Magendie, and many experimental physiologists, consider the corpora striata, and quadrigemina, as well as the cerebellum, to be connected with this function.

M. le Gallois pointed out* that sensation and motion were

* Expériences sur le Principe de la Vie.

more dependent on the spinal marrow than was generally supposed. He observed that, when a nerve was divided, all sensibility and power of motion ceased in the parts below the division, and concluded that these properties were derived from whence the nerves originated; and that as the nerves sprang from the brain, or spinal marrow, it is in these that the seat of sensation and motion should be placed. He found that in young animals he could preserve life for several hours after decapitation by pulmonary insufflation, during which time they possessed sensation and motion, which he considered more immediately depended on that portion of the medulla oblongata, giving origin to the eighth pair of nerves. If we open, he says, and cut away by slices the whole of the brain and cerebellum, and even some part of the medulla oblongata, the animal will continue to respire; but if the origin of the eighth pair be included in the section, respiration suddenly ceases. From numerous experiments he concludes that the principle of sensation and motion, as far as relates to the trunk, resides in the spinal marrow. These consisted in destroying the spinal marrow by irons, making various sections of it, &c. From these experiments he wished to shew not only that the life of the trunk depends upon the spinal marrow, but that the life of each portion depends only on that part from which it receives nerves; and, among others, adduces the following experiment as confirmatory of this opinion. He opened the breast and abdomen of a rabbit, tore out the lungs, the diaphragm, the intestines, and all the viscera of these two cavities, then cut off the head, leaving only the skeleton, the muscles, and the spinal marrow, when he found that life continued, and sensation and motion were present; but when he destroyed a portion of the spinal marrow, those parts supplied by this portion only were struck with death; and, on destroying the whole, death took place universally. He, therefore, concludes that the life of the trunk resides in none of the viscera of the breast or abdomen, nor in the brain, (although they are all necessary to the animal economy,) but in the spinal marrow. He, however, still considered the brain to perform an important part in directing motion: thus, on moving the arm, the principle of this motion depends on the spinal marrow, but it is the brain which wills this motion and directs it to the object. He observed, also, that some portions of the brain might be destroyed or injured without affecting sensation or motion, and considered that the seat of this principle was not diffused over the whole cerebral mass, but limited to a certain part named *sensorium commune*. When cold-blooded animals have been decapitated at the first vertebra they will still live; but although they move their body and limbs with as much force as is necessary to transport them from place to place, they remain in the same situation; and, on examining the motions they make, it is observed that they are irregular and apparently undirected to any object. He says, that in those cases where reptiles possess the power of moving after decapitation, it arises from the incomplete performance of this operation, and that the posterior part of the brain remains in union with the body.*

Dr. W. Philip, who has repeated Le Gallois' experiments, and acknowledges their correctness, deduces from them a very different conclusion. He says that motion is entirely independent of the brain and spinal marrow, and asks,† "Why, if the power of the heart depends on the spinal marrow, as it appears to do, from the experiments of Le Gallois, have fœtuses been born alive, where no spinal marrow had ever existed? Why does it continue to perform its usual motions after it is removed from the body? Why, if the various organs of involuntary motion bear the same relation to the nervous system, is the function of the heart uninfluenced by decapitation, and that of the stomach immediately impaired by dividing or throwing a ligature round the eighth pair of nerves? Why does respiration cease on the destruction of a certain part of the medulla oblongata, since the nerves of the muscles employed in respiration arise from the spinal marrow, which M. Le Gallois has proved to be capable of exciting the muscles indepen-

* This observation of Le Gallois' assimilates with the experiments of Flourens, Rolando, and others.

† On the Vital Functions, pp. 52, 53.

dently of the brain?" He considers that Le Gallois' doctrine cannot reconcile these objections, and is therefore erroneous. Although Dr. Philip's experiments have led him to conclude that motion is not dependent on nervous matter, they, at the same time, shew that it is capable of influencing it: an apparent contradiction which experiment proves to be the case, and which is as yet unexplained.

Dr. Philip has demonstrated that an influence is exerted by the brain over the motific function, from the effects which followed the *application* of different stimuli to this organ. Some experiments, performed by Professor Mayer* on the lower animals, proves still further the existence of this influence from the result obtained by *abstracting* a portion of the stimulus usually conveyed to the brain. He, in several instances, tied the vessels which supply the brain with blood, and found that after placing a ligature on one carotid artery, the circulation of the brain was not materially impeded, but that when both carotids were tied great derangement in the functions of the brain followed. He perceived giddiness, loss of sensation, motion, and consciousness, with indifference to the usual instinctive stimuli ensue, together with a feeble respiration and action of the heart, followed by death. Although, from experiments performed by other physiologists, these effects have not been found always to result, we know that, after operations on the human subject, even when only one carotid has been tied, some of these effects occasionally follow. Some experiments by Sir Astley Cooper shew the same result; and it is curious how interrupting the blood, flowing to the brain, should, in some cases, produce such marked effects and not in others. An ingenious explanation of this has been offered by Dr. Knox.† He has often found, on examining the brain, that the communicating arteries of Willis are exceedingly small and sometimes impervious. In the former case the free communication of blood between the carotid and vertebral arteries would be much impeded, and in

* Edinb. Med. and Surg. Journ. vol. xliii. p. 407.

† Anatomical Lectures, 1837.

the latter altogether prevented. Hence the brain would be imperfectly supplied with blood, and the ill effects described, result.

Loss of blood is now well known to produce the same effects on the brain's functions as an excess.* The cause of this will be explained in a subsequent part of this essay ; in the mean time these various facts point out more clearly the great influence which the brain possesses over sensation and motion.

Flourens, in his work on the nervous system, attempts to prove that the cerebral lobes are the seat of sensation and volition ; that the nerves, spinal cord, medulla oblongata, and corpora quadrigemina, are alone the seat of those impressions which give rise to muscular contractions, so as to produce motion of the joints ; and that the cerebellum regulates these motions so as to produce the actions of running, walking, standing, flying, &c. He found, that when the cerebral lobes were removed in an animal, it at once loses the senses of sight and hearing, but if the cerebellum only be removed, and the brain proper remain entire, these senses are unimpaired. If one hemisphere only of the cerebrum is removed, the sight of the opposite side is alone lost. He also observed, that the loss of the cerebral lobes was followed by a kind of lethargy, or deep sleep ; and it is this fact which induces him to think, that besides being the seat of sensation, the cerebral lobes are the seat of volition. When both hemispheres of the cerebrum were removed in a pigeon, without injuring the corpora quadrigemina, or cerebellum, the animal was immediately seized with more or less feebleness, which effect, however, gradually diminished, till it soon became evident that motion was nowhere materially weakened. But the senses of seeing and hearing, as above mentioned, were extinguished, and a state of stupor was induced, resembling profound sleep. The animal remained calm, and as if abstracted, did not move of its own accord ; and when it en-

* See Dr. M. Hall, On Bloodletting.

countered an obstacle, struck it again and again, without trying to avoid it. Yet it preserved its equilibrium, struggled if held, resisted every effort made to open its beak, swallowed water dropped into it, walked about when pushed, and flew when thrown into the air; the slightest irritation evidently annoyed it.* These phenomena, although they by no means show that sensation and motion were wholly lost, yet prove that they are considerably impaired. The French commissioners who reported on this subject say—"We should be content with holding that the cerebral lobes are the sole receptacle, where impressions on the senses of sight and hearing become perceptible to the animal. If we were to add anything to this concession, we should say that they were also the part where all sensations whatever take a distinct form, and leave durable traces and recollections; in a word, that they are the seat of memory, by which property they supply the animal with the materials of judgment."†

Rolando of Turin performed numerous experiments before those of Flourens were made known, which led him to the same conclusion concerning the seat of sensation. He observed in cocks, crows, kids, lambs, and guinea-pigs, that after the cerebral lobes had been removed, those animals stood motionless for hours together, but that they preserved their equilibrium, sought for support, and could be made to walk when struck violently. It is evident that sensation and motion, however impaired, were not destroyed in these experiments.

Magendie found that young rabbits, jackdaws, and magpies ran about and jumped vigorously and spontaneously after removing all the brain anterior to the optic thalami.‡ He accounts for the different result which he arrived at, from that of the two former physiologists, by the care he took to prevent extravasation and compression, and which he thinks was not sufficiently guarded against by them.

* Archives General, ii. p. 352.

† Journ. de Physiol. vol. ii. p. 381.

‡ Ibid. vol. iii. p. 155.

We may then fairly conclude, that as neither Flourens nor Rolando have shown that sensation and motion are totally destroyed on the removal of the cerebral hemisphere, whilst in several animals sufficient care being taken to prevent extravasation, little effect is produced; these functions cannot be said to belong exclusively to the hemispheres of the brain.

The experiments from which Flourens deduces that the cerebellum is the regulator of motion, are numerous, have been confirmed, and demand our utmost attention. On cutting away a slice from the cerebellum of an animal, the injury is at once followed by great weakness, but in a short time the animal regains its strength, and the senses are then found to be entire. It shrinks from the slightest threat or violence offered to it, and the motions of the limbs are generally vigorous and frequent, but its movements are exceedingly irregular, and, as it were, embarrass each other; and though volition is evidently exerted, no corresponding act succeeds; it strives to escape when irritated, yet it can neither fly, run, leap, or walk; and when the whole cerebellum is removed, it cannot even stand. If that organ be removed gradually in successive thin slices, the progressive circumscription of the locomotive actions is very remarkable. On removing only the first layers of the cerebellum in the pigeon, the sole effect produced is some weakness, and a kind of hesitation in its gait. When the sections have reached the middle layers, it staggers much, and assists itself in walking with its wings; yet it sees and hears perfectly, seems cheerful, and does not express pain. The sections being continued farther, it is no longer able to preserve its equilibrium without the assistance of its wings and tail; its attempts to fly or walk resemble the fruitless efforts of a nestling, and the slightest touch tumbles it over. At last when the whole cerebellum is removed, it cannot support itself even with the aid of its wings and tail; it makes violent efforts to rise, but only rolls up and down; then, fatigued with struggling, it remains for a few seconds at rest on its back or belly, and then again commences in vain, struggles to rise and walk. Yet all the while its sight and hearing are perfect, the slightest noise, threat, or stimulus at once renews its contortions. In these struggles there is not the slightest appearance of convulsions. The same effects where observed by Flourens in the guinea-pig. When the last layers of the cerebellum were removed, it lost the power of walking or standing, lay down on its belly, moved its legs as if running, and made vain efforts to rise. Such are the facts from which he has drawn the inference that the cerebellum is the regulator of all locomotive actions.

Rolando maintains that the cerebellum is the organ on which motion entirely depends. After removing the cerebellum from many mammalia and birds, he found that motion diminished in proportion to the quantity of matter removed. The experiments of Magendie, however, are hostile to this view. He says, that after having entirely removed the cerebellum in animals, they notwithstanding performed very regular movements. He has seen hedgehogs and guinea-pigs deprived both of brain and cerebellum, rub their noses with their paws in front, when a cruet of vinegar was placed under their nostrils. These movements, however, may be instinctive. Le Gallois mentions that, after decapitation, the trunk seems often to be influenced by a sort of instinct or will. He found that guinea-pigs, and kittens, on recovering from the stupor produced by decapitation, appeared to feel pain from the wound in the neck, as seems evident by the alternate motion of their hind feet towards that part. Sir G. Blane* divided the spinal marrow of a kitten by cutting it across the neck. The hind paws being then irritated by pricking them, and by touching them with a hot wire, the muscles belonging to the posterior extremities were thrown into contraction, so as to produce the effect of shrinking from the injury. In repeating the experiment, he found, that when the spinal marrow was cut through between the lumbar vertebræ and the os sacrum, the posterior extremities lost their irritability, but the tail retained it. It appears, therefore, that some motions take place independently of the brain, as is still further evinced by the birth of acephalous

* Lecture on Muscular Motion, read to the Royal Society, 1788.

fœtuses which have lived for some short period. Nay, fœtuses have exhibited motion when born without a brain or spinal marrow.

Dr. M. Hall* has lately endeavoured to prove that many of these motions described by Le Gallois, and by some termed instinctive, are independent of sensation and volition; and seeks to establish a new system of nerves which he calls excito motory. Having divided the spinal marrow in a frog below the occiput, on pinching the toe, the extremity is retracted. The same takes place in animals after decapitation, or when they have been stunned by a blow on the head. These experiments, similar to those of Le Gallois and Sir G. Blane, only confirm the views of the former, who considered that sensation and motion reside in the spinal cord, and that these functions may be exercised independently of the brain.

That sensation and motion derive their origin from two distinct sources, is fully proved by the experiments of Sir C. Bell. He has shown the impossibility of supposing that the nerves receive all their influence from the brain, and by the most conclusive experiments has demonstrated that sensation and motion may be traced to the spinal marrow, which he has proved to consist of a double cord—the anterior originating motion, the posterior sensibility. He has shown that the spinal nerves may be separated into fasiculi, some of which arise from the anterior, others from the posterior part of the medulla spinalis, and considers that each filament has its own particular endowment, which it retains through its whole course. Thus, the filament arising from the sensitive part of the cord, bestows the property of sensibility on every part where it is distributed, while that connected with the motific portion communicates the influence of the will to the muscle, and causes it to act. Thus, "a circle is established between the sensorium and the muscle; one filament or simple nerve carries the influence of the will towards the muscle, which nerve has no power to convey an impression backwards to the brain, and that another nerve connects the muscle with the brain, and

* On the Nervous System.

acting as a sentient nerve conveys the impression of the condition of the muscle to the mind, but has no operation in a direction outward from the brain towards the muscle, and does not therefore excite the muscle, however irritated."*

The experiments on which this opinion is founded, are too well known to require description. They have been confirmed by Magendie, and a host of physiologists, and are universally acknowledged as being conclusive.

Sir C. Bell has also demonstrated that there are two kinds of sensibility, one relating to the condition of our bodily frame, the other intimating to us the nature of the matter which surrounds us, and the properties it possesses. The former has been called common, the latter special sensibility. These are affected by different stimuli ; the impressions felt by the special organs of sight, hearing, smelling, and taste, are unheeded by the more common sense of touch which resides in the integuments ; while injuries and lacerations of the nervous substance imparting peculiar sensibility, are not followed by the pain they cause in the skin, where general sensibility is situated.

It is the opinion of Magendie and Desmoulins that all special sensibility is dependent on the trigeminal nerves, and they deduce this conclusion from the following arguments, viz. When the fifth pair is divided, all the special senses are destroyed, or at least enfeebled ; when the special nerves alone are divided, the animal still retains in part the capability of receiving odours, taste, sound, and light ; but if the fifth pair is divided at the same time, these sensations are utterly and entirely annihilated. The mole has no optic nerve, but instead of it there is a twig of the fifth pair ; in fishes there is no auditory nerve ; in the cetacea no olfactory nerve ; and yet these animals have in all probability a certain degree of the corresponding sensations. Certain of the special sensations may be produced in other ways than the contact or impression of the ordinary stimuli giving rise to them ; thus, for example, sound may be heard, although the external ear be plug-

* On the Nervous Circle.

ged up, if a watch be applied to the head, or put between the teeth. All these arguments are liable to powerful objections, some of them are fallacious. If the sense of vision depended on the fifth pair, it would immediately cease on dividing the nerve ; this is not the case ; no immediate effect is produced, but a gradual action commences, which terminates in the disorganization of the cornea and conjunctiva, producing also muddiness of the humours, and it is from these secondary causes that vision is rendered impossible. That the mole has no optic nerve, is denied by Carus and Geoffroy St. Hillaire. I have, however, carefully dissected the brain in six moles, and examined the base of the brain, and the nerves coming from it, with powerful glasses, without being able to detect any appearance of the optic nerve. It is unlikely, therefore, that the mole possesses the power of viewing objects distinctly ; it may indeed be enabled to distinguish light from darkness, as the fifth pair may possibly bestow such sensibility on the parts as to make it sensible of light ; and for this merely it does not appear necessary that there should be an optic nerve. As regards the absence of olfactory nerves in the whale tribe, it is not universal. I saw the brain of a young whale (Minor Rorqual) removed from the cranium, by Dr. Knox, which had the olfactory nerves fully developed ; and that gentleman having shewn that some of this class of animals possess olfactory nerves, while others do not, it is generally believed that the former only are endowed with the power of smell. Sound can certainly be heard when the external ears are plugged up, in the same manner as those animals are conscious of sound who have no external ear ; but it is by the general law which regulates the conveyance of sonorous vibrations. No doubt the trigeminal nerve has a great influence on the exercise of the special senses ; but this is to be ascribed either to the loss of that common sensibility which is its guard against irritations, and which appears indispensable to the proper secretion of mucus, lining the external mucous membranes. Thus, after division of the fifth, these become inflamed, cease to secrete the fluid which keeps them moist in a state of health, and a condition is occasioned which renders a proper performance of their functions impossible.

It was noticed by Fodera,* that the removal of part of the cerebellum was followed in all cases, either by motion *backwards*, or by that portion of the body which precedes retrograde movement. Magendie found, that on removing the corpora striata in mammalia, the animal darts forward with great rapidity; if it stops, it preserves its attitude of escape. On injuring the cerebellum, he observed that the animal attempted to move backwards. Hence he imagined there were two powers in equilibrium, one leading forwards, the other backwards; and that when either of these are injured, the force of the other preponderates, and produces an irresistible movement one way or the other, according to circumstances. On dividing one of the peduncles of the cerebellum, the animal begins to roll laterally on the same side as the divided peduncle, with great force, and sometimes with so much rapidity, that the animal makes more than sixty revolutions in a minute. The nearer the section is to their origin from the pons varolii, the more rapid is the motion. He has seen this movement continue for eight days, without stopping for a single instant. On dividing the cerebellum into two lateral bodies, perfectly equal, the animal was alternately impelled to the right and to the left, without preserving any fixed situation. Besides the powers, then, which impel an animal forwards or backwards, there appear to be others which govern lateral and rotatory motions of the body. Mayo† thinks the simplest and most rational explanation of these phenomena is, that these various injuries produce in the animal a sensation analogous to vertigo, and that the animal conceives itself to be hurried in various directions opposed to those which take place, and which are produced by the efforts he makes to repel this imaginary force.

That these movements are occasioned only by injuring par-

* Journal de Physique, July 1823.

† Mayo's Physiology.

ticular parts of the brain, is shewn not to be the case, by several experiments of M. Flourens, who found almost the same effects follow lesion of the semicircular canals in birds.* Division of the horizontal canals on each side occasioned a rapid horizontal movement of the head from left to right and back again, and loss of the power of maintaining an equilibrium, except when standing, or perfectly motionless. There was also the same singular rotation of the animal round its own axis, which follows injury of the crura cerebelli. Section of the inferior vertical canal on both sides produced violent vertical movements of the head, with loss of equilibrium in walking or flying. There was in this case no rotation of the body upon itself, but the bird fell backwards, and remained lying on its back. When the superior vertical canals were divided, the same phenomena were observed as in section of the inferior, except that the bird fell forward on its head, instead of backwards. All the canals, both vertical and horizontal, having been divided in another pigeon, violent irregular motions in all directions ensued. When, however, the bony canals were so cautiously divided as to leave their internal membranous investment uninjured, these motions were not produced. This would lead to the supposition that it is in the expansion of the acoustic nerve that the cause of these phenomena must reside; but why lesion of a nerve supposed to minister exclusively to the sense of hearing should produce such derangement in motion, has not been attempted to be explained.

Bellingeri† attributes to the hemispheres the power of producing the motions of flexion, and to the cerebellum that of causing extension. He points out, from the experiments of Magendie, Flourens, Serres, and others, that removal or injury of the anterior lobes of the brain is followed by flexion of the abdominal extremities, while division of the posterior lobes is followed by flexion of the thoracic extremities. In

* Memoires de l'Academie des Sciences, vol. ix. p. 454.

† Edinb. Med. and Surg. Journ. vol. xliii. p. 160.

support of the latter proposition he adduces the comparative weight of the brain and cerebellum at different ages. He concludes from the authority of Chaussier, that the weight of the cerebellum is the eighth or ninth part of the brain, and that in the infant the difference is greater. He observes, that the motions of extension are more predominant in the adult than in the infant, in whom the motions of flexion are most apparent, and which is incapable of sustaining the head and trunk, and supporting itself erect, positions easily maintained by the adult, from the greater development of the hemispheres in the fœtus, the flexed position of the body, and in infancy the predominant action of the flexor muscles. This opinion he considers farther illustrated, by having observed in those children who had the occipital region much developed, stand and walk earlier than those in whom it is depressed, or little elevated.* He considers also that the experiments of physiologists agree with this doctrine. The motions of retrogression observed by Magendie on injuring the cerebellum are to be explained by the spasmodic actions thus induced in the exterior muscles, which compel the animal to move backwards. Fodera has described the position of a guinea-pig, after removing the superior part of the cerebellum, as being that of the head thrown back, the hind legs forcibly separated, the fore legs straight and rigid, &c. and Bouillaud has observed injuries of the cerebellum followed by opisthotonos.

* The observations of Sir W. Hamilton (Monro's Anatomy of the Brain) agree in this respect with those of Bellingeri. He mentions that the young of those animals, (as the chicken of the common fowl, partridge, pheasant, &c.) who have from the first the full power of voluntary motion, and depend on their own exertions for subsistence, have the cerebellum as large as the adult; and in the calf, kid, lamb, and probably in the colt, the cerebellum at birth is very little less than in the adult. Whereas in those birds that have not at first the full power of voluntary motion, but which grow rapidly, the cerebellum does not arrive so quickly to its proper size; and in the young of quadrupeds that for some time depend on the milk of the mother for support, and which have at first feeble powers of regulated motion, the proportion of the cerebellum to the brain proper is very small; and by the aid of the full period of lactation, it reaches the full proportion of the adult. This is seen in the young rabbit, kitten, whelp, &c.

The latter physiologist has made numerous experiments, the results of which are, on the whole, similar to those of Flourens, Rolando, Magendie, &c.* He however concludes from them, that the regulating power of the cerebellum is confined to the muscles of locomotion only, and has no influence whatever over voluntary movements. He says, that the experiments of all physiologists shew that injuries of the cerebellum produce only disorder and confusion of those motions concerned in station and locomotion.

The same facts have received another explanation from M. Foville. He considers the cerebellum as the seat of sensation, and argues, that as it is by means of this function that we regulate muscular motion, (in proof of which he cites many cases of anisthœsia,) so when it is destroyed, the faculty of perceiving the movements being lost, we cannot answer for their precision or duration.

It will be seen, therefore, that great confusion is thrown on this subject by the difference existing among physiologists themselves. Farther particulars, all however of the same nature as those already quoted, may be obtained from the writings of Hertwig, Desmoulins, Shaw, Foderé, Serres, &c. ; it is unnecessary to enter on their consideration here.

Having described the facts which have been derived from various experiments, we shall now inquire how much pathology has contributed to our knowledge of the functions of sensation and motion.

Pathological Results.

The pathological facts which bear upon this subject are both numerous and important, and are much opposed to the hypotheses, which experiments on the lower animals have engendered. All pathologists agree in considering it a matter of extreme difficulty to reconcile, with any degree of certainty, the morbid appearances found in the brain with the symp-

* Recherches Cliniques et Experimentales, &c.

toms previously observed. We cannot read any account of the diseases of this organ without being struck with the violent symptoms, which in some instances occur with trifling lesion of its substance, while on the contrary it is common to observe morbid destruction of the encephalon or its membranes to a great extent, where unimportant illness had existed, or where it had not even been suspected.* It is not then from a few cases that we are entitled to draw any deduction concerning the functions of any part of the cerebral mass, for such are the contradictory effects often obtained from apparently the same cause, that by judiciously selecting a few well marked instances, great plausibility may be thrown on various theories, however dissimilar. It must be evident that such a mode of proceeding cannot tend to the advancement of science, but rather produces from limited facts a confidence in opinions, which are often opposed to extensive inductions, or, at the most, owe their reputation to the ingenuity, rather than the candour, of their authors.

The diseases of the brain, which more particularly confirm or nullify results obtained by experiment, are those in which some organic lesion has been discovered, and it is to these we shall more particularly confine our observations. It must not, however, be forgotten, that circumstances independent of these affect the functions of the brain in a manner not less certain, and with a violence equally destructive. Thus sensation and motion have been powerfully increased or diminished, when, on dissection after death, the membranes only have been found diseased; and these have often presented the same morbid appearances in the dead body, subsequent to the presentation of the most varied symptoms during life.

Irregularities in the circulation of the brain have also produced every kind of derangement to which either sensation or motion is liable; for this organ is not only influenced by the general quantity and quality of the blood, as are the other viscera, but is peculiarly affected by the unyielding nature of

* See remarkable case by Mr. Earle.—Medical and Physical Journal, vol. xxiii., p. 89.

the parts which surround it. Thus it is very probable that a healthy state of the brain depends in no small degree on a just balance of the circulation in the arterial and venous vessels, more particularly as we see all those circumstances which tend to disturb it produce derangement of its functions ; among these may be enumerated pressure, extravasation of fluids, mental emotions, external applications of heat, use of alcohol, &c.

In cases of insanity, we often observe that sensation and motion are not excited by their ordinary stimuli, or, on the other hand, these are morbidly irritable. Thus lunatics have had their fingers, toes, and even extremities mortified from the effects of frost, without having been aware of the circumstance ; and one, during a paroxysm, having thrust his foot into the fire, allowed it to be burnt away without exhibiting the slightest pain. In some cases, the sensibility of the cutaneous surface has been rendered so acute, as to produce more than ordinary pain from the receipt of the slightest wound, or the application of an external stimulus. Dr. Falconer* mentions a singular case of this kind—that of a gentleman, who, having suffered from paralysis, experienced a sensation of intense heat on feeling any cold body, and imagined his shoes were getting cold, when in reality they were growing warm from animal heat. The senses of sight, hearing, smell, and taste may in such cases give rise to perceptions unusual to those generally produced :—For instance, obscurity of vision, and flashes of light before the eyes ; imaginary sounds, obtuseness or great activity of hearing ; smelling more or less depraved ; and the taste so much so, that raw potatoes, candles, and even some disgusting substances, are devoured with the greatest avidity. Among the disturbances of motion caused by insanity, may be remarked the increased strength which lunatics often possess during the paroxysms, the immobility with which they sometimes appear to be affected, continuing in the same position often for days together ; and with others, on the contrary, the restlessness and great activity that singularly characterizes their movements.

* Mem. of the Medical Society, London, vol. ii.

The morbid appearances met with in the brain are numerous; most of them, however, are to be considered as the result of inflammation, such as adhesions, effusions into the cavities, congestions, abscesses, hæmorrhages, discolorations, and some say softening, but that this is always the case is denied by others. Besides the disorganizations arising from inflammation, there are others, such as different kinds of tumours, tubercles, cancer, ossifications, indurations of the cerebral substance, depositions of albuminous matter, hypertrophy, and hydatids. Notwithstanding the contrary nature of these diseases, the symptoms found in connexion with them are very similar, and are by no means of such a nature as to allow any distinction to be drawn between one or the other. Many are common to the whole, such as headach, delirium, coma, &c. Observation also tells us that the same morbid appearance in different cases produces the most varied symptoms, while, on the other hand, the most dissimilar symptoms have originated from the same apparent cause. Neither does the situation in which the disorganization has taken place, point out any data which may lead us to a knowledge of the seat or nature of the mischief, many morbid alterations of the same kind having taken place in different portions of the brain, that previously presented the same indications of disease.

The loss of sensation and motion may be either general or partial, complete or incomplete. One may be injured without the other, or they may be simultaneously destroyed. Some diseases have been found to affect one function more than the other. Thus loss of sensation has been more constant after cerebral hæmorrhage than that of motion; and the contrary has been observed as the result of ramollissement. The accurate researches of Foville have shown, that when sensation and motion are permanently affected in lunatics, the medullary portion of the brain is invariably diseased. In chronic cases he describes it as being sometimes of a splendid white and much indurated; at others, the hardened medullary substance has a yellow tinge, or a grey leaden colour.

We generally find that diseases on one side of the brain produce paralysis on the opposite side of the body; an effect which pathologists attribute to the decussation of the pyramids of the medulla oblongata. It sometimes, however, occurs on the same side; but as the hemispheres of the brain are connected by two sets of filaments, by one to the opposite, and by the other to the same side; in these cases the latter is supposed to convey the morbid influence.

Many remarkable cases have been published where sensation has been impaired without the other functions of the brain being altered. Mr. Liston* removed the metatarsal bone of the little toe from a gentleman; which operation, though generally causing much pain, in him produced no suffering. The sentient power was nearly, if not altogether lost, while that of motion was so entire as to enable him to use his hands in carving his food, in writing, holding the reins on horseback, &c. A similar case is related by Mr. A. Reid.† More frequently we find loss of sensibility confined to particular parts; thus, numbness of the fingers is a common symptom of incipient paralysis. Sometimes pricking and tingling sensations occur, at others a feeling of creeping things on the part. These sensations may be confined to the hands or feet, or extend over the extremities, and occasionally occur in various parts of the cutaneous surface. Exaltation of sensibility may likewise take place, producing acute pain in particular parts, which is much increased on the slightest pressure. Mr. Travers‡ relates the case of a man who injured his back by a fall, and who felt the most agonizing pain in the lower extremities from the slightest touch, "to use his own words, when any one even walks by his bedside, it is just as if a number of razors were cutting him down to the bone."

The abolition of sensibility may take place on the whole side of the body, or may be confined to half the face, an arm, a leg, or both, or either of the superior or inferior extremities

* Medical and Surgical Journal, vol. 31, p. 292.

† Same Journal for April, 1829.

‡ Constitutional irritation, a further inquiry, &c. pp. 358-9.

may be simultaneously affected. Some rare cases have occurred where loss of sensibility has taken place on one side of the body, and loss of motion on the other. Dr. H. Ley* gives a case of this kind, which is quoted by Sir C. Bell. It was that of a woman who, after delivery, had defective sensibility on one side, and loss of motion on the other. She could hold her child to one breast as long as she looked at it, but on the attention being removed, the child was in danger of falling; on this side she could not feel the application of the child's mouth to the nipple, though she could see it sucking. On the other side feeling was entire; but she was unable to hold the child to the breast. Dr. Bright† also gives a case somewhat similar; and Andral mentions one of a man who had the right side of his face without sensibility, and the left without motion. Loss of motion has also been known to take place alone, without influencing the other functions. In these cases the limbs are generally flexed; a symptom which has been thought by Rostan indicative of softening of the brain; but it is not to be relied on. This function may likewise be increased, a circumstance daily brought under our observation in convulsions.

It most frequently happens, however, that both sensation and motion are affected together. This may depend on any kind of disease to which the cerebro-spinal system is liable. Extravasations have occurred into the anterior, middle, and posterior lobes of the brain, and produced the same symptoms, viz. hemiplegia of the opposite side. Whether the effusion takes place on the surface or in the internal parts; diffused or circumscribed, paralysis, either wholly or partially of the opposite side, is the result. Sometimes extravasation, to a small extent, will cause the most dangerous symptoms, while at others, when it occurs to a larger amount, they are by no means so alarming. It seldom happens that an extravasation takes place without producing paralysis; sometimes it causes convulsions, which gradually gives place to coma. On some occasions the patients feel headach, pricking sensations of the limbs, a

* Medical Gazette, vol. i. p. 755. † Bright's Reports, Case 271.

feeling of debility, and other premonitory symptoms; whilst on others the attack is sudden, and at once acquires its utmost violence, and then remains stationary or diminishes.

Ramollissement is another morbid condition of the brain which causes much disturbance to the sensific and motific functions; unlike extravasation, it is generally the result of a slow action. The facts we derive, however, from our observation of this change in cerebral structure, are the same, and as much opposed. Softening may occupy the whole of both hemispheres, or of one only; large portions may be affected on one or both sides; and on the other hand, the ramollissement may have extended a very short distance, including brain not larger than the size of a hazel nut; and yet, in this last instance, the symptoms may be as well marked as in the others.

Such are the contradictory results a record of cases produces; and which every one, reading carefully any treatise on the pathology of the brain, cannot but observe. It would be useless to refer to these in detail; for although a careful study of them may materially assist the practitioner in his treatment, they throw no light on the attempts of physiologists to ascribe to particular parts of the brain distinct functions. On the contrary, they are decidedly hostile to every hypothesis hitherto advanced. Many cases may indeed be adduced confirmatory of such and such opinions; but if as many others are also brought forward which tend to an opposite conclusion, all arguments based on the former must be nugatory.

Diseases of the brain likewise produce disturbance in the organs of special sensation. Thus, besides their perversion, which we have already mentioned as being connected with a deranged state of mind, double sight, and spectral illusions of various kinds, have been observed to usher in cerebral hæmorrhage. Andral mentions the case of a locksmith, who, having experienced dizziness of the head for eight days, suddenly lost his sight. After having remained blind for fifteen days, he suddenly fell down deprived of consciousness, and paralysed on the right side. Consciousness soon returned, the hemiplegia continued, but he recovered his sight, which, however, always remained weak. He mentions another case where the sight was completely lost and again returned three separate times. Other cases have occurred where the sight has been improved, and vision rendered more acute under like circumstances. In cases of paralysis, where the sight has been affected, it has been lost entirely, or on one side only; and in this last case it may take place on the paralysed side or otherwise. Loss of vision, like the disturbance of general sensation or motion, seems to follow disease of no particular part of the brain. Flourens imagined it to be dependent on the cerebral hemispheres, and Serres on the optic thalami. But Andral says he has found alteration of vision dependent on lesion of all parts of the hemispheres. Disease of the cerebellum is sometimes accompanied by loss of vision, and the connection of this organ with the corpora quadrigemina by means of the *processus a cerebello ad testes* is supposed sufficiently explanatory of this fact. Hearing may also be affected before and after disease in various parts of the brain. In idiopathic inflammation of the dura mater, ear ache is a general symptom, and buzzing in the ears, tinglings, and total deafness often depend on disorganization of the cerebral substance. Taste and smell may also be impaired from a similar cause.

No fact is perhaps better established by experiment, than that wounds inflicted on the cerebellum, produce more or less loss of control over voluntary motion. If this organ be indeed the regulator of motion, as experiments performed on it would induce us to think, a diseased state of the cerebellum must cause more or less variation in the performance of this function. This is by no means always the case. Paralysis indeed often occurs in conjunction with diseased cerebellum, but it must be remembered that so it does also with almost every other part of diseased brain. Moreover, the cerebellum has often been extensively diseased without producing any effect on the motive powers. The conclusion we are able to arrive at from an inspection of morbid cases, will be seen by examining eight cases of cerebellar disease detailed by Dr. Abercrombie.* (Cases 3, 13, 82, 83, 84, 85, 88, 89.) From this it will be seen that in four there was no aberration of motion, although in some the disorganization had proceeded to a considerable extent. In one where both lobes were diseased, there was an unsteadiness of motion, and inability to lay hold of anything. In another *both* arms and legs were spasmodically acted on, from a small tumour in the *left* hemisphere. In a third case, there was *slight* paralysis of the *right* arm and leg, where the *whole* of the *right* lobe was much softened. In the fourth, epilepsy and paraplegia arose from disease of both lobes. These cases exhibit the opposite effects disease of this organ produces. In the appendix of this same work, so much celebrated for accuracy, are described twelve cases of organic disease of the cerebellum, with their dissections. Of these, three exhibited no affection of motion whatever ; one had paraplegia ; one with headach, sometimes so severe as to oblige the patient to remain in one posture ; one, walk unsteady ; three with convulsions before death, one of these with spasmodic action of the limbs ; one, numbness of left hand ; one, numbness of the right side, and one with constant motion from side to side.

In thirty-six cases mentioned by Andral, there were but eight, in which motion was not in some way disturbed. In these also sensation was equally affected. The works of Bright, Carswell, Hooper, Serres, Cruvelhier, and others, present also numerous cases in which we find extravasations into, and tumours, and softening of the cerebellum, all of a like nature to those already quoted, and which, although they generally have as a symptom paralysis, or convulsions, these are often well marked, and very violent from apparently trifling lesions, and are as often slight, when the whole or greater portions of the cerebellum has been completely disorganized. Cases of cerebellar disease also occur sufficiently

* On the Brain, &c. 3d edition.

often without disturbance of motion, to prove that this function cannot depend more on this portion of the encephalon, than on any other.

The effects observed by Magendie to arise from injury of the cerebellum, have seldom been seen to follow disease of that organ, however extensive. The same may be said respecting the corpora striata. Abercrombie* mentions two cases where both these bodies were diseased, only causing paralysis, in the same manner, as when other parts of the brain have undergone structural alteration. Cheyne† also describes two cases where both corpora striata had been injured by morbid action, yet the patients exhibited no desire to move forwards.

In the lower animals, particularly in the sheep, there has been noticed a disease named turnsick, characterized by a peculiar habit of turning round in one way, with the head twisted on the same side. As the disease advances, so does the rotatory motion, and they will continue to form concentric circles for hours together, until they fall exhausted. This is found to be occasioned in sheep by the existence of hydatids, either between the pia mater and brain, or imbedded in the cerebral substance. According to Youatt,‡ if hydatids are in both lobes, the head will be sometimes held on one side, sometimes on the other; if in the corpus callosum, or central parts of the brain, the sheep will march straight forward, with the head depressed, without the power of avoiding objects, and continually falling: if in the cerebellum or fourth ventricle, the muzzle will be elevated, and the head thrown back, while the sheep will run straight forward. The same disease occurs in cattle, but in them has been found to be occasioned by other causes, such for instance as compress the brain. Dogs also will describe circles for hours together, first, carefully avoiding obstacles, but by degrees the sense of vision becomes lost, and their mental faculties impaired, and then they strike

* Cases 31 and 43. † Cases 10 and 22.

‡ Supplement to Lectures in the Lancet, page 3.

against every impediment. In this last class of animals, hydatids have never been found, and in them the affection is dependent generally on spiculæ of bone, or effusions compressing the brain; in some few cases, however, no perceptible lesion has been discovered. That the human brain is subject to hydatids, has been much disputed by various pathologists. Cases where cysts have been found, are mentioned by Rostan,* and Headington.† By others, these are considered only as serous or vesicular cysts.‡ Although the origin of these bodies has given rise to many ingenious speculations, we shall not enter into the subject here, more particularly as we do not observe the same effects produced by them in man, as in the lower animals, and even in these the phenomena cannot be reconciled with the views of Magendie and others.

Bellingeri, in support of his doctrines regarding the seat of flexion and extension, has brought forward thirty-four cases, selected from the works of Morgagni, Lallemand, Bouillaud, Dan de la Vanterie, Avisard, Martin, Solon, Piedagnel, Hertin, and Serres. Of these, there are twenty-three in which, with symptoms of apoplexy or palsy, was connected a greater or less degree of flexion of the arms, or tetanic rigidity of the head and neck. These symptoms depended on disease or irritation of the hemispheres, principally confined to the optic thalami, corpora striata, posterior part of the ventricles, and the middle and posterior lobes. The remaining eleven cases, are those of cerebellar disease, causing different degrees of distension in the muscles of the head, trunk, and extremities. From these cases, in conjunction with the experiments and observations formerly noticed, he wishes it to be established, that one species of motion is produced by the brain, and an opposite one by the cerebellum. In the same manner he imagines the former to preside over adduction, and the latter over abduction. This is what he denominates nervous antagonism, by which he thinks all motions throughout the body

* Recherches, &c., chap. 10. Acephalocystes, p. 166.

† Med. and Surg. Jour., vol. xv. p. 504. ‡ See Hooper's 15th plate.

are governed. Thus opisthotonos, or spasmodic extension, depends according to him on some irritation or disease of the cerebellum, and posterior columns of the spinal cord; and emprosthotonos, or spasmodic flexion, is caused by morbid alteration in the hemispheres, or anterior roots of the spinal cord.

These views, although exceedingly ingenious, are no more susceptible of proof, than are the other speculations of physiologists, and are moreover opposed to a large number of facts. Mr. Travers observes,* "It is against the theory of Bellingeri that sensation is in no degree implicated in tetanus, whatever be the direction in which the spasms prevail, and especially that the acting power, whatever it be, is altogether preternatural which is employed to produce the involuntary contraction of muscles, in health obedient only to the will. If it were an excess or failure of natural action, we might expect a conformity in the natural structure, but it is an absolute perversion of healthy action, and therefore not illustrative of healthy conformation and function." That thirty-six cases should agree with his opinion, appears by no means surprising, when we read the list of authors from whose writings they are selected; but on contrasting them with the numbers which are opposed to this doctrine, it will be at once apparent, that pathology tends more to overthrow than support Bellingeri's hypothesis. Thus, though it has occasionally happened that flexion and extension are found as symptoms of certain diseased parts of the brain, there are numerous others where a great portion of the hemispheres and the cerebellum has been involved without any such symptom having been recorded—Andral mentions that three cases of *entire* softening of the cerebellum have come under his notice; of these only one favours Bellingeri's views.

Those causes which disturb the functions of sensation and motion in the brain, operate with the same result on the spinal marrow. Injuries of the spine have been followed by loss of motion, without loss of sensibility, and the contrary. Pott's

* Further inquiry concerning Constitutional Irritation, p. 338.

disease is often accompanied by paralysis of the lower extremities, and in such instances, motion is more frequently affected than sensation. Pott has shewn that this does not depend upon the curvature, as the paralysis often disappears, and leaves the curvature as it was. In this disease the bodies of the vertebræ are generally carious, and we should naturally expect that in accordance with the experiments of Sir C. Bell, loss of motion would take place, if the diseased action be communicated to the anterior columns of the spinal marrow. Should the disease extend, sensibility will become affected, and if a recovery takes place this property will return first. This is invariably found to occur. A case of Dr. Hunter's, related by Abercrombie, illustrates the effect produced by injury of a portion of the spinal marrow. A man was thrown down from a height of ten feet, and a month after the accident, was admitted into the wards of the Royal Infirmary, having with other symptoms, complete loss of motion of the lower extremities, without loss of feeling, and having all the muscles of the affected parts in a state of flaccidity. Inspection discovered extensive softening of the body of the cord, which affected chiefly the anterior columns. Ramollissement of the cord may, if confined only to the posterior columns, produce loss of sensibility alone, and we always find, if it extend to the whole substance of the cord, or pressure has acted on its entire thickness, both the sensibility and motion of the parts below the injury are destroyed. Several remarkable instances of paralysis have also occurred, with and without convulsions, where, after the most careful inspection, no morbid appearance could be found either in the brain or spinal marrow.

Diseases of the nerves have caused the same symptoms we have enumerated, as being dependent on diseased brain and spinal marrow. These convey impressions to and from the cerebro-spinal axis, and we may readily conceive that the sensibility and mobility of parts, may be more or less impaired according to the nerve affected.

From a survey of the facts and observations that have been noticed, and from a careful study of the details of numerous experiments, and pathological dissections, we conclude that the various theories hitherto advanced are altogether untenable. How can we suppose that the different portions of the brain can undergo a cancerous and tubercular degeneration;—be compressed by the extravasation of fluids;—or their whole substance be completely disorganized by suppuration, or the process of ramollissement, without in any way affecting those functions ascribed to them by physiologists? We never hear of the other organs of the body, such as the heart, lungs, liver, &c. suffering such dreadful lesions, without producing more or less derangement in the functions they perform, and it would be contrary to the principles of reasoning to suppose that the nervous substance alone should under such circumstances be enabled to perform its offices. It has been said that the functions of the brain are double, and that they may be carried on if one half of the brain be sound, in the same manner that we can see with one eye, respire with one lung, and so on. But instances have occurred where *both* hemispheres, *both* lobes of the cerebellum, and *both* corpora striata have been diseased without their supposed functions having been disturbed. One authentic case of this nature would throw considerable doubts on the truth of any theory, however plausible, and that there are many such, the records of pathology sufficiently prove.

I have thus endeavoured to describe how complicated and apparently opposed are the physiological and pathological facts connected with sensation and motion. In the last part of this paper we shall endeavour to reconcile the contrarieties that have arisen on this subject, and shew the conclusions that may rationally be deduced from the facts mentioned in the foregoing pages. But before proceeding to this inquiry, we shall enter into a consideration of what physiology and pathology have taught us with respect to Intellect.

SECTION II.

OF INTELLIGENCE.

Experiments on the lower animals have contributed very little to the elucidation of mental power, the nature of which is involved in as much obscurity as when it was subject to the unfounded speculations of heathen philosophers. These were of opinion that the viscera of the body, such as the heart, liver, spleen, bowels, &c. were the seats of the various mental faculties, or moral feelings,—an error that has been popularly transmitted to us in the writings of poets, and the remains of which may be still traced among the terms used in general conversation. A knowledge of anatomy and physiology however has shown that these only participate in the feelings and faculties through the nervous system, and that the brain is the sole seat of intelligence ; but whether it is dependent on this organ generally, or only on particular parts of it, is not yet decided.

The principal knowledge we possess of the manifestations of mind are derived from our observation of the disturbance caused in it by disease, together with the result of pathological investigations. The former proves to us that intelligence may be affected in a variety of ways, when the latter have been followed by no appearances of diseased brain ; and when disease has been discovered to a large extent, it is often doubtful how far the mental aberration is caused by it. It is also often difficult to distinguish whether the lesion which exists has caused the disturbance of mind only, or the death of the individual, or whether both effects depend on the one cause ; for we find, in conjunction with insanity, almost every disease to which the human frame is subject, and very often apoplexy, epilepsy, paralysis, and those affections known to depend occasionally on a morbid condition of the brain. The difficulties and opposing facts, therefore, with which an investigation of the functions of sensation and motion were accompanied, are, from the complication thus existing, increased when an attempt is made to scrutinize the seat of intelligence. The intimate connexion, also, that subsists between the mind and the body, and the facility with which they act on each other, must considerably modify any conclusion we may be led to form concerning the influence of disease upon the mind. Thus we know that the most trifling changes in the system such as repletion or fatigue of body, a feeling of cold or heat, changes in the atmosphere, &c., will often for a time prevent any great exercise of the mental faculties. There are also few diseases of long continuance which do not impair the memory, and the most trifling injuries often produce an irritation sufficient to prevent all processes of thought, and occasionally even lead to delirium. The influence of the mind over the body is still better marked; thus, great exercise of the mental faculties produces disordered digestion; various emotions accelerate the action of the lungs, and increase that of the heart, together with the strength of the circulation; depressing passions have produced various diseases, and even death itself has been occasioned in individuals who have suddenly heard of afflicting intelligence. In addition to this, the mind can be influenced by all the diseases which produce derangements in the other functions of the brain, and this by no means in a uniform manner, so that the uncertain phenomena, which have been observed in connection with this function, renders extremely difficult the establishment of any opinion which assumes a distinct part of the brain as its seat.

Little is at present known concerning the intelligence of the lower animals. That many of them perform actions evidently the result of a reasoning process, is certain. Thus it has been observed, that a dog, on being shut up in a room, has rung the bell and escaped on the servants opening the door.* The extent, however, to which different animals carry their sagacity, and the various modifications of this function to be found among the numerous races, are quite unknown. We possess no means of discovering either whether their intelligence is affected in the same manner as that of man, or by the same causes; circumstances which do not apply to sensation and motion, and which, in a great measure, render nugatory the experiments that have been performed as far as they relate to the illustration of this function.

It has been observed by Flourens, Rolando, and others, that, on removing the cerebral lobes, the animals apparently suffer

* Jesse's Gleanings.

no pain, and the injury produces no disturbance of sensation or motion, but they become dull and stupid, and apparently lose all consciousness. Many remarkable cases of injury the human brain has sustained have been published, which shew that the hemispheres are quite insensible, and that they are not followed always by loss of intelligence. Sir C. Bell* mentions the case of a man who had received a pistol ball which had passed through the head. On forcing his finger deep into the wound (the patient being quite sensible) he complained only of the integument. In diseased states of the hemispheres, however, they often become acutely sensible, as is manifested by the excruciating headache that is produced, in the same manner that bone, though generally insensible, when inflamed, causes the utmost pain on receiving the slightest injury.

Many cases have been recorded where *corresponding* portions of both hemispheres have been destroyed to a large amount without affecting the intelligence. In the Edinburgh Medical and Surgical Journal† will be found the case of a man, aged twenty-two, in whose hands a gun exploded, causing the breech to penetrate the frontal bone above the superciliary ridges to the depth of an inch and a half, carrying with it a piece of bone three-fourths of an inch in diameter. He was found shortly after by his father perfectly sensible. The piece of iron and bone were afterwards removed by a surgeon ; twenty-three days after the accident he was convalescent. Mr. Maunsall, who reports this case, says "It is quite certain a quantity of the substance of the brain was destroyed, and it is difficult to conceive that corresponding parts of both hemispheres did not share in the loss ;" yet he was not able to detect the slightest alteration in mental power ; "He pursues his usual avocations as formerly, attending to his farm, and occasionally weaving, and exhibits no appreciable deficiency in memory or acuteness of perception. Since his recovery he has been attending an evening school, and asserts that he finds no change in his capacity for acquiring knowledge."

* Anatomy, vol. ii.

† Vol. xliii. p. 76.

Dr. Abercrombie mentions the case of a young lady, who was subject, between her eighteenth and twenty-first years, to indistinctness of vision and irregular paroxysms of insensibility, with general muscular rigidity, but without convulsion. At the latter period her general health was much better, so much so that she married. Two months after, the vision was much improved; the paroxysms were suspended, "and her general health and spirits were such, that the evening before her death was spent cheerfully with a party in the house of a friend." She went to bed in her usual health, and at eight next morning was found dead. On inspection "the brain, externally, was found healthy, but when a thin section was cut from the upper part of the left hemisphere a cavity was exposed, through which a probe passed in every direction without any resistance through nearly the whole extent of the hemisphere." The whole of this hemisphere formed one great cyst, full of pultaceous matter, inclosed in a thin covering of healthy brain, which in many places did not exceed a quarter of an inch in thickness, and on the upper surface not more than one half or three quarters of an inch. *The right hemisphere had the inner part of the anterior lobe considerably softened.*"

A case is related by Dr. J. Johnson* of an eminent artist, who, for several years, had been subject to the most dazzling spectral images, the brightness of which was unspeakably distressing. The sight at length was totally destroyed, but "with the exception of some irritability of temper, there was not the slightest affection of the intellectual powers. The memory, the imagination, and the judgment were unimpaired. He was led about the streets by one of his servants; and he attended to all matters where his sight was not engaged, with the greatest punctuality." In the spring of 1835, he was seized with the usual symptoms of apoplexy. He lay in bed motionless and insensible, passing the urine and fœces involuntarily—the pupils dilated—and the power of speech gone. After a few weeks he was able to walk the city, and transact

* Medico-Chirurgical Review, vol. xxiv. p. 202, 1835-6.

business as usual—but the painful spectral images returned with increased intensity. In the month of August he was again seized with apoplexy, and died three or four days from the commencement of the attack. "The body was examined on the day after his death. There was nothing unusual in the membranes of the brain. The right lateral ventricle contained nearly two ounces of clear fluid. The left ventricle was occupied by a series of hydatid-like cysts of various sizes, and filled with fluids of various consistences and colours. This cluster sprang from the floor of the ventricle, by a kind of peduncle, and penetrated into every sinuosity of the cavity, pushing its branches anteriorly, so as to pass over and before, the thalamus nervi optici of that side, and even into the opposite hemisphere of the brain, destroying all the parts in its march. Both thalami were reduced to a pulp, as was indeed the *whole of the anterior lobes* of the brain, which would scarcely bear the slightest handling, without falling into a state of deliquescence. The optic nerves were pressed upon by the cystic hydatid mass, and reduced to a little more than the size of threads, and these of very soft consistence."

Dr. Bright* mentions a case of tetanus consequent upon a wound. The mind was not affected between the paroxysms. There was an irregular excavation on the anterior lobe of both hemispheres, in the same situation on each side, about the size of a shilling.

These cases, with others that might have been adduced, are decidedly opposed to the theory now so prevalent, which places the seat of intelligence in the anterior lobes.

The most complete loss of intelligence is occasioned by sudden pressure on the brain, and that pressure is the disturbing cause, is placed beyond doubt by the recovery of the function on this cause being removed; but if it take place gradually, no such effect is immediately produced. Thus, large tumours and abscesses may occur, which have considerably displaced portions of the brain, pushing parts of one hemisphere to the opposite side of the cranium; effusions of blood and serum

* Reports, Case 273.

may also take place slowly, causing large cavities in the cerebral substance, without producing mental disturbance. In these cases large portions of brain have been lost by interstitial absorption, a property which cerebral substance possesses in common with the other textures, and which prevents the effects of pressure. Thus, if the distension and pressure be gradually applied, the power of accommodation the brain possesses will prevent any great disturbance of the functions belonging to the healthy portion, until the disease has reached a certain extent, when its effects become manifested.

In some cases even when sudden pressure has been applied, this power of accommodation has caused one or more of the brain's functions to re-appear after having been lost for a short time ; and the following remarkable instance which came under my observation illustrates this : A musician became suddenly convulsed on board one of the Forth steamers, on recovering from which he was found to have paralysis of the lower extremities—loss of speech—when disturbed, tossing about of the arms, and violent motion of the head from side to side. The case book of Dr. Short, (under whose care he was admitted into the wards of the Royal Infirmary,) says, "he is quite sensible, and does what he is bid when spoken to," puts his tongue out when told, &c. He preserved his intelligence up to the moment of his death, which took place in the night of the day following the occurrence of the attack. On inspection, the two lateral ventricles were found much distended and filled with a mass of coagulated blood to the amount of three or four ounces on each side. The third and fourth ventricles were also filled with the coagulum, and it was traced through the fissure of Bichat to the spinal marrow, which it covered in its whole extent.

The records of pathology show that the intelligence is disturbed by the same causes that produce derangement of sensation and motion. We have mentioned some cases where it preserved its integrity when the disease was very extensive ; but, on the other hand, the application of apparently a slight cause is sufficient to occasion its complete destruction—after which it has sometimes happened that the intellectual faculties are restored either wholly or in part. Occasionally the effect of disease is only to weaken the intelligence, causing partial loss of memory; incapability of expressing ideas with fluency; an appearance of stupor and dullness, the patients being quite capable when roused, of pursuing their usual avocations, but generally exhibiting great indolence. On other occasions disease may produce the utmost excitement of mind, giving rise frequently to paroxysms of delirium which may exist at the commencement, or come on at a later period—may continue a shorter or longer time, and return at various intervals.

Many pathologists assert that they could not trace any morbid appearance in several cases of persons who had died insane; whereas others maintain that this arises from superficial observation, and that mental derangement is always the result of organic change in some part of the cerebral substance. Esquirol* mentions, that, on the examination of the bodies of 277 insane persons, he found but 77 with disease of brain; Pinel† (the father,) but 68 out of 161; and Georget‡ was not able to find alteration of the brain's substance in one half of his insane cases. Haslam,§ on the other hand, describes 37 cases of insanity which he examined, in all of whom the membranes were unsound, except one. Marshall ‖ gives 22 cases, in 21 of which serous fluid, varying in amount from one to twelve ounces, was effused into the cerebral cavities; and Mr. Lawrence,¶ who is surgeon to Bethlem Hospital, states, that he scarcely ever met with a case of insanity in which the brain was found entirely sound. Thus, one class of persons say that insanity is a disturbance of ideas only, or is a functional disease; while another party contend that it is always the result of organic changes in the brain or its membranes.

In support of the first opinion, it has been said that persons have completely recovered their reason, after remaining for some time insane; that on examining many persons who have died labouring under insanity, no disease of the brain or its

* Dict. des Sciences Med. vol. 3.
† Mag. Journ. vol. 6.
‡ De la Folie.
§ On Madness, &c.
‖ Morbid Anatomy of the Brain.
¶ On Man.

membranes has been discovered, and that the organic changes which have been observed in the brains of insane persons, have been found in others whose faculties remained perfect to the last. Though these propositions generally are correct, it does not follow, as is maintained by some, that insanity arises from mere moral causes; consists of disorder of the immaterial principle; is to be removed only by measures which operate on the intellectual faculties; and that the organic changes discovered after death are the effects, and not the cause of mental disorder. On the contrary, the supporters of the second opinion maintain, with equal truth, that mental derangement often arises from the same causes which produce numerous diseases, such as apoplexy, epilepsy, palsy, &c.; that decided cases of these disorders generally terminate in imbecility; that insanity is often periodical, connected with the alternate prevalence of inflammatory excitement and vascular debility, circumstances which increase or diminish the functions of all organs. Lastly, it is well known that insanity has followed various injuries of the brain, the repulsion of cutaneous eruptions, plethora, apoplexies, insolation, &c.

Arguing from the above facts, some are of opinion that organic change is the effect, others that it is the cause of insanity, and for the purpose of determining this question, have endeavoured to trace the origin of insanity to its source, and determine whether it be the result of moral or physical causes. The tables that have been drawn up for this purpose cannot be relied on. The reports are often fallacious, and it is often impossible to trace the origin of the disease. An individual may have his mind impaired for years without its being suspected, and to the circumstance (whether moral or physical determined by accident) which causes excitement is attributed the source of the malady.

Bayle is of opinion that insanity generally depends upon a chronic inflammation of the meninges. Several cases have been published tending to show that it arises from diseased sella turcica. Burrows states that it frequently arises from diseased liver; and others that it is occasioned by diseases of the heart, lungs, abdominal viscera, &c. These last certainly may be remote causes, (for it is difficult to conceive how the brain can be directly influenced by them,) and may operate by producing general excitement of the system. Thus delirium is occasioned by fever, mania has been produced by sprains and fractures of the extremities, and in women affected with cancer, which has subsided on the removal of the irritating cause, in the same manner as traumatic tetanus has been cured by the amputation of the wounded leg.

Much addition has been made to our knowledge of the pathology of insanity by Foville, Delaye, and Pinel Grandchamp, who, in every instance, compared healthy brains with those which were the subject of examination. Indeed the extreme care and accuracy employed in their investigations, causes the facts ascertained by them to be of great value, and renders it probable that similar appearances, not having been observed by others, arises from the imperfect method of investigation generally employed. The result of extensive observation carried on in this way appears to be, that in all cases where the intellect is permanently affected, the cortical substance is diseased. In acute cases it is more red, often with bloody spots, and minute extravasation, being apparently the seat of active inflammation. In chronic cases there is an increase of firmness and density, extending to no great depth, but uniform, which may be torn off, leaving the layer below soft, and resembling granulations. Foville has never observed adhesion of the cortical substance to the membranes in recent cases, although in those that are chronic this is common, hence he explains how the former are more susceptible of cure. It often happened that there was atrophy of the convolutions confined to the grey matter. In extreme cases of insanity, as in dementia, the grey matter was found in a complete state of ramollissement, which might be either conjoined or not with structural change in the medullary portion; in the former case the dementia is conjoined with paralysis or marasmus. From these investigations he concludes that morbid changes in the cortical substance are directly connected with intellectual derangement.* This opinion derives much support from numerous cases reported by Bouillaud† and Davidson,‡ who agree in the conclusion of Foville regarding the connexion of the cortical substance with the intellect.

Having now given an abstract of what is at present known on this subject, we shall proceed to explain the conclusions to which we have been led by an attentive consideration of the question.

PART II.

SECTION I.

ON THE PORTIONS OF THE NERVOUS SYSTEM MORE IMMEDIATELY CONNECTED WITH INTELLIGENCE, SENSATION, AND MOTION.

THE nervous system is universally allowed to furnish those conditions necessary for the manifestation of Intellect, Sensation, and Motion: but in what particular parts these are placed, or the limits assigned to each, are not determined. From the numerous facts collected, however, and more particularly from

* Dict. de Med. et Chir. Prat. Art. Aliénation.

† Traité Physiologique, &c.

‡ Medical Gazette, vol. ix. p. 664, et seq.

the circumstance that one of these may be lost without affecting the others, there can be little doubt that these important functions are situated in distinct portions of the cerebro-spinal system. In attempting to determine what particular part is connected with each respectively, it becomes important to remember that in no one single instance has it been known that mind was ever manifested without a brain, because this fact being universally admitted, we have succeeded in circumscribing the seat of intellect within the bounds of the cranium. Sensation and motion on the contrary, (which we must discriminate from irritability and contractility on the one hand, and consciousness and volition on the other,) remain perfect after the removal of a large portion of the brain, but cease on the destruction of the spinal marrow. We therefore conclude, that the principle on which sensation and motion depend, resides in this last portion of the cerebro-spinal axis, but that some part of the brain forms with it the seat of these functions.

In proceeding to examine what particular portions of the brain are more immediately connected with intelligence, sensation, and motion, it is necessary to attend to its structure as demonstrated by anatomists.

The structure of the cortical substance of the brain, is more vascular than the medullary, and is not fibrous but granular, although there is some slight appearance of fibres where it joins the white matter. It is not a simple layer, but consists of two strata, an internal and an external, the first $\frac{1}{30}$th, the last $\frac{9}{200}$th parts of an inch thick. Between these is interposed a stratum of white matter $\frac{5}{200}$ of an inch thick.

The circumstance of the cortical substance being differently arranged from other portions of nervous matter; being also more highly organized and delicate, would *a priori* lead to the conclusion that it is destined for some functions different from the rest; and it is an opinion supported by many physiologists, that it furnishes exclusively those conditions necessary for the performance of mental acts. This view may be presumed to be correct from the following facts :—

1. In the animal kingdom generally, a correspondence is

observed between the quantity of grey matter, depth of convolutions, &c. and the sagacity of the animal.

2. The results of experiments by Flourens, Rolando, and others, have shown, that on slicing away the brain, the animal becomes more dull and stupid, in proportion to the quantity of cortical substance removed.

3. Foville, Delaye, Pinel Grandchamp, Bouillaud, and Davidson, by an unusual degree of accuracy in pathological investigation, were always enabled to detect structural alterations of the cortical substance in cases of insanity; that is, by employing a degree of care which renders it probable that those cases recorded by writers where no alteration was discovered, depended on the unskilfulness of their attempts to demonstrate it.

4. An observation of the symptoms in those cases in which the disease has been afterwards found to commence at the circumference of the brain, and proceed towards the centre, shew that the mental faculties are affected *first*; whereas in those diseases which commence at the central parts of the organ, and proceeds towards the circumference they are affected *last*.

I am not aware that this last circumstance has been pointed out, it therefore requires some illustration. In meningitis the premonitory symptoms are languor, drowsiness, unwillingness to move, and inattention to the ordinary stimuli, although when roused these produce their usual effect. As the disease advances, excitement is occasioned, and delirium is produced. This may be more or less, or what is termed high or low delirium. In the former there is extreme pain with violent gesticulations and disorder of the motive functions, increased muscular strength, together with a rapid flow of ideas; in the latter, it is confined to muttering, with greater or less confusion of the intellectual faculties, and disregard of external stimuli. Lastly, coma follows, or complete loss of mind, attended also perhaps with loss of sensation and motion. But the opposite result follows in those cases where chronic abscesses, or softening, tumours or fungous growths, hydatids, &c. occur in the central portion, and gradually approach the circumference. In these, disturbances of sensation and motion are first perceived, as starting in the sleep, spasms, convulsions, paralysis more or less complete, loss of sight and hearing (from pressure on the origins of the nerves,) and lastly, the intelligence becomes impaired.*

All these facts therefore, we think sufficient to warrant our considering the cortical substance of the brain the seat of intelligence; and when the circumstances to be noticed hereafter are taken into consideration, such as the peculiar liability of the brain to pressure, the nature of the circulation within the cranium, as well as constitutional differences, this view is capable of explaining, as far as can be explained, all the phenomena occasioned by the connexion of mind with any certain portion of structure.

In the first part of this paper it has been pointed out how numerous have been the opinions concerning the seat of sensation and motion. Bellingeri thought all that part of the brain above the corpus callosum was the mental,—that below it, the sensitive and motor; and it is now generally believed that the higher portions of the brain are connected with intelligence, and the lower more immediately with sensation and motion. Anatomists have lately pointed out the structure of the brain so distinctly, that we can proceed to decide the boundaries of each with a tolerable degree of certainty.

We are indebted for our knowledge of the fibrous structure of the brain, to Malpighi, Veussens, Reil, Gall, Spurzheim, Rolando, Blainville, Foville, and Bell. I shall for the most part follow the account given by the last, both because he is the latest author on this subject, and because I have verified the accuracy of his dissections by repeating them.

It is agreed by all, that below the medulla oblongata the posterior portion of the spinal cord is connected with sensation, the anterior with motion; that they both consist of fibres arranged in parallel lines, bound together by sheaths of

* As cases illustrative of this, I may allude to those given by Dr. Abercrombie, and Dr. J. Johnson, p. 48,—and two cases reported by Dr. Bright, Guy's Hospital Reports, vol. ii. p. 280, *et seq.*

cellular tissue. On tracing them downwards, they are found ultimately to unite, and form nerves which are ramified on the surface of the body, and partake both of the property of mobility, and that of sensibility. On tracing them upwards, Sir C. Bell found that both columns partially decussated, and then again proceeded upwards in regular lines. He found the posterior columns pass to the optic thalami, the anterior to the corpora striata. So far they were distinct and separate, but, from these bodies minute fibres were given off, which mingled together, and could be traced to the cortical substance where they terminated. Hence the sensitive and motor portions of the cerebro-spinal axis may be considered distinct from each other for a certain distance, and to terminate at either extremity, where they give off numerous fibres to be mingled with each other: this takes place superiorly from the opthalmic and striated bodies, and inferiorly where the spinal nerves come off internal to the vertebral canal. Anatomy, therefore, shows us that the sensitive column extends from the optic thalamus on each side, to the termination of the spinal cord, and the motor column from the striated bodies, also to the termination of the spinal marrow.*

This view is consonant with that generally held with regard to the functions of the superior and inferior portions of the brain, and may, I think, be supported by all the anatomical, physiological, and pathological facts with which we are at present acquainted. As regards the cerebellum, it has been shewn by Reil to consist of medullary fibres, and layers of grey matter similar to those observed in the cerebrum. Mr. Solly has lately demonstrated that it receives fibres from the anterior columns; an important fact, as it proves that this portion of the brain is composed of the same structures, and most likely performs the same functions, as the cerebrum†.

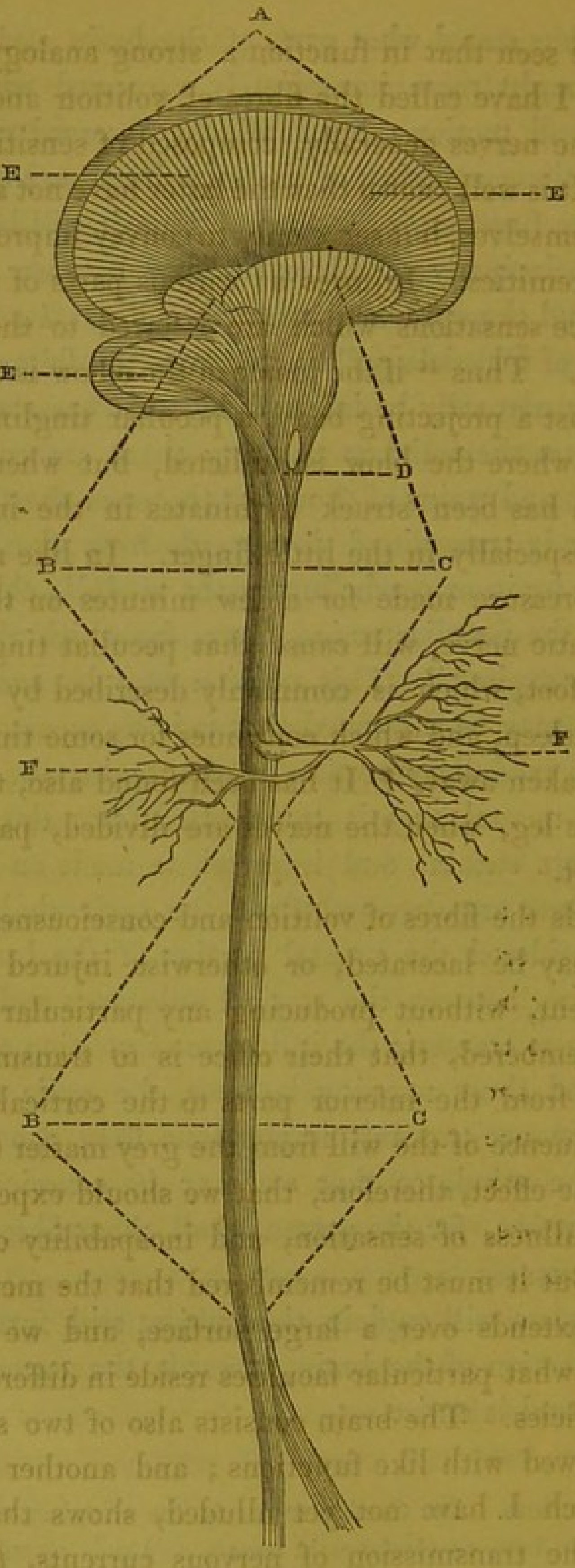
* Foville has pointed out the strong analogy existing between the central parts of the brain and spinal marrow. Phil. Mag. vol. v.

† On examining the 10th and 12th plates of Gall and Spurzheim's work, it will be seen that they delineate fibres passing from the anterior columns

I have thus stated what parts of the brain and spinal cord may be thought more immediately connected with intellect, sensation, and motion; but it will be observed that there is another portion consisting of the medullary part of the brain, for which no function is ascribed. This it will be recollected is formed principally of fibres running between the cortical substance and the optic and striated bodies. In Dr. Alison's "Outlines of Physiology," there occurs the following passage —"It may naturally be inferred in most cases of voluntary actions, where the volitions exciting them are consequent on recollections and trains of thought, (however short) some physical change is transmitted downwards from the higher portions of the brain or cerebellum to the medulla oblongata, and determines the peculiar action there, by which the voluntary muscles are excited." This opinion may be considered correct, and it may be presumed that it is by means of the fibres forming the medullary portion of the brain, the influence of volition (a mental act) is transmitted from the grey matter to the corpora striata, and impressions made on the external organs of sense are conveyed from the optic thalami to what may be considered the mental portion of the brain. Those fibres running between the cortical substance and the corpora striata serve to transmit the influence of volition to the motor column, and those running between the optic thalami and cortical substance transmit impressions from the sensitive column to the mind, so that we may be conscious of them. I shall therefore, for the present, call them fibres of volition and consciousness.

The diagram will explain this subject still further. It represents a section of the brain, towards the outer side, while the spinal cord is entire.

into the cerebellum. Dr. Gordon states in his criticism on these plates, that such fibres have no existence in nature, and it is singular that the authors of the work should not have noticed their existence, though the artist did.



A. The cortical substance or mental portion.
B. B. The sensitive column. C. C. The motor column.
D. The passage of motor fibres to the cerebellum.
E. E. E. Fibres of volition and consciousness.
F. F. Sensitive and motor fibres.

It will be seen that in function a strong analogy exists between what I have called the fibres of volition and consciousness, and the nerves generally, composed of sensitive and motor fibres. It is well known that the latter have not any peculiar function themselves, but serve only to convey impressions made at their extremities. Injuries at various parts of their course only produce sensations which are referred to their ultimate distribution. Thus " if the inside of the elbow is accidentally struck against a projecting body, a peculiar tingling sensation is felt, not where the blow is inflicted, but where the ulnar nerve which has been struck terminates in the inside of the hand, and especially in the little finger. In like manner, an accidental pressure made for a few minutes on the popliteal space or sciatic nerve, will cause that peculiar tingling sensation in the foot, which is commonly described by saying that the foot is asleep, and which continues for some time after the pressure is taken away."* It has been found also, that on amputating the leg, when the nerves are divided, pain is felt as if in the foot.

As regards the fibres of volition and consciousness, we know that they may be lacerated, or otherwise injured to a considerable extent, without producing any particular effect. It will be remembered, that their office is to transmit sensitive impressions from the inferior parts to the cortical substance, and the influence of the will from the grey matter to the parts below. The effect, therefore, that we should expect to follow would be dullness of sensation, and incapability of voluntary motion. But it must be remembered that the mental part of the brain extends over a large surface, and we are as yet ignorant of what particular faculties reside in different portions of its superficies. The brain consists also of two symmetrical halves endowed with like functions ; and another anatomical fact to which I have not yet alluded, shows that there are means for the transmission of nervous currents, (originating in trains of thought) from one hemisphere to the other, and

* Brodie on Local Nervous Affections, p. 3.

even from one convolution to others in the same hemisphere, without their being reflected from the sensitive and motor columns. Reil has pointed out that besides what have been called fibres of volition and consciousness, there are two other sets; one connecting together the near and remote parts of the cortical substance in the same hemisphere, the other running across from one hemisphere to the other, forming the different commissures.* Thus the mental portion possesses an apparatus which gives it peculiar facilities for transmitting the physical changes, or nervous currents, and we perceive there is an arrangement of fibres which somewhat explains that wonderful combination of the intellectual faculties, and those swift processes of thought which bid defiance to all attempts at analysis, and which it is impossible to follow.

The anatomical structure of the parts, therefore, in connexion with numerous physiological facts, afford strong reasons for believing that intelligence resides in the cortical substance of the brain; that sensation and motion more immediately depend on two distinct columns, the one commencing at the optic thalamus, the other at the corpus striatum, and both terminating where they unite inferiorly to form nerves: that the nerves consist of fibres, which convey the influence of impressions or nervous currents to and from the sensitive and motor columns; and that the medullary portion of the brain consists of fibres, which also transmit nervous currents arising from mental operations to and from the cortical substance, together with other fibres which perform the same office between one hemisphere and the other, or different convolutions in the same hemisphere.

Before entering into a consideration of how far the views proposed are consistent with the physiological and pathological facts brought forward in the first part of this Essay, it will be necessary to inquire what is generally understood by sensa-

* This opinion also was adopted by Gall and Spurzheim, but is partly denied by Foville, who does not consider the corpus callosum a commissure of the cerebrum, but as a plain derived solely from the crura, and therefore forming a commissure between them alone.

tion and motion. Metaphysicians consider that there can be no sensation without consciousness, and that the numerous impressions of which we are generally thought to be unconscious, arises from the circumstance that they are retained in the mind so short a period as to be immediately forgotten. Physiologists also have invariably believed sensation to be seated in some part of the brain, and have adopted the same definition. It is now, however, decided that associated movements for particular purposes, result from impressions in those animals who possess a spinal cord merely, and even in the higher animals, when the brain is removed. "Consciousness," according to Dr. Reid, is an operation of its own kind, and cannot be logically defined. The objects of it are our present pains, our pleasures, our hopes, our fears, our desires, our doubts, our thoughts of every kind, "in a word, all the passions, and all the actions and operations of our own minds while they are present." Dr. Brown does not consider it a distinct faculty of mind, he says,* "In the whole series of states of the mind then, whatever the individual momentary successive states may be, I give the name of our consciousness, using that term not to express any new state additional to the whole series, but merely as a short mode of expressing the wide variety of our feelings, in the same manner as I use any other generic word for expressing briefly the individual varieties comprehended under it."

These extracts are sufficient to show that consciousness cannot be separated from mind. Now the mind is universally allowed to be connected with brain alone; if therefore, the same sensitive phenomena are produced independent of brain, as when it is present, we must believe either that consciousness resides in the spinal marrow, or that consciousness is not essential to the performance of these actions any more than volition is. The so named sensations producing these, appear to me analogous to the involuntary motions of voluntary muscles; and the difficulty connected with this subject might be got rid of, if we consider sensation a function dependent on a portion of the cerebro-

* Lecture XI. on Consciousness.

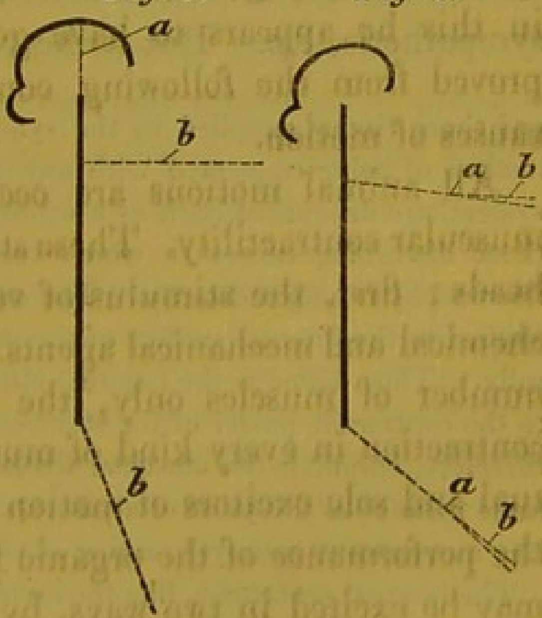
spinal axis, in the same manner as motion is a function seated in another part of the same organ; that they may both be exercised independent of mind, and yet are connected with it; but that as motion originates from the centre, while sensation is caused by impressions applied to the circumference, so volition may be one of the causes producing the exercise of the first, and consciousness one of the results occasioned by the latter.

It is obvious, however, that this view alters the meaning of the word sensation as it is at present received, and this is if possible to be avoided. It becomes necessary, therefore, to employ some new term to express those movements which are performed independent of mind, and which, *therefore*, are not connected with sensation. Dr. M. Hall has called them excito-motory, and has performed several experiments to show that they are *spinal* only, which are of the same nature as those previously brought forward by Sir G. Blane, and Le Gallois. This term is a sufficiently good one to express those movements which are independent of volition and consciousness, but unfortunately it has been applied only to a new system, or arrangement of nerves which he wishes to establish; in this he appears to have gone too far, as may I think be proved from the following considerations of the nature and causes of motion.

All animal motions are occasioned by stimuli acting on muscular contractility. These stimuli may be classed under two heads; first, the stimulus of volition; second, the stimuli of chemical and mechanical agents. The former acts on a certain number of muscles only, the latter are capable of causing contraction in every kind of muscular fibre, and are the habitual and sole excitors of motion in those muscles necessary for the performance of the organic functions. Motion, therefore, may be excited in two ways, by volition, and the external or internal application of chemical and mechanical stimuli. This has given rise to the terms voluntary and involuntary motions; the only difference between them being, that the former may be produced not only by chemical and mechanical stimuli, but by the influence of the mind, which the latter can not. But it must be remembered that what are termed voluntary muscles, often act independently of the will, on some occasions are thrown into violent contractions in opposition to its mandates, while at others the will may be exerted to cause motions and produce no effect. Thus, spasm may be produced by the sudden application of a hot iron to the skin, the prick of a sharp instrument, &c.; or convulsions, be occasioned by irritation applied to any part of the sensitive and motor column.*

It is to this last class of phenomena that Dr. M. Hall applies the term "Excito-Motory." He considers that they are produced by means of a reflex function,—this must be admitted, as the motor and sensitive filaments continue separate from their origin to their ultimate distribution. The difference between these and voluntary actions is, that, in the former, the impression is made on a sensitive nervous filament, the influence of which is reflected to a motor filament; whereas, in voluntary motions, the impression having been made, its influence is conveyed to the part acted on by means of the same filament throughout. Thus, in Fig. 1, volition arising in the cortical substance, is transmitted by a filament (*a*) to the motor column, and by means of the continuation of that filament (*b*) is sent to the muscles:—whereas, in Fig. 2, the impression made on the sensitive fibres at the outer extremity of the nerves, is conveyed by a sensitive filament (*a*) to the sensitive column, and reflected to a motor filament, (*b*) and so reaches the part acted on. In the one case, the conductor is perfect, in the

Fig. 1. *Fig.* 2.



(*a*) The nervous current, proceeding to, (*b*) that coming from the spinal chord.

* We observe continued involuntary movements in the heart, intestines

other broken. Probably the grey matter in connexion with the sensitive and motor columns bears a strong analogy to the inner layer of the brain's cortical substance, as it lies in immediate contact with the sensitive and motor filaments, and the reflex action must be conveyed through it.

Professor Müller* states that the brain also possesses this function, as shown by a vivid light and loud sounds producing reflected excitation of those parts supplied by the oculo-motor, and facial nerves, causing contractions of the iris, closure of the eyelids, &c. The same effects may be occasioned by applying stimuli to the extremities of the fifth in the face. Dr. M. Hall, however, considers all these actions spinal, and as the fifth and seventh may be traced to the spinal cord, he is so far right; the optic and oculo-motor, however, can not; and it would be therefore necessary to show that movements of the iris are not caused by the latter nerve, a point which the experiments of Mayo have established.

Physiologists are certainly much indebted to Dr. M. Hall for having clearly established this reflex function, and pointed out more accurately than had been done previously, the nature of those movements formerly denominated instinctive, sympathetic, &c. But if the views now advanced be admit-

and those viscera supplied by the sympathetic system of nerves. These, instead of being connected with any particular part of the cerebro spinal system, are dependent on it as a whole, and are fortunately placed beyond those disturbing causes to which voluntary motion is subject, and are influenced by it only indirectly. The stimuli which excite these motions are applied to the internal surface of the muscles themselves, and act mechanically. Thus, blood is the habitual stimulus to the heart's movement, food to the contractile power of the stomach, intestines, &c. These substances, therefore, stimulate the muscular fibres of these viscera mechanically, in the same manner as the prick of a pin would do, so that they differ from voluntary movements, merely by acting at all times independently of the will.

The internal sensations, like the involuntary motions of the hollow viscera, are connected with the sympathetic system of nerves. Little is known regarding them, although we may suppose they are " continually, though secretly, influencing the condition of the whole nervous system, and often to be the cause of remote morbid actions."—*Macartney, Report of Brit. Assoc.* 1834.

* Philosophical Magazine, vol. x.

ted, we must consider this reflex function as residing in the sensitive and motor columns, as they have been described, page 59, which will reconcile the difference existing between Dr. M. Hall and Professor Müller, and explain on the principles pointed out by the former, all the facts connected with this subject. It must also be considered, that these particular motions are in no way peculiar in their nature, or dependent on a distinct system of nerves, but that they are excited in the same manner, and act by the same means, as other involuntary motions,—that is, by stimuli applied to the sensitive column, either directly or indirectly, producing motion by reflecting the excitement so occasioned to the motor column, and from thence to the muscles.* In other words, as stated by a late reviewer,† these actions which are said to be chiefly connected with the sphincters, &c. differ in *degree*, not in *kind*, from involuntary movements generally.

The same reviewer‡ has also stated what deserves some slight consideration, viz.—that these movements, called by Dr. M. Hall excito-motory, are the same as the sympathetic actions of Whytt and Monro. They appear to differ, however, so far, that the one kind are excited most readily when the mind is absent, whereas in the other some mental feeling must necessarily intervene: while they are entirely prevented or suspended when the attention is strongly engaged. Thus the sudden contact of hot or cold bodies to the skin, prick of a pin, &c.,

* The following passage by Professor Müller, explains how this is accomplished: " As soon as the sensitive motion has reached the spinal marrow, it does not pass over the whole spinal marrow, but most easily to those motor nerves which have their origin nearest to the stimulated sensitive nerves; or, in other words, the easiest way for the current or vibration, is from the posterior root of a nerve or some of its primitive filaments to its anterior root, or to the anterior roots of several adjacent nerves. We see thus that the nervous principle in these currents or vibrations takes the shortest way, acting from sensitive fibres through the medulla spinalis or motor fibres; just as electricity takes the shortest way from one pole to the other." *Phil. Mag.* vol. x. p. 190.

† British and Foreign Medical Review, No. 5.

‡ It has been stated by Dr. Hall, in his Principles of Medicine, that Dr. Alison wrote the review alluded to.

if unexpected, will cause starting; but if a resolution be formed not to do so, this effect may be prevented. The mind exercises an influence over different muscles in different degrees; it also differs in various persons according to constitutional varieties. I have often seen the actual cautery applied as a counter-irritant in diseased joints; some, who resolve to bear the pain, do not move; while others, who look equally robust, cannot command themselves, and struggle violently. This modifying influence of the mind also is well seen in some American Indians, whose feelings of pride prevent their shrinking under the most excruciating tortures. The sympathetic actions of Whytt, on the contrary, instead of being induced, are arrested, or altogether prevented, by withdrawing the attention. This will appear, from the following passage in Dr. Alison's paper:* "The actions of hiccupping or sneezing, when just commencing, may very often be stopt by any thing that forcibly arrests the attention, as by calling out the name of the person. Dr. Whytt says, he had found a fit of hiccupping to be stopt by the effort of attention required in looking for two or three minutes on an object so small as hardly to be distinctly seen, such as the impression on a small coin. Every one must have observed how easily a fit of laughter, produced by the sense of tickling, may be stopt by a new emotion being excited, as by a loud sound, or the entrance of a stranger."† It is certain that this class of

* Med Chir. Trans. Edin., vol. ii., p. 178.

† And again,—" Many persons may be observed to sigh deeply immediately on finishing the reading of an interesting story, or hearing the termination of an interesting speech, to which they had been listening with what may literally be called breathless attention. Every one must have observed the coughing and sneezing which in a crowded assembly, in a winter day, infallibly succeed the profound silence occasioned by a speech of uncommon brilliancy and interest, and which imply that the causes of the sensations preceding these actions had existed for some time in many of the audience, but the sensations having been overpowered by other and more predominant feelings, their natural consequences had been suspended, until these feelings had in some measure subsided, and allowed the irritations in the air passages to become objects of attention to the mind."—p. 179.

actions cannot be produced without mind. Laughter cannot be caused by tickling an animal when the brain is removed, or sneezing or hiccupping. The stimuli which excite these are conveyed to the mental part of the brain, and by means of the reflex function it also possesses, reflected back before these effects can be produced. This is not necessary in the excito-motory actions.

It may be concluded, therefore, that there are only two kinds of motion, voluntary and involuntary, the former arising from the stimulus of volition, the latter from that of chemical or mechanical stimuli; and that the excito-motory movements of Dr. M. Hall are only involuntary motions, but more readily excited in some muscles than in others.

The principle conclusions arrived at, may be shortly summed up, as follows :—

1. The cortical substance of the brain furnishes the conditions necessary for mental acts.

2. The medullary portion is formed of three sets of fibres, and serves merely to conduct the influence of stimuli.

> The first set transmit the influence of volition from, and the result of impressions on the external organs of sense, to the cortical substance,—so that we become conscious of such impressions. Hence, they may be called the fibres of volition and consciousness.
>
> The second set connect together the two hemispheres of the brain, and convey the influence caused by mental changes from one to the other.
>
> The third set perform a similar office with regard to different parts of the same hemispheres.

3. Sensation, as it is at present understood by physiologists, expresses two things:—1*st*, That the influence of a stimulus has been conveyed to the sensitive column. 2*dly*, That this influence has been continued on through the fibres of the medullary portion of the brain to the cortical substance. In other words, we must be conscious of the impression that has been made, in order to produce a sensation.

4. The sensitive column commences superiorly with the optic thalamus on each side, forms the *posterior* part of the medulla oblongata and spinal cord, and terminates where the nerves are given off inferiorly.

5. The motor column commences superiorly with the corpus striatum on each side, forms the *anterior* part of the medulla oblongata and spinal cord, and terminates where nerves are given off inferiorly.

6. All associated movements are either voluntary or involuntary.

Voluntary movements are excited by a mental stimulus arising in the cortical substance of the brain, which is transmitted to the motor column by the fibres of volition, and continued forward to the muscles moved.

Involuntary associated movements are excited by chemical or mechanical stimuli, which are conveyed to the sensitive column, by the sensitive fibres in the nerves, and reflected to the motor column, whose filaments transmit them to the muscles acted on.

From this it follows that,

7. Voluntary and involuntary associated movements are occasioned by stimuli, the influence of which is conveyed by nervous fibres to the part acted on,—but that, in the one case, the stimulus is mental, in the other chemical or mechanical.

The movements termed Excito-Motory are of the latter class.

SECTION II.

EXPLANATION OF PHYSIOLOGICAL AND PATHOLOGICAL PHENOMENA BY THE VIEWS ADVANCED.

The numerous and apparently contradictory facts, brought forward in the first part of this Essay, may, I think, all be explained, and for the most part reconciled, by the views now advocated. They will also furnish other arguments in its support.

The experiments which have been made on living animals, although very curious in their results, appear to be of little value in determining the functions of each portion of the brain; and when we see them so directly opposed to the facts developed by pathology, we must attribute the discrepancy to numerous sources of error, which originate in the method of operating. Thus removing the cranium, or a portion of it, a preliminary step in these vivisections is alone sufficient to destroy that equilibrium of circulation on which the healthy state of the brain depends; while the most expert experimenters are unable to prevent hæmorrhage, which in so delicate an organ must assist in producing results that cannot be calculated on. When, however, the same result is derived from well performed experiments, as we deduce from observations of pathological phenomena, it tends to confirm the views drawn from either; and if to this, anatomy reveals such connexions as will warrant and bear out such conclusions, we may consider that every proof is given which conviction requires. In general, however, experiment is opposed to both the other methods of inquiry, and is, from the causes pointed out, to be distrusted; and we therefore hold, that when pathology and anatomy unite to explain an effect, we are bound, if these are always uniform, to consider them sufficient, more particularly when we remember that lesions produced by disease (although their limits are often difficult to be defined) produce results which are not liable to such violent objections, and are, therefore, much more worthy of confidence.

The three functions of the brain which we are considering, although in their nature and effects different, appear to be connected with the portions of the nervous mass on which they depend, in the same manner. They are all capable of being perverted, increased, and diminished by the same external or internal stimuli, or by the same morbid actions. In observing the effects of these, it must be remembered that the brain is influenced by them in a very different manner, and more directly than any other organ of the body. Its substance is incompressible, and it entirely fills an unyielding case of bone, so that the slightest pressure will occasion interruption of its functions; the proper performance of which depends upon a just balance of the circulation between the arterial and venous systems. Thus the application of a stimulus produces irritation, this causes excitement of the part to which it is applied, and the effect will be, an increase of the functions dependent on that part. If, on the other hand, instead of irritation, destruction of the part be occasioned, or sufficient pressure made on it, instead of an augmentation, a cessation of the particular function will ensue.

Any thing that tends to disturb the equilibrium of the circulation within the cranium produces these different effects, and they will be more or less marked, according to the degree of disturbance occasioned. Irregularity in the heart's action is the most frequent cause of this; and it may be occasioned by any of the numerous circumstances that are known to influence it, such as the variations in temperature, diseased action, use of stimulating food, alcohol, &c. An increased circulation of blood produces a rapid flow of ideas, sometimes delirium, attended with tinnitus aurium, and other disturbances of sensation, augmented muscular action, convulsions, &c. If it continues, or becomes greater, profound coma, or a loss of these functions follow. A diminution of blood is known to occasion the same results, convulsions, various disturbances of sensation and intellect, terminating in syncope, or a suspension of the brain's functions. Hence arise two methods of treatment in diseases of the nervous system, the antiphlogistic and stimulant, the latter only lately introduced by Abercrombie,* M. Hall,† and others. These physicians have shewn, that some forms of apoplexy, epilepsy, hysteria, &c. depend on plethora, while others are occasioned by a debilitated state of the system. One is cured by depletion, the other by tonics; and no circumstance more strongly exhibits the connexion between the practice and theory of our profession than this. The intelligence is influenced by exactly the same causes, and becomes disordered, from an increase or

* On the brain. † On bloodletting.

diminution of the natural stimuli. Excesses in diet and drink produce mania, and the same effect has been occasioned among the stranded sailors of the Medusa, and the ill fed peasants in some districts of Lombardy.

But the nervous system generally, and brain in particular, is liable to constitutional differences, or structural varieties, as well as other organs of the body; and we should not feel surprised that every individual is not affected in the same manner by changes in the circulation. There cannot be more than a certain quantity of blood within the cranium at once; but the balance between the arterial and venous systems may be altered in various portions of the brain's substance. Thus in some persons it produces ocular spectra, in others tinnitus aurium; in one the intellect may be principally affected, in another convulsions may be produced, or an increased degree of sensitiveness.

The circumstances now stated affect equally all the functions of the brain. It has been already mentioned, that each of these may be perverted, increased, or diminished, by the same causes. In those affections which produce disturbance of the mental powers, we may generally distinguish three stages. The symptoms in the first are, a sense of weight in the head, drowsiness, vertigo, &c.; in the second, delirium, a rapid flow of ideas, terminating in, thirdly, coma. The first is probably occasioned by the vessels changing their relative capacity in the cortical substance. As the disease progresses, the flow of blood becomes more rapid, the mental portion of the brain becomes irritated, and delirium or augmented action is the result. As the disease advances, the vessels become dilated, and a certain degree of pressure is produced; if this is sufficiently great, coma is occasioned. This may occur at once from sudden great pressure, or destruction of parts; but if the disease proceed slowly, the different effects I have described may be observed in succession.

The numerous varieties of hallucination depend on the constitution, habit of mind, external circumstances, &c. of the patient, and possibly on the part of the brain affected. But all writers have admitted the existence of three distinct classes of insanity. 1st, A degree of madness analogous to the incipient stage of nervous diseases generally, characterized by a change in the ordinary pursuits of the individual, who is more or less eccentric in his habits. The mental faculties are not injured; when roused the patient is found to possess his usual intelligence, but he is generally gloomy, reserved, and inactive. The second class simulates the delirium from disease, and there is excitement. It is known by the great mental disorder, the ideas follow each other with great rapidity, and without connexion. It is now also that the motor and sensitive tracts participate in the affection. Sometimes there is diminished sensibility, at others it is augmented. There is generally great activity of the motor organs, and the strength of the individual is often much increased. Lastly, Fatuity, or a total loss of mind, follows these two stages, and here the motor and sensitive columns have become more affected, and general paralysis is often the result. These advanced cases, therefore, closely resemble the coma of disease.

A disturbance of circulation, or irritation, causes the same functional changes in the sensitive column as in that possessing intelligence. It is perverted, increased, or destroyed, by the same means. An increase of sensibility causes pain, which is a wise provision of nature, and in a healthy state of the nervous system recalls consciousness; but when a morbid action is going on in the intellectual portion of the brain, the individual is often insensible to the strongest impressions. Destruction by accident or disease, or strong pressure, occasions total loss of sensation, and this may occur without the intelligence or motion being affected.

Motion follows the same law; external or internal irritation of the motor column produces spasms and convulsions, or excessive action more or less well marked. Even when the intellectual faculties are suspended, and volition therefore destroyed, the same results follow, shewing that it is independent of mind. But pressure on, or actual disease of that portion of the motor column, either within or without the cranium, to such an extent as will not only cause irritation but destruction, prevents this function from being called into action. Thus in cases of paralysis, although muscular contractility remains, external stimuli fail to produce flexion of the limb affected, and volition may be exerted with the same want of success.*

We see, therefore, that incipient disease, or irritation by means of moderate or partial pressure on any portion of the nervous system more immediately connected with intelligence, sensation, and motion, will produce excitement of that part, followed by an increased or augmented action; but that complete pressure, or destruction of the part on which each respectively depends, causes total loss of either.

When any part of the motor or sensitive tracts have been destroyed, a loss of their function follows in the portion below. This may arise from pressure, or disease affecting the whole diameter of the tract. It has been observed, that ramollissement has involved a great portion of the spinal cord, or has existed in some part of the tract within the cranium, or hæmorrhage has taken place in the latter situation without the usual effect being produced. It will be found, however, that in such cases which have been carefully examined, the whole thickness of the tract has not been affected. Mayo noticed, that a very thin portion was sufficient to preserve the nervous influence, if it remained sound. As the tracts diverge within the cranium, there is less liability here for the whole diameter to be involved; hence why we meet with cases of large chronic abscess in the cerebral lobes, disease of the corpora striata, &c. without producing disturbance, and others where death has taken place, and contrary to all expectation, the brain has been found extensively diseased. But all injuries of that portion of the tract in which the fibres are converged, and concentrated are followed by more marked effects; hence the fatal and immediate result of lesions in the pons varolii and medulla oblongata.

In the brain, an organ so extremely delicate, whose integrity

* I must refer to Part I. for numerous facts connected with a disturbance of sensation and motion.

is so easily disturbed, the parts forming which are so intimately connected, and capable of influencing each other, it ought not to cause surprise that the same effect is produced from lesion of different parts of its substance, or that injury of the same part may occasionally cause different results. It is this circumstance, however, which has hitherto prevented pathologists from ascribing to different parts of the brain distinct functions, and has thrown so much confusion and apparent contradiction on the study of this subject. The structural anatomy which I have shewn to exist, will however reconcile all the facts that have hitherto been considered as opposed to each other. Thus an effusion into the anterior lobe of the cerebrum may cause more or less paralysis. Now no sudden effusion of blood can take place in any part within the cranium, without causing a greater or less degree of pressure; and it will naturally act on the nearest portion of the sensitive and motor tract. Supposing the corpora striata to be the seat of effusion, these we know terminate the motor tracts within the cranium, and some disturbance of motion we should expect to follow; but from the close approximation of the sensitive tract we could not suppose it would altogether escape: hence why it is so general that sensation and motion are disturbed together. Cases have been pointed out, however, previously, where one is affected without the other, or where sometimes one, sometimes the other, is injured in various degrees, from a total suspension, to the most undefined feelings of numbness, or partial loss of mobility. This obviously depends on the greater or less degree of pressure made on the different tracts, or in other words, the degree to which they are affected either directly or indirectly by the lesion. Again, hemorrhage may take place in the cerebellum, the pressure then would be exerted on the medulla oblongata, where the different columns are concentrated, and where we should expect well marked effects to follow.*

* An interesting case, strongly corroborative of the truth of these observations, is recorded by Davies Gilbert, Esq. formerly president of the Royal Society of London. It was that of a female who reached her seven-

The explanation now offered points out the reason why partial affections of the brain, if continued, become general, and why an injury of one function leads to destruction of the rest, at once explains why lesion of different parts of the brain should cause the same results, and exposes the fallacy of the reasoning that placed the seat of motion—by some in the cerebellum, by others in the corpora striata, while another part acted as a regulator, keeping it in order.

It has been observed by all pathologists, that the same train of symptoms has been caused not only by different degrees of intensity in the same disease, but by the various diseases to which the brain is liable. Now as the morbid appearances observed after death are so different, although they give rise to the same symptoms during life, we cannot ascribe these to the nature of the diseased structure, but must attribute them to something which all these changes have in common; and it appears to me that they all act in one of two ways, either of which are sufficient to produce the morbid phenomena; 1st, Pressure with or without organic change; 2d, Destruction of the part by disease, on which one or more of the brain's functions depend.

teenth year without having ever betrayed signs of external sensation or voluntary motion. At an early period of her life she had convulsions. "Though she originally gave indications of sight, blindness came on, and cataract was observed in the eye. The sense of hearing, if it existed at all, was very obtuse; latterly it was impossible to doubt that she was quite deaf. The sense of taste seemed to be tolerably perfect, as fruit, confections, &c. were received with indications of pleasure."—"On removing the brain from the basis of the skull, so as to expose the nerves, they all appeared firm and healthy. But in the base of the skull itself not a vestige of dura mater was to be seen. The place was supplied by a thin transparent membrane, very lax and irregular, so that it afforded no protection to the nerves in their exit from the skull. On the back part, likewise, the whole, or the greater part of the tentorium was deficient, thus allowing the whole weight of the brain to act on the cerebellum."—*Med. Gazette*, vol. i. p. 562. In this case there can be no doubt that external sensation and voluntary motion were lost, by the nerves being pressed on by the mass of the brain, as they passed through their separate foramina, while the fibres of volition and consciousness being also affected, the mind had lost all connexion with the parts below.

Pressure, I have already said, is occasioned by a change in the circulation; and in many cases where organic alterations have been discovered, it is presumable that these do not act merely by their presence, but because they render the brain more irritable, and more likely to be affected by such causes as produce disturbance of the circulation. Thus it has always been noticed, that convulsions, epilepsy, insanity, &c. are generally excited by the abuse of alcohol, the passions, commencement of fevers, exanthematic eruptions, puerperal disease in the female, and indeed all affections causing great constitutional disturbance.

Were it possible so to regulate pressure or organic change, that the mental portion of the brain might alone be influenced, delirium, coma, and mental derangement might be produced, without affecting motion or sensation. In this case there would be no disposition to move, but spasmodic action might be induced by the application of stimuli. In like manner were it possible to circumscribe pressure or disease to the motor or sensitive tracts, we might cause loss of motion without loss of sensation, or convulsion and paralysis, while the mental faculties and sensibility remained perfect. In some rare instances this is the case; but the gradual manner in which the various portions of the brain are lost in each other, together with their proximity, and consequent liability of partaking in disease, sufficiently explains why in the generality of cases impairment of motion, sensation, and intellect, are more or less produced together.

I cannot conclude without remarking, that our knowledge of the nervous system has now made such rapid progress, that the nomenclature connected with it requires revision and alteration. The student is confused by the different meanings applied to the same words, the immense number of theories advanced, and the numerous circumstances it is necessary to take into account before the most simple effect can be satisfactorily explained. Those also whose knowledge keeps pace with the progress of science, must see the inconsistency of many terms in general use; and the difficulty of expressing *concisely* the various actions attributed to different portions of the nervous system. I am conscious, however, that this great revolution in physiology, is not to be accomplished by any feeble efforts of mine. It requires some mighty magician, whose wand is sufficiently powerful to break through the chains that time and custom have placed around this beautiful study; whose penetration is able to detect the fallacies and unfounded speculations with which it is encumbered; and whose genius and intellectual superiority will enable him to arrange the heterogeneous materials now collected, into a perfect system, and connect with it a terminology that will not only apply to the past and present knowledge of physiologists, but to whatever future discoveries may be made in this rich and inexhaustible field of inquiry.

With the Author's best Compts

CU

INAUGURAL DISSERTATION

ON THE

EFFUSION AND ORGANIZATION

OF

COAGULABLE LYMPH.

SUBMITTED TO

The Medical Faculty of the University of Edinburgh,

IN CONFORMITY WITH THE RULES FOR GRADUATION,

BY AUTHORITY OF

THE VERY REVEREND PRINCIPAL BAIRD,

AND WITH THE SANCTION OF

THE SENATUS ACADEMICUS.

BY

GEORGE STEWART NEWBIGGING, A.M.

CANDIDATE FOR THE

DEGREE OF DOCTOR IN MEDICINE.

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MDCCCXXXVII.

TO

WILLIAM PULTNEY ALISON, F.R.S.E.,

PRESIDENT OF THE ROYAL COLLEGE OF PHYSICIANS,
PROFESSOR OF THE INSTITUTES OF MEDICINE IN THE
UNIVERSITY OF EDINBURGH,
&c., &c., &c.,

THIS ESSAY

IS RESPECTFULLY DEDICATED,

WITH FEELINGS OF GRATITUDE AND ADMIRATION,

BY HIS FORMER PUPIL

THE AUTHOR.

ON THE

EFFUSION AND ORGANIZATION

OF

COAGULABLE LYMPH.

It has been truly said, that "the human frame carries in its composition and structure the principles of dissolution and decay;"* but it may with no less truth be affirmed, that it contains within it also the materials for repair. These are not, it is true, at all times present in the body, in a condition fit for application, but in healthy constitutions readily obey their proper stimulus; and it is worthy of remark, that this stimulus is but a modification of the same action which in a majority of instances developes the principles of dissolution. This important action has claimed the attention of medical men in all ages; for inflammation is indeed a formidable enemy or useful ally, just in proportion to the command which we are able to exert over its in-

* Thomson on Inflammation.

tensity, and while we dread its presence in many cases, we in probably as numerous a class regret its absence.

It is in what may thus be regarded as its more favourable character that we have now to consider inflammation ;* for next to resolution, its termination in adhesion or granulation must be considered as its most satisfactory result. These may, of course, occur in a locality where their effects may so interfere with the functions of important organs, as to cause great inconvenience, or the death of the individual ; but the aggregate of good gained by the process is probably more than sufficient to counterbalance the amount of evil which it may occasion.

Adhesion and granulation, though correctly described as distinct and different effects of inflammation, may in the following pages be treated of as the same process ; for in both there is the same secretion separated from the constituents of the animal frame. In the one case it forms the immediate bond of union between adjoining parts, or those separated by accident ; and in the other it furnishes a surface in such a condition as to secure its ready union, on their approximation, with any other surface similarly covered. This secretion has been variously named by authors, and the variety of nomenclature has, in all probability, been caused by the different forms which, under certain circum-

* I am aware that it is the opinion of several authors, that adhesion may take place independently of inflammation ; but such is not the view generally taken of the process in these countries, nor is it the one I feel inclined to adopt.

stances and in certain constitutions, it has assumed. Thus we find that, judging from the intensity of symptoms exhibited during life, the same extent of inflammation in a serous membrane will produce in one individual firm bands of adhesion, which in another would only produce a serous effusion, containing flakes of lymph. In the same manner, a wound in one person may heal kindly, and at once; while in another a similar wound cannot be made to unite at all by the first intention. One observer meeting with the first of these cases, would call the matter thrown out organizable; while another, on meeting with cases of the second description, would with equal propriety consider it as inorganizable. The nomenclature suggested by Dr. Thomson seems to be founded on these different modifications; for to that effusion which becomes an organized bond of union he gives the name of organizable, while he calls that inorganizable in which the adhesive process does not take place.* These two forms, however, may be reckoned as but species, comprehended under the generic name of coagulable lymph; and it may still be better, therefore, to retain this last term as expressive of the substance, and subdivide it according to the effects which variety of structure, or of the patient's constitution, may produce in this form of inflammation.

In the following essay allusion will alone be made to that kind of lymph which becomes the seat of organization;

* Thomson on Inflammation, p. 218.

and in its consideration I propose first to notice the process of adhesion or effusion of coagulable lymph;—secondly, to inquire into the manner in which this becomes organized;—and thirdly, as a branch of this last division, shortly to consider how far there is any good ground for supposing that blood under any circumstances becomes organized.

I. If the lips of a simple incised wound be brought together soon after its infliction, and kept in apposition, we find that in a very short time they will adhere, and the continuity of the parts be re-established through a living medium or cicatrix, which afterwards more or less resembles the divided tissue; though it would sometimes appear to be arrested, as it were, in its progress of assimilation, and to continue in a fibrous or fibro-cartilaginous state. This, when no larger vessel is injured, is perhaps the simplest example of adhesion or union by the first intention, and takes place in this way. On the division of the tissue blood is of course poured from the smaller vessels which are divided by the wound, and this may, according to some, become an organized connecting medium. Such, however, being a questionable result, we delay its consideration at present, and proceed to that mode of union which is admitted to occur by all observers. Supposing, then, for the present, that the blood has not formed the connecting medium, it must be separated from the part or gradually absorbed, and as it disappears the divided surfaces by degrees approximate each other, till they are separated only by a viscid gelatiniform substance, possessing some of the properties of the fibrinous constituent of the blood.

The time necessary for this process has been variously stated by different authors. Dr. Thomson says,* that in some experiments which he made on brute animals, (he does not say what animals these were,) he found a distinct layer of this coagulable lymph covering the wounds he had made, in less than four hours after they had been inflicted. Sir A. Cooper states six hours to be the time which, in dogs, intervenes between the infliction of the wound and the exudation of lymph. This period would seem, however, to be affected by the nature and habits of the animal, which is the subject of our experiment; for in man it is considered, that a somewhat longer interval must elapse, even in favourable circumstances where the constitution is good, and the parts brought soon into contact and excluded from the air, before lymph is poured out upon the surfaces of the wound. Sir C. Bell states, in his Lectures on Surgery in the Edinburgh University, that in about seven hours after the infliction of the wound, the coagulable lymph is effused. But perhaps even a longer period than this will be nearer the true average. Sir A. Cooper† mentions, that in twelve hours the edges of a wound will be firmly glued together; and if we allow a short time to elapse between the effusion of lymph and the agglutination of the parts, about ten hours may be regarded as the period which

* Op. Cit., p. 209.

† Lectures on Surgery, 18mo, 1830, p. 42.

intervenes between the infliction of the wound and the effusion of coagulable lymph. This, however, is, of course, but an approximation to the truth, for in such a question it is almost impossible to arrive at any definite conclusion.

It becomes an interesting object of consideration to enquire how the effusion of coagulable lymph takes place, for, as in the healthy state of the body there is no such product to be met with, so it may seem difficult to determine the seat of its formation on the supervention of inflammatory action. Microscopic observations have thrown little or no light on this subject, and hence we are left to the uncertain guidance of conjecture in attempting to account for the process. Some have held that it exudes from the half closed vessels, while others believe that it issues from the surface of opened cells. Mr. Hunter was led to adopt the latter opinion, because adhesion comes on about the time when surrounding parts begin to swell. Both of these hypotheses seem, however, to be very unsatisfactory, inasmuch as they only account for one modification of a general process. Were the production of lymph never met with, except when surfaces are divided, either of these might be a satisfactory way of explaining the nature of the phenomena ; but, as in many cases, there is no solution of continuity, it seems more philosophical to look for some mode of explanation admitting of more general application.

We should expect to find either a new organ brought into existence for the purpose of depositing this substance, or a new function induced in one with which we are already acquainted. But while there are no facts to encourage the adoption of the former opinion, there are many to render the latter almost conclusive.

The only conditions required for the performance of the function of secretion, seem to be the minute ramification of capillaries upon the surface of a membrane. The variety in the products of these organs is modified in a manner which, though inexplicable by us in our present state of knowledge, is not the less certain in its operation. Extent of surface, and peculiarity of arrangement may, perhaps, in some measure account for that variety ; but it is evident, that the different organs, where the secretions are separated from the blood, must each be endowed with a peculiar property or susceptibility, whereby, on that fluid circulating through them, one substance is separated in one gland while a totally different matter is separated at another. Whether these products are formed at the glands, or, existing in the blood, are only eliminated at those parts of the body where they appear, is an undecided question in physiology, though many facts, which need not be detailed here, would seem to favour the view of their circulating ready formed.

The effusion of coagulable lymph may be considered as, in many respects, possessing those characters which would class it among the secretions. It takes place, as seems now to be admitted, in the capillaries, and though the membrane on which these ramify, does not present an extended surface, yet this is a condition by no means always present where other substances, usually termed secretions, are separated from the blood. The capillaries engaged in the elimination of coagulable lymph, ramify in the cellular membrane, and this arrangement cannot be proved to be dissimilar from that observed in other secreting organs. Dr. Thomson* remarks, "that it has been supposed to be poured out from the smaller vessels divided by the solution of continuity; but it seems a more probable opinion, that it is chiefly, if not wholly formed by the secreting action of the capillary vessels of divided surfaces; for even previously, and during the exudation of this coagulable lymph in wounds and ulcers, the capillary vessels in the divided surfaces become remarkably dilated, and seem to pass into that state, which Mr. Hunter has so well described as occurring in adhesive inflammation." The same author adds, "that if the effusion of coagulable lymph ever does take place from the vessels actually divided, it would seem to depend on a change in the action of these vessels, by which they are in some measure converted from circulating into secreting organs." Whether this change takes place or not, though it may be a matter of curiosity, is of no real importance in the inquiry; for if the larger vessels, thus divided, take on a secreting action, they do so only in appearance, and not in reality. They are, in this respect, in the same predicament with large arteries in a state of inflammation, which, while they present all the char-

* Op. Cit., p. 210.

acters of such an affection, are not themselves, strictly speaking, the actual seat of these appearances. The redness, and other symptoms, reside in the vasa vasorum ramifying on the arterial coats, and but for the changed action of the former, the appearances indicative of inflammation would not be observed in the larger vessels. So it is in regard to the effusion of coagulable lymph from the divided vessels. These do not pour it out from their open mouths, neither would they appear to secrete it ; but the secretion, if it really does seem to take place from them, is performed by the vasa vasorum ramifying on their coats.

As in healthy blood several of the elements, of what may be termed the normal secretions, can be detected, so it seems very probable, that in the blood of an individual who has been attacked with inflammation, there may also be circulating the coagulable lymph which is to be eliminated at the part more particularly affected. "Inflammation" observes Dr. Alison,* "is in several instances attended with increase and alteration of exhalations and secretions already existing, and always tends to a change of the products formed from the blood at the part which it affects." In organic diseases, accordingly, which in many cases are probably the effects of a peculiar inflammation, the morbid matter which is found deposited in various parts of the body of the individual affected, is also found in the blood. This deposition must have been effected through the medium of the capillary vessels, and may contribute to favour

* Outlines of Pathology, 1st Edition, p. 215.

the opinion, that the coagulable lymph is separated in a similar manner.

The consideration here suggests itself, as to the resemblance which coagulable lymph may be thought to bear to any of the known constituents of the blood. Of these, the fibrin appears to approach to it most nearly in some of its characters; and the similarity between the two would seem to extend to the causes exciting the development of both. Thus, in blood withdrawn from the body of an individual suffering under an inflammatory attack, the buffy coat is developed on cooling, which resembles the plastic lymph often secreted at the same time so closely, as to lead to the question of how far the former may not be the constitutional symptom, and the latter the local effect of the complaint, while both depend on some peculiar arrangement of the fibrin of the blood. Dr. Alison, in his lectures, mentions a case which, though adduced by him in reference to another subject, is highly interesting as regards the present one. On bleeding a man in both arms, who had incipient inflammation in the wrist of one of them, he perceived the blood issuing from the inflamed limb to be more sizy than that issuing from the sound one. And this is an observation, which, though at first sight apparently inconsistent with one made by Gendrin, will not be found, on consideration, to be at variance with it. The last mentioned author, in his chapter on inflammatory changes of the blood,* remarks, that having bled two men in

* Histoire Anatomique des Inflammations, vol. ii. p. 438.

both arms, who had each inflammation in one of their hands—in the one case caused by whitlow, and in the other by the fingers having been crushed—he found that the blood, whether extracted from the sound or inflamed limb, was buffy; and thence he concludes, that the blood is identical in the veins of both sides, whether the vessels come from the diseased parts or not. This statement does not, it must be evident, in the least affect Dr. Alison's observation; for Gendrin does not mention how long inflammation had been established before venesection was performed, and unless, as in Dr. Alison's case, it was then only commencing, Gendrin's cases cannot be regarded as parallel with that of the former observer. For there is no doubt that, after inflammatory action to any extent has fairly set in, the sizy coat, when present, will be found on the blood from whatever part of the body it has been abstracted.

This analogy between fibrin and coagulable lymph, would seem to be strengthened by numerous observations of different authors, who have satisfactorily established that the proportions of the constituents of the blood in individuals suffering from inflammation of any importance, differs materially from that of those labouring under no such affection. The quantity of fibrin in the former, has been found to be about three times greater than in the latter, or in the proportion of seven and a half to two and a third.*

* See Cyclopædia of Anatomy and Physiology: art. "Morbid Conditions of the Blood."

The frequent occurrence of the buffy coat in blood abstracted from individuals, in whom the action prompting to the effusion of coagulable lymph had set in, affords scope for much curious investigation and hypothesis, though it has as yet engaged little of the attention of inquirers. It seems, however, very doubtful, if any very close analogy exists between these two substances; for if coagulable lymph be a modification of the fibrinous constituent of the blood, it is a modification, as regards its vital properties, to such an extent as nearly to efface its resemblance to the original. Any opinion as to their identity, accordingly, is at best an hypothesis, and quite unsupported by correct information, though it may be admitted that the elaboration which the fibrin may undergo while circulating through the capillaries, might account for a very considerable difference between it and this effusion, even if they were originally the same. Had there been any correct analysis of coagulable lymph, it would have been extremely interesting to have contrasted its constitution with that of the fibrinous part of the blood; but as I am not aware that we possess any satisfactory information on this point, upon which an opinion could be grounded, I am inclined, in the present state of our knowledge, to doubt their identity. Though they may be thought to resemble each other in some of their general characters, yet in their vital properties they appear to be totally different, inasmuch as coagulable lymph is capable of becoming the nidus of new vessels, while the fibrin of the blood, as will afterwards appear, in all probability does not possess this property, at least after its separation from those vessels which normally contain it.

De Blainville* considers coagulable lymph to be "a pathological fluid," having some analogy with synovia; but it seems probable that more extended observations will ultimately demonstrate it to be a secretion *sui generis*, and though resembling others in some of its external appearances, yet essentially different and distinct in its characteristic properties.

It may be inferred from the preceding remarks:

1. That in the human species, some time, probably about nine or ten hours, elapses after the infliction of a wound, before coagulable lymph is effused; and the same remarks will also apply to its secretion from the capillaries of an inflamed membrane.

2. That this substance is a secretion exhaled by the capillaries; and in no instance is it, strictly speaking, poured out from the divided vessels.

3. That there is no ground for doubting that it is a distinct secretion from the blood, and not analogous to any of the constituents of that fluid, such as they are made known to us in any observations hitherto offered.

II. Coagulable lymph is at first exuded in the form of a clear viscid fluid, which, gradually becoming condensed, assumes nearly the appearance of cellular tissue, in which

* Cours de Physiologie, vol. i. p. 276.

state it forms the cicatrix of the wound. Vessels are observed to ramify in it soon after its effusion, through whose medium a living bond of union is established between the divided surfaces.

The appearance of coagulable lymph at different intervals after its secretion, has been the subject of some experimental observations by Gendrin in his Histoire Anatomique et Pathologique des Inflammations. They were made on all the textures of the body, but those on the cellular tissue and serous membrane, have perhaps the greatest interest as regards the present subject. In the former he made flap wounds in some of the lower animals, and, by examining these at different intervals after their infliction, he ascertained the appearance of the lymph as the reparative process went on. By also modifying the manner of making these flaps, as well as the manner of healing them, he has enabled us to form some conclusion as to the time necessary for organization being established, though this is a point, the difficulty of determining which is attested by the variety in the opinions offered by different authors.

The first series of observations which Gendrin relates, were made upon flaps of skin, illustrating adhesion as taking place in cellular membrane. On the day after raising such a flap and immediately replacing it, the neighbouring cellular tissue on the surface of the body becomes œdematous, and between it and the flap, which is also swollen, there is found a semi-solid reddish substance feebly uniting the two parts together, in the interstices of which at this stage mercury runs easily. The serous effusion causing the œdema would seem to be absorbed, and the coagulable lymph, increasing and becoming firmer, to cause such condensation of the neighbouring parts, and closing of the mouths of the vessels, as about the fourth day, prevents injection from penetrating either into the lymph or inflamed tissue underneath. The coagulable lymph now assumes a greyish white appearance, becomes more transparent, and blends itself with the reddened cellular tissue, and on the eighth day after the wound, it can be scarcely distinguished from the neighbouring structures. It now presents evident appearances of being completely organised, for on its division, blood flows from the cut surfaces, and points like divided vessels are seen. The result of Gendrin's experiments as to the time required for the organization is rather vague, but in all probability no more definite conclusion could have been arrived at. He states it as his opinion, that there is no precise time when capillaries are sufficiently developed in the tissue of the cicatrix for transmitting the fluids, for he has succeeded in preserving flaps, after cutting off all communication with the wounded parts, except through the medium of the cicatrix, the fifth day after they had been raised and immediately reapplied, while in other cases, gangrene supervened on the section being made even so late as the twelfth day. This apparent discrepancy in his results may be accounted for, if not by idiosyncracy of constitution, yet by the condition of the animal at the time of the operation. In the hospital we have daily opportunity of seeing the effects of the same operation much varied by the state of the patient's health at the time, and by various other circumstances. Laying, of course, altogether aside the complications which the affections of the mind must create in all operations on the human species, the above remark may apply in such a way as to account for the variety, and it could only be by making the experiment on a very large scale, in exactly similar circumstances that any good average could be made. A project, however, which in its execution would involve greater sacrifice of animal life and suffering than the importance of the subject could warrant: the more especially that we find the time required for the process of reparation in mankind, to be different from that required in the lower animals. For it has been fully established by experiment and otherwise, that repair, and certainly reproduction, goes on more expeditiously and to a greater extent, the lower we descend in the scale of animals.

But even supposing the shortest period specified by Gendrin, namely five days, to be sufficient for the formation of capillaries capable of maintaining a healthy circulation, this is far beyond the time allowed by some authors for the same process in man, whose reparatory powers would seem to be much inferior to those of lower animals. The well known case of hernia, related by Sir Everard Home, would seem, if at all corroborated by other instances, to set

Gendrin's observations and conclusions completely aside. In that case, Sir Everard* states that "the vessels of the gut were minutely injected, the arteries with a red coloured injection, and the veins with a yellow one, and upon examination afterwards, all the adhering portions of coagulable lymph had a considerable artery going to each of them, and a returning vein which was longer than the artery;" and all this in twenty-four hours, for the man died twenty-nine hours after the operation, and Sir Everard Home reckoned that during the last five, no such secretion could have been going on when the pulse at the wrist was scarcely to be felt, and the powers of life were much weakened in every respect. Now, with due submission to so great an authority, some doubt must exist as to the correctness of observation in this case, and that the more, because it stands, so far as I have been able to ascertain, alone in the history of Pathology. There seems reason for thinking that the case has not been reported with sufficient accuracy as regards its details. May it not be supposed, for instance, either that old portions of exuded lymph had perhaps existed in the knuckle of intestine which was reduced, and had not, during the excitement of the operation been observed, or that a neighbouring piece of gut had on some former occasion been studded with coagulable lymph, and having, in consequence of the operation, taken on the inflammatory action, been reckoned along with the

* See his book on Ulcers, 1801, p. 33.

portion actually strangulated. There are many ways, indeed, in which such a mistake might have occurred, and it must at least be admitted, to be more consistent with the great mass of correct observations to suppose that such was the fact, than to subscribe to the accuracy of so anomalous a case. There is also the greater cause for suspecting some inaccuracy of observation or of statement in Sir Everard's case, since we know that Sir A. Cooper and Gendrin have not been able to inject the vessels in cicatrices, till about the eleventh day after the infliction of the wound. There may, no doubt, for aught we know, be something in the coagulable lymph effused in serous membranes which may allow the injection to run in its vessels easier than in those of the cicatrices of wounds, but it is not reasonable to insist that any difference can exist between them to such an extent as to require ten or twelve days in the latter for a full development of vessels, while, in the former, only one day would seem to be necessary for that process. But even in the coagulable lymph effused in serous membranes, a much longer time would seem to be necessary for such complete organization as to admit of its being injected. Thus, Mr. Villermé states* that in his observations on false membranes in man, he never saw vessels distinctly formed in them before the twenty-first day after the attack of inflammation, and at the same time quotes Stoll's opinion, who thought they were well organised

* Dictionnaire des Sciences Médicales, art. Fausse membrane.

by the twelfth day, and never earlier than the eighth or ninth. This discrepancy may, to a certain extent, be accounted for by the difficulty of fixing the exact time of the inflammatory attack; but in whatever way it has occurred, these statements corroborate the accuracy of those authors, who assign a much longer time than Sir E. Home as being necessary for the organization of coagulable lymph, whether in incised wounds or false membranes. But, though it may be much doubted if even the finest injection could have run so early as Sir Everard states, it cannot be denied that the rudiments of vessels could be distinctly seen in the coagulated lymph much earlier, for we have the authority of Sir A. Cooper that such may be the case. "On cutting into adhesive matter," he remarks, "within twenty-four hours after it has been deposited, small bloody spots may be seen which mark the future situation of the vessels which nourish it, but it is not till ten days after it has been formed, that adhesive matter becomes completely organized, for you will find that a fine injection would not enter adhesive matter sooner than the tenth or eleventh day after its formation.* These vessels have been remarked by several authors as extremely thin and delicate, much resembling those of the pia mater; and Lobstein† states this appearance to be so characteristic of them, as also the particular course in which they run, that a piece of newly organized cellular tissue might be distinguished by these features alone. He says

* Lectures on Surgery, 18mo, p. 42.

† Anatomie Pathologique, vol. i. p. 298.

their form and direction are extremely simple; they proceed in a regular course making few turns, and generally in groups like the lymphatic vessels of the limbs.

But though the appearances which the vessels of new formation present, seem now well ascertained by the microscopic investigations of late observers, yet as to the mode in which this organization takes place, different opinions have been entertained. Gendrin has furnished us with many interesting details bearing upon this part of the subject, and his account of the mere process seems to have been accurately drawn up from many highly interesting observations, though I am not inclined to subscribe to his opinion regarding the mode in which new vessels are produced. His chapters on adhesive inflammation, and inflamed textures, especially the serous, furnish us with many examples of the production of a new formative tissue, which ultimately becomes organised and thus constitutes part of the living frame. On the subject of inflamed textures, alluding to the serous, he remarks that when organization begins, the new tissue adheres more closely to the membrane than it did before, and that at those places where adhesion is most intimate, the latter is red and wrinkled, presenting a dotted appearance. It is then covered with small red prominences, in which, with a microscope, red distended capillaries can be seen to terminate, and that at the parts corresponding to them in the false membrane, there are small, red, funnel shaped cavities with their sides roughened as if by laceration, into which these prominences enter. Each of these small red cavities can be seen with a lens to form the base of from one to three yellowish striae which run upon the adhering surface of that membrane. The vessels when farther advanced in their formation, are seen to be prolonged into the false membrane, and to constitute the rugae above mentioned. He states that in examining the intestine of a guinea pig with a microscope, about the sixth or seventh day after injecting salt and water into the abdomen, small yellowish red streaks can be seen prolonged in the false membrane, which lose their colour as they recede from their origin. At a more advanced stage of organization, vascular filaments can be distinctly seen in the new tissue, which appear to be quite independent of the serous membrane, inasmuch as they look like diminutive isolated trunks which furnish small branches in different directions.

Gendrin concludes from the different experiments which he made on living animals, and from his observations at dissections of dead bodies, that the organised lymph owes its vascularity to blood being propelled by the impulse *a tergo*, from the neighbouring capillaries into the coagulable lymph, where, having hollowed out a passage for itself in the form of an irregular flexuous and unequal streak, the rudiment of a vessel is thus formed. This, if it meet with another like itself, joins it, but if not, continues to prolong itself in the least resisting parts of the new tissue. He conceives that this hollowing out of a passage by the impulse *a tergo* communicated by the heart and arteries, may be probably quite as well produced in the venous radicles by the peristaltic action of the absorbent capillaries.*

His reasons for coming to this conclusion, as drawn from his examination of the effects of inflammation on the serous membranes, seem to be founded on these asperities or prominences which have been already mentioned as being seen to sprout from the surfaces of the serous membrane into funnel shaped cavities in the effused lymph, which can be seen with the aid of the microscope to form the base of several yellowish and flexuous streaks, running upon the adherent surface of that membrane. These striae would seem to become vascular filaments incapable of carrying the red globules of the blood regularly, though occasionally admitting of their transmission. Uniting with each other, they form small trunks perceptible by the naked eye, through which the red globules pass easily, and the blood flows continuously, and not in jets as in the filaments already mentioned. These small trunks as they are now called, or red capillaries, are in some places elongated without dividing, while in others they branch out into small striae, which become colourless and invisible at the extremities, or anastomose with others similar to themselves, and thus numerous intersections are made of the red by the colourless capillaries. It is thus, if I have fully taken up the spirit of Gendrin's passage on that subject, that he accounts for what

* Op. Cit. Vol. ii. p. 365.

he considers the mistake of those, who think that new vessels in organizable lymph can be formed independently of the circulatory apparatus in isolated points, as in the coat of the vitellus. Mr. Hodgkin, too, considers this view of a "real generation of vessels," as he terms it, to be quite inadmissible, notwithstanding his allowing that "red vessels are first seen in the false membranes without our being able to trace their communication. My own opinion," he adds, "is, that at the inflamed part, the minute vessels not merely become distended, but that their delicate parietes, and the structure through which they ramify, become softened, and yielding by the pressure of the blood in the distended vessels, give way at numerous minute points."* Here too the opinion of Dr. Thomson† may be quoted in reference to the prolongation of vessels from the old into the new tissues. In speaking of the probability of the direct inosculation of the divided extremities of arteries, he observes that he is convinced that "folds of small branches are prolonged into the intermediate space, which become the channels of communication between the larger trunks that had been divided."

In summing up Gendrin's view of the formation of new vessels, it seems to be his opinion that where these capillaries are thus formed, they reunite into small trunks, which may be designated those of reinforcement. It is pro-

* Hodgkin on the Morbid Anatomy of Serous and Mucous Membranes, vol. i. pp. 49, 50.

† Op. Cit. p. 213.

bable that it is the action of these small trunks, which, in producing capillaries directed towards the serous membrane itself, and thus in some measure retrograde, is by a mechanism similar to that which produced themselves, the generating cause of the venous capillaries of which injections in false membranes found in dead bodies prove the existence.* He seems quite convinced from his numerous observations, that lymph is organized by vessels shooting from the inflamed surface, and in his conclusion he is supported by others on whose authority great confidence must be placed. Mr. James Moore of London considers,† that blood-vessels sprout into the lymph from all the inflamed surfaces, and branch through its whole substance; and Sir A. Cooper says, that the new vessels are formed by the elongation of the vasa vasorum of the surrounding arteries which become dilated, lengthened, and serpentine.‡ Mr. Cusack of Dublin, while he does not deny the possibility of vessels being formed in lymph independently of the *vis a tergo*, seems inclined to agree with the above authors in their opinion. In his Lectures on Surgery at the Park Street School, he is in the habit of quoting a case which he considers confirmatory of it, where, in a patient affected with Iritis, he distinctly saw a vessel running from the inflamed Iris into the crystalline lens, and in its course passing through the aqueous humour.

These observations, which would thus account for the

* Op. Cit. Vol. ii. p. 555.

† Dissertation on the Progress of Nature in Healing Wounds, 1789.

‡ Op. Cit. p. 43.

formation of new vessels by a *vis a tergo*, seem to be very unsatisfactory; for were this impulse of itself sufficient for their generation, the most absurd inferences would follow. Even in the absence of inflammation, the slightest increase of the heart's action might cause this prolongation of newly formed vessels into neighbouring tissues, and thus at no time could any part of our frame be safe from their inroad. If it be said that to cause this, a particular condition of the parts is necessary, we are brought no nearer our object than we were before, because it is just this particular condition which is the object of our inquiry. How far that will ever be ascertained seems extremely doubtful, beyond the simple statement that the coagulable lymph secreted in consequence of inflammation seems to possess the susceptibility of becoming the nidus of new vessels, and that these anastomosing with the vessels of the original tissues, thus establish the secreted lymph as a living part of the animal frame.

While then it seems very doubtful, if vascularity can be established in coagulable lymph by the mere impulse of the heart and arteries causing prolongation of the new vessels from the old, it seems probable that the seat of their formation resides in the lymph itself, as has been the view adopted by many authors, and is moreover supported by the manner in which vessels are formed in the chick in ovo. There we know that a vascular areola is formed around the yolk, before either the heart or arteries could convey blood to it; and hence we may infer that, though the life and nourishment of an embryo may be maintained very differently from the mode in which that of the adult is, yet for ought we know to the contrary, an analogous process may take place in each. If, therefore, we have any accurate observations tending to shew the probability of organization taking place in lymph, as it would seem to occur in the incubated egg, such analogy must present an amount of verisimilitude sufficient to throw upon those not admitting such a process the task of proving the contrary. Now, Beclard thinks "that the organisable matter of the agglutination changes into cellular tissue in which there form branched canals which gradually acquire the vascular structure, and which ultimately communicate with the vessels of the inflamed membrane."* He also adds, "On introducing a tube filled with mercury into any part of a recent adhesion at random, branched canals may be injected, the widest parts of which or the trunks, correspond to the centre of adhesion, while the branches running in two opposite directions, like those of the vena portæ, direct themselves to the serous surface, without always reaching those surfaces, and without the latter furnishing very decided villosities." This was also the view taken by John Hunter, who at the same time allowed the vascularity of the new tissue to take place by vessels passing from the inflamed parts.† His observations on this point, as made on the injected intestines

* Elements of General Anatomy, p. 103.

† Hunter on Inflammation, p. 19.

of individuals who had died of peritonitis, are thus given by himself in the following words :—" When vessels of this part are injected, we shall find that in those parts where separation has been made by laceration previous to the injection, the injection will appear on that surface like small spots or drops, which shows that the vessels had at least passed to the very surface of the intestines. In parts where the union was preserved, I have observed the three following facts. On separating the united surfaces in some places, the vessels come to the surface of the intestines, and there terminate all at once. In other places, I could observe the vessels passing from the intestine into the extravasated substance, and there ramifying, so that the vessel was plainly continued from the old into the new. In a vast number of instances, I have observed that in the substance of the extravasation, there were a great number of spots of red blood in it, so that it looked mottled. The same appearance was very observable between the old substance and the new, a good deal like petechial spots." After some remarks on these observations, he concludes that the false membrane or new tissue has the power of making blood-vessels and red blood independent of circulation. Now, these appearances on which this conclusion is grounded, might to a certain extent be accounted for by Gendrin's explanation of their being caused by the smaller white intersecting the larger red capillaries, and thus giving rise to the mottled appearance like " petechial spots," alluded to by Hunter, were it not for the result of the accurate observations made on the formation of vessels in the tunic of the vitellus. These so clearly show that vascularity may be established and maintained in a part, independent of the circulatory powers, as, in our present state of information regarding the process, to challenge our belief in its also occurring in the coagulable lymph.

This is the view also taken by Lobstein,* who considers that new vessels are formed by a vital action inherent in the coagulable lymph, independently of the agency of pre-existing vessels, from which, as admitted by Gendrin himself, it is impossible to inject the former even with mercury. Andral's† authority likewise supports the opinion of isolated vessels being generated in the new tissue before they communicate with those of the neighbouring parts. The same remark may also apply to coagulable lymph which he applies to fibrin, when he observes, "that it may at first be compared to the simplest life of those zoophytes that are composed merely of an amorphous gelatinous mass, and like the lymph, perform the functions of nutrition, secretion, and absorption, although destitute of any vestige of a circulating apparatus." This view is the more tenable when we consider the many corroborations which have of late years been added to the theory of the analogy of structure, of which this observation, if correct, is a beautiful example. The operation of this cause too will be much promoted by a pheno-

* Anatomie Pathologique, vol. i. p. 300.

† Andral's Pathological Anatomy, vol. i. p. 463.

menon observed by Kaltenbrunner* in examining the movement of the blood globules in the transparent tail-fin of a small fish. He remarks, that from their first formation, the globules of blood seem to have a disposition to flow towards the heart to which the canals formed by them are always directed, and when new vessels are developed in the cicatrix of a wound, the newly formed sanguiferous canal, before uniting itself with those which already exist, assumes the form of a crescent, the extremities of which are always turned towards the heart.

Andral further considers, that the first approach to organization is indicated by the formation of red points, such as are observed in the chick in ovo, from which he infers that the "chemical elements of this morbid production have the same tendency as those of the impregnated ovum to form such combinations as shall produce a colouring matter similar to that of the blood." In some cases he says, that a few red points only can be perceived, while in others we can perceive reddish lines or furrows of various lengths running in different directions. They are sometimes isolated from each other, sometimes anastomose. In other instances, he adds, we can observe regular blood-vessels which can be detached from the substance in which they are formed. "As their development proceeds, some of the branches of this independent circulatory system, which,

* See his paper on the circulation of the blood in volume ix. of the Journal des Sciences Médicales, p. 46.

at its commencement, was as perfectly unconnected and isolated as that of the yolk of the membrane in the egg, gradually elongate themselves so as to anastomose with the vessels of the adjacent tissues."* These views he supports by a quotation from a paper by Dr. Dollinger on the circulation of the blood, in the Journal des Progrès des Sciences Médicales, who is inclined to attribute the generation and motion of fluids in the lymph to the agency of electricity. These currents go on, according to this author, in canals which have not the coats of blood-vessels; and this conclusion,† he says, he would have come to, had he never heard of the phenomenon observed in incubation, for his own observations on small fishes, convinced him that these coats were formed piecemeal after the movements of the globules had been observed.

When vessels are formed, and communicate with those bringing on the arterial blood, there is, of course, thus established a regular current from the heart, which must, however, be again returned to the centre of circulation. In the case of false membranes, adhering by only one of their surfaces, it is comparatively easy to understand how the blood, circulating in the newly formed arteries and veins, is returned to the heart, because the apparatus in this case is, comparatively speaking, simple and continuous. In cicatrices of wounds or morbid adhesions, however, the appa-

* Op. Cit. 467–68.

† Journal des Progrès des Sciences Médicales, vol. ix. p. 13.

ratus becomes more complicated in consequence of there now being two connected surfaces. Thus in an incised wound, for instance, it seems very probable that the arteries at first only communicate with the venous capillaries of their own side of the wounds; but as the surfaces approximate each other, the cicatrix becomes denser, and the vessels being thus brought into contact with each other, unite and form a vascular net-work proper to neither surface, for the cicatrix is now assumed as a part of the body itself. There is no good reason for supposing that any of these vessels inosculate with, or join each other by open mouths, because, in the first place, such of them as were opened by the wound, would be plugged up with lymph long ere they could penetrate through the formative tissue; and, in the second place, even if their mouths were not closed, it is by no means probable that they could meet in the cicatrix so exactly as to fit into each other. Gendrin's experiments, too, corroborate the improbability of this inosculation, which was the opinion he himself was led to form on the subject, even though he strenuously supported the organization of the cicatrix by prolongation of vessels by the *vis a tergo*. He found that the vascular ramifications, however irregular they might be in their arrangement, were always prolonged in the tissue of the cicatrix before penetrating the flap, at which, in no case, did they appear to arrive directly, but ran for some length in a line parallel to the incision. Though, without doubt, a perfect anastomosis of the vessels does take place, it is extremely difficult to offer any explanation of the phenomenon, nor, so far as I am aware, has any satisfactory one been brought forward by authors. It is very probable, however, that the vascular communication between two divided surfaces may be established by their being closely approximated, while as yet the isolated canals developed in the effused lymph have not been endowed with vascular coats, and the globules of blood are still oscillating in them in the manner described by various authors. In the course of this oscillation, the globules proper to one surface may run into the canals formed in the other, till a net-work is thus produced, which, when these vessels are endowed with coats, and the blood begins to flow through them, is so perfect as to be traceable to neither side.

Dollinger describes these globules as in a state of constant antagonism to each other. At one time they may be considered, according to him, as separate pieces of animal organism, and at other times as having a relative existence dependent on their general connection with the sanguiferous system. "It is thus," says he, "that we see them approaching and repelling each other, moving and being moved, separating themselves from the sanguiferous system, and again uniting with it."* These observations, when taken along with the following, by the same author, would seem to favour the theory advanced above. "Sometimes small arterial currents meet each other in coming from op-

* Journal des Progrès des Sciences Médicales, vol. ix. p. 35.

posite sides, and form an anastomosis. From this a new current is established ; the globules of blood from the two sides approach each other in the current, but when the anastomosis presents itself, the globules coming from opposite directions mutually resist each other. I have seen two globules thus meeting mutually arrested, and each balanced by the other, then repel each other, approach and recede. At last one of the two yielding, takes a fixed direction, and returning, is followed by the other." Ramifications will thus be prolonged to either surface, till they join the vessels there, and produce the vascular communication ultimately observed to exist in the new tissue.

Before quitting the subject of vascular development in coagulable lymph, Laennec's description of the organization of false membranes may be referred to. He describes the first appearance of vessels to be irregular lines of greater dimensions than those vessels by which they are to be succeeded. He remarks, that the " blood seems as if it had been forced into the substance of the false membrane by a strong injection, and we find the corresponding portions of pleura redder than elsewhere, and, as it were, spotted with blood. After a time, the pseudo-membranous layers become thinner and less opaque, the lines of blood assume a cylindrical shape, and ramify in the manner of blood vessels, but still observing their augmented diameter. On minutely examining these at this stage, we find their external coat consisting of blood scarcely yet concrete and very red ; within this, there is a sort of mould or rounded substance, whitish and fibrinous, and formed evidently of concreted fibrin perforated in its centre, already permeable to the blood, and evidently containing it. Eventually, these vessels exactly resemble those which ramify on the inner surface of the pleura."*

These observations perhaps do not exactly bear upon the question, as to whether the new vessels are formed by the direct impulse of the blood from the heart and arteries, or by being first moulded in effused lymph, and then receiving from the arteries the blood which entitles them to rank as part of the vascular system. If correct, they at least throw some light on the structural anatomy of these vessels, which cannot but be interesting. Laennec seems however to support the theory of these lines of blood being formed by the impulse *a tergo*, but on the supposition of his taking the other view, though he describes their structure, he gives us no clue by which we can ascertain the mode of their generation.

Sir Everard Home who considered that extravasated blood could become organised, offers an explanation of this process, which, though not very tenable, may here be mentioned. In his Croonian lecture read to the Royal Society in June 1817, on the changes which blood undergoes during its coagulation, he gives an account of some experiments which he made along with Mr. Brande, in order to ascertain the manner in which coagulable lymph or extravasated

* On Diseases of the Chest—Translated by Forbes, p. 398.

blood was permeated by vessels and became a living solid. In these he was directed by an observation made a short time previously by M. Bauer in regard to the prolongation of the tubular hair in germinating wheat. M. Bauer remarked, that in the earliest stage of the vegetation of that grain, a kind of slimy pustule accumulates on the surface of the young root, through which a bubble of air bursts, (ascertained to be carbonic acid gas), and then blows, as it were, a tube, of which this slimy substance forms the walls. With this before him, Sir Everard set about to establish the likelihood of a similar process taking place in the animal economy. The conclusion to which he came from his experiments on this subject was, "that blood in coagulating gives out much carbonic acid gas, which in the course of its extrication forms a network anastomosing with itself on every side, through every part of the coagulum." In this way, he says, there is no difficulty in accounting for the manner in which blood extravasated in living bodies afterwards becomes vascular, "since all that is necessary for that purpose is red blood being received into the channels of which this net-work is formed."*

This is indeed a beautiful theory, and its simplicity and elegance are such as to make one wish it were a sound one. It is, however, by no means ascertained that extravasated blood ever becomes organised, and even if it were, I doubt much if this could explain the rationale of the process in

* Philosophical Transactions, 1818, p. 182.

such a nidus, at all better than it does with regard to coagulable lymph. That carbonic acid gas is given off during the coagulation of blood is now very well ascertained, and, though not so well established, it may be admitted to form such cavities or canals in the coagulum as are described by Sir Everard Home; but it remains yet to be proved that such can take place in the lymph secreted in the living body. It is not easy to see how this can be determined either in one way or the other by experiment made during life; and as it would appear that these phenomena are by no means the property of organic fluids alone, they cannot be fairly held as accounting for the vital process of the formation of new vessels.

But even supposing that such were the appearances discernible during life, it cannot be shewn that they would help us at all to an explanation on this subject. The question still remains as to the manner in which blood circulates through a false membrane, and it cannot be expected that canals thus mechanically formed can be fit instruments for circulation or secretion. We must at last call in the aid of a vital action to give them this property or power, and it would be better and simpler to ascribe to this at once the whole agency.

The results of the preceding observations would seem to be,—

1. That soon after the secretion of coagulable lymph, perhaps even in a few hours, blood vessels begin to form in it, but that no vessels capable of carrying injection can be

detected for several days, at least five, after the commencement of inflammation.

2. That the seat of the formation of those new vessels is in the coagulable lymph, which is endowed with this vital property or susceptibility : and that these new vessels are not referable to any mechanical origin.

3. That in these new vessels, blood is formed independently of that coming from the heart and arteries.

4. That the action of the heart and arteries, or the *vis a tergo*, has little or no effect in the production of new vessels, but can only act in establishing the connexion between these and the vessels of the original texture.

III. Physiologists have entertained very different opinions on the question as to whether or not blood can in any circumstances become organized. It is a subject still fraught with much difficulty, for while arguments are not wanting in favour of its being the seat of organization in some cases, there would appear to be sufficient evidence that in others it does not possess such a property. Without being at all inclined to deny the vitality of the blood, I think it is extremely doubtful if blood ever becomes organized when once separated from those vessels which normally contain it.

Mr. Hunter, however, and after him Sir Everard Home, were in favour of such a process taking place in blood in such a condition ; and the opinion of the latter regarding the manner in which the vessels were formed, has been already alluded to. It is to be feared that he has been precipitate in rearing up an hypothesis to account for a phenomenon whose existence he ought first to have properly established; for though many circumstances might lead to the inference that blood may become organized while contained in its vessels, no convincing observations have, so far as I am aware, been adduced in favour of such a process occurring in blood which has been extravasated. Mr. Hunter has throughout his writings explicitly stated his belief that the blood can in this state become the nidus of vessels, but one would almost be inclined to think that in his work on the blood, he had somehow taken up the impression that it had such a property, and perhaps never applied his powerful mind to the subject so closely and dispassionately as to be undeceived.

In all the instances adduced by him, the organization can at best be only said to have taken place in situations where blood had been previously effused, for it cannot be said positively that it took place in the blood itself. Though it may be admitted that vessels existed in the substance formed where blood had been extravasated, it seems extremely doubtful whether this nidus was the residue of the blood itself, or a new secretion which the former, acting as a foreign body, had excited the neighbouring capillaries to give out. Blood may indeed assist in keeping divided surfaces together for some time after a wound has been inflicted, but this would seem to be merely the agglutinating effect of its albumen, and not the living bond which is to form the cicatrix. Were coagulable lymph not effused, this agglutination by blood would in a short time be broken up, and granulation from the bottom of the wound take place in order to restore the continuity of the surface. As coagulable lymph is secreted, however, the blood is absorbed, and the former becomes the seat of vascular ramification. That this tissue was the residue of the effused blood, would seem at first sight to be proved by several morbid appearances, of which those occurring in the brains of individuals who have died after apoplectic attacks are perhaps the most striking. If the brain of one who has died a few days after such an attack, be examined, the effused blood will be found in a fluid state ; if after the lapse of a few weeks, the blood will still be found there, but enclosed in a cyst or sac ; and if the brain be examined a considerable time subsequent to this, when the patient has recovered from the first attack, but has died of a fresh one, or some other disease, nothing can be seen but a nucleus of coagulable lymph, from which the more liquid parts appear to have been gradually absorbed.

These appearances might seem to support the opinion of the fibrin of the effused blood ultimately becoming organized, were it not for the observations which practical surgeons constantly have an opportunity of making on the decided interference which the effused blood presents to the union of wounds. They find that the more completely a wound can be cleared from such superfluity, the surer are they of obtaining a favourable result in union by the first intention, and that in all cases the blood would seem to act only as a foreign body. This seems to be its effect in these apoplectic cysts to which allusion has been made. Its presence there, acting as a foreign body, sets up, by its irritation the adhesive inflammation around it, and coagulable lymph being poured out, forms a cyst just in the same manner as we find a bullet enveloped in other parts of the body. The blood is afterwards gradually absorbed, and thus when examined some months after the attack, the brain presents no appearance but this patch of lymph.

If blood could be extravasated without losing its vitality, there might be some grounds for admitting the probability of the organization of its clots. Observation, however, while it renders this extremely doubtful, favours the view that its being contained within its vessels, is one of the conditions necessary for the maintenance of its life; and as effusion from these would thus imply its death, that must be a state incompatible with any living process such as organization. Mr. Hunter thought that the coagulation of blood was the last exertion of the vital properties of the fibrin, and was analogous to the stiffening of the muscles after death. The analogy fails, however, in one important feature, because the stiffening of the muscles goes off in some time after death, but the buffy coat of blood withdrawn from the body is not so affected, but continues concrete. I need not at present enter more fully on this subject, as it seems now the more generally received opinion, that the coagulation of blood, when withdrawn from the body, may be regarded as the effect of its loss of vitality; and this remark may be carried still farther, because there seems ground for believing that, even when extravasated within the body, the blood is also in that case deprived of its vitality. Against this statement there may be urged the case of hydrocele, which is furnished to us by Mr. Hunter, where the coagulum of blood found upon the body of the testicle a month after the tunica vaginalis had been tapped, appeared to have been injected. Here, however, some mistake in observation may very reasonably be inferred, because Mr. Hunter himself tells us that "the surface of adhesion of the larger coagulum was injected for only about one-twentieth of an inch, and that the smaller one was in many places injected through and through, and in others only for a little way along the surface of the adhesion."* May it not be supposed that the phenomena described, if not occasioned by adhesive inflammation caused by the puncture of the lancet, may be explained by reference to what has been already said as to coagula of blood acting the part of foreign bodies, and thus setting up inflammatory action in their neighbourhood, which in its turn again prompts to the effusion of coagulable lymph.† This effusion seems in the

* Hunter on Inflammation, &c. p. 571.

† Since the above was written, I have been informed by Dr. Alison, that Mr. Clift, the Conservator of the Museum of the College of Surgeons of London, after a careful examination of the preparation alluded to, has come to the conclusion that the substance injected on the body of the testicle was not the coagulum of blood, but lymph subsequently effused.

case of the larger coagulum to have been so thin as one-twentieth of an inch, and in the smaller one may be assumed as having been in some places even thinner, and thus accounting for its being partially injected "through and through." Here, too, Mr. Hunter, in his anxiety to prove the organization of the clot of blood, seems to have gone too far, and entirely forgotten his own opinion as to the mode of formation of the new vessels. For if it really were the coagulum of blood which had become organized, should we not, according to his views, have had more of it injected, because vascularity is established, "not only by the impulse of blood *a tergo*, but also by the formation of vessels which the coagulum has the power to form in and of itself;" and a month should have been sufficient time to admit of a connection being opened between these isolated vessels and those of the testicle. The same remarks will of course apply to another case of supposed organized clot of blood in the uterus, also mentioned by Mr. Hunter along with the preceding.

On the whole, then, it may not be regarded as over-scrupulous scepticism, if these cases be not held as at all satisfactorily establishing a phenomenon which we have positive proofs does not take place in an overwhelming majority of cases. In such a question as this, no doubt one well authenticated case would amount to a positive proof of the possibility of the occurrence, rare though it might be, but the cases where it has been alleged to have taken place are so solitary, and so unsatisfactorily proven, (if indeed they can be said to be proven at all), that in our present state of information, till further corroborative observations on the subject be furnished, such a process cannot reasonably be held to occur.

There are, however, some cases in morbid anatomy which would serve to strengthen the probability of blood becoming organized when it is not effused from its containing vessels. The coagula in different blood vessels are adduced as instances, though even in them it is often doubtful whether the matrix of the new vessels is the original clot or the plastic lymph effused in consequence of their presence. Of such formation we shall now only notice those concretions termed phlebolites, which are sometimes developed in the veins, and have been described by different authors; as also such bodies occurring in the cavities of the heart as have been proved by injection or correct observation to be the seat of vascular ramification.

With regard to the formation of phlebolites various opinions have heen advanced, on the respective soundness of which depends, in a great measure, the alternative, whether these bodies can or cannot be regarded as assisting in the proof of the organization of blood. Andral considers that cretaceous matter is first formed behind the lining membrane of the veins, which is gradually protruded into their caliber, and may there either be suspended by a peduncle, or, in consequence of this giving way, may drop loose into the vessels.* The opinion of those authors, however, seems to be the more correct, who think that phlebolites are formed from the blood; and the delineations given by Dr. Carswell† shew that a coagulum is first formed in the vein, in whose centre a small nucleus is gradually developed in concentric layers, and after a certain time, the colouring matter having disappeared by absorption, the body is then found to consist entirely of fibrin. The change from this state would seem to take place in layers, till the whole body become, in a manner, ossified.

Such is also the result of my friend Dr. J. Reid's observations on the subject,‡ who tells me that he has seen phlebolites in many different stages of their progress; and from what he has remarked, it would appear that Andral's statements are founded on observations made only upon those bodies in their mature state. Dr. Reid has seen them as coagula of blood and of fibrin, arranged in concentric layers, varying in density from the centre to the circumference, with no calcareous deposit within them at all. Others he has examined which contained in their centre a very small quantity of gritty matter, while some were altogether a cretaceous mass. It is not easy to understand how these coagula of blood could remain unat-

* Pathological Anatomy, vol. ii. p. 423.

† See his Eleventh Fasciculus of Pathological Anatomy.

‡ See some excellent observations by this gentleman in the Edinburgh Medical and Surgical Journal, No. 122 and 123.

tached to the sides of the vessels without being carried forward in the course of the circulation to the heart, though such stagnation may, to a certain extent, be accounted for by the fact, that most, indeed I believe all the cases of such bodies being generated, have occurred in parts whose dependent situation or other anatomical relations impeded the free flow of blood through the veins. Laennec quotes many examples of organised coagula occurring in veins and arteries in other situations, but these were united to the coats of the vessels by one or more attachments.

At some period of the formation of all such bodies, whether phlebolites or others, it seems probable that there must have existed some attachment to the sides of the vessels, probably in consequence of the local irritation which they must there have excited; for without such living connection it is difficult to conceive that they could have progressed to the state in which we find them. In confirmation of this, Laennec remarks,* "that the more recent concretions are not adherent, but only those which are proved by their firmness and comparative dryness, and otherwise changed condition, (and also sometimes by the contraction of the vein,) to be of ancient formation." Dr. Reid, however, who, as I have said, has seen phlebolites in all their stages, has remarked that he never found any attached to the sides of the vessels, nor could he, in those which he examined, discover any appearance to justify him in considering that they had ever been so united. Though

* Op. Cit. p. 608.

much doubt must still exist as to the manner of their formation, the phenomenon cannot be regarded as unimportant in relation to the present question. It does not seem probable that they will be found to be the product of mere mechanical deposition of calcareous matter ; and I am rather inclined to adopt the opinion of Dr. Reid, speculative though it may at first appear, that " they are the result of a process resembling the formation of osseous tissue in the other parts of the body ;"* and if the mode of their formation may be thus explained, they may constitute an important argument in favour of the possibility of blood becoming organized while contained within its vessels. The theory of those who would attribute their formation to the mere separation and mechanical conglomeration of the earthy salts moving in the blood, seems scarcely tenable ; for all authors who have examined them, concur in the description of the calcareous layers extending from the centre outwards ; and this could not be the appearance presented, unless their formation took place by interstitial deposition, which is the characteristic mode of increase in all organised substances. Jules Cloquet† gives delineations of two, in one of which there

* Their chemical analysis, as given by Gmelin and verified by the report of Mr. Kemp of this city to Dr. Reid, shews that their constituents are similar to those of bone.

* Pathologie Chirurgicale. Pl. iii. I have lately examined several of those bodies which I found in the uterine veins of a woman of about 40 years of age, and found them to correspond very closely with the delineations given by Cloquet.

was a bony nucleus in the centre, enveloped by fibrinous layers, and in another the nucleus consisted of "whitish fibrin;" the description of which appearances would certainly favour the opinion of the calcareous matter being secreted in the coagulum, and not mechanically deposited by the blood in its circulation.

It may be thought by some, that I should have here adverted to the coagula formed some way up in the arteries, which have been torn by accident, or enclosed in ligature; but, as in these cases the fibrinous clots or plugs seem evidently the produce of the exudation of coagulable lymph, caused by the adhesive stage of inflammation, they cannot be considered as bearing on the present part of the subject. In all cases, indeed, of blood becoming organized, its colouring matter is generally absorbed before the formation of vessels, and thus, strictly speaking, it is the fibrin which becomes the tissue in which the new vessels ramify; but then, in arteries which have been tied or ruptured, the plastic lymph effused in consequence of inflammation is the original coagulum, whereas, in the former cases, it is probably the residue of a clot of blood.

Those polypous bodies which, under various forms, are sometimes found in the heart, may also favour the probability of blood becoming organized while contained within its vessels, though the doubt which seems to be connected with their original formation, must make us careful in admitting them as positive proofs. It is unnecessary here to take any notice of false polypi, as they have been called, which occur in the heart and arteries after death, inasmuch as they seem to be formed in the same way as the buffy coat is formed in blood which has been abstracted from the body. They seem to be the concreting of the fibrin which takes place either after death, or immediately before it when the circulation is extremely languid. They are found generally of a homogeneous yellowish appearance, without the least symptom of vessels having been formed in them, if we except the bloody discoloration which, however, is clearly the effect of the entanglement of the red globules in the meshes of the fibrin during its contraction.

But there are many instances of abnormal formations taking place within the heart during life, which certainly appear to become organized, though the mode in which this process takes place be not yet ascertained. If we adopt Laennec's* view, those vegetations or warty excrescences formed at the base and free margin of the valves, are mere modifications of organized polypi, and would therefore, as well as the latter, require to be noticed here. Dr. Hope's† opinion would seem, however, to be more correct, in considering these two productions to be differently caused, inasmuch as amongst other valid reasons, the vegetations seem to be attended with apparent lesion or disease of the internal membrane, while polypi are found to exist without any such appearance. The former cannot accordingly be considered as favouring the theory of the organization of

* Op. Cit. p. 612.

† Hope on Diseases of the Heart, 1832, p. 320.

blood, because their existence would appear to be caused by "inflammation modified by some other morbid cause;"* and hence it is more probable, or at least equally so, that they are formed from the plastic lymph effused by the adhesive inflammation in the lining membrane, than that blood was the original nucleus. These coagula, according to Hope, by irritating the lining membrane of the heart, effect their adhesion to its walls by the lymph exuded by the latter. It will be better, therefore, not to enter on the very debateable ground of the formation of these vegetations, but rather trust solely to such instances of organized clots as have been by the generality of authors supposed to commence independently of any morbid state of the containing vessels or cavities.

Organized polypi are considered by some to owe their formation to inflammatory action; but by others the opinion is held that they are produced without any such cause. The latter is the conclusion arrived at by Laennec, Hope, and others. They attribute their formation to "retardation, and consequent stagnation of blood;" and Dr. Hope† thinks that the adhesion to the walls of the heart is caused by the "irritating action of the body itself, whence there results an exudation of lymph which forms the agglutinating medium." It would seem that in going thus far, he invalidates the probability of the non-inflammatory origin of these bodies, because the action which he

* Hope on Diseases of the Heart, 1832, p. 323.

† Ib. p. 509.

now calls in for their adhesion, is such as would have singly occasioned a similar production. This being the case, before allowing that they can be formed by simple retardation, some positive proofs must be adduced of their formation in that manner, since we have so many instances of inflammation causing similar phenomena.

That these bodies, however, are not the product of the effusion of coagulable lymph, but can be formed in the absence of inflammation, is rendered probable from the consideration that we frequently find in the heart and larger vessels immediately after death, fibrinous masses of such consistency as strongly to favour the opinion of their having been formed during the life of the individual,—that these bodies are unattached to the walls of the containing cavities, and in many cases no appearance can be discovered on their surface, such as can induce us to infer that they had ever been so attached,—and that the lining membrane of the heart or vessels in such cases presents no traces of the previous existence of inflammatory action. When polypi have thus been formed, a question arises whether their organization takes place solely within themselves, or whether a connecting medium is first established with the walls of the heart. The remarks already made on phlebolites will be equally applicable here, for in both cases though the observations of some authors would lead us to think that organization must go on before there is any attachment, yet those of others are equally in favour of such being necessary. The latter view appears in some measure to be supported by an observation of Laennec on what he terms "globular excrescences," which Dr. Hope considers identical with polypi. He remarks that the peduncle attaching them to the walls of the heart, "seems as if it were of more recent formation and less perfectly organised than the body itself;" and if such be the fact, it may be inferred that organization may have been progressing to a certain degree in the excrescence before its adhesion to the walls of the cavity. It seems highly probable that here, as in the organization of the coagulable lymph effused in inflammation, the opinion of both parties may to a certain extent be equally sound. The fibrin of the blood thus coagulated within its vessels, may still have the power ascribed to it by Mr. Hunter, of "making blood vessels and red blood independent of circulation;" though that circulation of the fluids necessary for continuing the vitality of the clot may not take place till it be connected with the walls of the heart. Vessels may accordingly be developed in the new tissue of the polypus, even before it becomes united to the walls of the heart, and afterwards through the medium of the peduncle, those from that organ may be prolonged, and circulation* be thus established.

Whatever the process may be, we do not want examples† of such organised polypi, while there seems reason for believing that clots of blood have originally furnished the

* See Bouilland, Traite Clinique des Maladies du Cœur, vol. ii. p. 609.

† Ib. p. 606. Hope and Laennec as quoted; also Burrow's Lectures on the Blood, vol. xvi. Medical Gazette.

nidus without the presence of inflammation, though that action would also seem in many cases to favour the progress of their organization.*

Amid the many conflicting statements regarding the capability of blood becoming the formative tissue of new vessels, nerves, and lymphatics, it is very difficult to form any decided opinion. The conclusions, however, which would seem to follow from what has been stated, are,

1. That it is extremely doubtful if in any case the process of organization can take place in blood which has been extravasated.

2. That facts are not wanting which seem to support the probability, that while still within these cavities which normally contain it, blood may coagulate during life, and become the basis of an organized tissue. Whether this can take place, however, independently of inflammatory action, is a point of much difficulty to determine, though some observations appear to favour the probability that it may.

The organization of coagulable lymph and blood has thus far been considered, only as regards the ramification of blood-vessels, and no mention has been made of the other characteristics of the phenomenon, viz.—the development

* Other evidence might have been adduced of the probability of organization taking place in these bodies, such as the appearance of purulent collections in the fibrinous cogula found in the cavities of the heart, &c. I regret however that time will not at present permit me to enter on such considerations.

of nerves and lymphatics in the formative tissue. The appearance of these, however, need not occupy a prominent part in this paper, on account of the observations already offered on vascular formation. If in the latter case, it would appear that vessels are formed in the new tissue independently of any influence of the heart, by a vital process of whose nature we are ignorant, it may with equal fairness be concluded that nerves are developed in a similar manner. Observations too, which have been amply verified, go to prove, that where portions of nerves in living animals have been injured or removed, a substance is formed to repair the lesion, which sooner or later assumes their true vital properties.* Thus then, as it would appear that nervous substance can be reproduced in the living body when arrived at maturity, and as in fœtal development its formation is independent of its centre, so its generation in the new formative tissue would seem to be in the same predicament with the development of new vessels, and thus render further notice unnecessary.

The same remarks may be applied to lymphatics, for though in regard to their formation we have less correct information than in regard to blood vessels and nerves, yet there is good reason for concluding that their development in the new tissue takes place by a process similar to the others.

* See Dr. Alison's Outlines of Physiology, p. 139.

ON

SOME CIRCUMSTANCES TO BE CONSIDERED

IN RESORTING TO THE

OPERATION OF BRONCHOTOMY.

ith the Author's best compliments

A

PROBATIONARY ESSAY

ON

SOME CIRCUMSTANCES TO BE CONSIDERED

IN RESORTING TO THE

OPERATION OF BRONCHOTOMY;

SUBMITTED,

BY AUTHORITY OF THE PRESIDENT AND HIS COUNCIL,

TO THE EXAMINATION OF

The Royal College of Surgeons of Edinburgh,

WHEN CANDIDATE

FOR ADMISSION INTO THEIR BODY,

IN CONFORMITY TO THEIR REGULATIONS RESPECTING THE ADMISSION
OF ORDINARY FELLOWS,

BY

GEORGE STEWART NEWBIGGING, A.M. M.D.

AUGUST 1837.

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TO

WILLIAM NEWBIGGING, Esq., F.R.S.E.

FORMERLY PRESIDENT OF THE ROYAL COLLEGE OF SURGEONS,

&c., &c., &c.,

THIS ESSAY

IS MOST AFFECTIONATELY DEDICATED

BY HIS SON,

THE AUTHOR.

TO

WILLIAM WOOD, Esq., F.R.S.E.,

FORMERLY PRESIDENT OF THE ROYAL COLLEGE OF SURGEONS,

&c., &c., &c.,

THIS ESSAY

IS ALSO INSCRIBED,

IN GRATITUDE FOR PRIVATE FRIENDSHIP,

AND ESTEEM FOR HIS PROFESSIONAL CHARACTER,

BY

THE AUTHOR.

ON

SOME CIRCUMSTANCES TO BE CONSIDERED

IN RESORTING TO THE

OPERATION OF BRONCHOTOMY.

Wounds of the windpipe have generally been regarded with a peculiar dread, not only by those whose ignorance on such subjects precluded the possibility of their judging correctly upon them, but not unfrequently also by medical men themselves. That such an impression should have prevailed among the former class of observers is not at all surprising, because it is no uncommon occurrence to find that the less informed an individual is upon a subject, the more liable perhaps is he to form hasty and false generalizations from the too limited knowledge which he possesses of the various bearings of the fact brought under his notice. Thus it was well known to those not versed in medical matters, that in many of the cases where wounds about the trachea had been inflicted, the patients died after the accident, and the windpipe, with the importance of whose function all seem duly impressed, appearing to them to be the most vital organ in that neighbourhood, the conclusion was at once drawn, that its division or injury must be the sure and unfailing cause of death. The fatal result of such cases, however, is in reality attributable, not to the injury which the trachea has received, but to that done to other important structures in its immediate vicinity, and this, though no recently established fact, gives rise to the question why some surgeons should have for long regarded operations on the trachea as fraught with peculiar danger.

Simple wounds of the trachea are by no means such formidable accidents as they were once thought to be: and indeed they appear to be attended with but little danger. Even when rudely produced, as in those cases where they are the consequence of accident or the attempts of the suicide, they are of themselves seldom fatal, and in general heal kindly if they be not complicated with other more serious injuries. When however they are made with judgment, and by a skilful hand, as in the operation of bronchotomy, they are in a more favourable condition, and their result may be regarded with the same anticipation as that of other wounds of similar extent, in which the same amount of disturbance has been occasioned to neighbouring textures.* Louis, in his valuable memoir on the subject, goes so far in recommending

* Memoires de l'Academie de Chirurgie, vol. iv. p. 459.

the operation as to state, that bronchotomy should cause even less inconvenience than the simple process of blood-letting. Though such an eulogium, however, must be taken with much of the caution due to the statements of all strenuous advocates for a favourite remedy, yet it receives much confirmation from the opinion expressed by other high authorities on the same subject. Among these is Mr. Lawrence, who though not inclined to subscribe entirely to Louis's enthusiastic view, yet considers bronchotomy to be in itself "an operation of little pain, and no danger."* This seems now to be the conclusion arrived at by most surgeons of eminence; and accordingly there would seem to exist some other cause than an intrinsic defect in the remedy itself, which has given rise to the prejudice still entertained against it in the minds of many. Any objection against it will in all probability be found to have existed in some peculiar state of the patient on whom it has been performed; for in all cases where its want of success has been most signally marked, there is good reason for believing that other morbid changes had taken place, sufficient to account for death independently of any bad effect resulting from bronchotomy itself, and to these the fatal consequences ought in justice to be attributed.

* Medico-Chirurgical Transactions, vol. vi. p. 237.

It must be evident, that the indiscriminate recourse to any mode of treatment in medicine is both unsatisfactory and discreditable to the science, and in surgery, in like manner, without due indication for its employment, no operation ought to be undertaken. The surgeon, besides attending to the symptoms which would point to its adoption, should also weigh well those which may tend to discourage him from attempting it. In many cases, it is to be feared, bronchotomy has been resorted to where it could be productive of no real benefit, while in many too it has been omitted, where, in the present state of pathological science, there is ground for believing that it might advantageously have been performed. It may be argued that in the catalogue of unfortunate cases, where it has been tried, the surgeon at least gave the patient a chance of life, which at the time was fast ebbing, and must at any rate have sunk; but it should be kept in mind, that by thus having recourse to an operation without the existence of a favourable prospect of success, there is attached to the remedy an opprobrium which must ultimately prejudice the public against its adoption under any circumstances, and thus by using it where success cannot reasonably be anticipated, greater difficulty will be encountered in obtaining its performance in those other cases whose history would hold out a fair prospect of a favourable result. The surgeon should by no means refrain from the measure where the slightest chance of life can be gained for his patient; but before he recommends the operation, he should weigh well the physiological action of the organs more indirectly concerned in the disease, as well as those which it more directly involves, and ascertain, if possible, how far the condition of the former holds out a prospect of recovery.

It is not my intention in the following remarks to enter upon the consideration or description of the operation of bronchotomy, which, in whatever manner it be performed, is but a simple one, though requiring considerable coolness on the part of the operator, and in many instances great adroitness of manipulation. I propose rather to notice, first, some of the circumstances which would contra-indicate its being performed;—and, secondly, those which would incline us to adopt it, keeping in mind, in both investigations, the important fact that disease will often so alter circumstances, by its influence on the respiratory or other organs, as to render the operation hazardous which at first might otherwise have appeared safe and beneficial.

I. In considering those circumstances which contra-indicate the operation of bronchotomy, we must carry along with us a just impression of the important functions discharged by the parts concerned. In order to the maintenance of life, it is essentially necessary that a constant and ample supply of atmospheric air have ready access to the venous blood circulating through the system, and however variously the arrangement for this purpose may be modified in different classes of animals, still the same essential anatomical conditions of the organ is to be found in all. In man, and the higher animals, the structure necessary for the discharge of the function of respiration would seem to be a mucous surface to which air is freely applied, while the blood to be arterialized ramifies in the vessels distributed on the membrane. To promote this approximation of the blood to the air, the respiratory muscles of the chest are constantly in action, and as the demand for a supply of arterial blood to the body always exists, so we find that the facility and regularity with which the respiratory movements are performed are in proportion to the freedom with which air is transmitted through the lungs. Should any impediment however occur to the due arterialization of the blood, the system, as it were, immediately takes alarm, and by the laboured and hurried action of the subsidiary muscles of respiration, endeavours to compensate by the extent and frequency of their movements for the diminished quantity of air allowed to reach the lungs at each inspiration. This diminution may be the effect of obstruction to the transmission of air situated either in the larger air tubes or in the trachea itself, and checking its passage at its very entrance; or it may be caused by impediments situated in the smaller divisions of the bronchi, where the air, though it has reached thus far, cannot complete the process of decarbonization. The mucous membrane, for instance, which has been already mentioned as constituting an important part of the respiratory apparatus, may be so thickened by disease, or so covered by a redundancy of its own secretion, as to prevent that near approach of air to the blood circulating around the air-cells, which is necessary to secure its arterialization. It is of great importance that the nature and seat of these obstacles be ascertained, in order to decide on the probable success of surgical interference in mitigating the symptoms of suffocation attending all such affections.

It is evident that where the arterialization of the blood is prevented in the air-cells by well marked disease of the pulmonary parenchyma itself, or any other strictly local impediment, an increased supply of air through the trachea cannot be attended by any benefit; inasmuch as none could reach the minuter ramifications of the bronchi, however free the space for its entrance might be made. No one accordingly would ever suggest the propriety of opening into the trachea in those cases where the lung has been indurated by inflammation or infiltrated with pus, because such degeneration of the organ must necessarily prevent the due application of air to the membrane, and the usual changes in the blood cannot therefore be produced. Nor upon the same principle would any one recommend the operation, where the lung had been compressed into a useless mass by air or fluid in the cavity of the chest. These are conditions, however, in which its employment is too plainly contra-indicated to leave doubt as to its propriety, but there are other affections in which, on a superficial view, there may seem to be good reason for anticipating benefit from the operation, where, on a more mature consideration of the physiology of the parts, such a procedure would be no less forbidden than in the others. Of this description are those cases in which, while the complaints of the patients are limited chiefly to the larynx or upper part of the trachea, there is reason to suspect that the disease is not confined within such narrow bounds. It may extend continuously from the point marked out by the feelings of the patient; or, he may be correct in his insulating description as regards the trachea, while the disease has been propagated in patches as the bronchi descend into their branches;—or, again, there may be a healthy interval of considerable extent, but the lesser ramifications of the air tubes may at the same time present some complication in addition to the disease situated in the trachea.

In many instances experience and the history of the case can alone serve the practitioner, and these too may often prove insufficient for guiding him in his diagnosis: but in others he can derive much assistance from the information afforded to him by auscultation. The comparatively recent improvements in this mode of investigating thoracic disease, may be one reason why so little notice has been taken by surgical authors of the information which it may convey contra-indicating the use of bronchotomy, and yet the symptoms which it may unfold are of such importance, as, when present, should make the operator very averse to cutting into the trachea, however urgent may be the uneasiness produced by the impeded transmission of air through that organ. In many cases, the disease in the larynx or trachea will impart such vibrations to the air entering through them, as to render stethoscopic examination extremely difficult, and may sometimes so mask the sounds within the chest, as to frustrate any attempts to ascertain the state of the lungs. This, however, is not always the case, for though occasionally requiring some experience and very careful observation, it is in general possible to discover the presence of disease within the thorax; the surgeon, therefore, should be on his guard not to limit his attention to the affection of the windpipe, but to investigate carefully the whole respiratory apparatus. Should he detect inflammation of the substance of the lung, or of the lesser bronchi, he will be cautious how he holds out a favourable prospect to the friends of the patient, in the event of its being deemed expedient to give him the chance, such as it is, afforded by performing bronchotomy.

The objections against performing this operation, when bronchitis to any extent is present, are founded on the impossibility, in some cases, of affording relief to the patient, while there is reason to fear that in others, even where temporary relief may appear to follow it, the fatal termination may be hastened by such a measure. Inflammation of the bronchi is attended by a morbidly increased secretion of mucus, and in many cases also of a puriform fluid, which so long as its quantity or consistency does not wholly interrupt the access of air to the bronchial cells, may not be followed by any serious consequences. When, however, it has gone on to the extent that air can no longer penetrate through the quantity effused, the blood cannot become arterialized, and the patient necessarily dies asphyxiated. The inflamed state of the cells themselves may also give rise to similar effects, and their lining membrane may, besides being coated by this morbid secretion, be so thickened as to interrupt the progress in the change upon the blood normally produced in them. Now, in such cases of laryngeal affection as are complicated with bronchitis, though the trachea be opened, we in no manner relieve what is after all perhaps the more urgent affection of the two. The air may after the operation certainly penetrate into the bronchi, but cannot serve the end of oxygenating the blood, because in consequence of the muco-purulent infarction of the lesser air tubes, it can never reach the surface where that process is completed. The patient's symptoms may, on the contrary, so far from being relieved, become aggravated. The secretion will still go on and increase, and if he found any difficulty in expelling it before the operation, there is reason for believing that he will now find it impossible to do so with such readiness as to prevent suffocation from supervening.

A simple forcible expiration would, in many cases, seem to be sufficient for expelling the redundant mucous secretion from the bronchi ; but when this has been affected by disease, both in reference to quantity and quality—its increased effusion extending down to the smallest branches, as is the case in bronchitis of any extent—this simple effort is no longer sufficient for cleansing the air tubes. To secure this effect, recourse must be had to the more violent exertion of coughing, and the conditions necessary for its performance should be attended to.

Coughing is by no means a simple act, but depends on different, though closely associated movements of the parts concerned in respiration. Its first stage seems to consist in a deep inspiration, during which the rima glottidis is kept open, and the chest expanded to its full extent. After the lungs have been thus filled with air, a violent expiratory effort is made to expel it, while its egress is at the same time time prevented by the action of the constrictor muscles of the larynx: and on the withdrawal of this obstacle by their sudden relaxation, the air is hurried through the air passages with a velocity proportioned to the perfection in which these movements are performed. The impulse thus given to the air is necessary for the expulsion of the mucus which has lodged in the bronchi, more especially when that secretion is much increased, and extends into the lesser ramifications of the air tubes. Were it to pass through the bronchi with more moderate velocity, as in an ordinary forcible expiration, the impulse might sometimes be sufficient for detaching the mucus adhering to the membrane and carrying it forward into the mouth, if it were loosely attached and moderate in quantity; but bronchitis will cause such changes in regard to both these conditions, as to require the more violent exertion of coughing for its expulsion. In such a state of the lungs, the propriety of performing bronchotomy seems extremely doubtful. The patient, if he cannot relieve himself by coughing, will perish from the suffocation caused by the accumulating mucus; and the opening in the trachea deprives him of the power of making this effort. It must, in adults frequently, and in children always, invalidate the possibility of shutting the outlet of the air tubes synchronously with the action of the expiratory muscles, and without the resistance in this manner made to their contraction, violent expiration to a certain extent may, but coughing with forcible expectoration, cannot be accomplished. Various contrivances have been suggested to relieve the air tubes of some of their contents, through the artificial opening in the trachea, but all are at best uncertain, and nearly inefficient. An assistant may remain constantly beside the patient, ready to remove by brush or otherwise, the mucus as it is hawked up to the neighbourhood of the aperture, of which Mr. Porter, in his late work, gives several instances.* But such measures are not of sufficient efficacy to be relied upon, and must be comparatively useless where bronchitis is extensive: for the larger air tubes only, it is evident, could be thus relieved, and if they secreted as actively as we generally find they do when in a state of inflammation, even these would soon become so choked up, as to interrupt the transmission of air through the lungs.

It is possible, also, to relieve the bronchi to a certain extent, by instructing the patient to stop the opening in his trachea with his finger, and while it is thus closed to attempt a cough. Such an attempt may sometimes in the adult be followed by a considerable discharge of mucus, on suddenly withdrawing his finger from the aperture, but in the case of a young patient, it will be impossible so to school him, that he will perform his part with adroitness sufficient to produce an effectual cough, and the incapacity of any assistant to secure that effect, is too evident to require any comment. The expiratory efforts must take place at the same moment that a resistance is made to the air's passage through the

* On the Surgical Pathology of the Larynx and Trachea. Mr. Porter mentions one case in particular, where the life of his patient was saved by one of his pupils sucking out the mucus from the opening in the trachea, as it gurgled up into the wound.

trachea and this again must be suddenly removed at a time when the former are in full force. Now it is impossible for a young child so to understand what is going on, that he shall violently expire synchronously with the closure of the opening in his trachea, and that this shall be withdrawn with such exact promptitude, as to secure the expulsion of the mucus in the same way as it would be driven out by cough. To any one who reflects upon the subject, the difficulty must at once appear of thus attempting to imitate the association of a set of muscular movements which are by nature instinctively combined, when necessity for their exertion stimulates them to act.

All diseases of the larynx and trachea, in which bronchitis (at least to any extent) is also indicated, must, if the foregoing remarks be well-founded, be unfit cases for the employment of bronchotomy. Keeping this in view, accordingly, a prognosis may be formed of the probable result of the operation where this affection, or any similar one of the air cells, co-exists with the disease in the windpipe.

Cynanche Trachealis, if its pathology be rightly described by some of our best authors, is one of this class, and the history of bronchotomy in regard to it fully bears out the conclusion which might *a priori* have been formed of its utility. In croup, bronchotomy could of course never suggest itself to any one in the first stage, because no symptoms then indicate its employment, and other remedies of known efficacy are within the physician's reach, and after the deposition of the false membrane there is much reason for doubting the propriety of the operation. This membranous tube is, by the time that bronchotomy is indicated, rarely confined, even in those cases where it originates in the vicinity of the larynx, to the trachea, but more frequently extends either continuously or in patches beyond the bifurcation of the bronchi. In other cases, we know that it may disappear in the larger air tubes, while inflammation exists in the minuter divisions, where puriform matter in large quantities is not unfrequently secreted, and this is a condition which as decidedly as the former should warn us against attempting the operation. In other instances where bronchotomy would be equally unsuccessful, the inflammatory action has, there is reason to believe, commenced in the bronchial cells themselves, and when it has reached the trachea, disease has already proceeded to such an extent, as to preclude the entertainment of favourable hopes from any treatment, and least of all from opening into the windpipe.

Cases might be multiplied, if it were necessary, to illustrate these several phenomena, but it will be sufficient at present merely to allude to one furnished to us by Mr. Porter, where bronchotomy was unsuccessful in saving the patient's life, notwithstanding the almost cheering prospects of its efficiency which seem to have been held out by the immediate effects of the operation. In Case XI. of the last edition of his work, the patient was a girl of five years of age, who had troublesome cough without expectoration for one day before she became affected with imperfection of voice, occasional spasmodic breathing, and increase of cough which now resembled that of pertussis. For two days afterwards those symptoms gradually increased till they reached such a height as rendered tracheotomy, in the opinion of her medical attendant, her only chance for life. The operation was performed with great relief to the patient, and on the day following she seemed to be making progress towards recovery, and gaining strength,—the pulse falling considerably in frequency. An assistant was however under the necessity of sitting constantly beside her in order to prevent suffocation, by removing the mucus from the opening in the trachea, and her sleep was every four or five minutes disturbed by the urgent anxiety to get rid of this accumulation. Hopes were still entertained of her recovery till the fourth day after the operation, when notwithstanding the great attention of the assistant in cleaning the aperture of mucus, she died of asphyxia caused by its accumulation. Mr. Porter gives an account of the post mortem examination of the body, and after describing the appearance of the larynx, he states, that "the mucous membrane of the bronchi was red, swelled and puffy, and slightly smeared over with a yellowish substance resembling paste; and above an inch of the extent of the trachea situated between the diseases was left unchanged and healthy."

In Case XII. by the same author, there is another instance of there being no trace of inflammation for some distance round the site of the incision, while the larynx was covered with a thick layer of adventitious membrane, and at the bifurcation of the trachea further symptoms of inflammation were discernible, which extended downwards, accompanied by considerable effusion into the bronchi and bronchial cells. The patient in this, as in the last case, was much relieved for some little time after the operation. The details of these cases resemble closely those of one in which a friend in the course of last winter operated under similar circumstances. The patient, a boy of three years of age, was apparently moribund on the fourth day after he was first attacked with croup, and as death seemed certain at any rate, without recourse to such a measure, my friend thought himself justified in trying the effect of bronchotomy: as in the cases related by Mr. Porter, the relief, though immediate and great, was only temporary. The patient lingered on for some time, and died at the end of the second day after the operation.

These cases, though fatal, can scarcely be considered as wholly unsuccessful, because their result would seem to have been even more favourable than usually happens, inasmuch as life, so far as we can judge, would seem to have been prolonged by the operation. Others, if it were necessary, might be brought forward, but the preceding may perhaps be regarded as fairly representing the success of bronchotomy in croup, at least in Britain, if we except a very few solitary cases.* Such however are so rare, and bear so small a proportion to many others, if they were but chronicled, where the operation has been unsuccessful, as, in the present state of our knowledge on the subject, to cause much scepticism as to the advantage of its adoption.

Though success cannot be said to have attended bronchotomy in croup in this country, continental surgeons may seem to have been more fortunate. Thirty cases of croup are mentioned by M. Trous-

* See one by Mr. Chevalier—Medico-Chirurgical Transactions, vol. vi.

seau, in eight of which the patients were saved by the operation, and out of the twenty-two who perished, we are told that six died of contingencies, not imputable either to the operation, or to any modifying effect it might be supposed to have exerted upon the disease itself. According to his report, three were dead before the operation, and three died in consequence of the displacement of the canula, which could not be re-adjusted by the assistant left in charge of the patients.

The success of this French surgeon is so much at variance with the experience we have of the operation in this country, that we are inclined to adopt one of two opinions on the subject. We must suppose, either that M. Trousseau has been singularly fortunate in meeting with an unusual proportion of those cases, where the false membrane and bronchitic affection were limited to the upper part of the trachea; or, that some of the patients on whom he operated were not affected with genuine croup, as that disease is defined by authors in this country. "Croup," as the late Dr. Hugh Ley defines it,* "is now restricted in its application to an inflammatory affection of the lining membrane of the windpipe," whereas in several of M. Trousseau's cases, the disease, as described by him, for which he operated,

* On the Laryngismus Stridulus, &c.

was attended by other appearances, and these it would appear of such a character as to involve the doubt how far they could be considered as symptomatic of croup. Several of these cases are detailed in the Journal des Connaissances Medico-Chirurgicales,* and the following are the descriptions of the disease as it occurred to him. In the course of his report, on the case of one Théodore Chiquet, he remarks, "le docteur vit les amygdales tapissées de concretions pelliculaires, et quoique l'enfant eût peu de fiêvre et d'oppression, il pensa bien que l'inflammation couenneuse s'etait étendue dejà des tonsils au larynx." In the family where another case occurred, that of a child called Adam, two had died in fifteen days, and this was the third individual belonging to it who had been attacked in that short period. In giving the history of this case, he remarks, "une épidemie d'angine pharyngienne, pelliculaire tant qu'elle restait bornée au pharynx, envahissait promptement les voies aeriennes et faisait alors périr tous les malades sans exception. Le père des enfans nous dit, que la soeur ainée du petit Adam et son petit

* I have not had an opportunity of seeing this work, but have made extracts from the cases as they are detailed in the Encyclographie des Sciences Medicales, which I understand to contain a reprint of the Journal des Connaissances Medico-Chirurgicales.

frère avaient eu les amygdales couvertes des concrétions blanches avant d'être pris de croup, et nous pouvons constater en ce moment que les tonsils de notre malade étaient encore couvertes de fausses membranes." I need not adduce the descriptions of any of his other cases, as these are sufficient to create considerable doubt of the identity of, at least, some of them with real croup.

Though it must be admitted that in most, if indeed not all M. Trousseau's cases, he mentions the fact of something resembling the adventitious membrane having been expelled through the glottis before, or through the wound after, the operation of bronchotomy, yet his descriptions of those cases in which he operated, do not appear to apply to croup so well as to some other diseases. They agree more closely with the symptoms and morbid appearances observed in that affection of the fauces and neighbouring parts, described by Dr. Bretonneau of Tours under the name of dipthérite, where inflammation generally commences on the surface of the tonsils and pharynx, and frequently extends down into the larynx, thus giving rise to many of the symptoms which are observed in croup. In the former disease too, incrustations are met with on the trachea similar to those described by M. Trousseau, as occurring in many of his cases, and these may even extend down the windpipe, assuming the form of the membranous tube deposited in croup.

It may seem easier thus to criticise, than completely to refute the statements of M. Trousseau, and yet there are circumstances which render doubtful the probability of his cases being identical with croup as defined by us : and if there be a difference at all between the two diseases, it may be to such extent that in the one, the affection of the windpipe, when present, rarely extends beyond the trachea, while, with the other bronchitis is generally concomitant. Moreover, there appears to be perhaps another characteristic difference between the two, as regards their contagious nature. Though croup is known to be endemic, and at times perhaps even epidemic, yet there seems no valid arguments in favour of its being contagious, whereas the cases in Adam's family favour the supposition, that such was in all likelihood the nature of the disease described as croup by M. Trousseau.

While, then, it must be evident that these successful cases of M. Trousseau, as well as others by different surgeons, cannot be relied on as examples of the advantage accruing from the performance of bronchotomy in croup, there may still be some reason why the operation is not to be altogether discarded as a useless one. It is a question on which an unbiassed person may perhaps have some difficulty in making up his mind: for as the chief symptom of importance is impeded respiration, it must be evident, that if the obstacle to the air's entrance to the lungs be limited to the upper part of the trachea, bronchotomy, if it could be done below the site of such obstruction, ought to hold out the prospect of a favourable result. The extreme rarity of such an insulation of the affection, however, and the difficulty of getting the treatment of the case at that particular period, when, in the transition from the first to the second stage of the disease, suffocation is just commencing, but no bronchial affection to any extent is present, are circumstances which must materially lessen a surgeon's confidence in the efficiency of the remedy. Further evidences of its utility are still much wanted.

The conclusions which these considerations would point to is, that with the means of diagnosis which we at present possess, and the precedents of success from the operation, croup is not one of those affections in which, except in some very rare cases, if indeed in any, bronchotomy can be safely recommended as an effectual remedy: and even in these it is probable that other modes of treatment would be equally efficacious.

The amelioration of the symptoms which followed the operation in the cases previously alluded to, would seem indeed to hold out some encouragement for its adoption. The amendment, however, in such cases, is but delusive and temporary, and occasioned by no improvement in the disease itself. The urgent symptoms for which bronchotomy was performed, were, it is probable, caused chiefly by the adventitious membrane causing suffocation in the trachea, while the lesser branches of the air tubes, though in some measure obstructed, were not so to such an extent as to attract any particular attention during the violent paroxysms of dyspnœa produced by the former impediment. When it was removed, the patients, as might be expected, were in a state of apparent tranquillity when compared with their former condition, though the disease was still making a downward progress. As it descended, the dyspnœa accordingly increased, till the patients, now, on account of the opening in the trachea, unable to expel the increased secretion, died asphyxiated. The urgent symptoms might also, in some degree, be further mitigated by the afflux of arterial blood to the brain, caused by the freer access of air to the blood stagnating in the lungs. The cerebral system, besides being affected by the diminished supply of the blood circulating through it, in consequence of the congestion in the lungs, would also have its functions materially affected by the deteriorated quality of that little which had lately reached it. In some cases, probably in many, this refreshing supply might come too late,—that is, not until the brain had sustained a shock similar to such impressions from other causes, from which it could not ultimately recover though it might for a short time appear to rally. If, however, the deleterious effect had, in such cases, been more gradually brought on, that organ, being, as we know, though impatient of any sudden impression, yet capable of bearing the same amount if slowly produced, would now be invigorated by the fresh stimulus of better oxygenated blood, and thus for a time react favourably on the general system. This, however, could be only a temporary effect, for one cause of suffocation, and that, though slower yet equally formidable, would still continue in operation, and its nature would be such, that the very means tending to obviate the obstruction in the trachea, would also tend to increase the probability of a fatal result to the bronchitis.

In Phthisis Laryngea, on the general grounds already stated, bronchotomy cannot with propriety be resorted to, unless the state of the lungs be ascertained to be sound. However advisable it may be where these are in a good condition, as will be alluded to hereafter, it is to be refrained from in the far more numerous class of cases in which the disease is not limited to the larynx. Here, occasionally, the patient may for a short time obtain some relief from his uneasiness, by the freer access of air secured by the operation; but this will too frequently be only temporary, and may in some instances even hasten on his death. The most serious part of his complaints will derive no benefit from the remedy, while it is to be feared that the operation, simple and nearly harmless though it be in other cases, may be here productive of bad consequences. If before it, expectoration had been considerable, the patient will after it be unable, for the reasons already stated, to expel the mucous accumulation, and the pulmonary symptoms will, so far from being relieved by the operation, probably become aggravated.

II. If it be admitted that the co-existence of such affections of the lungs and air vessels, as have been noticed, constitute sufficient grounds for not resorting to bronchotomy in diseases of the larynx and trachea, the second division of these remarks must, in a great measure, resolve itself into the converse proposition,—that where no such complication exists, that operation may be performed with a fair prospect of success. Where the disease is thus limited to the larynx, or upper part of the trachea, the patient is just in the same condition with one in whom any extraneous obstruction impedes the entrance of air into the lungs. If the removal of such an obstacle bring relief in the latter case, so in the former, if the operation be performed below the site of the temporary obliteration of the air tube, an equal amount of benefit may reasonably be expected. There are cases, accordingly, in which bronchotomy, so far from being one of the last resources of the practitioner, becomes a valuable remedy in the treatment of some of the most formidable complaints.

The windpipe is subject to numerous modifications of disease, which till of late years were involved in much obscurity. Though their pathology, however, notwithstanding late improvements in it, cannot yet perhaps be regarded as precise, it is too evident from the history of such affections, that their respective effects resemble each other in the destruction which each occasions to the transmission of air to the lungs. This may not unfrequently amount to complete suffocation, and wherever this tendency exists, in the absence of any contra-indicant symptom, bronchotomy has been judiciously recommended by Louis, Lawrence, Porter, and others. In order that it be effectual, however, the operation must be had recourse to early in the disease, when milder remedies seem incompetent to subdue it, for when delayed too long, and the complaint makes rapid progress, several conditions of the system are induced, which must render the performance of bronchotomy either altogether futile, or materially lessen its probability of success. Thus, if the patient be not soon relieved, emphysema of the lungs and effusion into the bronchial cells will be apt to supervene, or the blood, being in consequence of the obstruction imperfectly arterialized, will become congested in the lungs, and thus reacting on the brain, asphyxia or coma will be the consequence. Though in some such cases the heart should still contract, and pulsation be felt at the wrist, yet at that late period of the disease little benefit can be expected from bronchotomy. The diminished quantity and deteriorated quality of blood circulating in the brain and other organs, may already have produced a permanently deleterious effect, by causing a state of insensibility and prostration of the vital powers, from which the patient cannot be roused by any means whatever. The result of these will be, that though some arterial blood may, in favourable cases, again circulate for a time, in consequence of the air's admission to the lungs, yet the depressing influence already produced may have been so long continued, and of so serious a nature, as to render recovery impossible. If the functions of the brain have been to any great extent deranged by the vitiated circulation in it,* asphyxia will at this stage be threatened, not by any mechanical impediment to the entrance of air to the lungs, but by the imperfect respiration induced through the intervention of insensibility. Accordingly it is probable, that after coma or convulsions have set in, it is too late to open into the windpipe; for by the time that these symptoms supervene, it may be inferred that the brain's functions have been too seriously affected to hold out any prospect of their being restored with sufficient promptness to save the patient.

In illustration of this remark reference may be made to a case related by Dr. Cheyne,† where, after inflammation of the larynx had continued for twenty-four days, bronchotomy was performed. Before recourse was had to the operation, the patient seems to have been in a comatose state; for as Dr. Cheyne states in his report, "his head suddenly fell on his breast, he ceased to respire, and the complexion had changed from the purple of imperfect circulation to the paleness of death." After the trocar had been intro-

* See Appendix.

† On the Pathology of the Larynx and Trachea, 1809, p. 163.

duced through the crico-thyroid ligament, the patient breathed for some time through the canula left in the opening. His pulse was distinct, but he never seemed sensible to any external impression, not even during the performance of the operation. He died about two hours after the trachea had been opened; but for some time before his death the pulse had been regular at the wrist, and the efforts of the respiratory organs seemed vigorous, though the inspirations had fallen to seven or eight in a minute. In his comments upon this case Dr. Cheyne observes,* "I am inclined to think that this gentleman died from the circulation within the head having become oppressed. I admit that I did not entertain this view until the patient was dead, and I had time to consider the case more deliberately. The change which took place was instantaneous, from a distinct feeling of his situation to an insensibility from which he never emerged. He breathed freely both through the canula, the mouth, and the aperture in the windpipe, after the canula was withdrawn. The diaphragm was capable of great exertion, and the lungs of being filled with air, yet his countenance never altered from the paleness of death." The progress of this branch of surgery, ever since the publication

* Op. Cit. p. 171.

of Dr. Cheyne's work, will in some measure serve to qualify the reflection which he himself made upon the treatment adopted in the case. "Upon reviewing this case," says he, "I scarce think any means were neglected; I rather regret that the larynx was perforated," &c.; and further on, "I am persuaded that the operation affords no additional chance of recovery."

It must appear that the charge of the inefficiency of the operation is imputable, not so much to the nature of this case as to the period at which bronchotomy was performed. No one can now say whether or not the earlier recourse to it could have saved the patient, but under similar circumstances it seems probable that surgical interference would in these times be resorted to at an earlier stage of the disease, after medical treatment had appeared to be productive of little or no benefit. Before the opening was made into the trachea, there seems to have been an impression made upon the brain, of such amount or duration, as to destroy the functions of animal life, while those of organic life continued moderately sound, and the operation was done too late to prevent the destruction of the former from reacting injuriously on the latter.

Whatever, therefore, be the nature of the laryngeal affection (provided always there be no pulmonic complication sufficient to contra-indicate the operation) where its effects are threatened suffocation, bronchotomy should be performed early if it is to be performed at all, and the more acute the attack the more prompt should be the application of the remedy if milder treatment appear to be inefficient. In cases of a more chronic nature, the lungs may gradually be brought to tolerate a diminution in the quantity of air which reaches them at each inspiration, but where the usual supply is quickly cut off, the system is less capable of accommodating itself to the privation, and in such instances the demand for the operation is more urgent, but at the same time its success is perhaps more demonstrably satisfactory than where the progress of the disease has been less rapid. It must be kept in mind also that cases not unfrequently occur for which there are medicinal agents of sufficient efficacy, if time were allowed for the full development of their effects. In these, however, the inflammatory action which threatens suffocation may not begin to yield to gentler treatment until the patient's fate is to a certain extent sealed. Such remedies may act well in gradually diminishing inflammation, but not in suddenly checking it, and if by any means assistance can be derived from some other measure, which will give time for their operation, the case may terminate favourably. Bronchotomy seems to hold the place of such a measure, and in this state of matters accordingly its history corresponds with the advantages to be thus anticipated from its use.

There are other cases in which this operation would also seem to claim a higher character than that very equivocal one of being a last resource; in which, on the contrary, it may form a very important part of the treatment. Those, namely, where, from idiosyncracy or other causes, bleeding or powerfully depleting measures cannot be adopted. If it was advisable in the former, it is doubly so in this class, because all active and efficient efforts to save the patient are in a manner forbidden, and the chief source of hope must lie in time so wearing out the disease as to allow of his ultimate recovery. Without the aid of bronchotomy, however, such waiting on may in some instances amount to certain death; for it is to be feared, that before the decline of inflammation, asphyxia may have terminated the sufferings of the patient. But if the more urgent tendency to suffocation be warded off, as it may be by this operation, we are enabled to treat him more deliberately, and either wait till active remedies may safely be applied, or avail ourselves of the longer time allowed us for less vigorous treatment.

Some of the most successful operations of opening into the trachea will be found to have been performed in cases to which the preceding remarks are more or less applicable. In the various forms of acute laryngitis, when that disease cannot be subdued in its earlier stage, bronchotomy holds out the best prospect of a favourable result. If the attack be violent, inflammation runs its course so rapidly that resolution cannot be attained by the most energetic measures and effusion of serum into the submucous cellular tissue, causing what is termed Œdema Glottidis, or of lymph upon its inner surface, will speedily extinguish life if air be not admitted artificially to the lungs. This remark, as to its rapid progress, may seem at variance with one made by Dr. Baillie,* that "very few cases have occurred of inflammation of the mucous membrane of the larynx, and of the trachea, so violent as to destroy life in a few days;" and he adds, that "in a practice of more than twenty years, he had only met with two such cases." Though his successors have profited largely by this physician's judgment in diagnosis and exertions in pathological inquiry, it is not improbable that even in his own time many sudden deaths may have occurred from acute laryngeal inflammation

* His Works, by Wardrop, vol. i. p. 51.

which may have been regarded as the effects of some other disease. Mr. Porter's remarks on the insidiousness of its approach, together with several cases narrated by him, appear fully corroborative of the truth of such a surmise.* In two instances within his own recollection, young men had gone to bed without any complaint, who were found dead the next morning. The day is perhaps not long gone past when such sudden deaths, in the ignorance of their true cause, might have been imputed to apoplexy, or some affection wholly unconnected with the respiratory organs.

Nothwithstanding Dr. Baillie's limited opportunity of studying the nature and treatment of such cases, the conclusions arrived at by him in regard to the latter, are fully borne out by the observation of later authors. " It evidently appears," says he, " from the cases which have been related," (three in all—one had been reported to him, and two he had himself attended) " that both general and topical bleeding, when employed early and strenuously was of no real use. Nor was any benefit derived from blisters, purgatives, expectorating or cooling medicines." Further, " this operation (bronchotomy) would probably enable the patient to breathe till the

* See Appendix.

inflammation in the larynx, more especially at the aperture of the glottis had time to subside." Whether this operation would be successful, can only be known by experience, but as far as we can judge *a priori*, it has so reasonable a chance of success as to justify a trial in so fatal a disease, and thereby to ascertain the degree of benefit to be derived from it."* The trial has since Dr. Baillie's time been made, and, as he anticipated, with a favourable result. Looking back indeed upon those very cases which he has himself recorded, there seems to be little doubt but that had bronchotomy been performed at an early part of the disease, the patients might have recovered. From the history of the cases themselves, and the *post mortem* examinations, no morbid change in the tissue of the lungs, nor bronchitic affection seems to have been present, but the larynx and upper part of the trachea were alone involved in the disease. The state of the lungs indicated by their not collapsing on the thorax being opened, seems to have been the consequence of emphysema, and serous effusion produced by the great and continued struggle for breath made by the patient.

In Mr. Lawrence's Memoir,† he describes a laryngeal affection apparently of a more chronic nature

* Op. Cit. vol. i. p. 65.

† Medico-Chirurgical Transactions, vol. vi.

than the preceding. In the cases there referred to by him, the inflammatory symptoms were not well marked, but the fatal progress of the disease, though in some instances very slow, is, if it be not successfully arrested, not the less certain. That eminent surgeon states, that at the time* he read his communication to the Medico-Chirurgical Society, he had examined after death five cases of this complaint, besides the two where bronchotomy was performed, and the particulars of which he relates. He remarks on these,—"Although I am unacquainted with the details of the histories and symptoms of these cases, I know that they were not acute diseases, that there was no stage of active inflammation, and that the patients lived many days after the difficulty of breathing had commenced." The *post mortem* appearances were similar in all, and are thus described by Mr. Lawrence in his account of one of those cases which he himself had seen. "The membrane of the chordae vocales, sacculi laryngis, and front of the arytenoid cartilages, possessed its natural colour, but was thickened and granulated on its surface, so as completely to shut the rima glottidis. The affection, entirely confined to the parts first enumerated, occupied a very inconsiderable extent of the membrane, just enough to

* June 6, 1815.

close the entrance of the trachea. The rest of the tube, the epiglottis and neighbouring parts, and the contents of the chest were perfectly healthy." In this form of laryngeal affection, the effect produced, namely suffocation, would appear to be the same as in the most acute form, but according to Mr. Lawrence's experience even less under the control of medical treatment. This might indeed be inferred from the frequently fatal result of the disease, though time be allowed for some effect being produced by the remedies, if the complaint had any disposition to yield to them. Mr. Lawrence considers that "local and general bleeding, blisters, and the various internal means are usually inefficacious, and that the operation of bronchotomy, by procuring an artificial opening for the air produces complete relief." This, however, is ineffectual, as he adds, unless early performed, on account of the debilitating effects on the constitution, which are in themselves fatal after a time, even if the impediment to the air's passage be removed.*

In this Chronic Laryngitis, accordingly, as much as in the acuter form, there are circumstances which, when the efficacy of milder remedies appears doubtful, would indicate the propriety of resorting to bronchotomy. The disease is in general limited in extent, and, at least at its commencement, rarely

* Medico-Chirurgical Transactions, vol. vi. p. 218.

complicated with bronchitis or other pulmonary derangement. After it has continued for some time, however, besides the constitutional symptoms mentioned by Mr. Lawrence, some organic change of the lungs, as emphysema or effusion supervenes, when, as might be expected, surgical interference will be of little avail. If, on the other hand, the operation be resorted to in good time in this as in the other variety of laryngitis, these are the idiopathic diseases of the larynx, in which bronchotomy is likely to be attended with the most favourable results.

It is not the province of this paper to enter minutely into the pathology of those affections in which bronchotomy has been advantageously employed, except in so far as they illustrate the principle stated in the commencement; nor without prolonging it to an inconvenient length, is it possible to weigh the arguments for and against the operation in individual modifications of the same disease. Such an investigation would indeed be highly interesting, but would call for more lengthened statements and more elaborate discussion than can be devoted to it in these remarks. It has appeared better for the present to confine them to the statement of some of the general principles, as they may be called, in accordance with which the adoption or rejection of bronchotomy is to be determined on, and briefly to apply these to some of the diseases where that operation may seem to be indicated.

Nearly allied to acute idiopathic Laryngitis is that form of the affection which is caused by acids, hot water, or other irritating matters incautiously taken into the mouth. Here, too, bronchotomy is indicated, and with another view besides that of relieving a mechanical obstruction. The inflammatory action caused by the irritation consequent on such accidents must no doubt materially thicken the lips of the glottis and neighbouring parts, thus giving rise to imperfect respiration; but another object is to be gained, besides relieving this tendency to suffocation, namely, the promotion of the sanative process at the seat of the injury. In the highly irritable state of the parts affected, it is evident that their constant movement, and the excitement produced by the permeating air must delay, if not altogether prevent their healing, and by removing the necessity for their action, we remove an offending cause. By performing tracheotomy, air is allowed free access to the lungs, and thus not only is the patient relieved from the sense of anxiety otherwise attendant on such accidents, but also the rest in this manner secured to the parts about the glottis acts beneficially in diminishing vascular excitement, and thus favours the abatement of the inflammation occasioned by the irritating fluid.

For similar reasons bronchotomy may be advisable in those accidents where, though no inflammatory action be present, the nature of the case is such that suffocation is threatened, and in many cases restoration of the parts to their healthy condition is prevented. A severe blow on the larynx, for example, may so alter its dimensions, or otherwise obstruct the caliber of the trachea, that though no thickening of the lining membrane immediately supervene, asphyxia may in a very short time cut the patient off, if air be not artificially admitted to the lungs.*

Where the windpipe is wounded, as in the attempts of the suicide, it may sometimes happen that the injury is so complicated with displacement of the neighbouring textures, that free respiration is effectually prevented. By securing, as in bronchotomy, the air's entrance to the lungs through an avenue unconnected, in some manner, with the site of the injury, the feelings of the patient are tranquillized by the easy breathing thus restored; and while the additional opening in his windpipe does not materially increase his danger, the wound itself can be leisurely

* See Appendix.

and effectively attended to, besides being also in a condition more favourable for healing, than when constantly liable to be disturbed by the air passing in and out of the thorax. Such accidents may, moreover, threaten instant death, in consequence of detached portions of the windpipe closing up its passage. Illustrative of this there is a remarkable case mentioned by Sir Charles Bell.* A man was brought into the Middlesex Hospital who had cut his throat, "There were times," says the report, "when he suffered violently from difficulty of breathing, and then a flapping of something in the throat could be heard. He died; and it was discovered that the knife had gone so critically that it divided one of the arytenoid cartilages, and the portion hung by the membrane so as to vibrate in the chink of the glottis, like a pea in a cat-call, and acting as a foreign body caught in the rima glottidis, occasioned suffocation; nor is this a singular occurrence." In the same work is mentioned a case where a girl in attempting suicide, plunged a knife into the trachea, and drew it downwards dividing five rings of the trachea. She lived for some time after the injury, and ultimately died from the divided edges of the cartilage turning inwards, which, with the swelling of the lining membrane, so diminished the caliber of the tube, as to produce

* Surgical Observations,—Part I. p. 45.

suffocation. The simple statement of these cases will, without any comment upon them, point to the utility of bronchotomy in similar predicaments, whatever be the manner in which they have been induced.

Cases of disturbed and impeded respiration sometimes occur in which it is almost impossible, even for the most acute and experienced practitioner, to form a correct diagnosis. They frequently appear to be either entirely functional, or so slightly to affect the structure of the organ concerned, as to entail no inconvenience on the subjects of them, if the temporary dyspnœa be relieved; or, if death be the consequence, to leave no morbid appearance which can account for the symptoms observed during life.*

Section, paralysis or irritation of the laryngeal nerves, as has been amply demonstrated by experiment and by the effect of disease, may so suspend or irregularly excite the action of the muscles which they supply, that the aperture of the rima glottidis may be closed to such an extent as in some cases to produce instant death. It is fully ascertained that when respiration becomes at all hurried, the aperture of the glottis is enlarged during inspiration and contracted during expiration. From the results of

* Dublin Journal of Medical Science—No. xxviii.

experiment it would also appear that when both the superior and inferior laryngeal nerves are cut, the muscles of the larynx no longer move in unison with the other muscles of respiration, and the aperture of the glottis remains permanently open. But since it so happens that the inferior laryngeal nerves are principally distributed upon those muscles which enlarge the rima glottidis, while on the other hand the superior laryngeal nerves supply those which diminish it, the section, or paralysis of the former must be followed by most important effects upon the facility with which air passes through the larynx during the respiratory movements. For it necessarily follows, that when the aperture of the glottis is contracted during expiration and the action of inspiration succeeds, the arytenoid cartilages are from the section or paralysis of the recurrent nerves no longer drawn outwards by their dilator muscles, but on the other hand are carried further inwards by the current of air rushing into the larynx, through which its passage will thus be seriously impeded or altogether suspended.

A nervous affection of this description may be caused in different ways, and its duration may vary considerably. It may amount to but a momentary derangement of function, and cause no further inconvenience to the individual, than the temporary anxiety attendant on obstructed respiration ; or, on the other hand, it may be prolonged till death supervene as the consequence. Where there is cause for dreading the latter result, it is evident that the prompt recourse to bronchotomy alone could save the patient ; for the functions of the parts concerned, even supposing their temporary derangement to be the full extent of the affection, might not return before the dyspnœa had terminated fatally. In other instances, perhaps of greater danger, the nerves may be more permanently irritated or paralysed, as where tumours press upon them in their course to the larynx.* If these could not be removed, it would in many cases be advisable to open into the trachea, for by doing so the transmission of air to the lungs would be secured independently of the nervous chain, over which it might be impossible to exercise any such immediate influence as to save the patient from suffocation.†

In no cases is bronchotomy more clearly indicated

* See Appendix.

† Dr. Marsh of Dublin, remarks in a valuable paper by him in the Dublin Hospital Reports,—" Dr. Johnson has stated to me, that he has seen a child in a state of asphyxia caused by this disease, (spasm of the glottis) recovered from apparent death by the instantaneous application of artificial respiration."—Dublin Hospital Reports, vol. v. p. 619.

than in those where a foreign body is impacted in the larynx, or forced through that aperture into the trachea, or one of its bifurcations. The form and dimensions of such a body, or its situation and mobility in the air passage will of course greatly modify the uneasiness which its presence causes to the patient. If it be large and impacted in the rima, instant death will be the consequence; or if it be moveable in the trachea, and more especially, if it be also of an angular form, it will, if not extracted, sooner or later cause fatal inflammation of the lining membrane of the bronchi. Though in some instances the symptoms may appear extremely mild, so much so, indeed, as to quiet the fears of the patient, and perhaps even of the surgeon himself, yet they have often been remarked to prove fallacious, for sooner or later, the presence of the substance in the air tube will bring on a fatal termination to the case. From instant suffocation, however, or the slower fate of pulmonary disease, bronchotomy holds out a favourable prospect of relief. If wedged into the rima, the foreign body can be reached through the aperture in the trachea, and either pushed up into the pharynx or extracted through the incision; or, if it have descended below the site of the operation, it will, in the greater number of cases, be forced through the artificial opening by the upward current of air, or in the event of this not taking place, be extracted by the operator. Of these different results, the history of surgery furnishes numerous examples.

In such cases, especially if they be of long standing, it must be admitted that some bronchitis is generally present, and not unfrequently to such an extent as might, agreeably to the principle stated in the earlier part of these remarks, contra-indicate the operation of bronchotomy. Where the bronchial inflammation is limited to a small space, no one would of course hesitate in performing the operation, and even where it is general and severe this may be regarded as a case, probably the only one, in which such a measure would be attended by a favourable result. The inflammatory action is so clearly the effect of an extrinsic irritant cause as to render the probability strong, that when this is removed, the bronchitis will subside.

In all the affections hitherto noticed under the second division of the subject, which are far from forming a complete catalogue of the various modifications of disease in which tracheotomy may be advantageously employed, it will be found that with the exception of the last, inflammation does not in general extend down into the lesser bronchi. As the reasons for which an exception is made in favour of that case appear to be sufficiently satisfactory, the position will still hold good, that diseased lungs, as laid down by all, and bronchitic inflammation of any extent, as perhaps not sufficiently insisted on by some surgeons, are contra-indicant symptoms of the operation of bronchotomy. The converse proposition is equally tenable, that their absence should encourage the surgeon in its performance, where other circumstances call for its adoption.

Cases sometimes occur, in which, though bronchotomy be not distinctly contra-indicated, its performance is still a measure of doubtful propriety, inasmuch as the restoration of the air passages to a healthy state, cannot reasonably be looked for. Of this nature are some of the varieties of Phthisis Laryngea, which, threatening the life of the patient, will in many instances prove inevitably fatal, unless some substitute be found for the transmission of air to the lungs. Where these were in a healthy state, bronchotomy has accordingly been useful; and though the nature of the laryngeal affection be such, which in most cases of this nature it probably is, that it is to be feared the patient must breathe through a canula for the remainder of his life, yet it would appear that even this, in time, ceases to be an annoyance of much importance to him, and he can, with comparatively little inconvenience, pursue his usual avocations even where these require some bodily exertion.* The parts about the larynx are prevented from resuming their function, because the lining membrane having become permanently thickened, or the ulcers, in the progress of healing, having left numerous cicatrices, the aperture of the rima glottidis has thus been rendered insufficient for the due admission of air into the lungs, and can rarely allow of the artificial opening in the trachea being with safety dispensed with.

* See Appendix.

APPENDIX.

Page 30.

Though later* experiments have set aside, in some measure the conclusions arrived at by Bichat on the subject of Asphyxia, his observations are perhaps less unsound in kind than in degree. The effects of venous blood circulating through the system, seem to be more of a negative than of a positive nature, inasmuch as though not absolutely deleterious, that fluid is insufficient for the due stimulus of the organs to which it is applied.

While Dr. Kay† is justified by the result of his most satisfactory experiments, in rejecting the theory of the French physiologist as to the destruction of muscular contractility by the presence of venous blood in its tissue, he himself admits that it is less favourable than arterial for the development of the phenomenon; and if such be its effects on muscle, there

* See Dr. Williams in Edinb. Med. and Surg. Journ. vol. xix.
Dr. Alison, ditto, ditto, vol. xlv.
Kay on Asphyxia.

† Kay, p. 150.

is greater reason for believing that it will extend also to the brain. The symptoms alluded to in the text, may perhaps be produced partly by the disturbance to the balance of circulation in the brain, caused by its no longer receiving a due supply of blood of any kind, even though the left ventricle may contract for some time after the blood has stagnated in the lungs and right side of the heart. While the coma may in some measure be thus accounted for, which appears in those cases where protracted obstruction exists to the due arterialization of the blood, it seems to be in a great measure caused by the circulation of venous blood in the substance of the brain. The conclusion arrived at by Dr. Kay, from numerous experiments carefully performed, is to the effect that venous blood, though certainly less nutritious and stimulating than arterial, may circulate through the brain without suddenly affecting the nervous system by contact with the substance of that organ. He remarks, however, "that its presence in the vessels of the brain occasions languor and feebleness, and if its circulation be prolonged, we may imagine that sensation would become still further impaired." *

If pathological phenomena be taken into consideration, there is further reason for believing that impeded respiration may, by producing venous circulation in the brain, occasion a similar condition. It must be frequently remarked that in some diseases of the chest, especially in the advanced stages of extensive bronchitis, the patient is frequently oppressed with irresistible drowsiness. Whether this symptom be the result of diminished circulation in the brain, or of the deteriorated

* Op. Cit. p. 198.

quality of the blood sent there, is still doubtful; but it seems not unlikely that both causes may be in action. Whichever be the true one, however, this tendency to stupor appears to be the effect of some modifying influence on the cerebral circulation exercised by the disease, and the impression thus made upon the brain may be of such amount or duration, as to bring that organ into a condition from which it cannot recover, even upon removal of the offending cause. The impairment of the cerebral functions thus produced, may, by causing coma, or in other words, suspending all sensation, interrupt the respiratory movements of the thorax, when fatal asphyxia will of course supervene.

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Though it may be unnecessary to multiply cases illustrative of the rapidity with which acute laryngitis may run its course, the two following cases, extracted from Mr. Porter's* excellent work, may show the qualification with which Dr. Baillie's statement on the subject must be taken.

"Case XIII.—In the month of April 1816, a gentleman residing about sixteen miles from Dublin, was attacked with what he conceived to be a sore throat. He was a large man, very strongly made, inclining to corpulency, but of active habits, and moderate in the pleasures of the table. He might have been about forty-seven years of age. He was taken ill

* On the Surgical Pathology of the Larynx and Trachea, pp. 98-9.

in the evening with shivering and an inclination to crouch over the fire, slight headache, pain in the throat, and trifling difficulty in deglutition. He had some warm drink, and went to bed, but passed the night rather restless and uneasy, and when towards morning, exhausted with watching, he had fallen asleep, he shortly awoke in a paroxysm of suffocation. Still when he had roused himself, the difficulty of breathing was not such as to occasion great alarm. He complained of a dryness or huskiness in his throat, and was annoyed by a short cough without expectoration. In the morning an apothecary who resided in the neighbourhood was summoned, and by the time he arrived, the symptoms had advanced so rapidly as to become serious and alarming. The patient was bled, had purgative medicines, and a large blister was applied to the throat, but without the smallest relief.

" Happening accidentally to be in the neighbourhood, I was called to see him about four o'clock in the afternoon. His face was then pale and swollen ; his eyes glassy and protruded ; his breathing loud, harsh, and stridulous ; and the efforts he made to carry on this function were frightful. His pulse very rapid, but not full. He perfectly retained his senses, and pointed to the thyroid cartilage, when questioned as to the seat of his distress. He died in about an hour afterwards, *twenty-one* hours from the first approach of the disease."

Case XIV. by the same author, is no less corroborative of the remarks in the text.

" On 16th February 1819, I was requested by a woman of the name of Mathews to examine the body of a boy to whom she had through charity given a lodging in a waste room, and whom she suspected to have taken poison. She could give no account of his illness, except that he had been dull and heavy the entire of the preceding day, unable to beg about the streets as usual, but complained of feeling his throat sore, and in the evening had gone to an apothecary's shop, where he got something in a cup, but what it was he could not tell. He went to rest early on his bed of straw, and was found dead next morning."

The appearances after death which are narrated in his work, satisfied Mr. Porter that the subjects of examination in both cases had died of Laryngitis Œdematosa.

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In illustration of such causes of suffocation I may here give in his own words a case mentioned by Mr. Liston.*

"A fine healthy child, aged eight, in running across the street, fell and struck the larynx with great force upon a large stone. She was taken up quite lifeless, and some time elapsed before respiration was at all established. A gentleman finding her face livid, opened the temporal artery, and applied leeches to the throat with some relief. I saw her about three hours after the accident. The breathing, inspiration more particularly, was exceedingly difficult, and this appeared to proceed not only from the injury to the larynx probably occasioning loss of power in the muscles, but

* Elements of Surgery, 1831, part ii. p. 257.

from collection of some fluid in the trachea and its ramifications. The child was evidently in such a state, that unless active measures were resorted to, and that speedily, a fatal termination would soon take place. Bronchotomy was performed; a quantity of coagulated blood and bloody mucus was evacuated from the opening; and when the discharge and coughing had ceased, a tube was introduced. In a short time the tube was withdrawn, and the aperture closed, and no unfavourable symptoms occurred."

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The following cases, taken from the work of the late Dr. Hugh Ley,* are, as well as others reported by him, of much interest in relation to this part of the subject.

"J. A. aged nine months, was always delicate, but never seriously ill until three months since, when the parents first observed something peculiar in its breathing. It seemed one day when wakened out of its sleep to be nearly choked. It had another attack on the same day, and after this there was frequent spasmodic crowing, especially when the child was excited, when it awoke from sleep, or after meals.

"When first visited the diagnosis was difficult, and a guarded statement was therefore made; but there was some suspicion that it might be hooping-cough, the sounds in inspiration resembling each other. But after a few more visits it became perfectly clear that the disease was that so well described and

* On the Laryngismus Stridulus, p. 40.

reasoned upon by Dr. Hugh Ley. The peculiar countenance, the distortion of the limbs, and above all, the visible enlargement of the cervical and even axillary glands, warranted a decided opinion as to the real nature of the complaint. The spasms or fits gradually increased, and more than once I was called in suddenly to witness the death of the child. Upon these occasions there seemed little or no hope of recovery; nevertheless in time the purple countenance disappeared, the blanched lips resumed their hue, and respiration returned. The child, however, rapidly fell away, and as it became weaker the fits returned with less violence, but greater frequency, coming on every quarter of an hour. Their character was the same, only that latterly there was less of the excited attempts at respiration. The infant was cheerful during the intervals, and now and then rallied, and gave slight hopes of improvement. Alteratives, aperients, and tonics, were employed, but without avail; the child died three months after the first symptoms of disordered respiration.

"*Post mortem* examination: The submaxillary, parotid, sublingual, and indeed all the glands throughout the body, were not only enlarged, but even apparently increased in number. The mesenteric particularly were diseased.

"The bronchial glands upon the right side surrounded the recurrent nerve which was completely embedded in a cluster of enlarged glands. On the left side there was to be seen but one, and that one not large. It was about the size of a pea, very hard, and seemed to press upon the nerve, squeezing it, as it were, against the trachea. The nerve in its course was accompanied by other glands.

"The larynx was healthy, the lungs gorged from congestion, almost resembling pulmonary apoplexy; the heart was hypertrophied, the left ventricle being also enlarged."

In another case which Dr. Ley attended along with another medical gentleman, the symptoms were similar to those enumerated in the last, and the child died of what its parents denominated a "choking."

The pathological appearances were the following: "No unusual congestion of the vessels of the meninges, or of those in the substance of the brain; the ventricles contained no fluid, and the brain was of the usual firmness in a child of that age.

"After removing the integuments from the front of the neck, the glandulæ concatenatæ could be felt enlarged, some of them appearing of the size of peas.

"The muscles being removed, and the par vagum traced from the top of the larynx to where it gives off the recurrent on both sides, three or four glands as large as peas were found upon and at the side of the recurrent, where it passed over the bronchi, just after their division from the trachea.

"On the right side, the angle formed by the innominata and subclavian artery was occupied by a gland; another behind the innominata was equal in size to a large almond, over which both the recurrent and par vagum passed, and a whole train of smaller glands accompanied the recurrent in its course by the side of the trachea, covering and obscuring the lateral filaments which proceed to the back of that canal.

"The mesenteric glands were much enlarged, some of them equal in size to pigeons' eggs. Peyer's glands at the lower side of the ileum were much developed and indurated, as well as the solitary glands. The others were in their normal state."

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Mr. Porter* narrates a case of Phthisis Laryngea, for which he performed bronchotomy, and the patient, after passing through a very dangerous state, ultimately recovered. The report a month after the operation is as follows:—

"Dec. 28. To look at this patient one might suppose him to be in perfect health, excepting the circumstance of the artificial respiration; his complexion is clear, the expression of his countenance tranquil, his sleep refreshing, his appetite improving; he still passes part of his drink by the wound, but it is probable the internal ulceration is healing, as there is now scarcely any foetor, and no purulent expectoration. However, on closing the wound, he cannot succeed in carrying on respiration in the natural way for a single minute; he makes a good attempt at speaking, but in a very hoarse rough tone."

On the 13th January following, he left the hospital quite recovered, except that he was obliged to breathe through the tube, in which condition he has continued ever since. Mr. Porter adds, "About three years after the operation, the tube became corroded and broke across, a portion of it dropping into the trachea, where it occasioned great distress, but was removed without difficulty. He has since continued quite well, and though breathing through a tube, earns his livelihood at the laborious occupation of a stone cutter."

* Op. Cit. 170.

Edinburgh: BALFOUR & JACK, Printers, 36, Niddry Street.

— Percy Esq

from the Author

CXR

ON THE

UNITY OF STRUCTURE

IN THE

ANIMAL KINGDOM.

BY

MARTIN BARRY,

M. D., F. R. S. E., M. W. S.

LATE PRESIDENT OF THE ROYAL MEDICAL SOCIETY OF EDINBURGH.

From the Edinburgh New Philosophical Journal for January 1837.

Fig. 3.

Fig. 4.

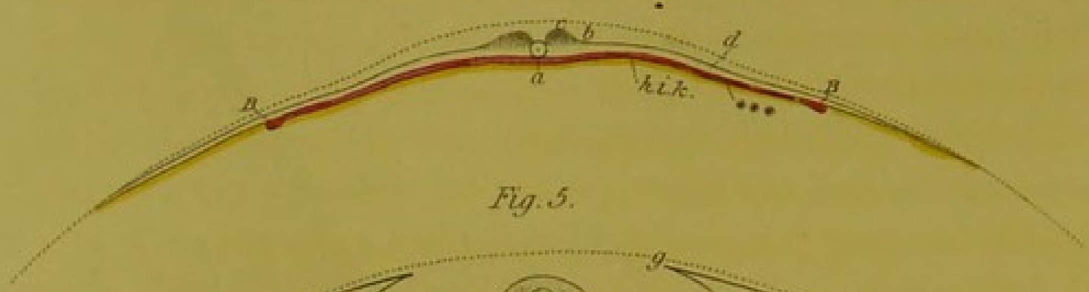


Fig. 5.

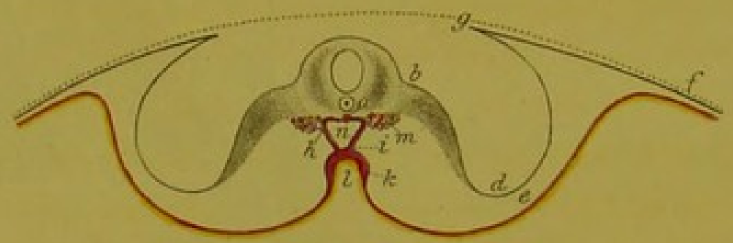


Fig. 6.

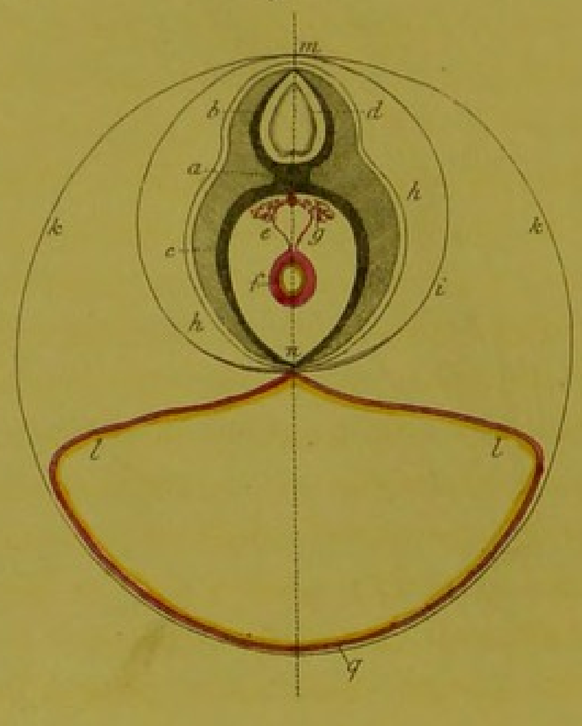
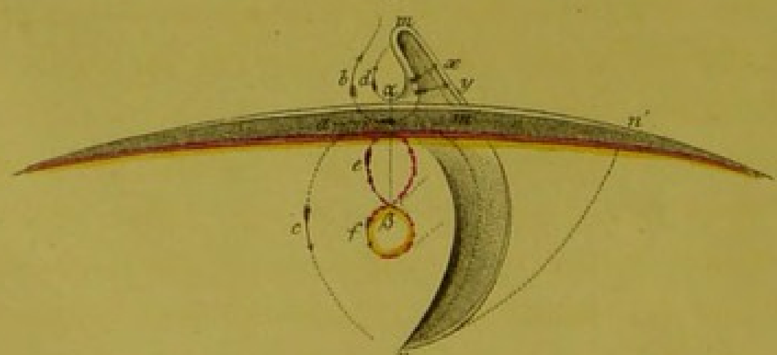


Fig. 7.



E. Mitchell, Sc.

ON THE

UNITY OF STRUCTURE

IN THE

ANIMAL KINGDOM.

All finite existencies presuppose design. This is a position which, happily in the present day, we may assume.

It has been usual to regard organic structure as manifesting design, because it shews adaptation to the function to be performed. It has also been suggested, that function may be equally well considered as the result of structure. And, truly so it may. Yet perhaps we are not required to shew the claim of either to priority; but may consider both structure and function,—harmonizing, as they always do,—as having been simultaneously contemplated in the same design.

The object of the present essay, is to offer a few considerations on structure only; but the subject is so vast, and our limits are so circumscribed, that these considerations must be of the most general character. Yet some details on development will be found indispensable.

The expression "organic structure," includes of course the structure of what we call animals and plants. But, while both are comprehended as beings contemplated in the same original design;—while the metamorphoses presented in a realization of this design, and the remarks that may be made on development in general, will apply equally to both ;—it is intended to restrict the further prosecution of the subject to animals alone.

The terms "lower" and "higher" animals, will be throughout this paper strenuously avoided, because they are calculated to mislead. Should they occur, it will be as forming part of a quotation. Such terms, if used in regard to the organs of relation only, are, to say the least of them, ambiguous ; because we do not know what parts of structure may not contribute to constitute these organs. If they be used to describe differences in the *degree* of elaboration only, such application of them presupposes a simply "ascending" or "descending" scale of structure, differing in *degree* alone,—a thing, the existence of which, it is in part the object of this paper to question, and then acknowledge or deny. We therefore disuse them, substituting the expressions general and special,—simpler and more complex,—diffused and concentrated,—homogeneous and heterogeneous,—less or more elaborate,—less or more developed.

It is important to appreciate exactly, the difference in meaning between the terms "individual" and "individuality." An element, or a set of elements, acquires a separate or distinct existence, *i. e.* an individuality, and there is thus constituted an individual.*

The constituent parts of an individual perform certain functions, in the sum of which consists its life. These functions are reducible to changes of condition, and of relative position,—to dismissal and renewal,—of the elements of which the individual is composed ; which changes are not identical in any two individuals. The effect of these continued changes, up to a certain period of life, is a more and more elaborate and special structure, performing more and more diversified and special functions.

Now, as the elements of an individual cease, in turn, to be constituent parts of the same, the identity of that *individual* must be continually changing,—can exist, indeed, at no two periods of time ; inasmuch as new elements are continually enter-

* "I exhort you to be particularly on your guard against loose and indefinite expressions ; they are the bane of all science, and have been remarkably injurious in the different departments of our own."—*Lawrence's* two Lectures ; being an Introduction to Comparative Anatomy and Physiology. 1826. P. 118.

ing into its constitution, while old ones are departing. But the same separate or distinct existence—the same *individuality*—continues.*

A law, not less vast in its importance, than it seems to be general in its application, may be supposed to direct structure in the animal kingdom. This law requires that a heterogeneous or special structure, shall arise only out of one more homogeneous or general; and this by a gradual change. The importance of this law appears to have been insisted on chiefly by Von Bär, who arrived at it by long and attentive observation of development.

Let us then inquire, in the first place, what analogy there is in the states of germs in general, at the earliest period of observation; and whether they have in common, a homogeneous or general structure.

In animals presenting the most simple manifestations of life, —" in which, every point of the creature is, as it were, an epitome of the whole, without any relation to, or dependence on, the rest; and capable, therefore, when separated from the rest, of an independent existence,"†—maturity alone appears sufficient to produce offspring, and simple separation sufficient to constitute a new being. Such is the case with many zoophytes.

Reproduction becomes less simple, as vitality grows complex; because now, "each point of the creature has a more close relation to, and dependence on, the rest, than before."‡ When something like ova begin to be discernible, they consist of a half-fluid, throughout homogeneous, more or less granulous mass. This is the state of bodies regarded as ova, in some Infusoria, some Polypes, and many other Zoophytes. Bodies of this kind have been called "Germinal Granules." Such imperfect ova

* Cessation of the changes spoken of, constitutes death. The state of being subsequently, forms a subject, of which it would here be out of place to treat. It is sufficient that revelation makes us acquainted with the fact, that *human* existencies continue, after they have ceased to be represented by combinations of elements, performing functions, the sum of which is called life.

† *Dick*, in the Trans. of Prov. Med. and Surg. Assoc., vol. iv. p. 344.

‡ *Dick*, l. c. p. 344.

seem to hold a middle place between "Shoots," on the one hand, and "Germinal Vesicles," on the other.*

The ovum of more elaborate structures,—perhaps of all the rest of the animal kingdom,—is a sac, containing a sort of Yolk, —the Germinal Vesicle,—and a Layer of granules. (Fig. 1. p. 120.)

The *Yolk* of ova generally, is very much the same in essential character; but performing a more important part in some animals than in others, it differs much in quantity.

The *Germinal Vesicle* is an exceedingly delicate, transparent sac; measuring in diameter sometimes less than $\frac{1}{100}$th of a line,† and containing a pellucid fluid. On the internal surface of the Germinal Vesicle, there has lately been discovered an opacity,—the *Germinal Spot* (*Macula germinativa*), consisting of extremely minute granules, more or less spherical in form. With a magnifying power of eight hundred diameters,—that is to say, magnified 640,000 times,—this spot has not yet been found to consist of other than homogeneous parts.‡ It has been already said, that it is contained within the Germinal Vesicle; the latter measuring in diameter sometimes less than $\frac{1}{100}$th of a line.

In some Infusoria, the contents of the Germinal Vesicle are rather a mass of granules, than a fluid and a spot; perhaps corresponding parts, in a less concentrated state. Indeed, may not "Shoots," "Germinal Granules," and the contents of the Germinal Vesicle, be, all of them, corresponding parts, in different states of concentration?

The *Layer of Granules (Germinal layer)*, containing perhaps, in part, the rudiments of the future Germinal Membrane, lies immediately on the internal surface of the Primary Membrane that contains the Germ and Yolk. This layer is more or less circumscribed,—often indistinct, because of its periphery coalescing with the Yolk. The Germinal Vesicle is found lying in the centre of this layer of granules, on the surface of the Yolk; though there are reasons for supposing that, originally, the Germinal Vesicle is situated in the centre of the Yolk.

* *Purkinje*, in Berlinerwörterbuch, Band x. S. 109.

† *Wagner*, in Ed. Med. and Surg. Journ. 1836. No. 127.

‡ *Wagner*, l. c.

We have then—

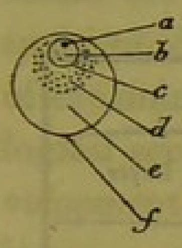
1*stly*, "Shoots;" as in many Zoophytes.

2*dly*, "Germinal Granules;" a half-fluid granulous mass, as in some Infusoria, some Polypes, and many other Zoophytes.

3*dly*, The ova of some Infusoria, in which the Germinal Vesicle contains a mass of granules.

4*thly*, Perfect ova, of more elaborate animals, viz.—

Fig. 1.



a Germinal Spot.
b Fluid contained in Germinal Vesicle.
c Germinal Vesicle.
d Layer of granules, having the Germinal Vesicle in its centre.
e Yolk.
f Primary membrane, enclosing the Germ and Yolk.

5*thly*, Superadded, in Mammals and in Man, there are the Graafian Vesicle, and its fluid,* viz.—

* In Mammals, and in Man, the part corresponding to the ovum of other animals, is called the *ovulum*.

For the discovery of the latter,—an epoch in the history of development,—we are indebted to the illustrious *Von Bär*. Von Bär was once a pupil of Döllinger, the head of the Würzburg School; who having expressed to the former a wish, that some young naturalist should, under his own superintendence, thoroughly investigate the development of the common fowl, Von Bär would most gladly have undertaken it, but for circumstances that required for a time his estrangement from the subject. Von Bär mentioned it, however, to his friend *Pander*, who had come to Würzburg, at his suggestion, to be a fellow-pupil of Döllinger. Pander undertook those researches; and hence his discovery of the primary separation of the Germinal Membrane into layers. *Von Bär* returned with renewed ardour to the subject, and discovered the Ovulum of Mammals; *Purkinje* having in the mean time found the Germinal Vesicle of Birds. *Valentin* next discovered the Germinal Vesicle in Mammals; and *Wagner* afterwards found the Germinal Spot. The last-mentioned author justly asks, Is this spot also to present some contained part?

For a particular account and drawings of these minute bodies, see *Von Bär*, "de Ovi Mammalium et Hominis genesi;" also the Ed. Med. and Surg. Journ. Nos. 127 and 128; and Müller's Archiv, 1836, Heft ii.; likewise a paper by *Purkinje*, "Symbolæ ad Ovi Avium historiam ante incubationem;" and one by *Bernhardt*, "Symbolæ ad Ovi Mammalium historiam ante prægnationem."

Dr Allen Thomson, one of the very few in this country who have attended to the subject of development, has given an epitomized but very comprehensive account of the changes in the Germinal Membrane of Vertebrated Animals, so far as ascertained up to the time when he wrote (1830), adding observations of his own. (See vols. ix. and x. of this Journal.)

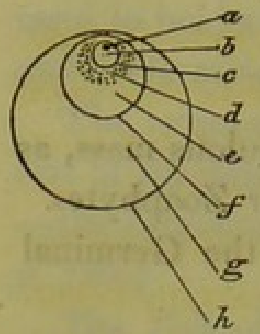


Fig. 2.

a, b, c, d, e, f, as above.
g Fluid contained in the Graafian Vesicle.
h Graafian Vesicle.

The following table * shews how generally, the more difficult to discover of these parts, have already been met with in the animal kingdom.

	Germinal		
	Vesicle.	Spot.	Layer.
Vertebrata.			
Mammalia, including Man,	—	—	—
Aves, . .	—	—	—
Reptilia, . .	—	—	—
Pisces, . .	—	—	—
Mollusca, . .	—	—	—
Articulata.			
Annelida, . .	—	—	
Crustacea, .	—	—	—
Arachnida, .	—	—	—
Insecta, . .	—	—	—
Zoophyta, . .			
Entozoa, . .	—		—
Infusoria, . .		—	

It is then fair to presume,—since this table contains "both ends," as they have been termed, of the animal world,—viz. Infusoria and Man,—that wherever there exists what is called a perfect ovum, all the above parts are present.

There are reasons for supposing that the Germinal Vesicle is formed before the Yolk,—one of which is afforded by its relatively greater size; † and, if so, the Germinal Vesicle, with its contents, constitute the primitive portion of the ovum, which in all animals, where found, appears to be essentially the same. ‡

It has thus been shewn, that in all classes of animals, from Infusoria to Man, germs at their origin are *essentially the same in character;* and that they have in common a homogeneous or general structure.

* Compiled from various sources.

† The Germinal Vesicle is met with in those ova only, that are not quite ready for impregnation; as it bursts on the latter taking place, and pours its contents among the granules of the Germinal layer, by which it is surrounded.

‡ *Purkinje,* in Berlinerwörterbuch, Band x. S. 111.

It appears also, that essentially, the *manner* of the metamorphosis, or metamorphoses, from a more homogeneous or general structure, to one more heterogeneous and special,—*i. e.* the *manner* of development,—*is universally the same.*

Such a proposition seems deducible from what we know of development, not only in all the Vertebrata, but in many Invertebrated animals; such as the Insecta, * Crustacea, † Arachnida, ‡ and even Mollusca; § and Von Bär seems to have meant the observation to apply to animals in general, when he spoke of development proceeding by "a continued elaboration of the animal body, through growing histological and morphological separation." ‖ Zoophytes themselves, so far as their development extends, may also be included, as subject to the same law.

To the *manner* of development, we shall presently return.

The Layer of granules, already spoken of, as having in its centre the Germinal Vesicle (fig. 1. p. 120), appears, on the bursting of the latter, to contribute to the formation of the Germinal Membrane (Plate I. fig. 3): though the central and most important part of the latter is perhaps constituted, by the contents of the Germinal Vesicle.

The Germinal Membrane in some of the Vertebrata, is at first a more or less circumscribed disk, covering only a part of the Yolk, and afterwards extending itself to surround and enclose the whole of it; in others, it encloses the whole of the Yolk from the first. This membrane in the Invertebrata, presents differences in this respect, regarding which physiologists are not quite agreed.¶

In most vertebrated animals, the Embryo is at first nothing more than the exuberant growth of a part of this Germinal Membrane, *near its centre*, (see Plate I. fig. 3.); *i. e. in the*

* See *Burmeister's* Entomology, translated by Shuckard, 1836, 8vo.

† *Rathke*, über die Bildung und Entwickelung des Flusskrebses, 1829, fol.

‡ *Herold*, Untersuchungen über die Bildungsgeschichte der Wirbellosen Thiere im Eie, 1824, fol. Also *Rathke*, in Burdach's Physiologie als Erfahrungswissenschaft.

§ See *Von Bär's* observations on the development of Snails, in his "Entwickelungsgeschichte der Thiere," &c., 1836, 4to.

‖ l. c. p. 231.

¶ See *Valentin*, Entwickelungsgeschichte des Menschen, &c. pp. 144 an 602–3. Also *Herold*, l. c.; and *Rathke*, l. c.

situation occupied by the Germinal Vesicle, before the bursting of the latter ; the part exuberant, projecting, but not being distinguishable from the rest, by a well-defined border. The projecting portion becomes more and more distinct, until its growing independence is manifested, in a tendency to withdraw itself from the remainder. (See Plate I. fig. 5.)

This separation of the central part of the Germinal Membrane from its periphery and from the yolk, gives rise eventually to the appended *Umbilical Vesicle* in Man and other Mammals. In Birds, the corresponding part is taken into the abdomen. In Frogs, the embryo occupies, from the first, so large a portion of the Germinal Membrane, and the latter so nearly surrounds the yolk, that the yolk becomes contained in the embryo, before the independence of the latter has time to manifest itself by a tendency to withdrawal.

Explanation of Plate I.*

Fig. 3. Transverse section of the Germinal Membrane and incipient Embryo of the Common Fowl.

Fig. 4. Ditto, more advanced.

Fig. 5. Transverse section of an Embryo of the Common Fowl.

- * Primary membrane enclosing the Germ and Yolk.
- ** Serous, or Animal layer.
- *** Mucous, or Vegetative layer.
- B Sinus or Vein, bounding the Vascular Area.
- *a* Chorda vertebralis.
- *b* Outer margin of the Lamina dorsalis.
- *c* Upper margin of the same ; afterwards the Mesial Line of the back.
- *bc* Lamina dorsalis.
- *d* Outer (and afterwards under) margin of the Lamina ventralis.
- *bd* Lamina ventralis.
- *e* Flexure of the serous lamina.
- *de* Membranous portion of the abdominal paries.
- *f* Margin of the lateral envelope.
- *g* Lateral part of the fold of the Amnion ; afterwards, the closing-point of the Amnion.
- *deg* Amnion.
- *h* Upper angle of the mesenteric lamina.
- *i* Under angle of the mesenteric lamina ; afterwards the suture of the Mesentery.
- *hi* The mesenteric lamina.
- *k* The vascular lamina on the Intestine.
- *l* Mucous lamina of the Intestine.
- *m* Corpora Wolffiana.
- *n* Mesenteric space.
- *o* Aorta.

Fig. 6. Ideal transverse sectior of the Embryo of a Vertebrated Animal.

- *a* Stem of the vertebral column.
- *b* Laminæ dorsales—their union forms the upper or dorsal Tube.
- *c* Laminæ ventrales—their union forms the under or ventral Tube.
- *d* Central portion oft he Nervous System or nervous Tube.
- *e* Vascular Tube.
- *f* Mucous Tube.
- *g* Corpora Wolffiana.

* Containing *transverse* sections only : selected from *Von Bar.*

h Skin.
i Amnion.
k Serous covering, resulting from the closing of the amnion at *m*. (See also *g* of Fig. 3.)
l Yolk-bag.
m n Central line, common to all the Fundamental organs.
q Vascular lamina, on the Yolk-bag.

Fig. 7. Formation of the Germinal Membrane into the Embryo of a Vertebrated Animal.

α β Central line, common to all the Fundamental organs.
a Chorda vertebralis.
b Formation-arc of the Laminæ dorsales.
c Formation-arc of the Laminæ ventrales.
d Formation-arc of the Nervous Tube.
e Formation-arc of the Vascular Tube.
f Formation-arc of the Mucous Tube.
m Ridge of the Lamina dorsalis.
m' That place in the Germinal Membrane out of which the ridge (*m*) arises.
n Ridge of the Lamina ventralis.
n' That place in the Germinal Membrane out of which the ridge (*n*) arises.
x Perforating formation-arc of the Eye.
y Perforating formation-arc of the Ear.

The *manner* of development seems to be as follows:—*

The Germinal Membrane separates into two disjoined layers; viz. into a Mucous or Vegetative (Plate I. Fig. 3, ***), and a Serous or Animal layer (same Fig. **); the latter being in contact with the Primary Membrane (same Fig. *), enclosing the Germ and Yolk; the former lying immediately upon the Yolk itself. The Vegetative layer is afterwards seen to be composed of two intimately united laminæ; viz. the proper Mucous (Fig. 4, ***), and the Vascular (Figs. 4 and 5, *h*, *i*, *k*). The Animal layer also, in the embryo at least, divides itself into two laminæ, viz. into the Skin, on the one hand (Fig. 6, *h*), and into a mass containing the Fleshy layer, as well as, in vertebrated animals, the Osseous, and the Nervous layers, on the other (Fig. 6,*a*, *b*, *c*, *d*). This division into layers, is the "*primary*" separation. During the course of this separation, the layers become tubes, or Fundamental organs. (See Plate I, Fig. 7.)

There occurs, at the same time, a separation of textures, in the substance of the layers or tubes; cartilaginous, nervous, and muscular substance, separating from each other; while a part of the mass becomes fluid. Some of the elementary textures also, assume the form of laminæ, which are subordinate to the original layers; the latter therefore, (now tubes), become the

* We here present, in a very condensed form, Von Bär's observations on the Vertebrata, as contained in his work "Entwickelungsgeschichte der Thiere," &c. 1828, pp. 153-159, &c.:—so modified, however, as to make the description applicable to invertebrated animals also.

central portions of systems. This separation into textures, is the "*histological*" separation.

Besides the above, there arise differences in outward shape; single sections of the tubes being developed into distinct forms or organs, destined to perform particular functions; which functions are subordinate members of the function of the whole tube; but differ from the functions of other sections of the latter. For example, the mucous tube divides itself into the mouth, œsophagus, stomach, intestine, respiratory apparatus, liver, urinary bladder, &c.; the peculiarity in the development being connected with either an increased or diminished growth. This is the "*morphological*" separation.

Thus, by a threefold division, the mass becomes heterogeneous; and the further back we go, the more do we find, not single organs only, but histological elements united.

"Fresh parts are acquired, not by *new*, but by *trans*formation. When, for example, the foundation of a cartilage forms, there was not previously a vacancy in the place it occupies, but a homogeneous mass; the *change* in which, consists in the appearance of an assemblage of opaque granules, and a surrounding pellucid fluid. This is the *manner* of histological separation; calling forth, as it were, antitheses."

"No part is formed, that was not previously in connexion with some part, earlier formed; no part has an isolated origin, then adding itself to the rest. Nothing swims freely around, annexing itself here or there, as formerly was said of the whole embryo, and even lately, has been conceived and taught of the spinal cord.* Each organ is a modified part of a more general organ;" and development proceeds from the centre towards the periphery. This is the *manner* of morphological separation.

It was to uniformity in the *manner* of the *primary*, of the *histological*, and of the *morphological* separations, just described, that we referred in the proposition, that essentially the *manner* of the metamorphosis, or metamorphoses—*i. e.* the *manner* of development—from a more homogeneous or general, to a more

* Such is the doctrine of Serres. See his "Anatomie Comparée du Cerveau;" also his "Recherches d'Anatomie Transcendante et Pathologique." 4to, 1832.

heterogeneous or special structure, is universally the same; and we have already mentioned researches, which seem to warrant this conclusion.

The *direction* taken by development, is, however, not the same precisely, in any two animals; and in different Classes, the direction (type) differs very widely. But of *direction*, or *type*, we shall treat more particularly hereafter.

It has then been shewn,—that *germs* from Infusoria to Man, are essentially the same,—and we know that there are some structural characters, common to all animals in a *perfect* state, —especially to those of the same Class, as, for example, the Vertebrata: there are besides, resemblances between some of the more elaborate structures, in certain of their embryonal phases, and many less wrought out structures, in their permanent conditions; which resemblances are observable, not only between animals included in the same great Class, but also, though more remotely, between animals belonging to different Classes.

To sum up these important facts: If the structure of germs has been found at "both ends" of the animal kingdom, as well as in the intermediate classes, to be essentially the same;—if between the homogeneous masses, forming germinal membranes, there is found no essential difference;—if the primary separation of this membrane into layers (the vegetative layer being always directed towards the yolk), and the subdivisions of these layers—incipient in the membranal, and completed in the embryonal states—are the same in character;—if the formation, not of textures only, but of organs also, proceed in the manner just described;—and, above all, if permanent structures, among many of the less elaborate animals, resemble most obviously, different degrees of histological and morphological separation, as presented in the embryonal phases of an individual destined to be more wrought out;—are we not entitled to conclude, not only that a heterogeneous or special structure arises only out of one more homogeneous or general; but also that, essentially, the *manner* of the metamorphosis, or metamorphoses,—the *manner* of development,—from the latter to the former state, is universally the same?

And are we not then led fairly to the conclusion, *that all the* *varieties of structure in the animal kingdom, are but modifications of, essentially, one and the same fundamental form?**

Now, seeing that not only the Vertebrata, but all Classes of animals, in their development, must pass *thus gradually* from a merely *animal* form, to the most special forms they respectively attain; further, that the *manner* of development may be considered as essentially the same in all;—is it surprising that there are resemblances between some of the embryonal phases of very different animals; and that some of the stages in embryonal life of the more elaborate structures, resemble perfect states of those that are less wrought out? Could it, indeed, have been otherwise?

Let us inquire a little more particularly into the development, firstly, of the Vertebrata; and, secondly, of some Invertebrated animals.

Firstly—Of the Vertebrata.

The layers into which the germinal membrane separates, become, as already said, tubes. (See Plate I. fig. 6.) These tubes are more or less bent towards the yolk, at each extremity; but extend the whole length of the animal, including its head and tail. Therefore, out of the upper tube,—constituted by a union of the laminæ dorsales (fig. 6, *b*.),—are formed, the arches of the caudal, lumbar, dorsal, and cervical vertebræ, the arched cranial bones, and the soft parts covering all of these; together with the central portion of the nervous system. While out of the under tube,—constituted by a union of the laminæ ventrales, (*c*) —are formed, the ribs, the soft parts of the thorax and abdomen, the hyoid bone, and all that portion of the neck, anterior (or inferior) to the vertebræ, the lower jaw, and some other parts, both osseous and fleshy, of the face. The bodies of the vertebræ, and the base of the cranium, are formed out of a portion of the animal layer of the germinal membrane, common to the upper and the under tube (fig. 6, *a*.)

The central portion of the nervous system in different animals, may, in its ultimate elaboration, produce very different struc-

* Whether this fundamental form is vesicular, as it has been supposed,—and in favour of which opinion, several facts might be brought forward,—we cannot now inquire.

tures; all grades between the splendid cerebral hemispheres in Man, and the mere rudiments of hemispheres in Fishes. The nervous portions of the organs of sense are, in all the Vertebrata, processes of the central part of the nervous system, through the Laminæ dorsales (Fig. 7. *x. y.*); so that, though so varied in different animals, not only all parts of the central portion of the nervous system, but all processes from the latter,—with a common origin, and the same *manner* of development,—may well bear a general resemblance to each other, in the perfect states of the less, and the embryonal states of the more, elaborate animals.*

(The nervous ganglia of the Cuttle, and perhaps of many other invertebrated animals, seem to correspond, not with the sympathetic, but with the spinal ganglia of the Vertebrata; a spinal cord and brain not being present.† It is remarkable, that in the Cuttle, there occur cartilaginous rudiments of vertebræ, under which the ganglia lie.)

The muscles of the trunks in different animals of the Class Vertebrata, are but modifications of the fleshy portions of the Laminæ dorsales and ventrales; and the muscles of their extremities, are only similar metamorphoses of those portions of the latter, that are carried out with the osseous (or at first cartilaginous) foundation of the extremities themselves. (See fig. 8, below.)

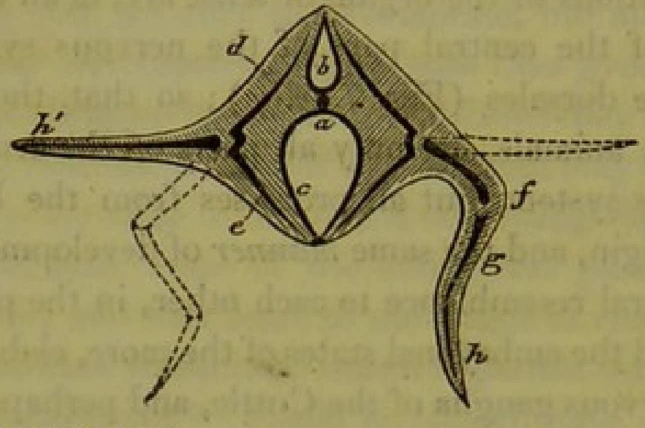
All the resemblances in the vascular system of different animals, are, in like manner, referrible to a common origin, and the same *manner* of development; and its varieties, to various modifications in *direction* (or *type*) and *degree*.

The Mucous tube originates, as processes, the mouth, œsophagus, stomach, respiratory apparatus, liver, urinary bladder, and other organs; in part also, and in conjunction with the Vascular tube, the genital organs: which parts, in all their varieties, bear a general resemblance to corresponding parts in different animals.

* It has been said that the spinal cord originates the brain. This is most untrue; the spinal cord does not exist before the brain; but there exists a central portion of the nervous system, out of which arise both brain and spinal cord.

† The term "brain" is here limited to the enlargement at one extremity of a mass, of which the other forms a spinal cord. (Von Bär, l. c.)

Fig. 8.
Ideal Transverse Section of a Vertebrated Animal, to shew the Type of the Extremities.



a Stem of the vertebral column.
b Arches of the Vertebræ.
c Ribs.
d Dorsal } radical portion. } of an Extremity, &c.
e Ventral
f Upper } middle portion.
g Under
h Terminal portion.
h' Terminal portion as a Fin.

(This fig. is taken from Von Bär.)

In the substance of the fleshy portion of the Lamina dorsalis and ventralis of each side, there is formed a series of osseous arcs (fig 8, *d e*), constituting the radical portion of the extremities, and that part of the base of the cranium, with which the superior maxillæ are articulated; and from a point near the middle of each arc, there issues a process, corresponding to the middle (*f g*) and terminal (*h*) members of the latter. Now, it is obvious, that with this common origin, and the same manner of development, corresponding parts in different animals of the Class Vertebrata,—whether arms, legs, wings, fins, maxillæ, &c.—are likely to retain a general resemblance; though the absence of the middle members, or modification of the whole extremity, &c. may render them very dissimilar in their details.

Corresponding parts of structure may, however, in different animals, perform very different functions. Thus, besides the extremities just mentioned, many other examples might be given; such as a fact pointed out by Geoffroy St Hilaire, that certain parts of the hyoid bone in the Cat, correspond to the styloid processes of the temporal bone in Man; and the different functions of the generative organs in the two sexes, afford a still more remarkable example.

It has thus been shewn, why corresponding organs may resemble each other in different animals of the Class Vertebrata. Of Invertebrated animals, we shall presently speak.

In development, germs, and even embryos, belonging to different groups of the same great Class, may long be indistinguishable; and still longer, those that are more nearly allied. But those belonging to different great Classes, begin to diverge sooner; or rather, the angle of divergence being greater, a difference is appreciable at an earlier period;* and in proportion to the angle of divergence in a germinal, are th structures unlike in a perfect state. Just as, in a tree, those branches that have been given off nearest to its root, become most widely separated in their terminating twigs.

In different Classes, development, though it proceeds in the same *manner*, yet taking thus different *directions*, attains, with materials perhaps essentially the same in primordial structure, very different ends (*types*).

Thus it proceeds in the Vertebrata or Osteozoa, with especial reference to the central portion of the nervous system; in the Arthrozoa (which include, besides the Articulata, some Zoophytes), having for its chief object, the organs of locomotion. In both of these Classes, therefore, it is the Serous or Animal layer of the Germinal Membrane, that is seen first advancing; and out of this, in these two Classes, there is thus produced, a very different system of organs.

In the Gastrozoa (*i. e.* the Mollusca and most Zoophytes), on the other hand, the organs of nutrition are especially the object; and in them, therefore, development proceeds chiefly in the Mucous or Vegetative layer.

To these priorities in development, and to the important influence they have on the direction which development takes in other parts of the system, are referrible the leading characters of Classes.† Yet it is in *direction* only, that development can

* The *primitive trace* is very different in Invertebrated animals,—for example, the Crustacea,—from what it is in the Vertebrata; and even among some of the Vertebrata, there are observable, in this respect, no small differences; as between the primitive trace of Batrachian reptiles, and that Birds,—(*Valentin*, Entwickelungsgeschichte, &c.)

† Hence we cannot compare animals, belonging to different Classes, in regard to what is called their "rank," unless we keep in view, not the *degree* alone, but also the *direction* of development. For the same reason, it is absurd to say, that one Class of animals can pass into another; such, for exam-

be said to differ in different animals; in *manner*, it remains the same.*

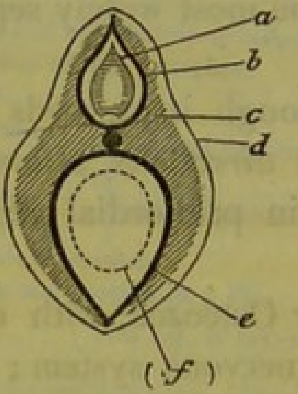
Secondly,—Of some of the Invertebrata.

The following diagrams will illustrate different *directions* of development, though the *manner* be the same.

Ideal Transverse Sections, shewing the Structures formed out of the Animal layer, respectively,

Of the Osteozoa (Vertebrata).

Fig. 9.



Upper tube—

a, Central portion of the nervous system; situated in the *upper* part of the Animal layer.

b, Arches of the vertebræ, some of the cranial bones, &c. (part of the internal skeleton.)

c, Fleshy layer.

d, Skin.

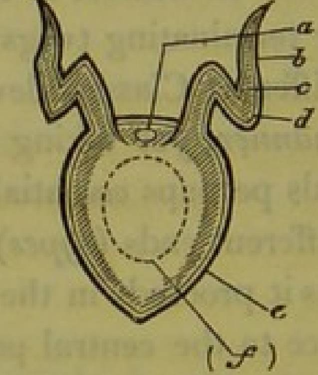
Under tube—

e, Ribs, lower jaw, &c. (part of the internal skeleton); the other parts of this tube, as *c* and *d* of the upper tube.

(*f*, Mucous tube.)

Of the Arthrozoa.

Fig. 10.



Upper tube, incomplete, viz.

a, Situation of what there is, corresponding to the central portion of a nervous system: situated in the *lower* part of the Animal layer.

b, External skeleton, secreted from the skin,
c, Fleshy layer, such as it is,
d, Skin,
} forming an Extremity, a Mandible, &c.

Under tube—

e, External skeleton, secreted from the skin; the other parts of this tube, as *c* and *d* of the upper tube.

(*f*, Mucous tube.)

The Vascular tube is not shewn in the above figures.

ple, as the Cephalopoda of the Class Mollusca, or the Crustacea of the Class Articulata, into Fishes of the Class Vertebrata. As well might it be said, that branches divergent at a tree's root, because they retain some characters in common, can be coincident in their terminal localities.

* There are, however, certain systems of organs more or less common to all beings. Among these are especially the nutritive or appropriative organs; resemblances between which, therefore, in corresponding stages of development, may be conceived to extend to existences of almost every kind. It has been justly said by Burmeister, that Osteozoa (Vertebrata), uniting in

It is obvious from the above,

1stly, That in the Osteozoa, the *central portion of the Nervous System*; in the Arthrozoa, the *organs of locomotion*, *mandibles*, &c., are the especial objects, in the early stages of development.

2dly, That the central part of the Animal layer is appropriated accordingly. Thus it may, perhaps, be said, that parts corresponding to the Laminæ dorsales of the Osteozoa, go to form the Extremities chiefly, in the Arthrozoa.

3dly, That the upper tube in the Arthrozoa is imperfect, though there is evidently a tendency in the extremities to its formation.*

4thly, That, from the direction taken by their extremities, the Arthrozoa must move about, with the thorax and abdomen uppermost; the relative position of the Fundamental organs being reversed. The organs also, formed out of the Mucous and Vascular layers, are found to be inverted, if compared with corresponding parts in the Osteozoa; but there occurs such an adjustment in the situation of the external parts,—as, for example, in that of the mouth and organs of sense; and, as what in the Osteozoa is the extensor, becomes in the Arthrozoa the flexor side of the body;—that, so far as these are concerned, it cannot be said that the Arthrozoa move about on their backs. Rather may it be affirmed, with Valentin, that "they have no true back, but only the tendency to form one."† But their thorax and abdomen are certainly inverted.

5thly, That the situation of what these animals have of the central portion of a Nervous System, is a part of the body corresponding very nearly to that occupied by the central portion of the Nervous System in the Osteozoa; viz., it is in the former (Arthrozoa) situated in the *under*—in the latter (Osteozoa) in the *upper* part of the animal layer,—supposing each of these Classes of animals to be situated *above* the yolk.

6thly, That the term "dorsal" vessel, is calculated to mislead;

themselves, in no small degree, ventral as well as locomotive properties, exhibit formal approximations to both Gastrozoa and Arthrozoa in their development. (Burmeister, l. c. p. 419.)

* Such is the idea of Valentin, l. c. p. 608.

† Loco citato, p. 607.

he part so called, obviously corresponding to the aorta in other animals; and, according to the above diagram, having a truly thoracic and abdominal locality.*

Of the development of molluscous animals, we know very little: enough, however, to render it quite safe for us to extend to them the laws already laid down; viz. of the heterogeneous arising only out of the homogeneous, and of identity in the *manner* of histological and morphological separation (the *manner* of development),† whatever may be the *direction* which the latter takes, and however limited its *degree*.

Even to Zoophytes, the same laws may be applied. The Germinal Granule of the Polype—a homogeneous, shapeless mass—separates into a softer portion, on the one hand; and a more rigid, a horny, or calcareous substance, on the other; and assumes its proper, more or less special, form. Even shoots themselves—those, for example, of the Hydra ‡—are at firs simple swellings, then cone-like, afterwards somewhat cylindrical, and gradually become funnel-shaped, like the parent: processes then appearing wart-like, at the circumference of the common cavity, and these by degrees elongating into arms.§

The whole animal kingdom then, (perhaps all organized beings?), may be considered as directed in development by the above laws; and all animals present besides, the antithesis of an

* The Germinal Membrane separates, as well in invertebrated, as in vertebrated animals, primarily into a Serous or Animal, and a Mucous or Vegetative lamina; between which, sooner or later, there is found a third, the Vascular lamina (Valentin, l, c, p. 605).

The above figure (10.) is not intended to present the *form* of any of the Arthrozoa. The form, indeed, of an *Osteozoon*, has been as far as possible adopted, in order to admit of an easy comparison of corresponding parts; the only purpose here, being to shew the appropriation of the Animal layer of the germinal membrane in the two Classes. We do not at present enter into any comparison in *form*, of parts of the external skeleton of the Arthrozoa, with the osseous system of Vertebrated animals (Osteozoa).

† See *Von Bär's* researches on Snails, already mentioned; also those of *Stiebel* and *Carus*, alluded to by *Burdach*, Physiologie als Erfahrungswissenschaft, Band ii. S. 179–180.

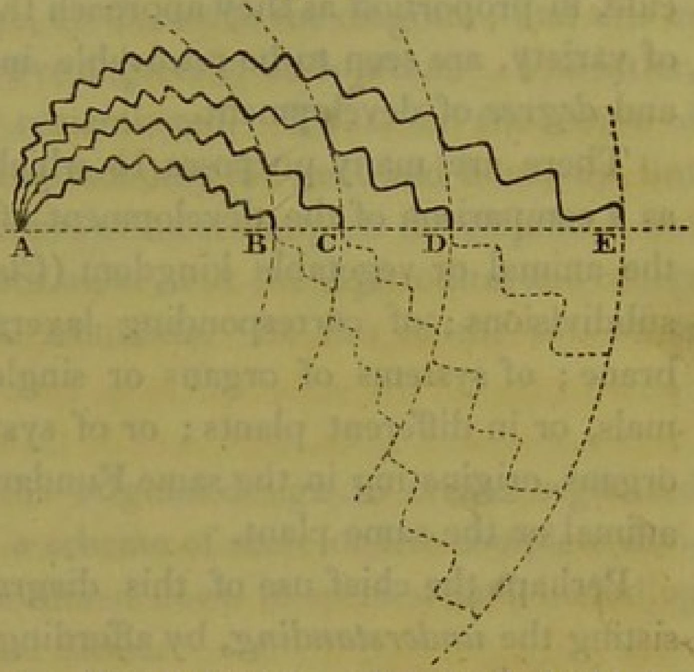
‡ *Carus*. plate i, fig. 1.

§ Burdach, l. c. p. 164–1.

internal or vegetative, and an external or animal portion of the body.

The following diagram is intended to illustrate fundamental unity, and the causes of subsequent variety in structure; the latter being acquired in development, and development being represented by curves.

Fig. 11.



Let the point A, represent the supposed coincidence in fundamental form, of four germs of the Class Vertebrata.

The curves drawn from the point A, to the points B, C, D, E, represent, respectively, the development of Fishes, Reptiles, Birds, and Mammals.

The identity of the curves, in curvature, corresponds to identity in the *manner* of development (*i. e.* in the *manner* of histological and morphological separation).

The *lengths* of the curves, together with the *degrees of undulation*, measure the *degree of aggregate elaboration* attained by each of the above, in the course of its development.*

The dotted *continuations* of the curves, measure the *differences* in the degree of elaboration.

The different *directions* of the curves, both general and particular, represent the different *directions* taken in development; *i. e.* modifications of the type of the Vertebrata; and serve to shew, that while there exist *resemblances*, *identities* are impossible.

The amount of *divergence*, measures the difference in *structure*, arising from the different *directions* taken in development, (difference in *kind*).

* This illustration is, however, a very coarse one. We cannot, for instance, represent the fact, that certain parts of structure in birds, are more wrought out, than corresponding parts in mammals. The term *aggregate* elaboration, has therefore been employed.

The *cross lines* (arcs) indicate, at the points where they cut the curves, *corresponding stages* of development. It is in corresponding stages of development that resemblances occur.

By the above diagram (Fig. 11.), resemblances between organized structures, admitting of comparison, are seen to be in the inverse ratio of the age,—the curves having a tendency to coincide, in proportion as they approach the point A ; and the causes of variety, are seen to be resolvable into differences in *direction* and *degree* of development.

There are many purposes to which it may be applied, such as a comparison of the development of the primary divisions of the animal or vegetable kingdom (Classes), or of any of their subdivisions ; of corresponding layers of the Germinal Membrane ; of systems of organs or single organs, in different animals, or in different plants ; or of systems of organs or single organs, originating in the same Fundamental organ, of the same animal or the same plant.

Perhaps the chief use of this diagram consists, firstly, in assisting the *understanding*, by affording something like an object, to which descriptions may be referred ; and, therefore, secondly, in assisting the *memory*, by means of association.

Let us, for example, refer to it a fact mentioned by Oken,* and since by Burmeister,† that certain Insects, differing in the degree of elaboration in the *perfect* state, differ in a corresponding manner as *larvæ* also. Suppose that at the point A, four germs of different Insects coincide essentially in fundamental form. Let the curves represent their development in larval (*i.e.* a part of embryonal) life; and let the germs be those respectively of one of the Diptera, Hymenoptera, Coleoptera, and Lepidoptera. The larvæ of the Diptera (gnat, house-fly), whose development is represented by the curve A B, resemble the footless and headless Leech; those of the Hymenoptera (bee, wasp, ant) A C, may be compared to Nais, in which there is a distinct head, but the feet are wanting ; those of the Coleoptera (May and caddis-flies), A D, are comparable to a third grade of the Annulata, " residing in tubes, and furnished with large bundles of gills."

* " Allgemeine Naturgeschichte für alle Stände," 8vo, Band iv. s. 469–470.

† Loco citato, pp. 419, 420.

Lastly, in the larval development of the Lepidoptera (butterfly, moth), curve A E, there is a resemblance to another grade of the Annulata—among which the Aphrodite—having, "besides a distinct head, many feet on the ventral side of the segments."

Now from this example it is obvious, that not only the four Families of perfect Insects, as well as their larval states,—but also those animals with which the latter, respectively, have been compared,—will be, as it were, all *located* in the diagram; and this in the order of their respective degrees of elaboration. The latter, therefore, will be easily remembered. Thus, in the curve of least elaboration, are located not only the gnat and house-fly, but also the leech. In the curve of most complete development, not the butterfly and the moth alone, but the Aphrodite, and others of the same grade in the Annulata. So also of the two other curves.

It seems as if, with the original design to create organized beings, there had arisen a scheme of more or less complete division and subdivision, continued down to species, and including in the latter, all individual forms.*

One of the supposed grand divisions may have included *animals*;† one of the first subdivisions, the type of the Vertebrata; subordinate to which, and co-ordinate to each other, we have the types of Fishes, Reptiles, Birds, and Mammals. Each of these groups presents its families,—each family, genera,—each genus, species,—and every species has its individual forms. So would the other Classes admit of being referred to subdivisions of the supposed scheme.

In thus speaking of Classes and other divisions of the animal kingdom, however, we by no means acknowledge the present arrangement to be perfect. The only sure basis for classification is—not structure, as met with in the perfect state, when func-

* Of the *order* in which the various beings were called into existence, we do not pretend to speak.

† Another of the supposed grand divisions may have comprehended *plants*; and this would explain why the resemblance should be so great, between the simplest forms of both. It is obvious, that an inappreciable shade of difference, between two general and crude structures, might occasion divergence to an almost immeasurable distance, in proceeding to the most highly organized and special states.

tion tends to embarrass, but—the *history of development*, at that period when structure presents itself alone; and, as Von Bär has justly said, this will perhaps "one day become the ground for nomenclature," * as it can be the only one on which to form a correct estimate of parts, in different animal forms.

Certain elements, proceeding from the elements of an individual, or from the elements of two individuals, constitute, by a separate or distinct existence, another individual, a germ; destined, like its parent or parents, to undergo, by a succession of elements, continued changes in its component parts; and, by degrees, to attain a state of being, represented by a form, belonging to the parent-type.

These elements, while they constituted part of the parent or parents, shared the state of being, peculiar to the latter. It is then easily conceivable, that, having themselves acquired a separate or distinct existence, the new being they constitute, should contain within itself, properties analogous to those of its parent or parents; and that therefore, in its progress towards its destined state of being, it should undergo similar changes; that it should attain the parent-type, and also more or less of individual resemblance to its parent or parents.

The elements of every germ must have innate susceptibilities of a certain definite arrangement; so that, on the application of stimuli, there results a certain structure.† These we shall in future call, innate susceptibilities of structure, or innate (plastic) properties. All innate properties are of course derived from the parent or parents. If the germ be animal, its leading properties are those characterizing *animals* in general. But it has others, common respectively to the class, order, family, genus, species, variety, and sex, to which the germ belongs. Lastly, it has properties that were previously characteristic of its parent or parents; in which, indeed, all the others are included. But no innate properties, except those merely *animal*, are at first, to our senses at least, apparent in the structure of the germ.

The sum of these innate (plastic) properties, determines the

* l. c. p. 233.

† The stimuli are those circumstances that produce development; such as nourishment, a peculiar ambient medium, and a certain degree of warmth.

direction taken in development; determines, therefore, the structure of the new being.

The *general* direction taken in the development of all the individuals of a species, is the same; but there is a *particular* direction, proper to the development of each individual, and therefore a particular structure, not identical with any other; for in no two individuals, is the sum of the innate (plastic) properties in all respects the same.

It has been already said, that as the elements of an individual cease, in turn, to be constituent parts of the same, the identity of that individual must be continually changing—can exist, indeed, at no two periods of time; inasmuch as new elements are continually entering into its constitution, while old ones are departing.

Hence, individual peculiarities in structure must, in their turn, become hereditary to succeeding sets of elements; continually renewed, as we have just asserted these elements to be There must, besides, continually present themselves, fresh peculiarities; and in their turn, these also must be inherited by sets of elements succeeding.

For the same reasons, the first set of elements, constituting a germ,—proceeding, as already said, from the elements of a parent or of parents,—must possess properties that were characteristic of the latter, at the moment when their separation took place; and can indeed possess no others, since the elements of the parents, and therefore the properties, are continually changing.

Hence it is, that the sum of the innate (plastic) properties can be in no two individuals the same; hence the *particular* direction of development proper to each *individual*; * and hence *individual* peculiarities of structure.

Strictly speaking, therefore, no two individuals of different births can have the same parentage; for though the *individuality* of the parent, or of each parent, does not change, yet, as *individuals*, the parents are continually changing.

The more nearly *cotemporaneous* separation of their elements, and the cotemporaneous derivation of nourishment from the maternal fluids, during fœtal life,—but especially the former,—are perhaps the causes why twins are sometimes so much alike in

* One *general* direction, as said before, being common to a *species*.

individual structure; and *super*-fœtation may be, in part at least, the cause why this is not always the case.*

The innate (plastic) properties include, as already said, some that are characteristic of animals generally, and others common to all the animals contained in that division of the animal kingdom, to which the species is subordinate. Now, the properties characteristic of the parent or parents, at the time of the separation of the germ, must include all of those transmitted to the latter.

This assists us to understand, why properties of the same kind should all, in a modified form, re-appear in the development of the offspring (see second paragraph of p. 22): and, indeed, since it is plain that "every step in development is possible only through the condition preceding,"† that "becoming depends upon having become,"‡ we see why those properties can re-appear in a certain order only; viz. in the order of their generality in the animal kingdom.

Thus, in development, the structure characteristic of the Vertebrata only, cannot manifest itself until there has been assumed, essentially, a structure common to *animals*,§ of which the Vertebrata are but a part, and to whose type, the type of the Vertebrata is subordinate. In like manner, structures subordinate to the type of the Vertebrata, cannot manifest themselves until after a modified appearance of the *general type*, of which they are but partial metamorphoses. More and more special forms are thus in succession reached, until the one most special is at length attained. ||

* There is, however, another cause why individuals, even of the same birth, should differ: viz. the different periods, at which the maternal portion of the germs may have been first secreted in the Ovary: for, though continually renewed, they must have, in consequence, a more or less peculiar state of being.

† Von Bär, l. c. ‡ Burmeister, l. c.

§ The necessary appearance, first, of a structure common to *animals* generally, affords indeed a principal reason for *supposing that there is essentially but one fundamental form.*

|| *Valentin*, an excellent German author, already quoted, says, "the development of the animal kingdom, and of the individual animal, are in the original idea, throughout, one and the same; but in the realization of single beings, perfectly different, and elaborated in different directions." The latter he conceives to take place in obedience to "metamorphoses" (a becoming more and more special) "of the original idea." Whether such is the case, we need not now inquire; but it is due to him, to acknowledge, that if there

To the law, requiring that a more fundamental type shall uniformly manifest itself before the appearance of one more subordinate, is perhaps referrible, the formation of parts that seem to answer no other purpose than the fulfilment of this law; viz. parts that either continue rudimentary through life, or not being used, disappear.

An example of the first, occurs in the appendix vermiformis of the caput cœcum coli, in the human subject; of the second, in the embryonal gills of land and air-vertebrata, which latter, having at no period an aquatic respiration, can never use gills.* Development proceeds to a certain point—though this point may differ in different animals—in obedience to the law, requiring that a more fundamental type shall uniformly manifest itself, before the appearance of one more subordinate; so that the special purpose to create Birds, Quadrupeds, and even Man himself, is, as it were, subordinate to the more general purpose, to create a Vertebrated animal. This explanation will perhaps apply to all parts present in a rudimentary state alone. †

any thing like probability in what we have proposed as an explanation of the re-appearance of general characters in individual development, it has, in some degree, resulted from reflection on the contents of his admirable work. —See the last 100 pages of his "Entwickelungsgeschichte," entitled, "Fragmente zu einer künftigen Gesetzlehre der individuellen Entwickelung."

* *Rathke* (Meckel's Archiv, 1827, p. 556.) and *Von Bär*, have described gills, in embryos of Mammals and of Man; *Huschke* (Oken's Isis, 1828, Heft I. p. 2.) in very small embryos of Birds.

† There are, however, certain parts of structure, that arise and disappear, not rudimentarily, for the fulfilment of this law; but to serve purposes required by the temporary relations of germinal and embryonal life. Such are the yolk, and umbilical vesicle, the amnion, chorion, and placenta, or corresponding parts; the gills, fins, and tail in the tadpole, or fœtus of the frog; to which examples, there might be added a host of others.

The metamorphosis of insects, furnishes a beautiful instance of the temporary presence of certain parts of structure, during embryonal life. Instead of an appended yolk, over which the Mucous or Vegetative layer, of the Germinal Membrane, is spread, to imbibe nourishment; that layer, in the larval state, becomes speedily a huge intestine, into which food is taken in prodigious quantity by the mouth. The vegetative process is, in this condition, the main object. But, as the pupal state is gradually attained, growth yields to transformation; and, as Burmeister has well shewn,* the intestine is, in part, metamorphosed into generative organs; which, in the Imago, or perfect insect, give origin to germs, destined to undergo like changes.

* l. c.

It has thus been shewn,

1*stly*, That a heterogeneous or special structure, arises only out of one more homogeneous or general, and this by a *gradual* change.

2*dly*, That the *manner* of the change, is probably the same throughout the animal kingdom, however much

3*dly*, The *direction* (or *type*) and *degree* of development may differ, and thus produce variety in structure; which however, there is good reason to believe, is

4*thly*, In essential character, *fundamentally the same.*

5*thly*, That no two individuals can have precisely the same innate susceptibilities of structure, or plastic properties; and therefore,

6*thly*, That though all the individuals of a *species*, may take, in their development, the same *general* direction,—there is a *particular* direction in development,—and, therefore, a *particular* structure,—proper to each *individual.*

7*thly*, That structures common to a whole Class must, in a modified form, re-appear in individual development; and,

Lastly, That they can re-appear in a certain order only; viz. in the order of their generality in the animal kingdom.

It has been our endeavour, throughout this paper, to limit the idea of fundamental unity of structure, to *essential* character alone; specific, and even individual peculiarities,—however inappreciable,—forbidding more. Each germ, even when presenting the merely *animal* type, must do so in a modified and peculiar form; on which the nature of its future metamorphoses depends: and if in the course of embryonal life, there occur resemblances in certain parts of structure, to corresponding parts in other animals, they are no more than *resemblances;* since individualities cannot be laid aside.

There is a danger in the present day, of generalizing too freely;* of carrying transcendental speculation much too far; of being so captivated by " the idea of a subjective unity, that real variety may be lost sight of;—as bright sunbeams veil myriads of worlds, that might shew to mortal man, what they are, compared with his world, and how little he is in the latter." †

* See an excellent chapter on the " Unity of Design" by *Dr Roget:* Bridgewater Treatise; vol. ii. p. 625.

† *Valentin*, Fragmente zu einer Künftigen Gesetzlehre der individuellen Entwickelung, in his Entwickelungsgeschichte, &c. S. 566,

from the Author

CXRXC

FURTHER OBSERVATIONS

ON THE

UNITY OF STRUCTURE IN THE ANIMAL KINGDOM,

AND ON

CONGENITAL ANOMALIES, INCLUDING "HERMAPHRODITES;"

WITH SOME REMARKS ON

EMBRYOLOGY,

AS FACILITATING

ANIMAL NOMENCLATURE, CLASSIFICATION, AND THE STUDY OF COMPARATIVE ANATOMY.

By MARTIN BARRY,

M. D., F. R. S. E., M. W. S.

From the Edinburgh New Philosophical Journal for April 1837.

FURTHER OBSERVATIONS, &c.

In a former memoir on this subject,* certain conclusions were arrived at, which, to save reference, it may be proper to repeat, viz.

1*stly*, That a heterogeneous or special structure arises only out of one more homogeneous or general, and this by a *gradual* change.

2*dly*, That the *manner* of the change, is probably the same throughout the animal kingdom, however much,

3*dly*, The *direction* (or *type*) and *degree* of development may differ, and thus produce variety in structure; which, however, there is good reason to believe, is,

4*thly*, In essential character, *fundamentally the same.* Yet,

5*thly*, That no two individuals can have *precisely* the same innate susceptibilities of structure, or plastic properties; and therefore,

6*thly*, That though all the individuals of a species, may take, in their development, the same *general* direction, there is a *particular* direction in development,—and, therefore, a *particular* structure,—proper to each individual.

7*thly*, That structures common to a whole Class must, *in a modified form*, re-appear in individual development; and,

Lastly, That they can re-appear in a *certain order only*; viz. in the order of their generality in the animal kingdom.

These conclusions, especially the two last, with the reasoning from which they are derived, sufficiently explain why, in the embryonal life of the more elaborate animals, there occur temporary resemblances in certain parts of structure, to the permanent states of corresponding parts, in animals less wrought out.

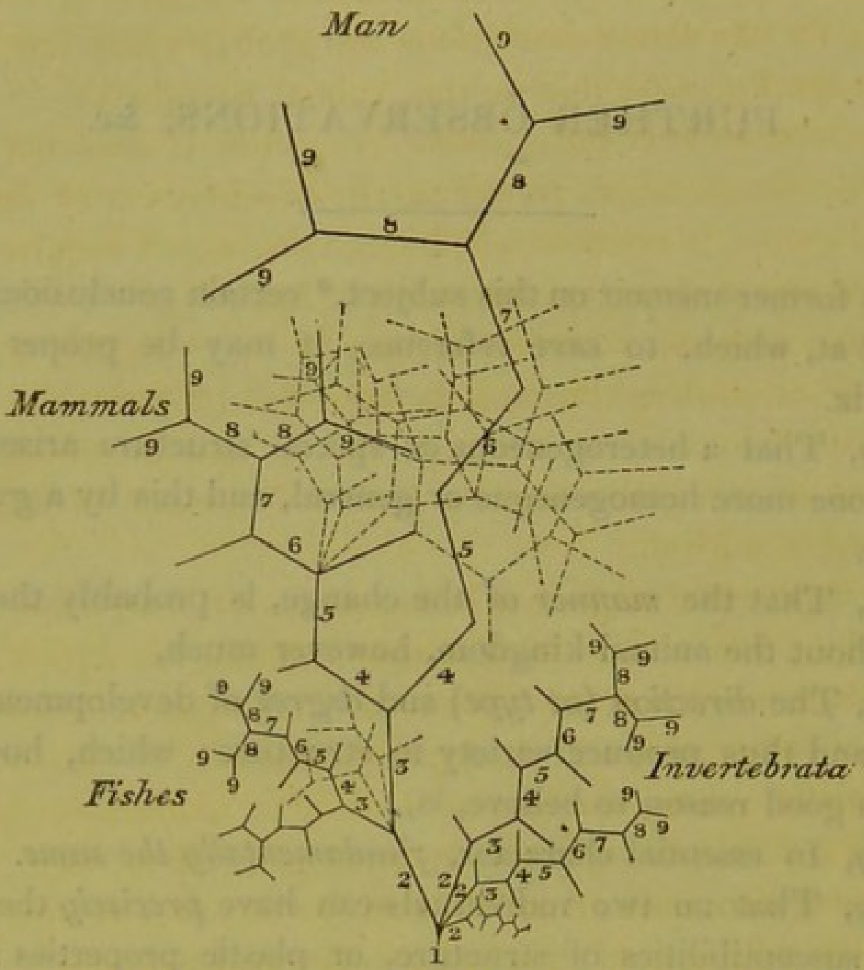
A Diagram will serve to illustrate some of these conclusions.

* See also the Edinburgh New Phil. Journ. for January 1837.

The Tree of Animal Development ;

Shewing fundamental Unity in Structure, and the causes of variety ; the latter consisting in *Direction* and *Degree* of development.

Fig. 12.



The whole figure represents the development of the entire Animal Kingdom. *

Any one of the primary divisions may rudely illustrate the development of a single organism, viz.—

Explanation—to be read from below upwards.

9. The *Individual* character in its most special form.
8. The *Sexual* character obvious, but the *Individual* character obscure.
7. The *Variety* obvious, but) *Sexual* difference scarcely apparent.
6. The *Species* manifest, but (the *Variety* unpronounced.
5. The *Genus* obvious, but not the *Species.*
4. The *Family* manifest, but the *Genus* not known.
3. The *Order* obvious, but not the *Family.*
2. The *Class* manifest, but the *Order* not distinguishable.
1. No *appreciable* difference in the Germs of all *animals* (Fundamental Unity ?)

* The lower *dotted* branches, indicate directions for the development of Birds and Reptiles ; the following out of which, would have rendered the diagram complicated and obscure.

To avoid complication, only binary divisions have beenused ; but *dotted* branches (the *upper* ones) are introduced, to shew that *all* the *remote* divisions admit of such addition, except those that indicate the development of sex.

The distance between the root and the extremities of the last twigs, shews the degree of aggregate elaboration or development.

(Slightly modified, the diagram might perhaps represent the development of the entire *vegetable* kingdom,—or any one of its primary divisions, the development of a single *vegetable* organism; for the above conclusions are probably not less applicable to the *Vegetable* than to the Animal Kingdom.)

This illustration is but a coarse one, since it does not shew the *particular* direction, proper to the development of each individual germ; in order to which, each line would require to be separated into a divergent fasciculus of lines.

It is not unusual, however, to hear of the "higher" animals *repeating* or *passing through* in their development, the structure of the "lower:" and though this is said in reference, of course, to no more than single organs, it is a mode of speaking calculated to mislead.

Such expressions might not be improper, did there exist in the animal kingdom a scale of structure differing in *degree* alone. But there is no such scale. We must "distinguish between the degree of elaboration and the type of structure."* Each class, order, family, genus, species, and variety of animals,—each sex and each individual,—has a structure peculiar to itself; nay, every organ also, must, from the first, be constituted with reference to the most special structure it is destined to attain. "The Blastema (germ) of the new being, must be already peculiarly organized, to produce, under requisite, favouring circumstances, this or that individual. A formless material, as the foundation of, and susceptible of constituting, any individuality you please, is merely an abstract notion of the mind, and exists nowhere in Nature; where there are only concrete realities,—more or less characteristic individualities, contained in a higher whole."†

Strictly speaking, therefore, no animal absolutely *repeats* in its development, the structure of any part of any other animal; and not only is the human embryo at all periods of its existence a human embryo, but the human heart and brain, closely as they resemble corresponding organs in other Vertebrata at certain periods of development, are never any thing else than the heart and brain of Man. If the young frog, the tadpole, resem-

* Von Bär.

† Valentin, Fragmente zu einer Künftigen Gesetzlehre der individuellen Entwickelung, in his Entwickelungsgeschichte des Menschen, &c. S. 591.

bles in some respects a fish, and spends a portion of its existence in the water, is it to be said that the tadpole *is* a fish? Would a highly developed fish constitute a frog? Besides, as said by Valentin,* a passage by the embryo of the so-called "higher" animals through the "lower" grades, would imply the possibility of an individual, at certain periods, laying down its individuality, and assuming that of another animal; which would abolish its existence as a determinate concrete reality.

No structure peculiarly *characterizing* any one set of animals in the perfect state, makes its appearance even in the embryonal life of any other.† Thus the perfect gills of fishes, and the air-sacs distributed through the body and the bones of birds, relating as these organs do, to the elements respectively, in which fishes and birds have their abode, are found in them alone, which could not be the case, did the so-called "higher" animals pass through the perfect states of those said to be "lower."

Besides which, as Von Bär has truly said,‡ were it a law of nature, that individual development should *consist* in passing through permanent but less elaborate forms, there is not a feature in embryonal life, nor a part then present, that we should not expect to find, somewhere at least, in the animal kingdom. Yet in what direction are we to look for an animal carrying about its food, as the embryo the yolk, or a pendant portion of intestine, like the vesicula umbilicalis? In Mammals, the incisors are the teeth which first appear; but no animals have permanently fore-teeth alone.

The same author has well remarked, that inasmuch as embryonal relations produce forms that are present in no grown animal, such as the pendant intestinal sac, just mentioned; it is also impossible that any embryo can repeat the state of many groups of animals. All embryos are surrounded with fluid; and consequently incapable of immediately respiring air. The real character of insects, therefore,—a lively relation to the air,—can never be repeated in an embryo. For the same reason, the embryo of mammals can never resemble perfect birds.§

* l. c. p. 592.

† Valentin, l. c. p. 596.

‡ Ueber Entwickelungsgeschichte der Thiere, Beobachtung und Reflexion. Königsberg, 1828. S. 204.

§ l. c. p. 204.

Besides these arguments, there are others; but it is by no means needful to bring forward more. We briefly recapitulate those now advanced.

1*stly*, There does not exist a scale of structure, differing in *degree* alone.

2*dly*, Individualities cannot be laid aside.

3*dly*, There exist permanent structures among the so-called "lower" animals, not met with in the embryonal phases of any of the "higher."

4*thly*, There are many phases of the "higher" animals, corresponding to which, we do not find any permanent structures among the "lower."

4*thly*, No structure peculiarly characterizing any one set of animals in the perfect state, makes its appearance even in the embryonal life of any other.

Lastly, The sum of the innate susceptibilities of structure is not the same in any two germs.

It has been said,* that "the assertion is nothing more than that Man, as Man, has once in the progress of his development, been upon that grade upon which the several classes beneath him remain stationary in the progressive development of the entire animal kingdom." But even thus qualified, it is by no means true. Man, in the progress of his development, is not upon that grade on which any other animals remain stationary, unless the latter belong to the same *type* as man†: and even then the resemblance would relate to certain parts only, because each order, family, genus, species, variety, sex, and individual, has its own peculiarities, which are repeated in the structure of no other animal.

When the great Meckel said, "the higher animal in its development, passes through *essentially* the lower and permanent grades; by which periodical differences, and differences between classes, may be brought together;"‡ he evidently meant no more, than that there occurred in the development of a single

* Burmeister's Entomology, translated by Shuckard, 8vo, 1836, p. 419.

† We admit, indeed, that the whole animal kingdom has essentially the same fundamental or merely *animal* form; but from this there is an immediate *divergence*. (See Fig. 12, p. 4.)

‡ System der Vergleichenden Anatomie; erster Theil, S. 396. Halle, 1821.

organism, a *modified* reappearance of structures common to other animals; and further, that he did not intend to say that *all* the structures of *all* " lower " animals reappear in the development of each of the " higher,"—is evident from a remark he uses in reply to one of the objections made by Feiler;* on which occasion, Meckel says, " It is perfectly indifferent, whether the human embryo passes through all, or only some of the grades of formation; if certainly ascertained facts demonstrate that it passes through *many*,—that it *always* passes through them,—and therefore that the analogies in question are not accidental."†

It may not be improper, by a few of the facts on which Meckel's proposition appears to have been grounded, to exemplify some of the conclusions at which we arrived when last on this subject; and by quoting which, we commenced the present paper.

The uniform appearance first, in the osseous system of the Vertebrata, of what are called the arches of the vertebræ, is referrible at once to the law determining the *order* in which structures essentially the same in a whole class of animals, manifest themselves in individual development; and to the law of uniformity in the *manner* of development. If in the Cephalopoda, there is permanently no more than the trace of a spinal column, corresponding to the arches of the vertebræ,‡ it shews that the last degree of development in these animals, is sufficient to produce no more than an approximation to the Vertebrata; but that, so far as they do go, they proceed, in this respect at least, by nearly the same road.

If the ilium is the first pelvic bone that becomes ossified in animals possessing a pelvis,§ and if there be an animal in which this is the only portion of the pelvis present; this shews undeviating fulfilment of the same laws, though but a rudimental structure be produced.

The absence of the sternum and the costal cartilages in most

* Ueber angeborne menschliche Misbildungen im Allgemeinen und Hermaphroditen insbesondere. Landshut, 1820.

† L. c. p. 411, 412.

‡ Meckel, l. c. p. 399.

§ Meckel, l. c. p. 400.

Fishes and the "lower" Reptiles,* proves that these parts are not necessary to the general type of the Vertebrata; further evidence of which, is given in the late acquirement of them by those animals in which they are present.

In Man the encephalon is small in comparison with the spinal cord and the rest of the nervous system; the cerebellum is small compared with the medulla oblongata; and the corpora quadrigemina are enormous in proportion to all the other parts of the encephalon.† Corresponding states are found through life in many animals. Now, this is just what we should expect. For certain parts of the cerebro-spinal axis, such as the spinal cord, the medulla oblongata, and corpora quadrigemina, must, in fulfilment of the law determining the *order* in which structures common, essentially, to a whole class, reappear modified in the development of an individual organism, precede, in their appearance, those that are of a more specific character, such as the large volume of the hemispheres in Man.

Having seen why, in corresponding stages of development, parts of the human organism should resemble, in their structure, corresponding parts in many perfect but less elaborate animals; it is obvious, that if human development be arrested in any of those stages, the resemblances become permanent. Hence malformations of *defect*. But sometimes the development of certain parts proceeds beyond the normal limits; and hence malformations of *excess*.‡

Examples occur especially in the vascular system. Thus, the human heart with a single cavity, is somewhat analogous, in its simplicity, to the heart of the Insecta, Crustacea, and Brachiopoda. A single auricle and a single ventricle, affords some resemblance to what we find the normal state in most molluscous animals and Fishes. The Batrachians have two auricles and a ventricle; the incomplete state of the interventricular septum, being analogous to what is regular in the more elaborate

* Meckel, l. c. p. 400. † Ibid. p. 401.

‡ J. F. Meckel was the first who satisfactorily explained congenital anomalies. Handbuch der Pathologischen Anatomie. Leipzig, 1812.

Reptiles. Anomalies in the pulmonary artery and the aorta, afford examples of the same kind of resemblance; as do also the subclavian, brachial, cœliac, and renal arteries; and the inferior cava vein. Malformations occur also, though less frequently, in the nervous system. Many are afforded by the osseous system, as well as by the digestive, respiratory, urinary, and generative organs, the organs of sense, &c.

Meckel attributes the greater tendency in certain parts of the body to malformation, than other parts, to the circumstance, that parts in the "animal series" corresponding to the former, present normally more numerous varieties than others.* Thus for example, the anterior or superior extremities are more liable to deviations than the posterior or inferior. This explanation is no doubt the true one. We would add to it only, a reference to the law determining the *order* in which structures common to a whole class reappear modified in individual development; for in proportion to the generality of the latter in the animal kingdom, will their individual reappearance be early and established, and *vice versa*. As a further proof of this, it may be added, also, that the liability of parts to malformation, is in the direct ratio of their lateness in appearing.†

The nervous system, as said before, is subject to fewer anomalies than the vascular, and also than the digestive, generative, and urinary organs; corresponding to the relative degree of normal variety in these parts in the animal kingdom. This affords a further illustration of the foregoing; and it may be added, as a proof of the greater universality of the same essential structure in the nervous system of the Vertebrata, that its development is much more pronounced than that of other parts, at an early period of development.‡

The coincidence between the presence of ovaria or testes, on

* l. c. p. 427.

† Hence if a fundamental and early-formed part be not developed, parts dependent on, and subordinate to it, do not appear. Thus, if the vertebræ be not developed, the ribs do not appear; and if the ribs are not formed, the sternum also is wanting. Again the lateral portions of the vertebræ appear before their spines; therefore the latter are never present without the former.

‡ See the third paragraph of page 15, in our former paper (p. 139 of the Journal).

the one hand, and of a certain habitus, as well as other circumstances in various parts of the body, on the other, is sufficiently well ascertained. It is known too, that castration has the effect of neutralizing this genital influence; rendering males, in general circumstance, less masculine, females less feminine; that is to say, it brings the sexes nearer to a mean state. Age, or the natural termination of the reproductive faculty, produces in degree the same effect. This is observable in the human species as well as in other animals.*

The fact, that malformations of the genitals occur most frequently in the organs of excitation and copulation,†—parts of subordinate importance, and not formed until a comparatively late period,—affords an example of the fulfilment of the law, determining the *order* in which innate formative properties are manifested. The co-existence of testes, on the one hand, and of ovaria on the other, with a male or female habitus,—formed, as those organs are, long before the external, less important, genitals,—such co-existence is recognisable in the fact observed by Sömmering, that the sexes may be distinguished in general appearance, before a difference in the external genitals themselves proclaims them. ‡ In cases, too, of malformed genitals, it rarely happens that the real sex is not decidedly pronounced in the general habitus; shewing further, the early operation of the latter law.

Another proposition of J. F. Meckel is as follows, viz. "That sexual differences, at least according to their origin, and periodical differences, may likewise be brought together;"§ in other words, that sexual differences may be compared to differences caused by the phases of life. It is not easy to suppose that Meckel intended to represent the sexes as differing in *degree* alone; and yet it is added afterwards, that "the inferior animals are purely females."||

* Old female birds acquire a plumage more or less similar to those of males; as well as spurs, combs, and even in degree, male instincts also.—Meckel, l. c. p. 446.

† Meckel, l. c. p. 447.

‡ Valentin, l. c. p. 595.

§ L. c. p. 396.

|| L. c. p. 425.

The circumstance, that what are called "neuter" Hymenoptera, particularly bees—those born for workers—by being conditioned in a certain way, may be converted into females or queen bees, leads obviously to the conclusion, that the so-called "neuter" bees, *are* really females, in an imperfectly developed state. But does it warrant the conclusion, which Meckel seems to draw, that females are scarcely more than imperfectly developed males? Female bees may rest in an imperfect stage, so that their sex is not obvious: by treatment, they become proclaimed as females: but, we ask, would any further treatment make them *males?*

Yet it is not easy to conceive that Meckel intended the expressions used, for literal acceptation. Perhaps this proposition is to be regarded as not less susceptible of a modified application, than the one alluded to before.

Sexual characters bespeak properties that are innate; though, from being nearly the last that make their appearance in development, they are among the least established, and *therefore* very liable to vary. The sexual character has been said to stand between the character of the species, and the special or particular character of the individual being.* This is true, in as far as specific characters *manifest* themselves prior to those of sex, and those of sex prior to the last touches, stamping the individual character; yet it must not be forgotten, that throughout development, *all innate properties*, from those common to animals in general, down to those distinguishing the species and the sex, are modified in their individual reappearance by individuality.

Now, just as parts of structure common to the *class* are, in essential character, fundamentally the same; so are those common to an *order*, *family*, *genus*, and *species*.† The *sexual* organs, also, are in both the sexes of a species, in essential character fundamentally the same;‡ just as *vertebræ* are fundamentally the same in all the Vertebrata. Male and female organs

* Valentin, l. c. p. 594.

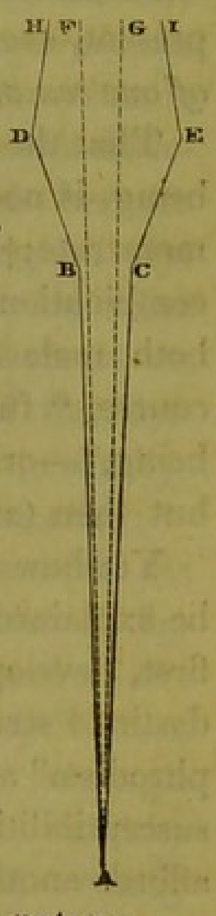
† It is only *individual* peculiarities, that are shared with no other being.

‡ An interesting proof of this occurs in the Order Marsupialia. Males have not, of course, a marsupium or pouch, unless in a rudimental form; but

have a common origin as processes, and take the same *general* direction, out of corresponding laminæ of the germinal membrane or tubes, and they have the same *manner* of development; but, just as parts of structure, at first common essentially to the *class*, become afterwards transformed, so do the *sexual* organs, which, essentially, are at first common to the *species;* and a difference in function follows. But from the first, as said before, development proceeds according to the *sum* of the innate formative properties, *sexual* properties being included in this sum; though their influence on development be not at first appreciable.

Let the point A, Fig. 13, represent the supposed fundamental form, essentially the same in all animals, so long as a merely *animal* structure is manifested. Two germs belonging to the same species, but of different sexes, start in their developement from this point A. Their divergence in developement is small, because occasioned by two influences only; one of which is sex, the other, individuality. At the points B, C, sexual peculiarities,—local as well as general,—exercise more sensibly their sway; and further developement takes them, respectively, to the points D, E. Here, if castration terminate the reproductive faculty in both, the result is,—not indeed the attainment of, for that is now impossible, but,—an approximation to, the mean state, F, G, which these individuals, respectively would have reached, had developement been influenced,—not by sex, but,—by individuality alone; the points H, I, being now attained. This we conceive may serve rudely to illustrate, what really takes place in nature.

Fig. 13.



It follows from the above, that we cannot adopt the theory

they have the marsupial bones. We need not, however, go for illustrations beyond the human race; in which the males have rudimental mammæ.

These examples will serve further to illustrate an explanation offered in the former memoir, regarding another branch of our subject (p. 25; or p. 140 of the Journal), viz. that rudimental structures seem to answer no other purpose than the fulfilment of the law, requiring that a fundamental or general type shall uniformly manifest itself before the appearance of one subordinate thereto, and special.

proposed in the Edinburgh Journal of Science for 1829–30 ;—that "there are, fundamentally, male and female organs in the same being, or originally in all embryos, elementary yet distinct parts, out of which both sets of organs may be formed by development." It is the *sum* of the innate susceptibilities of structure, that determines the direction taken in the development of every germ. Development must therefore from the first, have reference to the sex, as well as to the variety, species, genus, family, order, and class: nay more, development must from the first, have reference to the *individual* structure,—more special still than that of sex. Since, therefore, no properties can exist in an absolutely latent state,—*i. e.* without exercising their influence on development,—both male and female organs cannot be present, even in an elementary state, in the same being, *if those of one sex only, are to be developed.**

That the presence of both male and female organs in the same being, is not *incompatible*, most plants and certain animals demonstrate;† where normal and true hermaphrodism exhibits a combination of parts, for the performance in an individual, of both male and female functions. In such cases, there are of course, "fundamentally male and female organs in the same being,"—or at least there is the susceptibility of acquiring them ; but then (and herein consists the difference) *both are developed.*

Yet how then, is *anomalous* "hermaphrodism" (so called) to be explained ? To be consistent, we must admit that from the first, development has, here as elsewhere, reference to a certain destined structure ; ergo, that in cases of anomalous "hermaphrodism" at least, there are fundamentally the elements, or the susceptibilities, out of which it has arisen.‡ Be it so ; this but affords another proof of what has been so much insisted on al-

* Supposing the organs of both sexes present in the germ, and those of one sex only, to be developed ;—what becomes of the other set? Because, occasionally, parts similar to those in other animals, have appeared in the human structure, may it not as well be said, that, fundamentally, there are the rudiments of *all other animals* in man ? (!)

† Helix pomatia,—the garden snail,—affords a well-known example of the latter.

‡ Into the subject of casualties, happening during embryonal life, we do not enter.

ready; that in development, *general* structures must precede in their appearance, the more *special*. In an organism, the younger the embryo, the more alike,--because the less concentrated,—are its several parts or organs. In the animal kingdom, the younger any two embryos, the more alike are they, for the same reason. But, as already said, there is no *appreciable* difference between male and female organs in fundamental structure, as well in the animal kingdom at large, as in two individuals of the same species: though this by no means amounts to the assertion, that *either* male or female organs may be formed out of the same elements. Now, certain of the sexual organs, because of *deficiency* in their elements, or in susceptibility of structure, may advance *less* than is normal, towards concentration: certain of them, because of a *surplus* in their elements, or in susceptibility, may advance *further* than is normal: certain of them may take in development a *male* direction, certain others may proclaim themselves as *female*, because the male and female elements (or susceptibilities), respectively, *of these parts*, existed in the same germ. If the *surplus* relate to the chief organs and to the system generally, there is an *excessive* development of the sexual character: if the *deficiency* relate to the chief organs and to the system generally, males are *less* masculine, females *less* feminine, than is normal;—in other words, there is, in the latter case, an approach to the mean state spoken of before. (See at p. 13 the remarks on fig. 13.) What we have said of surplus or deficiency, and of the presence of both male and female elements or susceptibilities, may relate to one side of the body, or to both sides; to single organs on one side, or on both sides; all of which varieties are known.* The innate *cause* of such anomalies, we may perhaps never know; but the *manner* of their development, it does not seem difficult to understand.

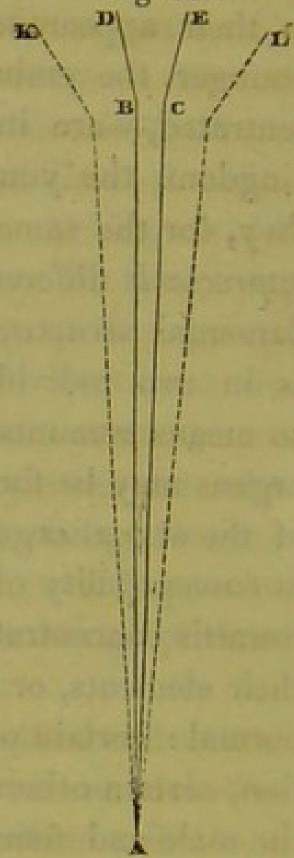
In further proof of the justness of this reasoning, may be adduced the fact mentioned by Meckel,† that hermaphrodism is frequent and complete, in proportion as the genital organs are simple, and in proportion as they resemble each other in the

* For an account of "hermaphrodites" in detail, see the late work of Isidore Geoffroy St Hilaire. 8vo, 1836.

† l. c. p. 457.

normal state; of which Fishes afford the best example. Now this is just what we should expect.

Fig. 14.



For, with a modification of the last figure (13),—let D, E (Fig. 14), represent, respectively, the points reached in the development of a male and female of a species, in which the sexual organs are very simple, and in which, therefore, the sexual difference is very small. It is plain, that a deviation here, would be more appreciable,—because relatively greater,—than if development had produced complicated structures, and carried the sexes further apart,—as, for example, to the points K, L: in other words —the less the angle of divergence, the more appreciable is a deviation, and therefore the more " *complete*" is the hermaphrodism.

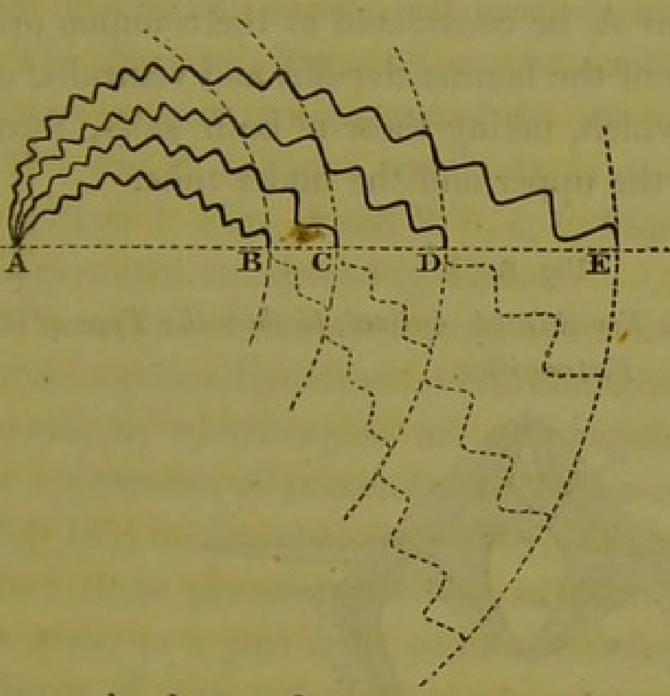
But, " in proportion as the genital organs are simple, and in proportion as they resemble each other in the normal state," when perfect,—the less pronounced must be the reference to them throughout development; the later therefore do they manifest themselves. Now, as already said, the liability of parts to malformation, is in the direct ratio of their lateness in development. Hence, in such cases, the more " *frequent*" is hermaphrodism.

We conclude, then, that the explanation before offered, regarding the necessity of a modified re-appearance in individual development, of structures common to a whole class of animals, and regarding the *order* of such re-appearance, is applicable to all congenital anomalies, including those called " hermaphrodites."

It remains to notice unity of plan, as obvious in organs of the same organism; various parts appearing like modified copies of each other. Organs of the same organism that admit of such comparison, being among those that originate in the same lamina of the germinal membrane or tube, analogies appear referable, 1*stly*, to a common origin,—and therefore 2*dly*, to a common fundamental and general form,—some resemblance, 3*dly*, being preserved in proceeding towards the special.

A diagram used in our former memoir being required here, we again introduce it, to save reference.* Let the point A, Fig. 11, represent the common origin,—the homogeneous nature,—and therefore the coincidence, essentially, in fundamental form,—of various parts arising out of the serous lamina of the germinal membrane of Man (Plate I, Fig. 3, * *):† and *firstly*, of those parts proceeding, respectively, from the laminæ dorsales and ventrales; constituting as the latter do, an *upper* and an *under* tube, (Plate I, Fig. 6, *a. b. c.*)

Fig. 11.



The curves, differing in *direction* and in *length*, may illustrate differences in *direction* and in *degree* of development of the vertebræ; including as well the development of those constituting the coccyx,—curve A B,—as that of those which, vastly more wrought out, enter into the formation of the cranial bones, —curve A E; the development of the intermediate vertebræ being represented by the intervening curves.‡

* For a more detailed application of the elements of this diagram, see pages 19, 20, of the former memoir (pp. 135, 136, of the Journal).

† The Plate here referred to, is contained in the former memoir.

‡ In our former paper, p. 20, (p. 135 of the Journal) we stated the applicability of the above diagram, in a comparison of systems of organs or single organs in different animals. Thus to apply it here; the curve A E, representing the development of the cranial bones in Man,—A C, and A D, may illustrate coresponding parts in osseous Fishes or other Vertebrata, less removed from vertebræ both in direction and degree.

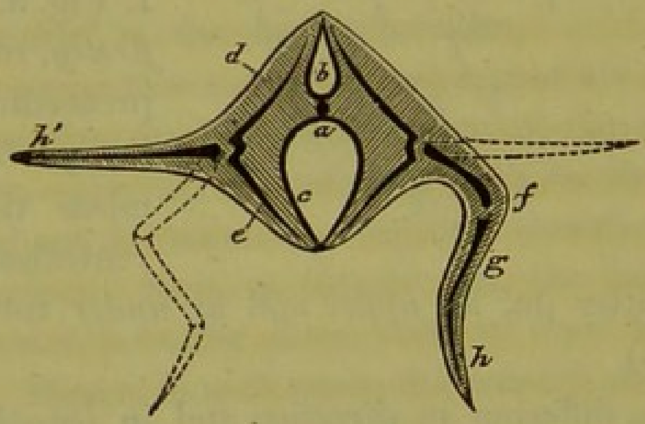
The development of the ribs being exhibited by one curve, that of the hyoid bone, lower jaw, &c. may be shewn by others.

If the curve A B, represent the development of the spinal cord,—A E may serve to shew that of the most elaborate portion of the hemispheres; and the intervening curves, the development of intermediate parts of the cerebro-spinal axis.* All the nerves connected with the latter, may be illustrated in the same manner;—they seem, as it were, rude copies of each other, —differing only in direction and degree.

Secondly, Let the point A be considered as the common origin, in the fleshy portion of the lamina dorsalis and ventralis, of a series of osseous arcs, which, taking those of both sides, form an *outer* tube, including the upper and the under tube.

Fig. 8.

Ideal Transverse Section of a Vertebrated Animal, to shew the Type of the Extremities.



a Stem of the vertebral column.
b Arches of the Vertebræ.
c Ribs.
d Dorsal } radical portion. } of an Extremity, &c.
e Ventral
f Upper } middle portion.
g Under
h Terminal portion.
h' Terminal portion as a Fin.

(This fig. is taken from Von Bär.†)

* Referring to the preceding note, we have again an instance in which the curves A C and A D, may illustrate the development of the hemispheres in animals whose brains are less removed from their primitive simplicity than the brain of Man.

† This figure also, was exhibited in our last paper. Its re-appearance is needful for the reason before given regarding Fig. 11.

The curves may now illustrate the development of the radical portion of either an extremity, viz. of the scapula and clavicle, on the one hand, and of the outer portion of the os innominatum,* on the other, or that part of the base of the cranium, which,—formed by one of those osseous arcs, and having coalesced with the cranial vertebræ,—serves to articulate the upper jaw.†

Again, if A represent a point near the middle of each arc, the curves shew the development of a process originating there, now into an arm or leg, and now into an upper jaw.‡

The diagram (Fig. 11) may be applied also in a comparison of various parts arising out of the mucus (Plate I. Figs. 3 and 4 ***, Fig. 5, *l*, Fig. 6 and 7, *f*), in close union with the vascular (Plate I. Figs. 4 and 5, *h*, *i*, *k*, Figs. 6 and 7, *e*) lamina of the germinal membrane of Man.

These united laminæ having become a tube, there occurs in certain sections diminished, in certain others increased growth, by which organs are originated, presenting the appearance of processes, in the one case *towards* (Fig. 15), in the other *from* (Fig. 16) the axis of the tube; these processes having, as their base, either the whole or a part only, of its circumference.

Fig. 15.

Fig. 16.

Some of these processes are in no small degree analogous to each other, and, as is the case with all other organs of a series,—with all animals indeed,—the more alike, the nearer to the period of their origin we view them.

Thus the lungs have been compared to the urinary organs,

* The inner portion of this bone being probably, as Von Bär supposes, analogous to ribs, derived from the under tube, and coalescing with a section of the outer, to constitute the pelvis.

† Von Bär.

‡ Or in some of the Vertebrata, into a wing, a fin, &c.

In Fig. 10, p. 16 of the former memoir, (p. 131 of the Journal), there was given an ideal transverse section, shewing the structures formed out of the serous lamina of the germinal membrane in the Arthrozoa. There is a remarkable tendency to repetition in the segments of their dermo-skeleton, including that portion of the latter that enters into the formation of the head; and in certain of them the legs insensibly pass into maxillæ. No doubt the same tendency to repetition is universal in the animal kingdom.

and the genitals to portions of the alimentary canal.* But having proposed to enter upon general considerations only, we cannot go into the details of comparison.

With this common origin, and therefore coincidence in fundamental and general form, it is not surprising that organs should present analogies. Besides which, there seems, however, unity of plan in proceeding from the general to the special,—a tendency, as said before, to repetition of parts in the several sections of the same tube. Development appears to take the same *general* direction in the several sections, with various *particular* directions, according to various particular and proper functions, in their subdivisions.

It appears, then, that unity of plan, which we have seen to direct *general* structure in the animal kingdom as a whole, extends to the *general* structure of an individual organism. Thus, particular organs originating in the same lamina of the germinal membrane or tube, of the same organism, may perhaps be compared to individuals of different sexes in the same species.

A great deal of labour seems to have been lost, in endeavouring to find out corresponding parts,—as well in different organisms as in the same organism,—because directed to the examination of *perfect* structures. How much of this labour,—perhaps, too, some octavos,—might have been spared, had due regard been paid to the *fundamental similarity* in structure, and to the identity that exists in the *manner* of development, of two germinal membranes. To a few general and easily understood principles, are referable all analogies,—whether in the same organism, or in different organisms,—as well as all congenital anomalies.

The same remarks are applicable to Classification; which, as already said,† can have no sure basis in structure, as met with in the *perfect* state; when *different* functions, performed by *corresponding* parts of structure, tend to embarrass and mislead. Nomenclature also, depending thus on data that are uncertain, must be fraught with error.

* The resemblance is very striking in animals of simple structure, as well, indeed, as in many of the Vertebrata; in which, for example, the oviducts are scarcely distinguishable from parts of the intestine.

† Page 22 of the former paper (p. 136 of the Journal).

The fact is, that naturalists have begun, just where they should have ended. They have attended to details, but neglected general principles. Instead of analyzing, their process has been one of synthesis. Their attention has been directed to the grouping of the *twigs*,—as if thus they were to find their natural connections, without even looking for assistance towards the branches, or the trunk that gave them forth. But the simile is inadequate; the labour lost, has been greater than even this supposes. For in the *grown tree* of *animal* structure, parts, once essentially the same, not only have diverged in their development, and become elaborated into very different forms,—but, as said before, perform *very different functions* also. Hence a *positive*, in addition to a negative source of error.

But what other course *could* naturalists have taken? Truly none: their "circumstance" allowed no other. It is only now that a way is beginning to be opened, by which it may by and by be possible to proceed in an opposite direction; viz. from trunk to branches and to twigs.

This, if ever accomplished, must be by means of the *History of Development* or *Embryology*, both human and comparative; a science almost new, and regarding which, there prevails in this country the profoundest ignorance and indifference. The French are in advance of us; but it is to *German* enterprise, industry, and perseverance, that we are indebted for almost every fact known to us on this subject; at least of those brought to light in recent times.* It is to be hoped, however, that ere long this science will begin to obtain, even among ourselves, some degree of the attention which its importance claims.†

* When St Hilaire proclaimed in France the principle, that zoological research can have no solid basis but in *anatomy*,—and that it is not the organs of the functions in their totality, but the materials constituting these organs, between which, resemblances are to be sought for,—he advanced a most essential step: yet there was still wanting, more regard to *Embryology*.

† Dr Allen Thomson's excellent paper (see vol. ix. and x. of the Ed. New Phil. Journal) we have already noticed.

The recent appearance, too, of a "Sketch of the Comparative Anatomy of the Nervous System, with Remarks on its Development in the Human Embryo"—by John Anderson, M.E.S., 4to, 1837,—shews that there are grounds for such an expectation as is expressed above. We have only just glanced the volume through, but seen enough to say, that it contains many valuable and well-arranged facts, admirably calculated to illustrate the doctrines of the great Meckel and others, published in Germany so many years ago. Had we read this essay before writing the present memoir, some of the facts it contains might have been adduced by way of illustration.

If these remarks are not uncalled for, in reference to nomenclature and classification,—they will not perhaps be deemed unworthy of consideration, when applied to a science, in the study of which, nomenclature and classification are but *means*. But independently of these, does it require much penetration to discern, whether it is easier, in the study of *any* science, first to commit to memory isolated facts, and then proceed to arrange them ;—or, having first become acquainted with general principles, to trace their applications ? In other words, having first studied structure in its unity,* to follow it out in development, and find the causes of variety to be resolvable into *direction* and *degree* ? If the latter method be the easier, *Embryology would incalculably facilitate the study of Comparative Anatomy.*

* It is not intended that *human* structure should be thus first learned : an acquaintance with it, obtained in the usual manner, is here presupposed.

On Unity of Function in Organized Beings. By William B. Carpenter, M. R. C. S., Senior President of the Royal Medical Society, and President of the Royal Physical Society, Edinburgh.*

From the Edinburgh New Philosophical Journal for July 1837.

There are few things more interesting to those who feel pleasure in watching the extraordinary advancement of almost every department of knowledge at the present time, than the rapid progress of philosophical views in sciences which have hitherto been too much confined to mere observation. The insulated facts which have been gradually collected by various labourers in the vast fields of comparative anatomy and physiology, are now made the basis of generalisations alike important from their extensive range, and interesting from the unexpected nature of the results to which they frequently lead; and though the application of the laws thus obtained may sometimes appear forced, and inconsistent with the usual simplicity of nature, further investigation will generally shew that the difficulty is more apparent than real (frequently arising solely from our own prejudices), and that it is in many cases the result of that combination of unity and variety by which is produced the endless diversity and yet harmony of forms so remarkable in the animated world.

The object of the present essay, which has been partly suggested by Dr Barry's valuable papers in the last two numbers of this Journal, is to carry out to particulars some of the general principles there laid down, with the addition of others which had previously suggested themselves to me. It is far from my present intention to enter into a critical examination of those papers, more especially as they have in view the laudable object of exciting the attention of English physiologists to a branch of study which has by no means received from them that consideration which its importance demands.

The time has long gone by when similarity in function and external form were considered sufficient for the recognition of analogies between organs; anatomists are now aware of the

* The above essay was read as a communication to the Royal Medical Society, 14th April 1837.

necessity of resting their comparison upon the elementary structure of organs, their connections with each other, and the changes they undergo during the progress of their development. Neither of these grounds of judgment can, I think, safely be trusted to alone; whilst, combined with each other, they furnish a body of evidence which is quite irresistible. The truth of these observations will, I trust, appear in the sequel; but I might, in the mean time, adduce in illustration the mode in which the true character of the wings of insects is to be ascertained.

If we pass in review the various means by which the locomotive organs of different classes of animals have been placed in relation with the resisting or impelling powers of the atmosphere, we shall observe a community of function, and a general similarity of external form, concealing a total difference of internal structure. In most cases, however, we may remark that the wing or other organ of propulsion, however it be constructed, is only a variation from the usual form of a corresponding part in the neighbouring groups; since " nature, in effecting a new purpose, is inclined to resort to the modification of structures already established as constituent parts of the frame, in preference to creating new organs, or such as have no prototype in the model of its formation." The question, therefore, naturally arises with regard to the wings of insects, whether they are to be considered as new organs, superadded to those which are found in the adjoining classes, and in the early stages of their own existence, or whether they can be shewn to be the result of an extension or increase of development on the part of some structure already present, although perhaps assuming a different form. We shall then first inquire what inference may be drawn respecting the real nature of the wings of insects from their anatomical structure. They may be readily shewn to consist of a fold of external membrane, extended upon ribs or nerves, which are principally formed of *tracheæ* connected with those in the interior of the body. It is only recently that the circulation of fluid has been observed in the wings. Carus describes it as visible in the pupa of many species, but he does not seem to have detected it in more than a few cases after the last metamorphosis. My friend Mr Tyrrell of Exeter, informed me, however, about two years ago, that he had witnessed it in many perfect insects, especially the common house-fly, if examined sufficiently soon after its emersion; and I have since had several opportunities of confirming his observations, which have, I believe, been presented to the Royal Society. The truth appears to me to be, that the circulation goes on as long as the wing continues to grow, but ceases when it has arrived at its full size; and this view coincides with the fact that slight injuries of the wing are not repaired in adult insects. The question has been much agitated, whether the circulation takes place in distinct vessels, or whether the fluid passes along the interstices of the membranes forming the wings. Analogies would certainly lead to the belief that distinct vessels exist; and it is easy to explain the difficulty of detecting them in the wing after it has become dry, from the fact that when no longer distended by fluid, they collapse and become shrivelled, so that a transverse section of a rib shews only one canal, that of the trachea, which is kept open by its elastic spiral filament. Mr A. Pritchard of London, pointed out to me a few months ago, however, a wing in which three tubes were distinctly visible in each rib. This structure is exactly analogous to that which exists in the gills of aquatic insects, and hence Oken, followed by Blainville, termed the wings *aërial gills*, an idea which, however ridiculed by succeeding writers on entomology, will, I think, ultimately appear to be supported by the strictest analogy in structure, situation, and development.

The branchiæ of water insects plainly resemble the wings in being composed of expansions of the tegumentary membrane spread out upon nervures formed by tracheæ and vessels. Sometimes the membrane is continuous, so that the gills assume a foliaceous appearance, like that of the wings, but in other cases it is divided, so that the branchiæ more resemble the filamentous tufts of the nereis. The elementary structure is the same, however, in both cases. The position of the branchiæ is constantly varying; sometimes they are attached to the thorax, sometimes to the abdomen, but in every case they have an important relation with the movements of the animal, and are frequently the sole organs of progression with which it is furnished.

From the *structure* of the wings, and their correspondence with the acknowledged respiratory organs of aquatic insects, we might infer their nature with considerable probability; we shall next briefly trace their *connections* in search of the same object. If we cast a glance at the gradual development of the organs of locomotion formed by appendices to the trunk in ascending the scale in the articulata, we shall see their first appearance in the setæ of the earth-worm, and the filamentous tufts of the nereis, the latter serving both as branchiæ and as instruments of progression. In the higher annelides, one of the setæ of each tuft is more developed than the rest, forming a long tubular-jointed appendix to each segment, which is evidently the rudiment of the leg perfected in the myriapodes. The twelve segments forming the body of the caterpillar (which may be regarded as for the time an annelide), are each provided with a pair of legs;* and these are sufficient to execute the movements which the animal requires in this stage of its existence, when the whole energies seem as it were concentrated on the nutritive system. When the adult insect emerges from the chrysalis, however, after losing for a time all appearance of external members, it is found that the nine posterior segments forming the abdomen are entirely destitute of appendages, whilst the three thoracic segments are provided not only with three pairs of legs, but with two pairs of wings attached to the second and third segments. If these wings had taken the place of the legs which disappear during the metamorphosis, there might have been some ground for considering them analogous organs; but if we contrast their position on segments which retain their legs with that of the branchial tufts of the annelides, it must, I think, be acknowledged that we thus derive from their *connections* another strong argument in favour of the view I am advocating.

It remains for us now to consider their development; and though I regard this as an important link in the chain of evidence, I cannot see that it affords more than a corroborative proof, or that we should be entitled to take up such a bold position without a firmer foundation. After the third moult, the

* I am of course speaking in this, as in other cases, of the regularity or typical form.

rudiments of wings may usually be traced in the caterpillar, assuming the form of laminæ of mucous tissue, and permeated by tracheæ;* and during the chrysalis state, their development proceeds gradually towards the form which they ultimately assume. Now, as the tracheæ permeate not only the wings but the whole bodies of insects, it is evident that this circumstance of itself assists us little; the development of the wings of some aquatic insects, however, affords us more valuable testimony. "As long as the insect dwells in the water, its rudimental wings are true water gills; but so soon as it has quitted the water, they transform themselves into air gills; for, in both cases, fluids circulate in their vessels, which doubtlessly receive oxygen from the air." †

To enter into all the arguments by which this position might be supported, and to refute the objections which may be urged against it, would lead me too far away from my present object; but I may observe, that it is only by taking an extensive view of comparative structure that we can have any hope of arriving at accurate results; and great care is necessary to dismiss from our minds all prejudice in favour of any particular mode of organization as a standard or type of the rest. Let us suppose an entomologist to form his views of the structure of animals in general from that of the articulata; he would expect to find the wing of a bat or bird constructed on the model of that of an insect; and yet he would not be acting more absurdly in maintaining that this organ is an appendage to the respiratory system in vertebrated animals (especially considering its remarkable connection with this system in birds) than many entomologists in being led by their previous acquaintance with other types of structure, to consider the wing of an insect as a modification of its leg.

In speaking of the separation existing between different groups of organized beings, it is to be recollected that the minor variations from a particular type, whether that be of a class, order, genus or species, are frequently of such a character as to approximate some of its divisions to neighbouring groups; and that, sometimes, the minor or secondary character may become so predominant as to leave us in doubt to which

* Burmeister's Entomology, p. 6. † Ibid. 442.

group any individual belongs. I might refer to the characters of the mollusca, so strongly marked in the cirrhopodes, although the latter group unquestionably belongs to the articulated series; or to the characters of the bat and bird, so strikingly displayed in the pterodactylus. Without wishing to enter into the discussion of the circular and quinarian theories, I may state my conviction that Messrs Macleay, Fries and Swainson, are perfectly correct in maintaining, that the types of each group are definitely separated from one another; but that their aberrant members (where the chain is complete) have the strongest relations of affinity. Every one must perceive that the extended researches which are at present being carried on, both in zoology and botany (and these not confined to the existing epoch, but extending to past ages) are every day contributing to fill up the links that before seemed deficient; and it is now generally regarded as the true character of a complete natural group, that it passes by almost imperceptible gradations into every adjoining one. To take the example of the cephalopodes and fishes. Although the former are universally regarded as the most developed of the mollusca, no conchologist would assume the class as the type which most prominently represented the peculiar characters of that division of the animal kingdom. In like manner, fishes, which are the least developed of the vertebrata, are far from being typical of their division. We might expect, therefore, on the principles just laid down, that the hiatus should not be very wide between these two classes; and although Cuvier was of opinion, that an impassable gulf separates the vertebrata and invertebrata, more extended research has shown, that though there may be little general resemblance in form between any fish and any cephalopod, yet there is a very gradual transition in the structure of most of the systems of these two classes. Thus the nervous system, and internal skeleton of the highest cephalopodes, may almost be placed on a level with those of the lowest cartilaginous fishes; the arrangement of their circulating apparatus is strikingly intermediate between that of the mollusca in general and that of fishes; and whilst, in their organs of locomotion, we see a beautiful adumbration of those which are characteristic of fishes, so, in many fishes we may trace the remains of those usually regarded as peculiar to the cephalopodes.* No inferior group of mollusca presents such remarkable approximations to the class of fishes in any stage of development; and in none of them do we observe that symmetrical form and elongation of the trunk which is so prominent a feature in the structure of the naked cephalopodes.

We find among the classes which make up the sub-kingdom radiata, a still greater tendency to pass into one another; so that it is almost impossible to fix with precision the limits to each; and every botanist is aware, that however definitely even the primary divisions of the vegetable kingdom may be formed, many obstinate transgressors of their boundaries will be met with, which exhibit a very troublesome fondness for their neighbours' domains.

Dr Barry has quoted from Burmeister the very ingenious remark, that the osteozoa (vertebrata) unite in themselves the development of the nutritive system, which is characteristic of the gastrozoa (mollusca) and the locomotive apparatus of the arthrozoa (articulata). This is a beautiful confirmation of the arrangement of the invertebrata, suggested by Lamarck, who regarded the mollusca and articulata as forming two parallel lines commencing with the radiata below, and terminating in the vertebrata above; each has its own characters of elevation and degradation, and neither can be considered as in every respect superior to the other. It appears to me, that, in the nervous system of the vertebrata, we may trace the combined characteristics of those of the mollusca and articulata. In the former we find a circle of ganglia around the œsophagus, specially connected with the organs of sense, and therefore with the function of nutrition; and in their higher species, these ganglia are almost entirely supra-œsophageal, and thus pass into the cerebral ganglia of the vertebrata, whose spinal cord on the other hand (which is now generally regarded as in itself an originator of power, if not also a seat of sensation), being specially connected with the locomotive organs, is a fair representation of the double nervous column possessed by the typical articulata. Whilst, therefore, this system, being necessarily connected with all the other organs of the body, unites in the

* Cyclopædia of Anatomy, vol. i. p. 525.

vertebrata the types which it presents in the other two great divisions of the animal kingdom where it is distinctly marked, each of the other systems of the vertebrata is, I think, developed upon a single uniform plan. Thus we should not be led to look in insects with any analogies with their nutritive system, nor among the mollusca for any representation of their locomotive organs. The whole structure of the typical mollusca is devoted to the perfection of their nutritive system, and we consequently find, an asymmetrical development prevailing throughout, involving (except in the highest cephalopodes) even their organs of locomotion; and we fully recognize this asymmetrical form in the structure of the thoracic and abdominal viscera of the vertebrata in general. In the articulata, on the other hand, where the functions of animal life so greatly predominate, symmetrical development of the organs of locomotion is the prevailing character; and the form of the nutritive system is made partly to yield to this. This symmetrical development is everywhere characteristic of the organs of animal life in the vertebrata; and the resemblance forcibly occurs to us between the subdivisions of these organs in the vertebrata and the higher articulata, keeping, however, this great principle in view, that in the former, the organs of support are in part of the *neuro-skeleton*, whilst in the latter these are formed by the *dermo-skeleton*. It appears to me, therefore, that in the study of each division of the animal kingdom, we shall find parts analogous to the rest, and that the sum-total of the effect is produced by the proportional development of each system, which would seem, therefore, finally resolvable into a question of degree only.

It by no means follows, however, from this doctrine, that the whole animal kingdom is formed upon the same type, and progressively developed in such a manner that the transitory states of the higher animals furnish exact representations of the permanent forms of the lower. What is meant to be maintained is, that each organ in the progress of its evolution presents analogies in elementary structure and in degree of development (by no means necessarily in external form) with the permanent states of the same in the classes beneath; and this is again to be understood with the limitation just now expressed, which will prevent us from seeking in insects any forms analogous to the nutritive system in the Vertebrata, or from looking in the Mollusca for any representation of their locomotive apparatus. Moreover, it usually happens that the development of the different systems does by no means proceed *pari passu*, and hence the embryo cannot be considered as presenting in its totality any resemblance or analogy with beings beneath it; and it is deficient in this very important faculty, the power of maintaining its own existence. But in certain cases where it is necessary that it should possess this power, it is attained by preserving such a harmony in the development of the different systems, that they shall all act in unison with one another; and the being does then present a perfect transitory resemblance to those of the class beneath. Thus it would be difficult to demonstrate that the tadpole is not a fish *pro tempore;* no naturalist would hesitate in what class to place it, if only acquainted with its early form; and the same observation will apply to the caterpillar, whose structure is altogether that of the annelides. Taking this view of the case, therefore, metamorphosis does not essentially differ in nature from those changes which every animal undergoes in the progress of its development; but the embryo is adapted for deriving its subsistence from the world around, instead of from its parent, by causing the development of all its structure to go on *pari passu*, so that each organ may harmonize in function with the rest.

Putting aside, however, for the present these extraneous but deeply interesting questions, I proceed to the proper subject of this paper, which is, to apply to *function* one of the laws propounded by Von Bar with regard to structure, namely, that,

1. A special function arises only out of one more general, and this by a gradual change.

To this law I shall add a second, that,

2. In all cases where the different functions are highly specialized, the general structure retains, more or less, the primitive community of function which originally characterized it.

The division of the changes which take place during the existence of the living animal body into the *organic* functions, and those exclusively *animal*, will answer very well for my present purpose, although, as we shall presently observe, it is only in the more specialized forms that we see them distinctly separated. I put aside for the present that series of changes occurring alike in the plant and the animal, which have for their object the continuance of the race, not the maintenance of the individual; these will be a subject for after consideration. The organic functions being common to both kingdoms, it becomes a most interesting topic of inquiry how far the organs which perform them have the same elementary structure in each, how far the changes produced by them are similar, and how far analogy can be traced in their gradual specialization.

As all the changes which are essential to the existence of a living organism may be regarded as consisting in the assimilation of matter from without, and the liberation of excrementitious matter from within, so the two functions of absorption and excretion may be regarded as comprehending the sum of the acts by which these changes are produced. In the lowest plants and animals we find no provision for any more complicated processes. In the Algæ, for example, the whole surface is absorbent; no part more than another can be regarded as peculiarly exercising this function; every cell derives from the fluid in contact with it, or from the surcharged cells in its immediate neighbourhood, the fluid essential to its existence. In like manner we might advert to the structure of the gemmules of the Porifera and Polypifera as furnishing an example of a similar mode of nutrition in the animal kingdom; but as these beings are mere embryos, it is not perhaps fair to adduce them in illustration. We very early find in the animal kingdom a tendency to specialization of the organs of absorption, by the appropriation of a continuation of the external surface for the purpose. In the common hydra, for example, we may regard the animal as entirely composed of a stomach and its appendages; and this stomach may be regarded as simply a reflection of the tegumentary membrane *inwards*, as the experiments of Trembley sufficiently prove, by shewing the mutual convertibility of these two surfaces. We may then express the form of the absorbent portion of the general surface by such a sketch as the following (Fig. 1). Now, although we have here a decided internal stomach, we still have the tissues deriving their nutriment by *immediate* absorption, partly from the fluid within the bag, and partly from that on the exterior, as the experiments before allud-

ed to seem to prove. Here, then, is the lowest degree of specialization of the function of absorption in the animal kingdom; and perhaps we may regard the condition of the absorbent surface in the lichens as somewhat analogous to it, since in these it is generally only *one* surface that absorbs freely, namely, the one least exposed to the sun and air. The first appearance, however, of any extension of the surface for this purpose (such as we find in the radical fibres of some fungi, but more particularly in the mosses), takes place by an *external* prolongation; and we may therefore consider Fig. 2. as illustrating, in contrast with Fig. 1, what may be regarded as the type of the absorbent system in plants. The final cause of this difference in the direction of development will subsequently come to be considered.

Now, it will be remarked, that as soon as a particular part of the surface is modified for absorption, the tissues in general derive their nutriment indirectly through the medium of a circulating system, however imperfect. The organs of circulation are therefore to be regarded, not as essential to our idea of a living being, but as superadded in those cases where the transmission of fluid from one part to another has become necessary. Cuvier endeavoured to shew that the development of the organs of circulation in animals proceeds *pari passu* with that of a distinct respiratory system; I think it is evident, however, that we are to look for the fundamental cause of both in the specialization of the absorbent surface, through which the aliment is introduced which is to undergo subsequent change. We find in the mosses and fungi more or less separation of the nutritive apparatus from the rest of the plant, by a distinct axis of growth or stem; and in this we find the cells elongated in such a manner as to approach the form of vessels. In the Algæ, on the other hand, where there is no necessity for any transmission of fluid, the cells approach more to the normal spherical form; and if one part of the frond be taken out of the water, it will wither, although the rest be actively vegetating. In ascending through the scale of cellular plants, we find the absorbent system becoming more and more specialized, and the vascular communication more complete, until we find in the Phanerogamia the extremity only of the root modified to imbibe fluid, and the nutriment rapidly conveyed by the vessels of the stem to distant parts of the plant, where it undergoes certain processes of elaboration, which render it fit to be applied to the purposes of nutrition.

The compound Polypifera may probably be regarded as presenting us with the first appearance of a distinct circulating system in animals. The motion of water through the pores and canals of the sponges, can scarcely, I think, be regarded in this light, since the proper function of absorption does not commence until the fluid comes in contact with the soft tissue lining these passages; which have been justly compared, by Dr Grant, to the ramified roots of a plant turned inwards. It is in the Echinoderma, however, the bulk and solidity of whose tissues prevent that immediate absorption, either from the stomach or the external surface which prevails in less developed animals, that we first perceive a complete vascular system; and this is employed like that of plants in receiving directly, from the absorbent surface, the fluid aliment, and in conveying it to the distant parts of the organism. We are then to regard the stomach and alimentary canal of animals as organs to which no analogy exists in plants; in the latter, the nutriment is directly received from the surrounding medium, in a fluid form, no solid material being capable of being introduced into their system until first dissolved. Their food, therefore, consists of water, holding various matters in solution; and, I think, is capable of being proved, that water and carbon in some forms constitute all that is essential to the growth of plants. They are, therefore, entirely dependent on the inorganic elements around them; and as these are constantly within their reach, vegetables have no need either of organs of locomotion, or of an internal cavity to store up or prepare their food. Animals, on the other hand, being chiefly dependent upon matter previously organized, which can only be procured under certain circumstances, require peculiar means of obtaining it, and a particular apparatus for preparing it to be introduced into the system. We cannot regard any substance to have been so introduced, until it shall have been absorbed; and the only difference between the skin and the mucous membrane in this respect being, that the latter absorbs with the greatest facility, it is evident, that the aliment taken into the stomach bears no different relation with the organism in general, than when applied to the exterior surface of the body. These views may appear trite and almost self apparent, but physiologists are in the habit of overlooking them.

Pursuing the development of the absorbing system in animals, and the gradual specialization of the function, we find, that, in the higher classes, the process no longer takes place by the general circulating system (as by the mesenteric veins in the Echinoderma), but that a new set of vessels is interposed which is still more peculiarly adapted for the purpose. It would seem that the earliest true lacteal vessels are found in fishes; and they possess many communications with the venous system, both in this class and in the reptiles. Nearly the same may be said of the lymphatic vessels whose office it is to perform interstitial absorption throughout the system. In the Mammalia, however, the absorbent system is still more specialized by the want of all communication with the veins, except through their terminal trunks. By thus tracing the gradual evolution of the special absorbent system from its more general type in the lower classes of animals, we arrive at a knowledge of its real nature.

Let us now study this function in another point of view, by applying to it the second general principle with which we set out. Although the roots of plants are evidently their special organs of absorption, there can be no doubt that the leaves and other succulent parts of the general surface perform this function when the former are absent, or afford a deficient supply of nutriment. In many of the epiphytal parasites, the latter are evidently only absorbing organs; and no one can have observed the effects of atmospheric or artificial moisture on a desiccated plant, without perceiving their importance. That the special function of the leaves is of a totally opposite nature, admits of no doubt; and we have here, therefore, a most interesting example of the principle, that the general surface, even in the most highly elaborated organism, retains more or less its primitive community of function. Nay, in the plant, the leaves possess a peculiar power of adapting themselves to the discharge of this office; for not only do they present a broad expanse of permeable cuticle (I think it probable that absorption of fluid does not take place through the stomata, but by the general surface); but they extend this, when occasion requires, by the formation of numberless lymphatic hairs, which, like the radical hairs of mosses, &c., have a strong attraction for atmospheric moisture. Decandolle has remarked in his Theorie Elementaire, " That when any part of a plant cannot, from peculiar circumstances, discharge the duty appropriated to it, the function is performed, wholly or in part, by some other organ. It is evident, that this is but a result of the general principle I have above laid down; and the reason that plants differ in this respect from animals is, simply, that in the former the specialization of function is in no instance carried so far as in the latter; so that, any part of the general surface can perform, in a considerable degree, the function of all the rest. In the animal kingdom, we perceive that the external surface of most aquatic tribes forms part of the general absorbent system; but that in the inhabitants of the air, its function is partly changed, and it is rather an organ of exhalation. The experiments of Dr Edwards, however, shew the importance of cutaneous absorption both in fishes and reptiles; and the human body, in certain states both of health and disease, is greatly dependent upon it. A curious instance of the extent to which it may take place from atmospheric moisture alone, was related to me a few years ago whilst in the West Indies, by the governor of the island in which I was residing. A jockey, who had been in training for a particular race, being much depressed by thirst, on the morning on which he was to ride, drank a single cup of tea; the stimulus to the cutaneous system was so great, that he increased in weight 6 lbs., of which 5 lbs. must have been from atmospheric moisture. The facility with which absorption takes place through the lungs (which are to be regarded as excreting organs) is another example of the same fact; and I think that the present state of belief derived from experimental inquiry, with respect to the relative functions of the veins and absorbents, might have been anticipated by a knowledge of the principles I have been attempting to demonstrate.

In retracing the ground over which we have passed, we remark, that in the simplest organisms, that both animal and vegetable, a permeable membrane is all the apparatus necessary for absorption; and that vessels only become requisite where the fluid has to be conducted to a distant part, either to serve for the nutrition of the system, or to undergo a change in its own constituents. We have remarked, also, that the digestive apparatus of animals is to be regarded rather as an appendage to the absorbing organs, rendered necessary by the nature of their food and mode of obtaining it, than as forming an essential part of the system.

We shall now endeavour to analyse the excretory system in a similar manner; but here we meet with greater difficulty from the increased complexity of the function. We cannot regard the rejection of the excrementitious portion of the food as a part of the function of excretion as performed by animals, any more than the reception of the food by the mouth is a part of the function of absorption. It would be better, therefore, to limit the term *excretion* to the throwing off matter which has been already assimilated. This process, which is constantly taking place in most of the tissues of plants and animals, bears a strong relation, in point of activity, with the tendency of each structure to spontaneous decomposition. Thus the bones of animals and the heart-wood of plants will exist almost for an indefinite period after the death of the individuals; and in them little change takes place during life. In the softer tissues, on the other hand, whose decomposition is so rapid after vitality is extinct, the processes of interstitial deposition and absorption are vigorously performed throughout the whole existence. Hence it may perhaps be inferred, that the power which living bodies possess of resisting the usual decomposing influences of heat, moisture, oxygen, &c., is due not so much to anything essentially different in the affinities which hold together these elements during life and after death, but to the vital actions by which every particle exhibiting the least tendency to disorganization is immediately removed, and replaced by matter newly assimilated. It is a curious fact that after *animal* life is extinct, a certain degree of *organic* life frequently remains, by which the excretory functions go on for a time; thus carbon is exhaled in considerable quantity from the skin for a certain period after death, perspiration has appeared on the skin, urine has been secreted into the bladder, and it is even said that the hair has grown. It is only when these excretions are finally stopped by the want of circulation, respiration, and other vital functions, that decomposition can properly be said to commence.

With regard to the excretory functions of the lower classes of plants and animals, we have very little certain knowledge. The general surface in them seems to answer all the required purposes; and the first organs of secretion we can detect in animals seem rather appendages to the digestive apparatus than parts of the excretory system. Though some may regard the function of respiration in a distinct light, I see no reason for considering it as anything else than a part of the series of changes by which superfluous matter is discharged from the system. Our present knowledge of the elementary structure of glands reduces the lungs to the same type with the liver or kidneys; both consist of an excretory duct upon the minute ramifications of which bloodvessels are distributed, a part of whose contents find their way through the permeable membrane which forms the tubes or cells; and the branches, although possessing a different form, have evidently the same "fundamental unity" of structure. In regard to their functions also, there would seem no further difference than this, that whilst the excretion by the lungs serves an important purpose, the maintenance of animal heat, that of the liver answers another object by giving assistance in the digestive process. Both have alike for their object the excretion of carbon from the system, and their functions may perhaps be regarded as in some degree vicarious.

The respiratory organs are found specially developed both in plants and animals, as soon as a particular part of the surface is set apart for absorption; and the fluid is brought to them by the circulating system before being applied to the general purposes of nutrition. In plants we always find them formed by expansions of the external surface, beneath which the fluid is exposed to the influence of the air; and this is the type on which the brancheæ of aquatic animals are constructed, whatever may be the modifications of their form and situation. In air-breathing animals, on the other hand, the prolongation of the surfaces takes place internally, so that the air comes to meet the blood, instead of the blood being sent to meet the air. Figs. 1 and 2 therefore will equally well serve as representations of these two principal types of the development of the respiratory system. We find, however, many interesting intermediate forms, such as the pulmonary branchiæ of the Arachnida; and in tracing the development of the air-bladder of fish into the lung of the reptile, and at the same time the progressive disappearance of the gills, we have a beautiful example of the gradual change which (where the links are all within our reach) may everywhere be observed throughout nature. I think that the structure of the respiratory organs affords a beautiful illustration of the argument which might be raised on *a priori* considerations in favour of the doctrine of "fundamental unity of structure."* The function of respiration is a very simple one, and it is essentially the same not only throughout the animal kingdom, but in vegetables also, as I shall presently shew. It might be regarded then, as a necessary result of the law, which everywhere prevails throughout creation, of the attainment of every *end* by the best adapted *means*, that the essential structure of the organs should be the same where the function is the same, but that the disposition of these parts should vary with the circumstances in which tnat function is to be performed. I need not point out the evident correspondence of this conclusion with existing facts.

The experiments of the late Professor Bennett and Dr Daubeny, on the gaseous changes produced by vegetables, warrant (I think) the conclusion, that the disengagement of carbon, which by union with the oxygen of the atmosphere forms carbonic acid, is constantly going on, and is essential to life equally with the respiration of animals; while the fixation of carbon, which only takes place during the stimulus of sunlight, is rather analogous to the digestion of animals. The latter process in a healthy plant far more than counterbalances the other; and

* This term I derive from Dr Barry.

thus the greatest part of the solid matter of the tissues must be obtained, since it does not appear that much carbon is taken up by the roots of plants in general. The fixation of carbon, however, only takes place in the green parts of the surface; and the fungi being entirely destitute of this power, can only vegetate on decaying organised matter, which affords a regular supply of carbon to their radical absorbents, and they give out a large quantity by respiration from the general surface.—Now, although in the highest vegetables, the leaves are the principal organs for effecting the gaseous changes already alluded to, these changes take place more or less by the whole surface, and the access of atmospheric air to the roots is of great importance to the health of the individual. The functions of the spiral vessels of plants are not certainly known, but from the quantity of oxygen they contain, they would appear to partake in the process of respiration.

In tracing the gradual specialization of the respiratory system in animals, we may perceive that its perfection is marked, not by its apparent extent, but its concentration. Thus the ramified tracheæ of insects, extending throughout the whole system, afford an amount of respiration superior in proportion to that of most vertebrata; but the apparatus is evidently formed on a low type. The same might be said of that of birds, which is extended in a similar manner, and for a similar purpose. The large size of the air-cells indicates the comparatively small extent of surface actually employed for the performance of the function; whilst the minute subdivision of the lungs in the higher mammalia, and their complete enclosure in the thoracic cavity, mark the highest degree of specialization of which this apparatus is capable. In all cases, however, we may observe that the general surface retains more or less of its primitive community of function. In the soft-skinned Batrachians the experiments of Dr Edwards have well demonstrated the importance of cutaneous respiration; and similar experiments on the human body shew that the same process is constantly taking place; and it would appear that where there is much local action, as in inflammations, the quantity of carbon discharged from the skin is very much increased. It would be interesting to investigate if this excretion like that of the liver is increased when the functions of the lungs are impeded by disease.

The exhalation of fluid is another part of the function of excretion which might be separately considered in the same manner; but my limits forbid me to dwell upon it. I must also be very brief with regard to the acknowledged organs of secretion. We find that in plants the secretions are usually formed to be stored up in the system, where they answer some purposes not well understood; a few are exuded from the surface; but it is not a little remarkable that some of the principal excretions of plants take place by the roots, the special organs of an opposite function. I am disposed to believe that this excretion, whose importance to the agriculturist is now acknowledged, necessarily results from the process of exosmose which must exist wherever endosmose is carried on; and as it would seem probable that a part of the descending sap, or of the previously formed secretions, is mixed with the absorbed fluid for the purpose of increasing its density and maintaining the endosmose, it necessarily follows that some of it must be lost in this manner. The greater activity of the vital functions in animals, and the larger quantity of the solid ingesta, require a more special provision for excretion besides that which takes place by the respiratory and exhalant systems. Accordingly we find biliary and urinary organs very low in the scale; but these are still formed upon the same general plan. We see the simplest type of their structure in the mucous crypts of the alimentary canal; and as the excretory ducts are but prolongations of the external surface, so their minute ramifications by which the gland is formed, are to be regarded in the same light. As all the glands, therefore, have the same elementary structure, and differ only in the peculiar adaptation of each to separate a particular constituent of the blood, it is a necessary result of the second law to which allusion has so frequently been made, that either the general surface or either of the special secreting organs should be able to take on, in some degree, the function of any gland whose duty is suspended; and observation and experiment fully bear out this result. The "fundamental unity of the structure" of glands has been made apparent, not only by comparing those of different degrees of development in the same organism, but by the study of their gradual development in the animal scale.

I have now sketched an outline of the doctrine of Unity of Function with regard to the changes essential to the maintenance of individual organisms, both of plants and animals; we may next briefly direct our attention to the reproductive system, and examine how far it is from the first a special apparatus, and whether its functions are completely separated in any case from those of the nutritive organs. In tracing the development of the reproductive organs in the cellular plants, we observe that in the lowest tribes the multiplication of cells may be considered as alike the production of new individuals and the extension of the original organism; each cell is capable of maintaining an independent existence, but each is connected with those around it in forming one general structure. Where special reproductive vesicles are evolved, different from the cells which form the plant, we find that at first no particular part of the general surface is modified for their development; but in the higher algæ, the lichens, and especially the fungi, we can trace the gradual separation of the reproductive from the nutrient system. In the flowering plants we have still two modes of reproduction; the special apparatus of fructification furnishing seeds; and the nutritive system furnishing buds, which may be regarded as extensions of the original stock, or as new individuals. The doctrines of Morphology, however, prove to us that even the fructifying system is but a different form of corresponding parts in that of nutrition; and hence the separation is never complete in vegetables. In the lowest animals, we may remark a similar difficulty in fixing the precise limits of individuality; and this is a necessary result of the gradual specialization which this function undergoes in common with every other. Where distinct gemmules are formed, (which in their homogeneity resemble the spores of cellular plants,) they are at first produced from any part of the external surface, as in the hydra; but in ascending the scale we find a particular apparatus adapted to the evolution of the embryo, such as the curious ovaries of the echinoderma. As we advance, the structure of the ovum becomes more and more complex, and the analogy which its parts bear to those of the seeds of plants is sufficiently obvious. I may, however, point out the correspondence both in structure and function, between the cotyledons* of plants, especially such as are membranous) and the temporary branchiæ, which, as is now well known, may be traced in the embryos of all the higher animals.

That the embryo of flowering plants takes its origin in a simple vesicle, analogous to that which forms the entire germ of the cryptogamia, is now well understood ; indeed, I think it would be easy to apply in detail to vegetables the doctrines of "fundamental unity of structure," which Dr Barry has shewn from the researches of German embryologists to exist throughout the animal kingdom, and which he has spoken of as applicable to organised beings in general.† One speculation I may hazard at the present time, leaving it to abler botanists to decide upon its merits. The embryo of flowering plants continues to be developed during the ripening of the seed, so that at the period of maturity the cotyledons are fully formed, and the plumula and radicle are ready to elongate themselves into an ascending and descending axis. The spore of a cellular plant, on the other hand, being a simple cell, first produces others similar to itself, and these gradually form a leaf-like expansion, such as Mirbel has beautifully shewn in the marchantia, and such as exists at a certain period in the germination of ferns also.‡ This leafy expansion it is from which the stem, roots, and gyrate fronds of the latter class originate ; and when these are fully formed, it decays away. Although the mode of the development of the stem seems in Mr Dickie's view to prevent us from regarding this leafy expansion as a cotyledon, I scarcely see how we can regard it in any other light ; since, physiologically speaking, it differs only in this, that the embryo of the fern forms it whilst maintaining an independent existence, and the embryo of the flowering plant whilst supplied with nutri-

* Where the cotyledons are *fleshy*, that is, contain a store of albumen within themselves, they evidently supply also the purpose of the yolk-bag in the ova of animals.

† I think it due to myself, however, to state, that, as far as regards the vegetable kingdom, these views were previously entertained and expressed by me, although Dr B. was, I doubt not, unaware of the fact.

‡ Magazine of Zoology and Botany, vol. i.

ment from the parent. The analogy, then, between the spore and the seed, is something like that of the tadpole and the frog, both of the former being less developed states of the latter, but modified to maintain an independent existence. Taking this view of the case, the fronds of such plants as the marchantia, which are permanent, and never develope a distinct axis of growth, must be regarded as cotyledons, and are obviously analogous to the perennial branchiæ of the lower classes of animals. It is interesting to remark that the simple cell, which is the type of the lowest plant as well as of the lowest animal, is also the type of the earliest embryonic condition in both kingdoms; and there is no more perceptible difference between the germ of a plant and an animal, than there is between those of the different classes of either kingdom.

In tracing the gradual development of the functions peculiar to animals, namely, sensation and voluntary motion, we may, I think, even here find that the special type is evolved from one more general. If the views which I have elsewhere stated be correct, it follows that the irritability of certain tissues in plants is analogous to that of the muscular fibre of animals; and that the actions immediately connected with the maintenance of the organic functions of the latter, are the direct result of external stimuli on their organism. The possession of a nervous system must, I think, certainly be regarded as the distinguishing characteristic of animals, although our means of investigation will not always enable us to detect it; but the functions of this system in the lowest classes of animals, would appear to be almost entirely confined to the conduction of impressions from one part of the organism to another. As we rise in the scale, we observe that the instinctive actions which are the necessary respondence of the organism to external stimuli, are gradually overpowered by the influence of the will; and although, as has been recently observed,* we may regard the nervous system as living and growing and carrying on its actions within the body of an animal as a parasitic plant does in a vegetable, and as not communicating any influence which is immediately essential to its organic functions, yet we must perceive (to use the words of the

* British and Foreign Medical Review, vol. iii. p. 10.

same author) "that the objects of the existence of animals require that the mental actions of the nervous system should exert a powerful controlling influence over all the textures and organs composing an animal."

The organs of sensation, when examined in the ascending scale of animals, will, I think, afford us illustrations of the same general principles. We may perceive that the special functions of sight, hearing, and smell, are rather elaborated out of the general sense of touch than superadded to it; and there would not therefore appear, *a priori*, any physiological impossibility in the fifth pair supplying a certain power of sight when the optic nerve is absent, as in the mole; and, if the phenomena of the transference of sensation should ever be indisputably established, their explanation on the same principles will be easy.

Without entering into any detail with regard to the structure of the various organs of locomotion in animals, it is easy to observe the intimate connection which exists in the lower classes of this kingdom between the exercise of this function, and those movements which are essential to the maintenance of the organic life. Thus the cilia, which in so many of the aquatic tribes are almost the sole instruments of progression, serve also to bring supplies of food to the mouth, and of water to the respiratory organs. In the higher classes we see each of these functions performed by a special apparatus, but still a connection may be traced; and I know not a more striking illustration of it than the structure of the locomotive system of birds. In this class, as in insects, a high amount of respiration has to be combined with general buoyancy of the body; and this object is attained by the general diffusion of the respiratory organs. But in insects, the principal organs of progression are merely an extension of the respiratory system; whilst in birds, a special locomotive apparatus is evolved, which still, however, retains a certain connection with the function of respiration.

ON THE

VOLUNTARY AND INSTINCTIVE ACTIONS

OF

LIVING BEINGS.

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(*From the Edinburgh Med. and Surg. Journal, No.* 132.)

THE inquiry on which I am about to enter derives a peculiar degree of interest from the extent of the field embraced by it, and the importance of its character; whilst the complicated nature of the relations subsisting between its objects renders it one of no ordinary difficulty. This difficulty has, I think, been much increased, by the erroneous method in which the investigation has usually been prosecuted, as well as by the number of exploded theories, whose shades still hover in the darkness that envelopes the subject; and these have been productive of injurious effects, by the doubt which they have often cast over established facts, and by the number of fallacious statements which they have almost inseparably mixed with truth. I am far from supposing that it is in my power to shed new light upon the questions I am about to discuss. I have little claim to novelty in any of the views I shall bring forward, since they have almost all been propounded by different authors, of more or less reputation in their respective departments; and the object I have chiefly in view is to show in what manner they may be harmonized and connected, so as to form one uniform system.

Before entering upon the investigation, however, it may be advantageous to make a few remarks on the comparative value of observation and experiment, in the elucidation of the causes of the phenomena exhibited by living beings. By *observation*, we take cognizance of the sequences of these phenomena as presented to us by nature; but their complication too often renders it impossible to analyse them with such clearness as to be able to attribute each effect to its peculiar cause. Hence the *experimental* inquirer endeavours to arrange his causes into new combinations, in such a manner, as to produce a different set of results by the comparison of which, the *vera causa* of each ef-

* The substance of the following paper was read as a communication to the Royal Medical Society, March 23, 1837.

fect may be arrived at by the method of exclusion. And it will be remarked, that observation is here necessary to take advantage of the new set of phenomena presented by experiments ; and the inductive processes founded upon each are precisely similar. But there are obvious limits to the employment of experiment in the investigation of the laws of vitality. The physiologist has by no means the same power of selecting and arranging his causes, for the purpose of observing their results, as that which is possessed by the chemist or the mechanician. If he take away an essential part of a living structure, it no longer exhibits even a trace of those properties of which it is his object to ascertain the laws ; and, on the other hand, he fails in all his attempts to produce any of the phenomena of vitality by new combinations of inorganic elements. Here, however, a judicious and careful system of observation will almost supply the place of experiment; for the ever-varying forms of organized beings by which we are surrounded, and the constantly changing conditions in which they exist, present us with such numerous and different combinations of causes and effects, that it must be the fault of our mode of study, if we do not arrive at some tolerably definite conclusions as to their mutual relations. In our investigation of the laws of vital phenomena, therefore, we may advantageously commence with the observation of those instances in which the results are presented to us in the simplest form ; and if we can thus attain a knowledge of their *veræ causæ*, it will be of great assistance to us in the analysis of the more intricate combinations to which we afterwards proceed. Let me not be understood, however, as wishing in the slightest degree to underrate the value of experiment ; but merely to show in what manner its place may in some measure be supplied, when difficulties stand in the way of its employment.

One of the chief difficulties which arises at the outset of our present inquiry, originates from the self-esteem inherent in man, which has led him to arrogate to himself the sole prerogative of reason ; and to maintain that the springs of action which prompt the movements of the lower animals are of a character essentially different from those which regulate his own. Hence has sprung the absurdity of the application of the term instinct to the psychical endowments of every being under the sway of the " lords of creation," and the difficulties which have consequently been raised in the analysis of their actions. This doctrine is, however, rapidly giving way before a more extended spirit of philosophy ; and few who have fully investigated the subject are now indisposed to allow that many of the lower animals are endowed with the power of carrying on processes of reasoning, as complete as those performed by man, though of a less complicated character. It is not my intention to enter into an elaborate discussion of this question at the present time; but considering it as decided, I shall rather seek to distinguish the purely instinctive actions, from those which are the result of mental processes, and to determine the parts of the organism, on which they are respectively dependent.

In this examination, I shall therefore follow the principles which I have just laid down, by commencing with the simplest class of the instinctive actions performed by living beings. Although many writers have objected to the application of the term *instinct* to the vegetable kingdom, it has been, I apprehend, principally because the ideas of sensation, consciousness, and volition have been more or less mixed with their notion of its import. But, as I shall presently show, though these conditions frequently accompany instinctive actions, and sometimes partake in their production, they cannot be truly regarded as essential to them.

The first action of a living being is the absorption and assimilation of its aliment. No one will deny that this is the result of the adaptation of its organism to surrounding circumstances. But there are in the mode in which this process is performed in plants, some peculiarities which claim our attention. What power of *selection* do the roots possess, and how is it regulated? From the little that is known on this subject, I think that it may be inferred that the rejection of any particular ingredient of the fluid in contact with the roots, results either from the want of adaptation in the form or size of its molecules to the pores of the spongioles, or to an organic change effected by it on their delicate tissue. Again, it has often been asked—why do the roots of plants always direct themselves towards a damp soil? This fact has frequently been adduced in proof of the sensibility enjoyed by vegetable organism; but few now regard it in any other light than as an illustration of the exquisite design manifested in the laws of the vegetable economy. It is an established fact that the root only increases in length by additions to its point, (except in a few instances of no importance to the present inquiry;) and that the addition is made in the direction of least resistance, which will always be that where the soil has been rendered yielding by the percolation of fluid. Another fact relating to the growth of the roots has been less frequently noticed. "When two roots of the same kind are planted, the one in a sheltered, and the other in an exposed situation, the former pushes forth its roots in all directions, more especially where there is the greatest supply of nourishment and the highest temperature; while the latter, which, were it to act in the same manner, would be speedily overturned; multiplies its roots in the direction of the strongest blasts, and these acting like the stays of a ship's mast, preserve the trunk in its vertical position." * The author from whom I have quoted this fact does not attempt to explain it; but I think that it may readily be accounted for in the following manner. Mr Knight has shown that the motion of the trunks of trees by the wind is of material assistance in the downward propulsion of the sap; for having confined a stem in such a manner that it could only vibrate in one plane, he found that its increase in diameter in that direction was considerably greater than in the transverse line. It is evident, that the same cause will influence the growth of the roots given off from the longest diameter of the stem; and that a tree which is violently acted on by blasts of wind which strike it most frequently from one quarter, will of necessity send out the strongest and longest roots in the same direction. The tendency of plants to grow towards the light may be explained upon similar principles. The illuminated side of the stem becomes hardened and contracted by the fixation of carbon and the exhalation of moisture; whilst the darkened side continuing to grow more luxuriantly, incurvation of the axis takes place. In all these cases of instinctive action, therefore, the effect is manifestly produced by the immediate agency of external stimuli upon an organization fitted to respond to it.

It would occupy too much time to attempt at present to demonstrate the close connection which every process of vegetable growth has with the nature and degree of the stimuli which excite it; and I must content myself with adverting to one or two of the most remarkable of the evident motions exhibited by plants. We can have no hesitation in allowing to certain tissues, in particular vegetables, a power of contractility evinced by the effect of a stimulus applied to the part itself, scarcely inferior to that which characterizes the muscular fibre of animals. Thus the leaves of the lettuce force out their milky juice upon the slightest touch; and the contraction of the vesicles on one side of the filament of the barberry, when irritated by the point of a pin, causes its immediate curvature. Many similar instances might be enumerated; but there are other vegetable motions still more remarkable, where a stimulus applied to one organ produces an effect upon a distant part. Of this character are the closing of the trap of the *Dionæa*, and the folding of the leaves and drooping of the petiole of the sensitive plant. The latter phenomenon has been well explained by Dutrochet and Mayo; the contraction of the part irritated forces a portion of the fluid contained in its vesicles along the vessels of the petiole; and thus being propelled into the intumescence at the junction of the latter with the stem, distends the *upper* side of it, and thus produces flexion of the leaf-stalk. A similar effect is produced

* Fleming's Philosophy of Zoology, Vol. i. p. 18.

by irritating the lower part of the intumescence, or by cutting a notch in it; the contraction of its tissues enables the elasticity of the upper portion (which in its perfect state it counterbalances) to produce a similar depression of the petiole. The impression is here propagated from the part irritated to a distant organ, but not by means of an instantaneous influence transmitted by a nervous system. The vital property of contractility called into play by its appropriate stimulus, gives rise to a series of strictly mechanical actions; and by the peculiar adaptation of the structure of the plant to these, motion of distant parts is excited.

Some interesting facts connected with the action of poisons on plants lead to the same general result. The effects of metallic irritant poisons appear to be propagated solely through the circulating system. Thus arsenic introduced into the ascending current of sap will destroy the vitality of the line of the trunk and branches, along which that portion of the current passes, without immediately injuring the remainder of the tree. In one of Marcet's experiments, a quantity of arsenic introduced into one of the branches of a lilac, was six weeks in producing the death of the entire plant; and it was remarked by Drs Christison and Turner, in their experiments on the effects of poisonous gases, that those which rank as irritants in relation to animals, appear to act locally on vegetables without any of that sympathetic influence on general life, which is one of their most remarkable effects in the other kingdom. The action of narcotic poisons is somewhat less easy of explanation. They seem at once to destroy the excitability of the parts to which they are applied, and their action is more universal than that of the former class; but I do not myself see any necessity for referring the transmission of their effects through the plant to the operation of a nervous system.

I have dwelt at some length on the phenomena exhibited by vegetables, because I apprehend that the proper explanation of them will assist us in our researches into the instinctive actions of animals. All the actions manifested by plants, may I conceive, be regarded as the direct, and, in many instances, the obvious result of the *respondence of their organism to stimuli fitted to excite it;* and whenever any of these stimuli produces an action in a distant organ, its effect appears to be propagated solely by the circulation of fluid.

My next object will be to prove, that the purely instinctive actions of animals may be comprehended in the same general definition; but that they differ from those of plants in this important respect, that they are not merely connected with the system of organic life, but also with that appropriated to the discharge of the exclusively animal functions, namely, the nervous and muscular apparatus. From the nervous system being more or less involved in their performance, they are put in some respects on a new footing; but I hope to show that no strictly mental processes are necessary to their manifestation; and that this system acts only by its respondence to stimuli expressly adapted to itself, and by the immediate transmission of the excitation produced by these stimuli to distant parts of the organism.

Before entering, however, upon the consideration of the animal kingdom, let us pause for a moment at the threshold to inquire what are to be regarded as its essential characteristics. The naturalist seeks to establish his classification upon external signs easy to be recognized and comprehended; hence he has recourse to the possession or absence of an internal digestive cavity, the nature of the food, the effects produced by respiration, &c. as his chief diagnostics; but none of these can be alone relied on, and a distinction founded upon them is at best but a superficial one. The physiologist, on the other hand, endeavours to separate the animal from the vegetable kingdom by its possession of the powers of sensation and volition, manifested by the act of voluntary motion; and this is certainly to be regarded as the essential character of an animal, since a being enjoying it would still belong to that division of the organized world, whatever might be its structure; and, on the other hand, a being formed in all respects like an animal, with the exception of its nervous system, (were it possible for such a being to exist) and the consequent deficiency of the powers which it confers, must unhesitatingly be placed in the vegetable kingdom.* Every one must be aware, however, of the difficulty of carrying any such test into practical application; since among many of the lowest tribes of organized beings we observe motions which can scarcely be referred with certainty either to the accidental influence of external causes, or to a stimulus originating in the individual. It appears to me, however, that there has been too much anxiety to draw a definite boundary line; and that without having recourse to the third or intermediate kingdom, proposed by some continental naturalists, we may consider the transition from one division to the other to be of the same gradual character, as is apparent between all great natural groups, when none of the connecting links have ceased to exist. It has, I think, been too much the custom to attribute the motions of the lowest animals to the same spontaneous powers of whose existence in the highest classes we can have no doubt; without sufficiently attending to the fact, that in the former, there is no trace of the presence of those parts of the nervous system which in the latter

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* I do not of course allude to *monstrous* productions.

correspond (to say the least) with their manifestation. I shall endeavour, therefore, to trace the successive complication of the chain of causes and effects in the actions performed by animals, reasoning rather from below upwards, than from above downwards; since it appears to me that animals of the inferior orders (especially those now included in the division Acrita) bear much more resemblance to vegetables in the *totality* of their vital actions, than to the higher members of their own kingdom.

It is necessary that, before proceeding farther, I should specify the sense in which I am about to employ certain terms to which different authors have attached a great variety of meanings. These terms relate to the process by which the thinking mind takes cognizance of the qualities of external objects; a process which, though apparently simple, is resolvable into many steps, each of which has its appropriate designation. In the first place, an *impression* is produced upon the organ of sense by its appropriate stimulus, and this impression is propagated along the nerve which connects it with the *sensorium commune.* We are justified in regarding the formation and propagation of this impression as a strictly corporeal function, although we cannot trace the organic change of the nervous system by which it is accompanied.* This impression conveyed to the sensorium gives rise to that mental change which is termed *sensation*, which may be regarded as the passive reception by the mind of the impression made upon the organ of sense, which thus communicates to it the simple notion of the presence of an external object. For this change to take place, let it be observed, consciousness is all that is requisite; and if consciousness exist, and the nervous communication be perfect, sensation must follow an impression. The mental change termed perception may or may not follow according as the attention is directed to the sensation; and this change consists in the formation of a notion of the qualities of the external object, derived by inference from the sensation. The first stage of the process is therefore purely corporeal; the third purely mental; the second is the stage of transition by which the body communicates with the mind.

Now for each of these steps in the action of the body on the mind, I think that a corresponding step may be traced in the reciprocal action of the mind upon the body. Before a perception can occasion any corporeal change, it must have given rise to various mental processes, such as association, judgment, &c. with the nature of which we have at present nothing to do. These, however, all terminate in the formation of a *volition*, which may I think be regarded as a strictly mental act,† and as holding a

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* Prichard on the Vital Principle, p. 147.
† Roget's Physiology, Vol. ii. p. 535, note.

corresponding rank with perception in the scale I am attempting to describe. This mental act gives rise to a physical change in the sensorium, to which I do not find that metaphysicians have given a name; a change which corresponds in an opposite direction with that of sensation, and which for convenience I shall at present denominate the *motive action*.* This motive action propagated along its appropriate nerve, stimulates the muscular fibre, and thus produces voluntary motion; and this stage of the process, which for want of a better term I may denominate *stimulation*, † is evidently reciprocal to the impression at the commencement of the nervous cord. We may then arrange these processes in the following table, which will shew their mutual relation.

Impression		Stimulation.
↓		↑
Sensation		Motive action.
↓		↑
Perception ——→	Mental acts ——→	Volition.

I have thus endeavoured to analyze the steps of the process by which voluntary motions result from impressions on the organs of sense. We have now to examine whether there can be no more direct connection between an impression and a motion. The whole class of what are usually regarded as automatic or strictly involuntary motions will at once occur to us. Adopting the doctrines of Haller on the irritability of muscular fibre, we perceive that the contraction of the purely involuntary muscles, such as the heart, and the muscular coat of the alimentary canal, results from a stimulus applied directly to themselves, without the intervention of nervous agency. I scarcely perceive how we can distinguish this contraction from that which occurs in the irritable tissues of plants, and the structure, by which it is performed, gradually loses its peculiar character as we descend in the animal scale, until we can perceive no trace of it whatever. These contractions may then be regarded, like those of vegetables, as forming part of the *organic* functions of the being, since they are entirely independent of nervous influence; and as forming, together with the changes (probably of a strictly physical character, although called into play by vital action,) which constitute the functions of absorption, assimilation, &c. the

* The term motive action I employ as corresponding with the "influence of volition" of some writers. If volition be a purely mental act, and an organic change take place in the nervous system as its consequence, it is evidently desirable not to confound these processes, as has been done by those writers who speak of *motion* as the direct result of volition. I am no advocate for the multiplication of terms, and shall feel happy to dispense with these, if it can be shown that they are unnecessary.

† I employ the term *stimulation* to designate this stage of the process, as implying the action of the nervous power upon the muscular fibre, which corresponds, according to the Hallerian doctrine of irritability, with that of other stimuli applied directly to the latter.

lowest class of instinctive actions in which we can trace most clearly and immediately the respondence of the organism to external stimuli.

Now it is probable that in the lowest animals which present any traces of a nervous system, it exists in that form which is such an interesting stage in the development of the higher organisms—namely, a number of nervous filaments radiating from the circumference, but unconnected with a common centre. In the sub-kingdom Acrita, no vestige of a nervous system can be detected ; and it is generally supposed to be present in a *diffused* form; that is to be distributed in insulated globules through the tissues. Our ideas of the transmission of nervous influence forbid us from believing that, in the first of these cases, and much less in the second, there can be anything like a *sensorium commune;* and I am much mistaken if a rigid analysis of the motions of these animals would not enable us to refer most of them to the immediate action of external stimuli, and thus to the same class of instinctive actions as the motions of plants and the contraction of the purely involuntary actions of animals. Let us take for example the common polype *(Hydra viridis ;)* in its bodily structure we may regard it as *all stomach*, and every action it performs, is directed towards filling its digestive cavity, since its generative functions are altogether beyond its control. The irritable tentacula surrounding its mouth contract upon the slightest touch, and inclosing whatever may be in contact with them, endeavour to convey it to that aperture. Now we have here a remarkable analogy on the one hand, with the *Dionæa muscipula*, whose curious motions would seem to have a similar object; and, on the other, with the motions of the muscular part of the alimentary tube in higher animals, a correspondence, indeed, so strong between the *effects*, that it would be unphilosophical to suppose the *cause* to be different. With regard to the other motions exhibited by the same animal, I am inclined to believe that they may be mostly accounted for by the direct stimulus of light, heat, &c. like those of plants. I am far from wishing, however, to deny to the creature some degree of sensation exciting pleasure or pain, and of volition in directing its movements; but I conceive these to be very small, and to be but little effectual in the maintenance of its organic functions, which are supplied by this simplest kind of respondence of the organism to external stimuli, which I may call *organic instinct.*

It is a principle of which every one must be aware, that in proportion as we rise in the animal scale, we find the action of external stimuli giving place to that of internal volition. Thus we all know that most animals are more susceptible than man of atmospheric changes ; and that those individuals of the latter species are usually most cognizant of them, whose mental faculties are the weakest, or least appropriately employed. It does not necessarily follow, however, that these changes do not produce sensations in him ; but, on the contrary, it is probable that from the attention of the mind being directed to other objects, no perception of them takes place. I think that we shall be able to trace in the different muscles of the human body a gradation similar to that which we observe in the animal scale, with regard to the effects of the two kinds of stimuli.

Having now disposed of the first or lowest class of instinctive actions of living beings, we next pass to those which are connected with the nervous and muscular systems, and are therefore peculiar to animals, involving the organs of the life of relation. I have already stated my belief that in some of these, the nervous system acts merely as a *conductor* of stimulus from one organ to another, without the necessary intervention of any mental change ; and this I imagine to be the principal office of those connected fibres which we see in some of the Echinodermata on which no ganglia exist. The nerves, then, taken in this simple view, serve to establish an instantaneous communication between distant organs of the body, and at the same time to collect and harmonise the impressions made on all, so that no part may act independently of another.

There has been much controversy amongst physiologists as to the classification of those muscles which, being called into play in the living body by the stimulus of nervous power alone, are more or less under the control of the will. My friend Dr John Reid has suggested to me that the difficulty may be overcome by regarding every muscle in the body which is supplied by motor nerves, as equally susceptible of stimulation from two different sources, namely, volition, and sensation without volition. Thus any one will involuntarily draw back his foot if the skin be pricked or pinched ; and the same motion will be performed by the body of a frog after the brain has been removed. The muscles of the leg are not, however, frequently called into play in this manner, being more commonly acted on by volition. In the diaphragm, on the other hand, the uniform alternation of contraction and relaxation is kept up by the constant stimulus of the " respiratory sense," or " besoin de respirer," originating in the lungs, whilst the will is much seldomer called upon to act, and, as long as the stimulus continues, cannot altogether control the muscle. Hence the difference between the actions of the diaphragm and those of the most purely voluntary muscle in the body, is not one of *kind*, but simply depends upon the respective proportions of the two stimulating powers. I shall presently have to extend the view which Dr Reid has suggested to me, by showing that the contraction of a muscle may result not only from the direct stimulus of a sensation, but even from that of a simple impression. The following tables will show what I think may be regarded as the three modes of communication between an organ of sense, and a muscular fibre excited to contraction by nervous influence.

1. Impression.	——————→	Stimulation.
2. Impression.		Stimulation.
↓		↑
Sensation.	——————→	Motive action.
3. Impression.		Stimulation.
↓		↑
Sensation.		Motive action.
↓		↑
Perception.	——————→	Volition.

The first class of movements evidently corresponds with the excito-motory actions of Dr Marshall Hall, the Sympathetic of Dr Whytt and other writers. The constant association of particular muscular movements with certain impressions on the organs of sense has long been known, and has been a fruitful topic of discussion amongst physiologists. It has been usual to ascribe them to the intervention of sensation between the impression and the contraction ; but of this I see no further proof than that they are always accompanied in the normal state of the system with this change in the sensorium (consciousness of course being present,) and that it is therefore difficult to suppose that they can take place independently of it. I think that it might be replied, however, that if the purely involuntary muscles contract by an impression immediately produced upon them, there is no great difficulty in supposing that in another instance contraction may be produced by an impression made on a distant part, the nervous cords acting simply as its conductors. The question is not, however, to be decided by *a priori* argument; it is one of fact, and to facts we shall now recur.

Whytt, Legallois, and many other physiologists have noticed the remarkable motions occurring in the extremities of animals after the brain has been removed, and have shown that the integrity of the circle of sensitive and motor nerves completed through the spinal marrow, is essential to their performance, since, when this circle is broken by the destruction of the spinal marrow, the motion ceases to follow the application of a stimulus. Hence, they concluded, that *sensation* remains in the spinal cord after the destruction of the brain ; and Cuvier has sanctioned this view, by regarding them as a test of that process. But this assertion arises solely from the desire of preserving an apparent uniformity in the effects of impressions on the muscular system ; and while laying great stress on the constancy of the accompanying sensations while the brain is entire, they have overlooked the fact, that *perception* will follow as well as *sensation*, if the attention be awake and not directed to other objects. The same argument then which is used to invalidate their dependence upon perception, will also hold good against their being the result of sensation; for, except the continuance of these motions, we have no reason to believe that sensation can exist when the brain has been removed; and to say that sensation remains because these motions result from the application of stimuli; and that the motions follow the stimuli because sensation remains, is obviously arguing in a circle. It is impossible, therefore, to determine by experiments of this kind, whether the act of sensation can take place in the spinal cord or not; but inferences of a more certain kind may be drawn from pathological phenomena. Thus Mr Mayo relates a case* of palsy and complete loss of sensibility in one leg, in which nevertheless irritation of the toes produced retraction of the leg, without, as he was assured, any sensation on the part of the patient.

An interesting case, having a similar bearing, has been communicated to me by my friend Mr Madden, in whose words I shall relate it. "In the autumn of 1834, I was in attendance upon a case of complete paraplegia, in which it was necessary to employ the catheter twice daily. On several occasions, when the point of the instrument was passing the prostatic portion of the canal, where a slight obstruction existed, I observed that the patient jerked his legs violently; but upon inquiry he positively denied having experienced any sensation, being not even conscious of the presence of the instrument in the urethra. The disease appeared to have been originally induced by two severe injuries received a twelvemonth before. Upon dissection, the spinal cord in the lower part of the dorsal region was found completely disorganized, being converted into a semifluid pulp. The preparation has been placed in the Museum of the College of Surgeons." It may be objected that in this case the diseased state of the spinal cord forbids us from asserting that the motions were the direct result of the impression made in the urethra; but, it will be recollected, that such motions are not unfrequently perceptible in the healthy state of the nervous system, when any obstruction exists to the passage of an instrument; and that the phenomenon so frequently occurred in this instance as fully to point out the relation of cause and effect. I have no doubt that many cases similar to these will be detected, when the attention of practitioners is sufficiently called to the question.

* Outlines of Pathology, p. 154.

Again, Dr Ley * mentions a person in whom the *par vagum* appeared to be diseased; the lungs suffered in the usual way in consequence; and the patient had evidently laborious breathing, but said distinctly that he felt no uneasiness in the chest. Among the cases detailed by Sir C. Bell, at the end of his work on the Nervous System, there are several which have an interesting bearing on this question. Thus he mentions a case (151) in which there was no power whatever over any of the voluntary muscles, but those of the eyes and face; the tongue of the patient refused utterance, and her legs and arms lay motionless; yet she could swallow easily, and all the respiratory movements were performed. There are many other cases on record of the same kind; and in some of these it is related that muscles usually styled voluntary, but over which the will had no power, owing to the existence of paralysis, were excited by impressions connected with the respiratory organs. Now it is evident that there was in these cases no deficiency in the conducting and stimulating power of the nerves, nor in the mental act of volition; it must have been, therefore, in the process of motive action that the defect lay; and as sensation can only act through this channel, it is obvious that the impression derived from the respiratory organs must have produced direct stimulation, sensation accompanying the change, but not being essential to it. My meaning will perhaps be made more apparent by the following table.

Impression. ——————→ Stimulation.
↕
Sensation.
↕
Perception. ——————→ Volition.

In another instance (173) related by Sir C. Bell, the contrary state existed; the external respiratory muscles of the neck and chest would not obey the usual stimulus so as to dilate the chest for inspiration, although they were perfectly under the control of the will. Now if it is necessary that sensation be produced, and an act of volition excited, where is the seat of deficiency of power? Certainly not in the brain, for volition was strong; nor in the nerves of sensation, for these conveyed to the mind the sensation of distress; nor in the nerves of motion, for in the voluntary movements of the frame these muscles were put in action. The defect was evidently in the production of stimulation as a direct consequence of impression.

Without entering further into this question, I think that we are warranted in coming to this conclusion, which I state in the

Essay on Laryngismus Stridulus, p. 417.

words of a late most able review on the subject. "As it is only by exciting a peculiar unknown change in the spinal cord that impressions on any sensitive nerves excite sensations in the mind, so it is quite possible that these changes in the spinal cord may not be wholly prevented from taking place in cases where disease of the brain or injury of the cord itself so far affects the spinal cord as to prevent sensations from being felt; *and that these changes, not the sensations which in the natural state accompany them, may be the causes of the sympathetic or involuntary motions.*" *

We may now briefly inquire what class of motions result in the usual conditions of the body from the influence of impressions only. It is of course very difficult to specify these; but I think that there is evidence that all the motions *immediately* concerned in the supply of the organic functions are thus performed. And in many of the lower animals possessed of a nervous system, and a complicated digestive apparatus, but endowed with little power of locomotion, such as the greater part of the acephalous Mollusca, these appear to be almost the only kind of actions which the organism is called on to perform. In the higher animals, the most obvious of these motions are connected with the act of respiration, which some authors have most unaccountably referred to an exercise of volition; but there are others as complex, although usually more directly controlled by the will, as for instance those of deglutition, defecation, and urination, which have been performed by acephalous infants;† and those essential to copulation which have been performed by men and animals labouring under complete paraplegia, in some of which cases it is stated that ejaculation took place without sensation. If, as Sir C. Bell believes, a peculiar column in the spinal chord is requisite for associating the roots of the nerves concerned in respiration, why should not each of these complex associated actions have its peculiar tract also? Instinctive movements referable to this *excito-motory* class, may, I think, be excited by atmospheric influences, which need not produce a definite sensation; and to this head I should refer the commencement and conclusion of hybernation in animals, (that of plants being entirely referable to the organic instincts,) and the activity of insects in sultry weather, especially before a thunderstorm. It would, however, be very premature to state this

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* British and Foreign Medical Review, Vol. iii. p. 38.

† It might be objected to this view of the actions of acephalous infants, (all of which, it may be remarked, are *immediately* directed to the supply of their physical wants,) that if unpossessed of *sensation*, they must be regarded as mere automata. It may, I think, be fairly replied, that whether the movements are produced by sensations or are the direct result of impressions, they are still purely automatic, unless we suppose that the spinal cord may be the seat of *volition* as well as of sensation.

opinion with confidence in the present limited state of our knowledge on these subjects.

The next class of muscular movements comprehends those which are the direct result of sensations acting immediately on the motor nerves without the intervention of volition; and this will, I believe, comprehend all the remaining purely instinctive motions of animals, which minister less directly to their organic functions. I still call these *instinctive* actions, because they are the direct respondence of the organism to external stimuli; and do not appear to me to be dependent on the will, although more or less under its control, and although consciousness is essential to their production. They still present the same certainty and uniformity as are observed in the previous cases; they are performed without education in the first instance, and are not improved by practice. It would appear that the impressions made upon the organs of special sense can act in no way more direct than this; and the reason is evident. It is by them that animals take cognizance of distant objects not in immediate contact with their bodies, and therefore not holding a direct relation with their organic instincts. Now we observe that in many of the lower animals, certain actions result immediately from *sensation*, which in man are only performed after *perception* has taken place, and a notion thus formed of the character of the external object, which is only acquired by education. Thus the sight of an infant or of a person who has newly acquired this sense is educated by the touch; whilst many animals manifest by their actions that no such mental process is necessary; their sensations being, as it were, converted into motions without farther intervention. Thus a duckling upon being hatched will at once run to the nearest water; and a fly-catcher, just out of its shell, will peck at an insect within its reach, and seldom miss its aim. Where a succession of complicated motions is required for a particular purpose, as for instance the construction of a habitation, I think it probable that there may be a general act of volition controlling the whole, though each individual action is the result of its appropriate stimulus. It is generally allowed that there is in the *mind* of the animal performing the actions constantly observed in its species, nothing like an adaptation of means to end, this adaptation being in the physical confirmation of the nervous system, which, to use a very rough but approximate simile, may be constructed like the barrel of an organ, to play any tune that is set upon it, when the impulse is given by the motion of the handle. *

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* It has been well remarked by Mr Macleay, that "perfection among the Annu-

To the same head may be referred a great variety of instinctive actions in man, though these are more liable to be obscured by the exercise of volition. Thus, for example, the motions necessary to maintain the balance of the body, or to save it from immediate danger, cannot be regarded as voluntary, since they may be performed when the attention of the mind is directed to other objects, and when perception cannot therefore take place. I am disposed to believe that the associated movements which have been acquired by habit may in like manner be performed by nothing more than a general act of volition directing the organs of sense to the appropriate objects; but that each separate movement is the result of a distinct stimulus from without acting on the shorter chain which habitual excitement has thus formed, although an effort of volition was at first necessary for each. As an illustration of my meaning, I may advert to the example so often cited, of a person playing a complicated piece of music whilst the attention is fixed upon a distinct train of thought. There is one case which would even lead to the belief that habitual muscular movements may be excited by *impressions* only; I refer to that of the lady mentioned by Dr Percival, who was much addicted to snuff-taking, and in a fit of profound apoplexy, when no other movements could be excited, irritation of the nostrils with a feather produced contraction of the thumb and finger of the right hand. But it would be absurd to draw a conclusion so important from a single case of this kind. I could wish to have dwelt longer on this part of my subject, but I have already exceeded the usual limits of a communication, and, in summing up that portion which relates to instinctive actions with one or two additional remarks, I may use the language of one of the most philosophical writers on this subject. "In effect, is instinct any thing else than the manifestation without of that same wisdom which directs in the interior of our body all our vital functions."

If we trace the successive steps of the process of digestion, by which the aliment is prepared for the action of the absorbent system, a process which is more specialized throughout the animal kingdom than any other, we shall observe, that in the higher classes, each of the different combinations I have above described has its distinct office in the supply of the organic instinct, and that we may trace along the alimentary canal a series of actions at first purely voluntary, and becoming more and more instinctive as we pass along, corresponding exactly with

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losa seems always tending to make the animal a complicated machine, guided solely by the instinct implanted in it by its Creator; whilst in the Vertebrata, perfection seems to tend to make the animal a free agent, and to render it independent of external circumstances."

those which we meet with in descending the animal scale. Thus there can be no question that, in the human being, the prehension of food, and the conveyance of it to the mouth, are strictly voluntary acts ; and these are the result of mental processes of a still higher order, connected with the special sensations, and having a more remote bearing on the function to which they minister. In descending through the animal scale, we shall find that the exercise of volition for this purpose soon gives place to pure instinct. The mastication of the food may be regarded as partly an instinctive process, partly habitual ; requiring, in the adult, sensation to excite it and the general control of volition ; it may therefore, I think, be regarded as an example of the highest class of instinctive actions, which we may denominate *sensori-motor*. The act of swallowing, on the other hand, is the result of an impression rather than a sensation, and is therefore (as Dr M. Hall has shown) one of the lower class or *excito-motor* actions. If Brachet's experiments be correct, the motion of the parietes of the stomach is caused by an impression conducted and reflected by the *par vagum*. The remainder of the motions of the alimentary canal, if Haller's theory be admitted, belong to the class of organic instincts, being the result of a direct impression. I think that if we revert again to the animal scale, we shall perceive that the sensori-motor actions must be lost when there is no longer a central sensorium ; and that the excito-motor actions cannot take place where there is no connected nervous system ; so that in the sponges and other connecting links between the animal and vegetable kingdoms, whose food is constantly in their immediate proximity, the supply of the absorbent system is effected wholly by the direct stimulus applied to the tissues themselves.

Now a consideration of these facts (which might be similarly traced with regard to the respiratory and generative systems) will lead us to see why the impression should, in the higher organisms, be followed by sensation ; and why, in the highest sensation, should give rise to mental acts terminating in volition. Each train of actions requires for its maintenance the stimulus of food, and this has to be supplied by the train above. Thus a cistern-full of water may be speedily emptied by a cock occasionally opened at the bottom, but may be kept full by a ball-cock floating on the surface, and communicating with a reservoir. Now here the action of the ball-cock at the top is not essential to the flow of water at the bottom, but is consecutive to it ; it is, however, essential to the continuance of the latter by the supply which it thus insures. Just such is the case with regard to the food of animals. The acephalous infant would not be able to maintain its own existence, because incapable of performing those higher processes which are essential to the maintenance of those which it can execute; and yet these last are fully adequate, as long as its food is supplied from extrinsic resources, just as they are sufficient for the support of those simpler beings whose food is constantly within their reach.

If we turn our attention to the other extremity of the alimentary tube, we may observe a similar necessity for the sequence of sensations upon impressions. In the lowest animals, as in plants, the discharge of excrementitious matter is an act as completely involuntary as the introduction of aliment into the system. Thus in the sponges, the currents of water issuing from the fæcal orifices are observed to continue without intermission during the life of the animal. In proportion as we ascend in the scale, however, we observe special reservoirs adapted for the temporary retention of the excrements; and a particular set of associated muscular movements required for emptying them. If we believe, as I think that we have a right to do, that part of these movements at least are, like those of respiration, the result of impressions only, we have no difficulty in understanding why sensations are associated with them in the perfect organism. These sensations give rise to volition, by the action of which the otherwise involuntary movements are controlled and regulated; and we have constant opportunities of witnessing the result of deficiency in this controlling power.

A similar illustration of the necessary connection of sensation with impressions in ministering to the support of the organic functions might be drawn from the function of respiration. According to the view already stated, the muscular movements required for its performance are simply the result of an *impression* producing direct stimulation through the nervous circle. But we will suppose that during sleep or slight intoxication, a person falls into a position in which the respiration is obstructed by stoppage of the mouth and nostrils, or pressure on the trachea; the *sensation* then produced will call into play other muscular movements, probably to be regarded as instinctive, for the purpose of getting rid of the obstruction. But if the sleep be too profound, as that resulting from narcotics, or severe intoxication, the individual will perish because no *sensation* is produced on the brain, although the respiratory movements would have been continued if not interrupted by external causes. Many a drunkard has been drowned by the accidental immersion of his face in a street puddle.

If the views above stated be correct, the office of the nervous system in its simplest form is merely to convey an impression from one part of the animal organism to another; and next, to refer all these to the *sensorium commune*, where they may be harmonised and more or less controlled by mental influence. Now, the number and variety of the *organic instincts* going on in the system, and which are common to it with the vegetable kingdom, require to be placed in more direct and immediate relation with one another than could be effected by the circulating system, which is their only mode of communication in plants. This is accomplished by means of the sympathetic system of nerves, which also has for its office to convey to the processes of organic life the influence of mental emotions. All the sympathies manifested in these functions are, I think, to be referred to this class of nerves, whilst those of the organs of animal life are, as I have endeavoured to prove, performed by the spinal chord and its nerves.

Another important inference presents itself with regard to the localization of instincts. If the views above stated be correct, the instinct originates in the organ which is the subject of the impression, whether internal or external; and from this impression or the sensations which follow, certain motions result. These may be accompanied with various mental changes, which are not, however, essential, further than that they may give rise to intellectual operations and voluntary motions as the consequence of them, which have the gratification of the instinctive desire as their remote object.

In proportion as we rise in the scale of animal existence, we perceive an increase in the purely mental powers, manifested in the obscuration (not the total suppression) of the instinctive tendencies, and the consequent variation between the actions of two individuals of the same species placed in similar circumstances. This increase appears to me to bear a constant relation with that of the hemispheric ganglia, or the part of the nervous system corresponding to them; but it seems obvious that we are not to look in these masses for the seat of those bodily instincts which belong, not to the *sensorium commune*, but to the whole organism.

It is easy to perceive the final cause of the fact already noticed, that the actions which in the lower animals and in the infant are instinctive, and therefore involuntary, are in the adult human being the result of reasoning processes called into action by sensation and perception, and terminating in an act of volition. If the organization of the human system had been adapted to perform all the actions necessary for the continued maintenance of its existence with the same certainty and freedom from voluntary effort as we perceive where pure instinct is the governing principle, and if all his sensations had given rise to instinctive perceptions, instead of those perceptions being acquired by the exercise of the mind, it is evident that external circumstances could have created no stimulus to the improvement of his intellectual powers, and that the strength of his instinctive propensities would have diminished the freedom of his moral agency.

In whatever point of view we regard the physical, mental, or moral constitution of man, we cannot but be struck with the degree in which he is left to his own resources. He alone is obliged to protect himself by clothing from the inclement elements;—he alone is furnished with the ingenuity necessary to provide it. It is a part of the instinctive or innate constitution of the bee or ant to lay up stores of food for the period of dearth; in man it is left to his own prudence and foresight, and though to all the actions *immediately* necessary for the maintenance of his own existence and the continuance of his race, a powerful instinct strongly impels him, these propensities could not be gratified if the means were not provided by the exercise of the mental powers which he enjoys in a degree far exceeding those of any other terrestrial being.

In tracing the progressive complication of the psychical manifestations of the human being during early childhood, I think that a remarkable correspondence may be observed with the gradual increase in mental endowments which is to be remarked in ascending the animal scale; and that a careful analysis of these changes would thus establish in regard to them the beautiful law which has been shown to govern the development of the corporeal structure. I must leave it to abler metaphysicians than myself to work out the details of this application, confining myself at present to such a sketch as may illustrate my meaning. The first actions of an infant are evidently of a purely instinctive character; they are directed solely to the supply of its physical wants; and if the previous argument be correct, they may result from impressions, without the necessary intervention of sensations, though, if the nervous system be perfect, the latter must follow. This is evidently an analogous state to that which exists in the lowest animals possessed of a nervous system and entirely governed by instinct. The new sensations which are constantly being excited by surrounding objects, call into play the dormant powers of mind; perceptions are formed, and notions thus acquired of the character and position of external things; and the simple process of association and its concomitant, memory, are actively engaged during the first months of an infant's life. At the same time an attachment to persons and places begins to manifest itself. All these are the characteristics of the great majority of the lower Vertebrata, as far at least as our knowledge of their springs of action enables us to form a judgment. As the infant advances in age, the powers of observation are strengthened; the perceptions become more complete; and those powers of reflection are added which prompt him to reason upon the causes of what he observes, and to perform actions resulting from more complicated mental processes than those which guide the infant; at the same time we observe the development of the moral feelings, but these are manifested only towards beings who are the objects of sense. I think that we may discover among the more sagacious quadrupeds, instances of reasoning as close and prolonged as that which usually takes place in early childhood; and the attachment of the dog to man is evidently influenced by moral feelings of which he is the object. Up to this point, then, we observe nothing peculiar in the character of man; and it is only when his higher intellectual and moral endowments begin to manifest themselves, especially those relating to an invisible being, that we can point to any obvious distinction between the immortal Ψυχη of man, and the transitory Πνευμα of the brutes that perish.

General Summary.

The following positions may be regarded as advanced in the preceding pages. No attempt has been made to prove several of them; since, the ground having already been so frequently discussed, every one has the means of forming his judgment upon them.

1. Many living tissues possess the property of contractility upon the application of a stimulus.

2. This contractility is especially manifested by the irritable parts of certain vegetables; and results in all these cases from the action of a stimulus either *directly* applied or conveyed through the circulating system.

3. This contractility is also especially manifested by the muscular fibre of animals, and may in them be called into play not only by the stimuli which act upon plants, but by another of a peculiar nature, commonly denominated nervous influence.

4. Whatever actions (whether consisting of visible motions or not) are performed by the tissues of plants, may be regarded as the direct respondence of their organism to external stimuli, and as solely connected with their organic life.

5. All the actions (whether consisting of visible motions or not) essential to the organic life of animals, are in like manner produced by the *immediate* action of external stimuli;* and being entirely involuntary, may be called *organic instincts.* Under this head are included (besides many less apparent changes,) the motions of the heart and alimentary canal.

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* The term *external* is here employed in the usual metaphysical sense, implying something distinct from *mental* action. The stimulus may originate in the corporeal organism itself.

6. The first office of the nervous system is to convey to a distant part the *impressions* made upon it, and to produce (by its *stimulation* of the contractile tissues) motions necessarily connected with them. These actions, being purely instinctive and involuntary, may be called *excito-motor instincts.*

7. All that is required for these manifestations is the completeness of the circle of concentric and excentric nerves. In vertebrated animals, the cerebro-spinal axis and nerves proceeding from it are of course solely concerned in this function.

8. In the lowest animals possessing a simple nervous system, these actions make up the greatest part of the sum of the life of the individual; and in the higher, they are immediately connected with the supply of the organic instincts.

9. Where a more complicated nervous system exists, the impressions give rise to mental changes termed *sensations,* the seat of which is some part of the cerebral mass in the Vertebrata, and probably the ganglia connected with the nerves of sense in the Invertebrata. With various sensations, certain involuntary motions are instinctively associated; but as *sensation*, a mental change in the sensorium, cannot immediately give rise to *stimulation*, an organic change at the extremities of the nerves, a *motive action* must be propagated from the sensorium along the nervous conductors, and this cannot result from an external impression wherever sensation does not exist. The instinctive actions thus resulting are still purely involuntary, although they may be controlled in man by the higher power of the will. Certain habitual actions may come to take place nearly in the same circle, which may be called that of *sensori-motor instincts.*

10. Voluntary actions require *perceptions* in addition to sensations and impressions. Perceptions give rise to mental processes terminating in *volition*, which produces motive action and stimulation. Volition is of course confined to the brain, and probably to the cerebral lobes.

11. No distinct division of the spinal marrow is necessary for the performance of the excito-motor, or sensori-motor instinctive actions. The same nervous matter may act as a conductor either to the influence of the will (motive action) or to that of a simple impression (stimulation.)

12. As all the nerves of sensation terminate ultimately in the cerebro-spinal axis, (the spinal cord and its prolongations as far as the *crura cerebri* and *corpora quadrigemina*) and all the nerves of motion arise from it, it follows that all motions must be the result of some stimulus applied to this system; and this stimulus may either be given by an impression from without, or by a mental change within (or in the brain above.) If we regard the cineritious matter of the brain as a seat of conscious-

ness, sensation, the intellectual powers, and volition, the medullary portion of the hemispheric ganglia being merely a conductor, (a position which I do not wish to be understood as advocating,) it necessarily follows, from the positions previously taken, that the sensory and motor tracts in the brain simply convey *upwards* to the cineritious matter, the influence of the impressions existing in the cerebro-spinal axis, and *downwards* the motive action resulting either immediately from sensation, or from volition.

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ON

CERTAIN MODIFIED FORMS

ASSUMED BY THE

INDUCTIVE PROCESS IN DIFFERENT SCIENCES;

BEING

AN ATTEMPT TO ELUCIDATE AND EXTEND SOME DOCTRINES OF THE NOVUM ORGANUM.

By ROBERT MORTIMER GLOVER, Esq.

From the Edinburgh New Philosophical Journal for August 1837.

ON

CERTAIN MODIFIED FORMS

ASSUMED BY THE

INDUCTIVE PROCESS IN DIFFERENT SCIENCES.

Of late, great importance has been rightly attached to the cultivation of those doctrines in primary philosophy, which regulate the formation of our practical rules of scientific inquiry. Indeed, as the doctrines alluded to are axioms including nearly all science in their relations, although in themselves of an abstractedly simple nature, it is very needful for the notions entertained with regard to them to be explicit. The proper functions of experiment and calculus, with other topics of no secondary consequence, can be thoroughly understood, only when investigated in their connexions with the theory of the Inductive Logic. And the Novum Organum itself exists as an everlasting memorial of the utility which may at any time result from the attention of scientific men being directed to the study of the laws that govern the mind in acquiring its knowledge, and the bearing of these upon actual inquiry :—for in the work is displayed the mode in which its immortal author was enabled to frame a code for future investigators, and perhaps to alter the bent of the energies of his time, from having conceived more enlarged views of the province appertaining to induction, than those possessed by his predecessors. In the present day, the light derived from numerous successful efforts to explore nature, has been reflected upon the study of methods and systems; and many illustrious disciples of the Baconian school in this country and abroad, have thus been able to refine greatly the precepts of their master. It seems to be generally supposed, that the labours of Stewart, Playfair, Laplace, the present Herschel, and others nearly equally eminent, who have treated of the applications of the Baconian philosophy, have almost exhausted the subject, and that if little can receive further elucidation, still less remains to be explored. But we believe, if the opinions of writers on induction be rigidly examined, a greater want of unanimity among them, even on very essential points, will be detected, than could be credited before hand. In particular, writers on logic are often by no means in accord with those who have described induction not exactly as a form of mental procedure, but by the help of certain signs in nature correctly supposed to correspond with successive steps in the mental operation. Besides, much ill defined language is currently used in speaking of the inductive process, its character and relations,—thus, it is often said, that physical laws have the power of enabling events to be anticipated by means of *others* which *have been* observed; and this is asserted sometimes when perhaps no very clear ideas are entertained of the *character* of this curious property attributed to physical laws. Further, the category of inductive sciences seems not very accurately defined. Metaphysicians have debated among themselves whether the precepts of the Baconian philosophy are properly applicable to the science of mind,—and whether the investigation of mental phenomena can be considered to involve the practice of a method of procedure at all analogous to the experimental inquiries of physics. And although in the northern part of our island, these questions have been answered in the affirmative,—a response has not been so generally given by the English and Continental metaphysicians. In like manner, writers on the philosophy of medicine differ greatly as to the extent of application admitted in their science to precepts which have been found invariably fertile in results, as applied in pure physics.

Our object in this essay is to make an effort to reconcile some of the above stated discrepancies, and to clear up (if possible) other portions of the theory of the inductive logic which appear to us in need of elucidation; and these intentions we purpose to effect, by detecting and defining certain forms which induction seems to assume in different sciences, when that process is regarded not in the mind, but through its corresponding signs in nature,—and which forms do not appear to be distinguished as yet in a clear manner by writers; while, at the same time, we endeavour to show how those varieties come to be, as it were, developed out of the fundamental process which is performed in mind,—which does never vary in essential character, whatever phases it may assume, when the indices correspondent to it are regarded in nature. As our space is necessarily somewhat limited, we shall only premise further, that our purposed divisions will regard methods of inductive procedure, and not individual instances, as in the classifications of Bacon, and that if the circumstances in the very constitution of the different sciences, which compel the inquirer to take diverse routes in arriving at their truths, have already been described, the subject, so far as we are aware, has not been treated as a whole in the particular way proposed.

It is perhaps scarcely proper to remind the reader, that all our knowledge is rendered available to the reasoning faculty by means of what is termed generalization:—for, as all processes of pure reasoning may be resolved into syllogisms, which can proceed only from generals to particulars,—until the mind has arrived at general notions, it cannot of course be capable of reasoning either on the subject-matter of the knowledge afforded by scientific inquiry, or on that of the information acquired in the ordinary relations of life. To that intellective faculty which has the power of forming general notions is given the name of abstraction; while its mode of procedure is termed induction or the inductive process. Abstraction is not regarded by metaphysicians of the present day as a simple faculty of the mind; but its real nature is of little concern here;—let it be understood, however, that induction is its mode of procedure, and generalization its result. And, first, let us attend to the result, in order that a clear conception may be had of what is required in a method of procedure, the great object of which is that this result may be attained.

In a logical point of view, a science may be regarded as a collection of general terms, each of which in all sciences, except those generally considered abstract, expresses common circumstances possessed by a certain number of particulars, from the examination of which the genus has been formed. In the abstract sciences, as for example in geometry, and that department of mental science, which, by the disciples of Reid, is called the doctrine of first truths, the highest and most inclusive principles are ideas of relation which subsist solely in the mind itself, and are found therein; so far, therefore, in those sciences there is no occasion for an inductive process, since the most general facts are also the simplest elements of belief, and as in geometry the only further foundation requisite for the whole series of truths composing the science, is, that some purely intellectual forms be described by references to those elementary principles, the science is altogether independent of induction. But, in the study of nature, both external, and within ourselves, all science (except the above mentioned portion of mental science, and perhaps a corresponding part of the doctrine of ethics) requires an analysis of a mass of phenomena, which at first sight appear exceedingly heterogeneous and complicated, in order that they may be resolved into simpler combinations, which, however, are expressed in terms more inclusive the farther the analysis is pushed. In other words, after the whole of the universe has been resolved into separate and distinct parts, these are again combined by the mind, and arranged into mental *loci*, according to laws furnished by itself. The grand object of this system of arrangement is not that the purpose of distinctness may be answered, nor that knowledge may thus be properly treasured up, but it is that this knowledge may be reasoned upon, in order, in fact, that the intellective process, which is carried on in syllogisms, may take the place of that which constitutes induction; and that those wonderful effects may be produced which flow from comparing and combining the results of human inquiry.* Such being the case, it may be conceived, that in framing those genera, the mind is not compelled to take notice only of such properties as are believed most essential to the constitution of the individuals to be grouped together; on the contrary, the abstraction may be of whatever properties are chosen, according to the notions entertained of their fitness for an end in view. All that is absolutely necessary to be attended to in the formation of a law, being that the properties fixed on for its types have an actual existence in all the particular instances composing the included genus. Thus, the Linnæan arrangement of plants is as just a system, so far as the mind is concerned, as that of Jussieu. It is true, the one system takes cognizance of a greater number of characters in composing its genera than are considered in the classes and orders of the other, and also of such characters as are believed most essential to the very nature of the individual plants. This system is therefore physically the more perfect of the two, but it is not therefore more logical than the other. In that respect both are alike,—both sufficiently accurate in logical structure, but framed for different ends.

The preceding observations may in some degree illustrate a great maxim of the Kantians, which makes the fundamental principles of all science repose in the intellect itself;—asserting the human understanding rather to dictate the laws which regulate its acquisition of knowledge, than receive them from the external world.† Indeed all general notions are the workmanship of the mind, and often cannot be ascertained to correspond exactly with existences and actions of nature. And this, even, on the understanding that such notions are derived in all cases by an exercise of the intellective faculty from real impressions. For example, the intellectual forms which are the objects of

* It is properly remarked by Whately, that those who propose in teaching logic, to substitute the Organon of Bacon for that of Aristotle, show a total want of comprehension of the intentions of either. This may be placed in a very strong light, when we reflect, that without the exercise of syllogistic reasoning, Watt would have been unable to apply the inductively raised laws of Black to the improvement of the steam-engine,—a fact which we could easily prove, were there space or occasion at the present time.

† Philosophie de Kant, par Villiers, p. 301, 8vo. Metz, 1801. The same truth is elaborately illustrated by Dr Brown in his 5th lecture.

geometrical reasoning, and which, being ideas of relation, have somewhat of the character of general notions, are not to be found pure in nature. And something similar, or at least analogous, holds of physical laws also; for these are either general terms signifying the agreement of a number of particular facts or phenomena in some common properties, or else abstractions of some actions of Nature from others with which they must in many cases be viewed in their real state, somewhat combined.

The characteristic, or what may be termed the logical characters of all physical laws are similar. For a definition of a physical law, in logic, it is enough to term it a statement implying a connexion observed between some properties and others, in any definite class of instances. It is quite essential, that the class of facts to which a law is applicable should be defined, but all the particular instances included in that class need not be known.* By the term property is meant a structure, a quality, or a function. Our observations with regard to laws apply to such general expressions as include *all their particulars* with logical certainty; and if in any place another meaning be attached to the term, it shall be stated explicitly.

On examination, the above definition will probably be found to include every thing absolutely requisite to constitute a physical law; and to be so general, that scarcely a law will be found without some physical or metaphysical properties superadded to those in the definition. But when illustrations are sought, they will doubtless be found in accordance with our

* This distinction is believed to be of great importance; perhaps the following illustration may explain more fully its nature. The first law in the theory of gravitation was proved nearly as we are about to mention. Galileo found experimentally a few balls of different materials to obey the law of gravity within very short distances of the earth. Newton proved by calculation, that the same law extends to the moon. And by trials of very dissimilar substances on the surface of our planet, it seemed to be made out that the property of gravitation could belong to them only because it belongs to all matter in their circumstances; those bodies being so unlike, as that they could scarcely owe the property to anything, except a common material nature. Thus, when the law of gravity is stated as holding true of matter within certain limits, it includes in its expression (with logical propriety) innumerable individual instances, many of which probably may differ somewhat from the instances originally experimented on. But if the grounds of the original conclusion were correct, this latitude of expression cannot be objected to.

statement. Thus, to take two examples differing in some respects from each other; the series of laws composing the Newtonian doctrine of gravitation, and the generic terms of the method of natural families of plants, present laws expressing generally, in the one case, the fact, that matter, in separate masses, and within certain observed limits, has been found endued with the property of gravitation, *—and in the other, that in certain groups of plants, the individuals resembling one another in form, do also agree in respect of medicinal and culinary virtues.

Subordinate to the great logical characters of physical laws, there are other characters of a physical, or a metaphysical kind, which, not being all common to such expressions, but some of them peculiar to particular laws, serve to distinguish those. The chief of these characters depend upon the relations preserved between properties connected in laws, in time, and in space. Characters deduced from such relations, may be termed metaphysical: their existence was clearly pointed out by Dr Brown. The physical characters belonging to laws are very various; and in this inquiry may be considered accidental or contingent.

A law, stating that the properties to which it applies preserve a relation one to another, so that the presence of none is antecedent to the appearance of the others, is an expression like the description of a natural family, or the theory of the circulation reduced to its utmost simplicity. For as, in this latter case, it is only stated that the performance of the circulation of the blood is a function essentially connected with a peculiar structure,—the prior presence, whether of structure or function, is left undetermined. But where one property precedes another in the order of time—one being a uniform antecedent, and the other a uniform consequent, *i. e.*, when this order is found to occur regularly in certain contingent physical circumstances, —the law is then one of cause and effect. Since the phenomena of gravitation are now found to be consequent upon the re-

* Dr Brown first shewed, in his usual forcible manner, that the law of gravity could not be extended with logical propriety or physical certainty, beyond observed limits. See sect. 8, p. 177 of the 1st vol. of his Lectures, 8vo ed., 1820.

lative position of gravitating masses, because the attractive influence requires time for its transmission, the law of gravity is one of cause and effect. Matter, in separate masses, and these at distances not extremely minute, being the uniform antecedent;—the phenomena of gravitation the uniform consequent; and the occurrence of the law within certain definite distances (added to what is said just above), the contingent circumstances.

But besides the statement of an existing relation between properties, a physical law often carries with its terms the presumption of an existency in nature, more remote and subtile than the observed properties, and which causes those to preserve their known relations. In other words, the law excites in the mind the idea of something which not being really discoverable in nature, is nevertheless believed to exist. Thus, a law, expressing the relation of properties, as cause and effect, gives rise to an idea of power, or of a mutual adaptation between antecedent and sequent,—the cause of observed phenomena. This latent adaptation is meant when an attractive force, enabling the masses of matter to act on each other reciprocally, is spoken of. The law of gravity does not state the existence of any such adaptation, but merely tells a bare fact. As, however, the human intellect feels inclined to give a reason for everything it discerns, and the occurrence of gravitation being an inexplicable fact as beheld, by the invention of a hypothesis which does assign a reason for the fact, a mode is thus contrived to harmonize the actions of nature with the constitution of the mind. In like manner, when in the system of natural families, a very curious connexion has been established between outward conformation and internal properties, it is perhaps impossible to refrain from believing that this connexion has a cause in some more intimate organisation of the plants in which it may exist, or in the nature of the principle of life itself, which may thus hold together by an appropriate bond of union two sets of properties, which, in their known natures, furnish no reason for the actual relations they may maintain. The belief in the existence of ultimate principles is derived from experience; it arises from the discovery of the causes of events in preceding cases; and when any inexplicable connexion consisting in nature is detected, there is an instant tendency in the mind to suppose a reason for it.*

Our opinion, as given above, is in a great measure opposed to the well known doctrine of cause and effect, promulgated with so much eloquence by Dr Brown: but it is now by no means an act of daring to venture the avowal of more speculative notions, with regard to cause and effect, than those published by that justly celebrated metaphysician. For at present his theory is generally dissented from; and we believe that it is not in accordance with the genuine spirit of the Philosophy of Bacon, nay, that brought to bear upon actual inquiry it would be found to have an effect extremely prejudicial.

According to Dr Brown, all that can be conceived, or rather all that should be conceived by the mind of cause and effect, is the invariable antecedence of one property with the consequence of another, under certain contingent circumstances. Besides this invariable relationship, no idea of power or force should be conceived. And, by way of illustration, he analyzes, with his wonted elaboration, the law of gravity, in which he says, all that can be rationally or philosophically conceived of the phenomena of gravitation is stated, viz. the simple fact. Or, to the statement of the simple fact, according to his doctrine of causation, a sound philosophy ought not to attach any hypothesis of the existence of a principle connecting together the properties which are the subjects of that law: the supposition that the phenomena of gravitation are owing to an attractive force exerted between masses of matter being unwarranted by the known facts. Such must be his meaning; and accordingly

* It will be seen from what is said, that we are of those who assign to vital principles a place in physiological inquiry. There is not space here to enter into a discussion of that question, so involved in controversy; but we will ask those who deny that such ultimate principles can have *any* place in philosophical inquiry, how they can account for such a fact as that given in a recent paper on development, by Dr Barry, viz. that all animal germs are fundamentally the same,—or that, from structures essentially the same, exposed in the Universe to circumstances utterly unable from diversity to produce such diverse creatures (as can be found experimentally), all the varied forms of animalized beings are developed? There can only be one answer:—The differences amongst germs which give rise to such dissimilar beings, exist in their principles of life! or are differences in innate susceptibility.

he censures the query in which Newton couched *his* belief in the existence of an ultimate principle,—the cause of gravity.

Were one, unacquainted with the Newtonian Philosophy, and likewise with any theories of causation, to behold two masses of matter gravitating to one another, he would naturally ascribe the fact to the existence of an attractive force, or the exercise of a secret sympathy; and, if one of the bodies were drawn more towards the other than this one unto it, he would suppose the power residing in the one to preponderate over that power residing in the other; for the feeling in ourselves of what is required to produce analogous effects by muscular exertion, is alone sufficient to produce both convictions. The hypothesis of the existence of an attractive force is admitted by Condillac to be a forced conviction of the mind, and therefore allowable in a philosophical sense also.* Dr Brown himself nearly admits at one time all that the most speculative transcendalist could desire to have from him in favour of the legitimacy of researches into the nature of ultimate principles; for while lamenting the defection of Newton from sound philosophical views, with regard to the proper objects of physical inquiry indicated by the query as to the cause of gravity, this circumstance is attributed by him to the influence of a "human infirmity," from which the greatest minds are not exempt.† The advocates for transcendental or speculative inquiry, when inductive investigation is apparently pushed as far as possible, merely maintain, that, from the very constitution of the human mind, it is not possible for us to refrain from attempts to acquire some notion of existencies in the being of which we are compelled to believe, although they themselves be not before the senses. Both Dr Brown and Mr Stewart ‡ regard a conviction of the existence of something to be explored, as the legitimate and necessary precursor of scientific inquiry: hypothesis is the stimulus to investigation which in the human race as a whole, and in individuals, has ever been urged on by the presumption of success thus afforded. And if the existence of some principle beyond such a law as that of gravity were not supposed,

* Traité des Systêms, vol. i. pp. 240–2.

† See Brown's Lectures, vol. i. sect. 8, p. 167.

‡ See Stewart's Lectures, vol. ii. c. 4, p. 403.

there could be no inducement to inquire after such an entity. Now, the laws of chemical affinity are exactly correspondent with that of gravity; and Davy succeeded in determining the dependence of chemical affinity upon the electric states of bodies. Nay, of late, Mossotti has by abstract reasoning generalized all the phenomena of attraction and repulsion, whether of a mechanical or chemical character, into actions of a common hypothetical principle, which must coincide with the cause of gravity.

Physical inquiry may be regarded not improperly as a constant struggle on the part of the mind, to acquire such a perfect knowledge of the phenomena and scheme of external nature as it has of those ideas of relation generated within itself, which form the basis of geometrical science. Over such ideas its control is complete; it developes them into propositions according to the laws of its own constitution. Now, the formation of general notions is one step towards the reduction of physical science to so complete an intellectuality. But the real or essential principles of connexion between properties have not yet been discovered. Could they be known, physics would become a demonstrative science. But the mind endeavours to supply their place, by supposing the existence of such principles as the cause of gravity. And be it noticed, that those ideas of power or force are like the fundamental principles of geometry, ideas of relation which, according to Locke, have their birth in internal sensation or reflection, *i. e.* in the intellect itself.

It is generally believed that Bacon banished the study of causes from his philosophy. So far is this from being the real state of the case, that, on the contrary, he created a branch of philosophy, the express object of which he makes to be to inquire into their nature. In fact, while the ancients vainly endeavoured to arrive at a knowledge of ultimate principles by speculation, and from such principles assigned hypothetically to deduce effects, and thus to demonstrate all the real phenomena of nature out of their own unassisted reasoning, as was afterwards attempted by Descartes, Bacon proposed first to investigate the real existing and observable connexions among properties, and not to speculate until this investigation had been carried on as far as possible. He separated the study of causes from the study of observable actions, and assigned the former to metaphysics, and the latter to physics.* And Newton, deeply imbued with the spirit of Bacon's philosophy, followed its precepts to the letter, when, having arrived at the law of gravity inductively, he began to speculate as to the nature of the cause of gravity ; at the same time defining most distinctly in his 28th query, the true aim of philosophy to be the determination of such lofty inquiries as that which regards the cause of gravity.

Physical inquiry consists in seeking after connexions between properties existing in nature, or in endeavouring to discover where such connexions cannot exist. Hence there are negative and positive laws. But all definitions of laws, by an appropriate and slight change in expression can be made to apply to negative as well as to positive cases. Perhaps sufficient has now been said with regard to the results of inductive inquiry, to enable all the varieties of inductive procedure to be understood.

We turn, then, to view the objects of contemplation proposed on introducing our subject. And since a law framed by induc-

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* Since the above made statements may be supposed to involve controvertible matter, we shall support them as fully as our limits permit. In the first place, then, it is sometimes not very easy to get at Lord Bacon's meaning, even when that ought to be exceedingly clear. This has been remarked by Mr Stewart, who says, " In one passage he approves of the opinion of Plato, that the investigation of FORMS is the proper object of science, adding, however, that this is not true of the FORMS which Plato had in view, but of a different set, more suited to the grasp of our faculties." This is nearly the language of the Novum Organon, (Part 1, sect. 2, aph. 51). And elsewhere Bacon declares, that he understands by the word Form the law through which the actions of individual bodies are performed (Nov. Org. P. 2, s. 1, aph. 2). But elsewhere he evidently means by FORMS the most remote principles that we can conceive. Thus, he tells us, that the " FORM of any nature is such as, that where it is, the given nature must infallibly be ;" (Nov. Org. P. 1, s. 2, aph. 4). And although, in the very next sentence to that in which the passage we have just rendered occurs, he seems to allude to something still more essential than a FORM, yet, as in the inquiry after the FORM of heat, he concludes heat to be an " expansive bridled motion, struggling in the small particles of bodies ;" we think that his FORMS do also correspond with such principles as the cause of gravity, or the cause of light, but that he has another inferior set of FORMS, such as physical laws. And as he divides his philosophy into the study of FORMS or metaphysics, and the study of effects or actions up to the FORM which he calls physics, proposing, by means of the knowledge acquired in physics, to produce all sorts of mechanical actions, (Nov. Org. P. 2, s. 1, aph. 9), his meaning is thought to accord with the interpretation above given.

tion should include the class of facts to which it is applicable, in a perfect manner, every legitimate species of induction must be capable of affording complete proof. But it is evident, that, in such a case as the law of gravity, every individual instance included in the expression cannot be examined, or the labour of proof would be illimitable: how, then, is the requisite degree of evidence in such a case obtained?

Aristotle believed it necessary, for every particular instance, subject to a law to be examined, before the expression could be logically certain: "Nam inductio fit ex omnibus singularibus."* But the examples of induction with which he was acquainted, were cases in which it is requisite to examine every instance belonging to a law before the due amount of evidence can be collected. As the subject is placed in an exceedingly favourable light by some sentences of Gassendi, we shall take the liberty of quoting those:—

"Etenim ipsa quoque inductio syllogismus reipsa est; et quadamtenus quidem mediæ inter enthymena et gradationem conditionis,—* * * hic cum dicitur, v. c. omne animal gressile vivit, omne item volatile vivit, omne etiam natatile, omne reptile, omne zoophytum; igitur omne animal vivit; assumptiones hinc plures sunt, justa generaliores species gradus animalis collectæ, et quasi in unam coadunatæ, quam ista propositio intelligatur præcedere, omne animal aut gressile, aut volatile, aut natatile, aut reptile, aut zoophytum est.

"Scilicet, nisi hujusmodi propositio supponeretur, suppressare licet, subintelligeretur tamen, consequentioris vis nulla foret; cum si præter enumerata existeret aliud quodpiam animal, conclusio evaderet falsa.

"Unde et licet intelligi, debere inductionem, ut legitima sit, continere omnium specierum, partiumve enumerationem; ne si una quæpiam deficiat, ea exceptionem faciat, probationemque labefactet. Quanquam, quia ut superius semel, iterumque monuimus, difficile plerumque, aut impossibile etiam est enumerationem omnium fieri, dici, aliquibus enumeratio, solet, quod Lucretius, et Horatius, cætera de genera hoc; supponendo videlicet, præter membra enumerata occurrere nullum, quod secus se habeat."†

He goes on to say, that there may be an induction, concluding in the negative, as well as an induction concluding in the affirmative. Except the error of supposing induction to be a species of syllogism,‡ the above passages give a sufficient notion of the

* De Inductione (Analyt. Prior. lib. 2, c. 23.)

† Institutionum Logic. P. 3, Canon 11.

‡ An error not confined to this writer, as is shewn in a very powerful article in the Edinburgh Review, vol. lvii.; but common to him with most au-

opinions entertained at present with regard to the mode of procedure proper in induction, in order that the evidence may warrant the conclusion. Dr Whately, in terms synonymous with those of Gassendi, asserts that an inductive inference, drawn from a part of a class with regard to the whole, can only be supposed legitimate through a species of logical fiction, in assuming that one or two of a small number of instances do adequately represent the class to which they belong.* Now, we maintain, that, in the greater number of inductions performed in physical inquiry, such a supposition involves no fiction, but rather a positive fact; a class of facts, the individuals of which are in external aspect somewhat dissimilar, being often sufficiently represented for all the purposes required in the induction by a very few instances.

The more essential properties of bodies are the objects of scientific investigation; and it is probably only where the induction has regard to such properties, that one fact can be taken as a specimen of others analogous with it. Now, there are instances created in nature with the properties common to their class, so highly developed in them, as that the relations of those can be more readily discerned. And often by the aid of experiment, those properties can be so tested as to enable it to be known, that, in the instance experimented on, where one property is placed in a certain situation, another will attend it in a certain order. And the mind having such a knowledge of a class as to be able to divest its individuals of their accidental properties, and to discover in them one essential arrangement, defines the whole class to possess that arrangement,—which be-

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thors on logic; although not participated in by Aristotle, according to the reviewer. We find Aristotle say, that "quodam modo opponitur inductio syllogismo." And in his chapter on Induction, he seems to assign distinctly the province of demonstrative reasoning to syllogism, and the discovery of physical truth to induction. When he says that syllogism is "natura prior et notior," he probably alludes to reasoning from an obscure and unanalyzed whole to its parts.

* See Whately's Logic, Art. Induction throughout; also some strictures of Mr Stewart in the 2d vol. of his Lectures, p. 345, upon a passage from Dr Wallis of Oxford.

ing found, in a certain number of well-marked cases, dependent upon the relationship of some properties, is supposed, upon the ground of an intuitive conviction of like effects being owing to like causes, to be dependent upon the same properties in all the other cases. If the primary definition did not include the whole class, neither should the last inference affect the whole class; in that case, the extension of the conclusions beyond the individuals known to possess a defined arrangement, would be a mere presumption. But let it be clearly understood that there is a power in induction to determine the nature of individual instances which may not have been wholly examined, by means of an investigation of other instances apparently only analogous. Thus, let us suppose, that a definition of the term animal were formed, stating that an animal is a being possessing sensation and voluntary motion; and that it could be found, by a comparison of some of the different grades of animalized being, that just in the ratio of the development of nervous matter, was the state of those functions, in an increasing or a decreasing ratio; and that where this nervous matter exists (as in the genus Echinus and the sub-kingdom Acrita, generally banished by naturalists of the present day from the animal kingdom) not in the form of filaments connected with a common centre, the functions are wanting; would we not be entitled to conclude, that, in all animals, the development of a nervous matter in the filamentous and radiated form, bears an exact ratio to the aforementioned functions? If we do not admit that a few instances can be taken as specimens of a class, containing individuals apparently dissimilar, then, indeed, the mode in which the mind arrives at laws in physical investigation is often incompatible with logical propriety,—a proposition truly monstrous!

But it will doubtless be asked, in what way a conviction can be got of the essential nature of connexions investigated in Nature, when, in the properties themselves, no reason for this essentiality can be detected. Our answer is the admitted aphorism, that we are compelled, by the very constitution of our minds, to take the constancy and invariableness of relations observed among properties, as warrants of the essentiality of the order of relationship. Could the true principles of essentiality,—

the FORMS of Bacon and of Aristotle—be discovered, we should then have reasons from which it might be possible to know the extent to which certain relations, observed in a single instance, could reach throughout Nature; and our knowledge of the external world would be a perfect knowledge, so far as it should go. But so long as those principles remain undiscovered, the logic of physics must owe its coincidence with fact to an admission, on empirical grounds, of the existence of an essential series of phenomena, where there is but the evidence of their observed order being constant. We have said, however, that the mind endeavours to supply this deficiency in its evidence with respect to the actions of Nature, by feigning the existence of such principles of essentiality, the want of which it must perceive. And thus the necessary defect in inductive evidence, which many writers on logic have misplaced, arises from no logical fiction or physical impropriety in regarding one individual of a class as a specimen of its brethren, but from an imperfection in the media of communication between the understanding and external nature.

Instances which possess an organization so highly organized as to admit of them being taken for specimens of the class to which they belong, are termed by Bacon prerogative. And it is the chief merit of his philosophy, that he perceived their place and their power.* He has not, however, given any clear general definition of them, but abundant examples to shew their utility; and also a classification of individual instances, in which all the varieties of prerogative facts are minutely described. Here we shall consider them in general, since our object leads us to view them, not as they differ among themselves, but according to their place in the general theory of induction.

A good illustration of a prerogative fact is afforded by the famous experiment of the soap bubble, by which Newton discovered, in a single instance, the proximate structure upon which the various colours of all bodies are dependent. This instance is composed of several parts. In the first place, an appearance of coloured rings was observed upon the surface of the soap bubble, and their order of appearance in some degree

* Nov. Org. P. 2, s. 2, Aph. 22.

estimated and compared with the thickness of the bubble at different parts; in the second place, the instance was varied by using a layer of water placed between the object glass of a telescope and a flat surface; thus the thickness of the layer of water could be measured, where the different rings appeared, and also the order of their array became more regular; in the third place, it was found that the condition of the ambient body did not affect the order of appearance, although it did the strength and variety of the colours; in the next place, it was found that different transparent bodies would not, under the same thicknesses, exhibit the same colours; lastly, it was discovered that the transparent body viewed obliquely, did not exhibit the same colour at the same place, as when viewed directly, and that bodies undergo changes in colour by alterations in their mechanical condition (as well as can be observed) according to the law, which at this part of the inquiry might be supposed to exist. This famous experiment enabled Newton to frame a law, which states that the causes of the different colours of *bodies* exist in the sizes of their component particles.

When one instance does not afford a sufficient display of properties to allow of an extensive inference being drawn, other instances must be got together, which in a mass have such varied characters as to make up a strong case. Thus, in Dr Wells' theory of dew the great doctrine of which is, that in all bodies on the earth's surface, the dew-attracting power bears a uniform ratio to the power of radiating heat; the author proves his main fact, by taking platinum, gold, silver, lead, charcoal, grass, and gravel, with such like instances; cases which, put together, may be supposed to afford a fair specimen of the relations preserved by the properties in question throughout all bodies whatever, there being among these instances every conceivable variety in radiating power from the zero of burnished silver to the maximum of porous charcoal; and he finds, that, in the cases experimented on, the relation between the properties is regular. He therefore draws an inference for all bodies in the circumstances of those which he has tried.

When induction, therefore, takes cognizance of the more essential properties of bodies, and investigates those by means of instruments, an inference including all facts in certain contingent circumstances can be drawn from a few analogous facts in such a condition; and the mind, in framing this it may be universal generalization, does not necessarily make use of any fiction, logical or physical, but proceeds upon what may often with reason be believed to be a sure fact.

But where the properties are not of this essential and intimate kind, and do not admit of being investigated experimentally, so as to allow of their relations being determined, a universal conclusion cannot be drawn without the use, by the mind, of that logical fiction of which so much is said by Dr Whately and others. Thus, to give an example which may perhaps illustrate an oversight of writers on induction, we quote the following from Dr Brown:—"If, by the term general law," he says, "be meant the agreement in some common circumstances of a number of events observed, there can be no question but the view is a just one, and that what we have already found in a number of events, may be applicable to that number of events; in the same manner, as, after having combined in the term animal the circumstances in which a dog, a horse, and a sheep agree, we cannot err in applying the term animal to a dog, a horse, or a sheep. But the only particulars to which we can, in this case, with perfect confidence apply the term animal, are the very particulars before observed by us." * Now, here we perfectly acquiesce with the argument of Dr Brown: but it is sufficiently obvious, from the examples already given, that his observations do not apply to all cases of inductive inference. Logicians generally give examples of inductive generalization, which do not shew the occasional and frequent power possessed by facts of exhibiting the properties of their class in a distinct point of view, as in the above instance of Dr Brown. But let the example produced by him be contrasted with the one given by us of the mode in which a correct notion of the connexions and relations of some properties in all animals could be attained, from an investigation of them in a few, and it will

* Brown's Lectures, vol. I. sect. 8. p. 176.

appear that *his* example does not give a fair view of the entire character of the inductive process.

It may be inferred, therefore, that some distinctions should be drawn as to the methods of inductive procedure ; and we shall now attempt to classify, and define, at least the more prominent modifications. These seem to be nearly as follows :—1. There is a form of procedure, in which, in order that a law may be expressed with logical precision, or possess physical certainty, it is absolutely necessary for every individual instance included in the original statement to be examined. Thus, in systematic Botany, when the external conformation of a class of plants has been described, and it is found, that, in some plants of that class, the particular configuration of the family exists along with a peculiar medicinal or culinary virtue ; it yet cannot be stated, on the grounds of such a knowledge, what may be the virtues of other plants of the order. A presumption may be formed from the investigated cases, as to the nature of the relations of certain properties in the individuals not examined ; but it must be a mere hypothesis. If, however, the botanist had the power of experimenting upon a cruciferous plant, so that he could find the four crosswise-placed petals and the peculiar shaped pod to be essentially connected with the virtues of a plant,—in such a manner, as that while the structure was modified, the other property should also undergo modification,—and in fact so that a certain not-to-be-doubted relation could be detected between the two sets of properties,—he might then conclude, on the conviction of the uniform order of nature derived from past experience, what were the virtues of all cruciferous plants. But he cannot perform such a precise experiment, and therefore must be content to collect every instance, before drawing a general conclusion. 2. There seems to be a class of sciences, of which we shall take Medicine as an example, in which most of the inductions are defective ; or, more properly, where there cannot be formed in most cases any complete induction, as in all such cases logically defined genera cannot be procured, since new instances are being continually created,—beings with diverse constitutions ; so that from the examination of already existing cases, no perfectly certain inference can be drawn as to the whole class of analogous cases ; and where, besides, the differences between individuals are such as to prevent one individual being taken as a sufficient example of another; so that the induction can only conclude with certainty as to an individual. And the history of medicine affords proof of the enormous difficulty thus opposing generalization. Suppose that the diseased structure of the intestinal glands could be found in one case to preserve a constant relation with the symptoms of fever; yet this invariableness of accompaniment should only afford a presumption as to what may exist in other cases; for, there can be no conviction in the uniformity of nature, when the actions of nature in each individual are known to differ.* 3. In this present division the groups of facts are arranged in genera, each of which is not illimitable throughout the known universe, but confined, and finding some similar, and many closely analogous to itself, so that the law framed of one group can easily be transferred to another; while in each group, the investigation is capable of being abridged by means of prerogative instances. By way of illustration, we shall take the doctrine of the circulation of the blood, introduced by Harvey, which at the same time will give a good example of the course of inductive procedure ordinarily pursued in the physical sciences. If, then, we take that celebrated doctrine, and spread it out, so as to display all its parts, and ask proof for every assertion made in it, we should demand such a knowledge of the structure of the heart and arteries as to be sure of their powers and capabilities to allow of the course alleged, and to perform the functions ascribed to them,—evidence that the heart sends the blood into the aorta, like evidence of it being sent along the arteries into the minute veins, of the return, and the same kind of proof of the lesser circulation as of the greater. It is believed that when Harvey announced the circulation, he

* A paper was read before the members of the Royal Medical Society, on the 6th of April last; the object of which was to prove, that in medical reasoning, the only constant source of uncertainty is in idiosyncracy. There may be great complexity in the relations of properties—great difficulty and perplexity in the investigation; but the only constant source of uncertainty arises from individual peculiarities. See Dr Abercrombie on Certain and Uncertain Sciences; he classes together medicine, political economy, and ethics.

was not able to furnish all of those proofs, and, in particular, that he had not evidence of the actual passage of the blood from the small arteries into the small veins. Of the lesser circulation he probably could only offer the analogy of the parts performing it with those concerned in the greater. Yet his doctrines, founded on the proof he gave, must be acknowledged possessed of such evidence, as that, if more be added, it can only amplify the notion he gives of the circulation. Two grand facts are the proofs of this great theory: 1, the prerogative fact of the valves of the heart and veins; and, 2, the analogy of the parts engaged in the lesser circulation with those that perform the greater. But the adaptation of the valves to their function is the grand proof of the whole theory. Now, the theory of the circulation was proved originally on deer; and the extensive analogies, which in fact are but covert similarities, traceable throughout the animal kingdom, allow of physiological doctrines being transferred readily from one genus to another. Many inductive doctrines in Chemistry resemble very closely, or rather exactly, the law of the circulation, both in their original frame-work, and in the mode of transference they admit of to other genera apparently only analogous but essentially similar. 4. There is another modified form of induction, the most definite of all, which may be described as follows:—Here each law is not confined, as in the third species, to a single group of a few facts, nor do any exactly corresponding groups exist, to which the law when framed is applicable. But each law extends throughout the known universe, and although the class of facts to which it applies may, or rather must, be defined, the number of instances is illimitable. Each law, however, can be framed from the examination of a few prerogative cases. And as in this kind of inductive generalization, the laws themselves form again parts of a mightier whole, which is framed from them in much the same manner as they themselves from their facts, at length an axiomatic expression is reached, which, arrived at from the investigation of a very small number of instances comparatively, yet includes in its expression an immense array. Illustrative examples exist in Dr Wells' theory of dew, and the laws of gravity. We are aware, that all those different forms of inductive procedure agree in kind, except, perhaps, the one particularised as practised in medical science; and also, that the divisions between them, however carefully drawn, are exceedingly nice, and perhaps such as, by a close analysis, might be found to disappear. Indeed, the mind gains all its inductive knowledge by one process viewed in connexion with its own functions, and that is by complete proof; the various steps of which we have endeavoured to relate as fully as the vast extent of the subject would permit within moderate limits. Complete enumeration of all the instances composing a law, is that degree of proof which would be always essential, were it not for the indices supplied by prerogative facts. Indeed, we may regard all those forms of inductive procedure but the third variety, as derived from that simple form, by the introduction of prerogative facts within the spheres of the different genera existing in nature. Thus, as the science becomes more elevated and complicated, there is the greater power possessed of arriving at extensive inferences by means of well related facts. But it must be borne in mind, that the prerogative facts are those needing most the resources of experiment and calculus, in order to make them known so as to be of use in drawing inductive inferences. Residual facts are those left in a genus, uninvestigated, or rather partially explored, in order that the prerogative facts may be studied; and that property of physical laws called anticipation, is nothing more than the power possessed in some cases of abridging inductions by means of the prerogative facts.

Thus, the great property of those prerogative facts is, that they admit of being experimented on, being indeed, when completely known, exactly similar to the results of experiment; since they then afford a view of the relations of the properties composing them in very varied circumstances; it follows, therefore, that to term a science an experimental science, is just as if we were to say, that it abounds in prerogative facts. So that if the science of mind be, or be not, an experimental science, the question can best be determined by seeing whether its facts admit of being classified into some such heads, as the prerogative instances of Bacon, contained in the Novum Organon.

Many applications might be made of the observations in this essay, if these latter be founded on truth. In particular, the history of science might perhaps be elucidated still further through their means.

Note.—It is proposed to term the forms of induction described above in their order. 1. Simple. 2. Enumerative. 3. Prerogative; and 4. Complex. The following formulas will express the simple and prerogative forms. 1. Of the Simple form. Let there be any number of instances, as $n\,A$; and of these some are found possessing the property a; before it can be said that this a exists in all $n\,A$, they must be all examined; and also the same must be the case should a be found connected with the property b in any of $n\,A$, before it could be said that $a+b$ exists in all $n\,A$. And if a, or $a+b$, should not be found in $m\,A$; then the law states that $\overline{n-m}\,A$ contain a or $a+b$. 2. Of the Prerogative form. Properly speaking we should start here with the knowledge of the existence of the property a in $n\,A$, or $\overline{n-m}\,A$; let $n\,A$ then contain a; here, instead of seeking to enumerate every instance before obtaining a law for the class, it is enough to know that in A', A'', or A''',—the prerogative instances, a is connected in a manner believed essential with b, or $b+c$, or $b+c+d$ in order to frame the law—"All $n\,A$ contain $a+b$, or $a+b+c$, or $a+b+c+d$." One sufficient prerogative instance can enable a negative conclusion to be drawn, just as in the case of a positive law. The downward application of laws framed from the study of prerogative facts furnishes the means of verifying the observations already made.

We are informed by an eminent authority in logical science, who honours these pages with his general approval, that Duns Scotus distinguished two species of induction, corresponding with our first and second forms. Bacon confounded the induction given by way of example by Aristotle, and which therefore was our first form, with the second or uncertain form practised in medicine.* The great improvements effected by Bacon on the views of his predecessors with regard to induction, consisted in the extensive grasp he took of the province in the cultivation of science appropriated to induction; and also in shewing the power possessed by particular well chosen facts. These, the most important and original of his notions have yet received a too *implicit* attention from those who have written on his philosophy. Until about the epoch of the Novum Organon, philosophers were not in possession of such instruments as are requisite to make known fully the relations of most of those instances termed prerogative. Till then, therefore, induction was described as a mode of mental procedure; Bacon described it by its corresponding signs in nature. Therefore it was, that his precepts were so powerful in displaying the advantages attendant upon the cultivation of science, inductively.

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* Nov. Org. P. 1, s. 6, Aph. 105.