An Essay
on
The Development of Our Knowledge Regarding
The Functions of The Brain
By
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Too often, in these days of modern medical triumphs, do we applaud our generation, forgetting that the labours of many centuries have built the steps up which our age has trodden to success. Too often do we over-estimate the intrinsic value of modern achievement, and reckon not of the great debt that is owing to the efforts and accomplishments of former generations.

It is true, that, when we look back and contemplate the long road on which medical knowledge has travelled, we find it strown with the remains of shattered doctrines and broken systems—"the shards and remnants of the vessels which once held human beliefs"; yet, as we look upon these ruins, do we not become conscious of the fact, that what knowledge we possess today is in very great part but a heritage: and that it comes to us only because great lives have laboured in the search for what was true, when often, indeed, the light that guided their toils was scanty and dim?

Of all the branches of medical science, none has perplexed the minds of past
Ancient Ideas concerning the Brain.

The ancient Indians.

The ancient Egyptians.
generations so much as the Physiology of the Brain, and the accumulation of exploded dogmas and worthless doctrines, regarding the high functions of that organ, forms a great mound which bears witness to the attempts which were made to satisfy man's minds.

All medical knowledge seemed to have originated in India, from there to have travelled into Egypt, and then to have found its way into Greece. What the Indians thought of the brain and its functions we know little or nothing, and it is probable that they held this organ in the same small esteem as did later the Egyptians. The ancient Egyptian philosophy referred thoughts and affections not to the brain, but to the heart, while they considered judgment as seated in various internal organs—sometimes the liver, sometimes the kidneys. It seems evident that, in those remote times, the brain was looked upon in a kind of padding to support the bones of the head and face, and hence, while many rites were practiced and many prayers offered for the preservation of the heart of the deceased, the brain was passed over with but little consideration.
The Greeks
for its future welfare. Moreover, though the organs of the abdomen and thorax were carefully treated for their preservation, by the process of embalming, it appears that often the base of the skull was pierced in order to ablate this useless pulp within, which if not removed, would only burden its dead possessor in his future state.

The Greeks were destined, however, to make the first advances in the study of the brain, and their progress stands out in singular contrast with the extraordinary accumulation of doubts and conjectures which had been handed down to them. Depending less on former legends substantiating what knowledge they had received, with accurate observation, and thus sifting out the fertile grains of truth from those of barren conjecture, the Greeks did much to put medical knowledge on a sounder basis. Their age was one of transition, and the simple faith in the old mythology fast dwindled away. The influence of Egyptian philosophy, however, shows itself in early Hellenic thought, but even at such a remote period as 550 B.C. much more
accurate physiological views seemed to have been entertained by Pythagoras of Samos.

Pythagoras was the first of the Greeks who is recorded to have attributed any function to the brain, and according to him, this organ was supposed to be the seat of the soul. The soul he divided into two portions, the rational and the irrational, the former being placed in the brain and the latter in the heart. The first was immortal, the last perishable. He imagined that, after death, the rational passed into the regions of the dead, but later it came back to the world to inhabit some other body—brute or human, and that having thus suffered purification, it was received by the Gods and returned to the eternal source from whence it had come.

Euphiletus Locras, who was a contemporary of Pythagoras and author of a work: "De Anima Mundi" in which he treats of the different functions of the body, has little to say regarding the nervous system. The brain is to him "the seat of the soul" and he says that it is "the origin and root of the medulla,
Alcmaeon

Hippocrates
"and that a process extends from it through the vestibule of the back."

Thus another interesting name is that of Alcmaeon. He was a disciple of Pythagoras and is said to have been the first who attempted the dissection of the dead body, although it seems probable that his anatomy was confined to the lower animals. His records show that he discovered the cochlea, and he affirmed that hearing resulted from the concave form of the interior of the ear, since all hollow places resounded when any noise entered them. The soul, whose seat was in the brain, he imagined to be immortal and in perpetual motion, and moreover it possessed several properties. For example, it received the odours inhaled during respiration, and so produced the sense of smell. While, by means of its humidity, its moderate heat and its softness, it gave the sense of taste to the tongue.

Even the brilliant mind of Hippocrates was not destined to add any material improvements to the abstruse ideas held by these philosophers regarding the
Although the light which his knowledge shed on almost every subject connected with medicine, was more brilliant than had ever shone before, yet it did not penetrate the darkness that obscured further progress regarding the brain. His knowledge, regarding that organ, was necessarily limited by the prejudices of the time in which he lived, when the human body had hitherto beenuntouched with the dissecting scalpel.

According to Hippocrates, the brain was of the nature and texture of a gland; it served as a receptacle for the redundant moisture which circulated throughout the body, and was finally discharged in a fluid state through the ears, the eyes, the nose, sometimes into the gullet and spinal medulla. Certain diseases, termed mental diseases, were ascribed to the retention or excessive discharge of this fluid. The brain he also considered to be the organ of reproduction, for he states that the semen was prepared by it, and then conveyed by the spinal marrow to organs specially prepared for it. Hippocrates had no distinct knowledge
Plato
Concerning the nature and the uses of the nerves, though he seemed to have a somewhat confused idea respecting the nervous power, which Lawrence places in the veins. In his work—"De Locis in Homine"—he says: "If the spirit 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 produced."

Plato, the leader of the Idealistic School and a contemporary of Hippocrates, regarded the brain as the seat of the governing principle and considered it to be the organ affected by the senses, whereby memory and opinion arise, and from which all knowledge springs. He has shown himself, however, to be ignorant of the proper distinction between nerves, tendons, and ligaments. Although so ignorant of these instruments which transmit sensation, yet in his "Phaedrus," he has treated of the philosophy of sensation with such precision, as might show that he had formed a distinct conception of its nature.
Aristotle
In the "Phaedo," 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."

If a different nature was the system of Psychology of Aristotle, which was divisible into the headings of imagination, judgment and sensation — a system which in the progress of anatomical knowledge, became inapplicable to the structure of the nervous system as revealed by dissection. Aristotle had described the brain as the coldest and most bloodless of bodily organs, of the nature of earth and water, and whose chief function was to temper the excessive heat of the heart, or the cooler regions of the firmament. Condense the vapours arising from the earth. The heart was the seat of life, of sensation and all intellectual faculties, "though some," he says, "are of the opinion that the powers of perceiving and feeling are in the brain." Indeed his views
Hersophilus and Erasistratus
were very similar to those of earlier writers of
other nations of antiquity. Like others before
him too, he confounded the nerves with the
tendons and ligaments and ascribed their
origin to the heart. His abstract ideas
concerning the soul, of which he treats in
"De partibus animatis" are more philosophical.
"Solem," he writes, "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. Hence it appears why animals stand
in need of heat."
Thus, it was not
until some years later that solid progress
was made in the investigation of the function
of the brain.

Under the Ptolemies of Egypt,
there flourished two very celebrated anatomists,
Aerophilus and Erasistratus, and these two,
as far as authentic records prove, were
the first to dissect the human subject.
Hersophile
Their opinions demand some consideration, for they were consequently the first who properly investigated the nature of the brain, and who attributed to it and the nerves, their proper functions.

To Herophilus, the brain was the seat of the soul which resided in one of the ventricles; it was moreover, the source of all the vital actions and sensations. The point where all the sinuses of the "dura mater" met, he termed the "vires passa", which to this day, retains this denomination, with the addition of his name -- "Corcular Herophilii". He also, it is ascribed, the discovery of the true nerves which he arranged in three divisions. The first division consisted of those real nerves, whose origin was in the substance of the cerebrum, the cerebellum and spinal marrow. These he regarded as the organs of motion and sensation, having found that those which communicated sensation and obeyed the mandates of the will, were traceable either to the encephalon or to its continuation -- the spinal marrow. The other two divisions evidently consisted of nothing...
Erasistratus
more than tendons and ligaments. The optic nerves were also especially described by him. These he called "the optic poxes" which, he maintained, had a perceptible cavity, which he did not find in any of the other nerves.

The accounts left by Erasistratus, of the appearance of the Cerebrum, the Cerebellum and the nerves as revealed by dissection, are very complete and clear.

"We examined," he says, "what the nature of the human brain was, and we found it divided into two parts as in all the 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 various windings and turnings, resembled the intestineum jejenum. The Cerebellum was in a like manner folded and twisted different ways, so that it is 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, the great variety and multiplicity of the foldings in the brain, was undoubtedly designed for some particular end. Besides, we observed all the apophyses or productions of the nerves which came from the brain; so that, to state all at once, the brain is visibly the principal of every thing that passeth in the body: for the sense of smelling proceeds from the nostrils being pieced 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. Enquiries into rejected the humoral doctrines of Hippocrates and founded a system of his own, respecting the relation between the nervous system as a structure, and mental phenomena as its functions. According to his new doctrine, the air which had
been inhaled, was passed into the heart, after some process of elaboration in the lungs, and from the heart it was transferred by the arteries to the ventricles of the brain, where it again underwent a changing process into "vital spirit." This idea of "vital spirit," although absurdly erroneous in itself, yet is of interest and importance, for in it may be seen the first attempt to show that mental phenomena are the results of the functional activity of the brain and cord. Thus it will be seen that a great advance had been made by those eminent anatomists, and when it is remembered that their labours were accomplished in an age so barbarous and so prejudiced against anatomical investigation, and yet led to the generally correct results, it must be admitted that they occupy no small place in the building up of the true physiology of the brain.

No new light appears to be shed on the anatomy and physiology of the brain by the remaining Greek physicians, nor do we find anything new amongst the Romans,
The Romans.

Rufus.
until we come to Rufus of Ephesus, in the time of the Emperor Trajan. Rufus distinguished two kinds of nerves, those of sensation and those of voluntary movement, and traced them to their origin in the brain. He says: "The upper part of the brain is called the varicose, the inferior and posterior parts forming the base, and the process arising from it is the cerebellum. Two kinds of nerves arise from the brain, and these are the sensory and the voluntary by which sensation and voluntary movement are produced, and all the actions of the body are accomplished. Some of the nerves arise from the spinal marrow and its investing membrane." Later on he says: "The senses which proceed from the brain and spinal marrow are divided into the active, the sensory, the voluntary, and the tensive." He also pointed out the decussation of the optic nerves at the infundibulum and besides discovering the nervus palatinus and the par vagum, he distributed the nerves coming from the brain into seven pairs.

The Anatomy and Physiology of the brain were thus proceeding on the lines of careful observation and further additions were made by Arataeus...
Asiático
of Cappadocia.

Although the physiological opinions of Hæteseus seemed to be rather extraordinary, his anatomical contributions respecting the brain were of great value. Like Erasistratus, he maintained that the nerves were not only the organs of sensation, but also the source of all the action and movement of the limbs. He discovered also the interesting feature of the decussation of the pyramidal tracts in the medulla oblongata, and to this decussation he gave the name of Chiasma. "This fact," he writes in his "De Nervorum Resolutione," "explains why there is a paralysis on the right side of the body, following an injury to the left hemisphere of the brain, and vice versa." To the stomach he ascribed the faculties, and this organ he imagined to preside over pleasure and pain and to affect the mind through its consent with the soul. He is the first writer, moreover, who remarked upon the influence which the mind exerts over the health of the body and the reaction of the body on 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 Mortis Chronicis", the following account of paralysis is given, which would seem to indicate that he was not unacquainted with the distribution of the nerves into sensory and motor: "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 insensitivity, 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 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, though very seldom,
"They undergo also a loss of sense."

Schools and sects had risen up in support of various doctrines; some were for laying the medical craft upon an accurate knowledge of the human structure; others were for reducing the whole art and science of medicine to a system of therapeutics. "For," said the latter, "it is not the cause, but the cure of diseases which concerns us; not how we digest, but what is digestible. Of what value then is a knowledge of the anatomy and physiology of the body, when all that is necessary is to know the drugs that cure particular diseases?" Such was the blind reasoning and futile argument which tended to delay further progress, until the acute mind of Galen pointed out the path on which alone knowledge could advance.

Galen, was of Oriental origin, a Greek from Asia, and though he later travelled widely in the pursuit of medical knowledge, his first years of education were spent at the great medical schools at Alexandria and Pergamos. It has been seen already how uncertain, how doubtful
and how contradictory even the latest medical teaching then was, yet clear, how precise, how accurate were the methods of this man, as he put to the proof the arguments of the day! Galen might well be considered as the greatest of the ancient builders of Physiology, leading the way, as he did, in what we call today experimental medicine, and unquestionably is the Creator of the Physiology of the Nervous System. Indeed, it has been said of him by an eminent Physiologist of the present day that, "regarding the functions of the Nervous System, this great Master knew practically all that was known during the Middle Ages, the Renaissance and up to the Seventeenth and Eighteenth Centuries." In everything he is original, believing only what his eyes told him was true, and in all which his scientific genius revealed, we can trace the Master mind. Galen's anatomical researches were followed up by dissections, and convinced that he had interpreted his results aright, he undertook to overthrow the fallacies of his day that were hiding the truth.
By simple methods he showed that the heart was not the organ from which the nerves originated; that the brain was as hot as the heart and therefore could not be the instrument for cooling the heart as Aristotle had imagined.

According to him, the faculties of the body were divided 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 believed it governed sensation and movement. The powers, he maintained, which distinguished animals from vegetables. These three faculties produced three kinds of actions which were designated by the same epithets, that is: natural, vital and animal. These actions were again classified into 'internal' and 'external'. The internal actions were imagination, judgment and memory. The external were the five senses and muscular motion. The internal vital actions were such passions as anger, the external being motion, the pulsation of the arteries and the distribution of the spirits through them.

The internal natural actions were sanguification, the digestion of food and the actions connected
With it: the external were the distribution of the blood by the veins, for the purpose of nourishing, enlarging and preserving the body. According to Galen, the brain received the "vital spirit" from the arteries, and having transformed it into "animal spirit" in the ventricles, distributed it throughout the body by the Channels of the nerves; and this spirit which as contained in the arteries is "vital spirit" and which in the brain is elaborated into "Animal spirit," is not the substance of the mind but only its instrument. The "animal spirit" radiates and diffuses from the brain as a stimulating force, comparable with that which radiates from the sun—a note which is sounded again in those days of radium and other forms of "Condemned Energy."

"It is not the brain," he says, "situated in the skull like a great king in his capital, and around him all the scenes—the servants that do his will—due his not Conscience as that here is situated the Seat of the Soul." — "Cerebrum in Capite Tanquam in arce magni instar regius collocatum, venes omnes quasi apparitores et satellites habere circumjectos: quicquam in Conficiat ut in sa
"Fascia principatus animae necesse sit."

His discovery of the recurrent laryngeal nerve, or as he called them - the vocal nerves, showed that the voice does not come from the heart as philosophers had conjectured and as poets had sung, but that the voice, through the mediation of those vocal nerves, is subordinate to the brain. "If you lay bare the heart of an animal and press upon it with the hand, you will interfere with neither the respiration nor the voice: but on the other hand, if you remove the brain and press over one of the ventricles, you will at once see that the animal is rendered incapable of uttering a sound, that the breathing has ceased, with loss moreover of all sensation and voluntary movement." And further on he says: "But the most direct way to deprive an animal of its voice is to section the nerves which lie near the arteries in the neck" — "nervos vocales — eos quos ipsum inveni."

He distinguished sensory from motor nerves, calling the first "sensit" and the second "hand" nerves, and above all he pointed out that
Those nerves had no power in themselves, but merely conducted impulses, to use a modern word, to and from the brain and spinal cord, and gave thus "life and movement" to the whole body. Galen distinctly taught that the nerves of the senses were distinct from those of motion, and that the former originated in the anterior part of the brain or cerebrum, while the latter come from the posterior part, made up of the cerebellum and medulla oblongata, or from the spinal cord which was the continuation of the latter.

The important lesson taught in Galen's work was that the body was a physical structure, and that consequently its great functions could only be determined by the physical method of experiment, and it was the employment of this method which he showed would be the key to all subsequent discovery in neuro-muscular physiology.

Yet how soon this great lesson was to be forgotten!

Scientific investigation practically ceased in the Chaos which was subsequent to the fall of the Roman Empire, nor did it again
The Arabs.

Scapion, Phazes, Auuicenna
receive cultivation until the Arabs had established their powerful empire. Within a century, this great race, armed with tremendous forces of religious enthusiasm, had annihilated one of the great existing empires, and indeed had threatened the very existence of the nations of Western Europe. It was only natural then that such a display of physical vigour should be accompanied by an intellectual activity almost as wonderful. Unfortunately, religious dogmas stood in the way of further advance in the Physiology of the nervous system, which, without any material additions, stood in much the same condition as Galen had left it for a very long period. The works of older writers were translated, and their opinions adopted, without any attempt on the part of the Arabs of ascertaining the truth of either anatomical or physiological statements. Attention was concentrated upon the study of Chemistry, in which wonderful progress was made, especially in the empirical treatment of disease.

Serapion, Rhazes, Avicenna
and the other Arabian physicians followed the opinions of Galen. Saltz A. Abbas agreed with Aristotle respecting the brain, namely, that it was the coldest organ of the body, and antagonised the heat of the heart: "for," he says, "these parts of the body which are vascular and contain much blood are naturally hot; whereas such as contain little blood are comparatively cold, and of this latter class are the brain, nerves, and fat."

A good chapter regarding the manner of operating in dropsy of the brain was written by the great surgeon Alhacæris: he observed that water is effused not only into the surface membranes, but also into the ventricles of the brain—a situation which he regarded as incurable and in which no prudent surgeon would operate.

It is not a little surprising to find that, although the Arabs must have derived great advantages from the remains of the Alexandrian Library, so little was accomplished in the study of Physiology or even Anatomy, and as has already been remarked, the cause
The Middle Ages.

William of Salicetum
must be attributed to the fact that religious sentiment was so very bitter against the dissection of the human body.

A similar state of affairs obtained in nearly all the young nations of Europe. The Church held the gate of learning and all those who would enter must accept her doctrines and pursue her ways and methods. Truth and science, indeed, simply came to mean what Hippocrates and Galen had written; no experimental work was indulged in and inquiry became mere interpretation. Only a few important original observations were made during the long period that intervened between Galen and the Renaissance.

William of Salicetum, born in 1280, makes some important remarks, while speaking of wounds in the thorax, upon the nerves of this part. He observes that those which proceed from the dura mater produce pain, derive their origin from the brain and serve for the purpose of voluntary motion, while those arising from the cerebellum and spinal marrow, serve
Guido de Chaulia

The Renaissance
for the actual or vital functions, a circumstance which is illustrated by the symptoms of apoplexy. In these views, therefore, he somewhat approached the theory which Willis propounded four centuries later regarding the differentiation of function between the cerebellum and cerebrum. The former, according to Willis, presided over the vital or involuntary actions; the latter over the animal or voluntary actions.

Guido de Chauliac, an English physician flourishing in the year 1363, records the very interesting case of a man who recovered after the removal of a considerable portion of the cerebrum, or anterior part of the brain, a circumstance, all the more worthy of remark because of its being, perhaps, the first case of its kind upon record in the annals of surgery.

Although the intellectual revival, which, during the fifteenth and sixteenth centuries produced such striking results in art, literature and religion, was slow in affecting the condition of medicine, still it was not without its influence, and progress was being made steadily on the sound basis of scientific investigation, giving rise...
The 16th Century

Vesalius
At the end of the great anatomists. Numerous anatomical works were now published, and the brain, amongst other things, received a considerable share of attention. Naturally, in the light of new discoveries, much controversy ensued regarding the opinions and statements of Galen; for, it must be remembered, that the greater part of Galen's work was confined to experiments on pigs, monkeys, sheep and the like, and consequently in various anatomical details, he was found at variance with what human dissection revealed. Figuring in these controversies we find such men as Ingrassia, Vesaliius, Fallopius and Eustachius, but of all who entered into these disputes, the most eminent was Vesaliius. Although Vesaliius called into question the anatomical knowledge of Galen on which the world had relied for many centuries, affirming indeed, that Galen drew his descriptions from the bodies of apes and other brute animals, yet he was not able to point out more than two or three errors in his anatomy and physiology of the nervous system, the greater part of which, he was under the necessity of adopting. With Galen, he considers the
Brain to be the seat of the rational soul, which, by the animal spirit and nerves, acts on the sentient and moving parts of the body. Like Galen too, he believes that from the blood vessels in their winding course, the vital spirit is formed, from which, with a certain amount of air which has insinuated itself into the brain, the animal spirit is first prepared. After a process of elaboration in the ventricles of the brain, a portion of the animal spirits passes into the ventricle of the cerebellum and into the spinal marrow and so to the nerves arising from it. The spirit thus being transmitted into the nerves, is transmitted by them into the organs of sensation and movement. "Nerves, therefore," he contends, "serve the same purpose to the brain that the great artery does to the heart, in so much as they convey to the instruments to which it ought to be sent, the spirit prepared by the brain and hence may be regarded as the true attendants and messengers of the brain. The material, however, for the animal spirit, is supplied by the vital spirit, abounding as it does in the arteries which in numerous series reach both the hand
and the thin membrane (Dura mater and arachnoid) investing the brain, as also the air which in breathing is drawn in towards the brain, on the one hand through the minute holes drilled in the fifth bone of the skull (Ethmoid) for the special purpose of smell, and on the other hand through those orifices in the skull which lead towards the palate. From the air which has thus made its way into the brain and from the vital spirit, which on account of the numerous flexures, becomes more and more fitted for use by the brain, the animal spirit is by the special power of the brain, elaborated in the right and left ventricles, and in the cavity common to the two known as the third ventricle. A portion is carried from the third ventricle, directed along the aholong Channel (aqueduct of Sylvius) between the bodies which resemble the uterus and testes, to the ventricle of the Cerebellum (fourth ventricle) which is formed by the sinus of the Cerebellum and partly by the cavity of the beginning of the spinal medulla. From the other ventricles of the brain likewise, the spirit is carried into the nerves springing directly from them, and so to
The organs of the senses and voluntary movement.

"Meanwhile, we will not too anxiously discuss whether the spirit is carried along certain hollow channels of the nerves, as the vital spirit is carried by the arteries, or whether it passes through the solid material of the nerves, as light passes through the air. But in any case it is through the nerves that the influence of the brain is brought to bear on any part, so far I can certainly follow out the functions of the brain by means of dissections, with great probability, and indeed truth."

He shows in this Chapter on dissections that it is the nerve itself which is the essential agent and not its membranes, for the membranes may be removed without interfering with movement: moreover he classified the nerves with regard to their hardness and softness. The former being for the purpose of movement, the latter for sensation.

"But how the brain performs its functions in imagination, in reasoning, in thinking and in memory, I can form no opinion whatever; nor would he descend to the level of speculation regarding what was inexplicable to him."

The attacks of Vesalius upon Galen.
doctrines, induced many anatomists and physiologists
to stand forth in defence of the principles which had
been the standard for so many Centuries.

The controversies succeeded in bringing to
light new truths, and various points were
added to the knowledge of the brain and its
functions.

Joan Baptista published a work in
1537 in which he pointed out the distinctions,
unnoticed before his time, between the cortical
and medullary portions of the brain.

Vesaleus discovered that the brain
derived its motion from the pulsation of the
arteries, and ascertained that in some
animals the brain might be removed without
deferring those animals to life.

Vesaleus gives the following account
of the transverse portion of the brain which
has been denominated in his honor the "pons
Vesalei;" I observe another large process
of the Cerebellum which I have not found
noticed by any, though the following description
will show its great importance. This arises
from either side of the Cerebellum a process
which passes downwards and forwards embracing the spinal cord in the same way as the broad transverse muscles of the larynx, forming the third pair of common muscles (inferior pharyngeal) embrace the top of the gullet. Any one may see the position of this process in the skull, where is a well-marked transverse depression just in front of the foramen for the spinal cord. The modern opponents of Galen accuse him wrongfully when they say that he was wrong in attributing the origin of some nerves to the cerebellum, for the auditory nerves, and I believe some others also, arise from this process. May I give a name to my discovery? When I saw the spinal cord passing under this transverse process, like a canal under some bridge, I, for the sake of clearness, called it the bridge of the cerebellum, and have long been accustomed to use the term." Vesalius was the first, moreover, who divided the brain into three portions, by adding the medulla oblongata.

In tracing out the progress of science through the centuries, the trend of investigation is found to vary from time to time and the
The 17th Century

Descartes
Pages of history show that where attention becomes concentrated on one line of thought, another for the time, suffers and is brought to a standstill. Thus it was, that throughout the Sixteenth Century and a part of the Seventeenth century, anatomical inquiry had, so to speak, pushed experimental investigation to the wall, with the natural consequence that no material physiological progress had ensued in this period.

Nearly a hundred years after Vesalio, we come to the views of Descartes, when, indeed, we seem to be stepping back to some of the teaching of the Ancients.

Descartes, born at Tour in 1596—where Francoic zealour had checked the career of the all-conquering Arabo many centuries before—makes a great figure in the history of human thought. He was a great mathematician, an accomplished physicist, and a brilliant philosopher, but he was neither an anatomist nor a physiologist.

It is true he studied both Anatomy and Physiology, but not with the ardour of an enquirer and only for the special purpose
of constructing out of the current knowledge of the
time, a physiological basis for his philosophical
views. On this basis, he desired to show
that the same physical laws which governed the
working of the universe were also applicable
to man—that is, that man might also be
regarded as a machine, working in accordance
with physical laws. He utilized the
doctrine of the animal spirits to explain the
phenomena of sensation and movement, and
these animal spirits he speaks of as an 'air' or
a 'wind' or a 'flame', but throughout he
treats them as constituting a delicate fluid which
was amenable to the physical laws governing
fluids: for him the nerves were tubes along
which the spirits flowed in a wholly mechanical
manner. Out of these facts he constructs
an ideal nervous mechanism having the
brain as a centre, and the nerve tubes
carrying the animal spirits to the bodily parts,
radiating from this centre. His exposition
of the phenomena of movement is as follows:

"Now as these spirits enter thus into the ventricles
of the brain, so they pass thence into the pores
of its substance and from these pores into the nerves. And according as they enter, or even only tend to enter—more or less into this or that nerve, they have the power of changing the form of the muscle into which the nerve is inserted—and, by this means, of making the limb move. The primary reservoir of the animal spirits is the pineal gland—"the little gland in the middle of the substance of the brain." The ventricles forming secondary reservoirs. The minute heat of the heart supplies the energy of the animal spirits which flow down the tubular nerves and so carry out the movements of the body. The nerves moreover, contain very delicate threads or their cavities, which originate from the substance of the brain and determine the outflow of animal spirits from that organ. He can now explain the phenomena of sensation.

In order to understand how the brain can be excited by external impressions which affect the organ of sense, so that all the members can be moved in a thousand different ways, imagine that the delicate threads, which as I have already said arise from the inside of the brain
and form the mass of the nerves, are so disposed in all those parts which serve as the organs of any sense, that they can easily be set in motion by the objects of the senses, and that, whenever they are thus set in motion, even ever so little, they, at the same instant, pull upon the parts of the brain whence they take origin, and by this means open up the orifices of certain pores which exist on the internal surface of the brain.

Through these pores, the animal spirits, which are in the ventricles, immediately begin to make their way, and thus pass into the nerves, and so into the muscles which carry out in the machine of which we are speaking, movements exactly like those to which we ourselves are excited when our senses are affected in the same way.

Various psychical phenomena, such as habit and memory, he explains on the assumption of various physical properties in the nerves. "Consider also" he says, "that an important feature of these delicate threads is the property of being easily bent in every kind of way by the mere force of the spirits which press upon them, and of
 retaining, just as if they were made of lead or
upward, as it were, the shape into which they
were last known until, by some further
action, they are made to assume a new one.

The pineal gland, besides being the chief
reservoir of the spirits, as already remarked,
is "the seat of imagination and of Common
sensation" — "the rational soul." Such were
the fantastic and unreal anatomical ideas
of Descartes and as a natural consequence
his physiology was equally unreal and
fantastic. It must be admitted, however,
that Descartes succeeded in showing that
it was possible to interpret not only the
physical but also the psychical phenomena of the
body, by the same method which was making
such wonderful progress when applied to
the phenomena of the material world.

Indeed it has been written of Descartes' exposition
of the nervous system: "If we read between
the lines which he wrote, if we substitute in place
of the subtle fluid of the animal spirits, the
molecular changes which we call a nervous
impulse, if we replace his system of tubes
Maepigia

Vioosens
with their vascular arrangements by the present system of concentrated nerves whose linked arrangement determine the passage and the effects of the nervous impulse. Descartes' opposition will not appear so wholly different from the one which we give today.

Malpighi, by his microscopic investigations, added much to the histology of the nervous system, although he has left very little concerning its functions. It appears to have investigated the fibrous nature of the medullary portion, for he states that in fishes, this part of the brain resembles the pipes of an organ. Besides, he had observed the same fibrous structure in the brain of sheep, oxen, and other animals; but, indeed, it could not be observed in the posterior part of the medulla oblongata.

Contemporary with Malpighi, was Vierneaux who wrote largely on the brain, and dissected that organ with great care. He was the first to trace the medullated fibres and exhibited the connection which existed between the Cerebrum of the Cerebrum and the
Willis.
Corpora pyramidalis, by means of longitudinal fibres of white substance. A very interesting fact is brought to light, in pointing out that boiling the brain in oil, facilitated the tracing of these fibres. Yet of all those who investigated the structure and functions of the nervous system during the seventeenth century, the most eminent was Thomas Willis.

Willis was born in Wiltshire in 1631, and received his education at Oxford and eventually practised as a physician in London. Unlike Descartes, Willis possessed a thorough practical knowledge of the structure and functions of the brain, in health and in disease; his views, indeed, were the views of Descartes, yet modified by a much more exact anatomical knowledge and by sound physiological deductions. In 1664 Willis published his "Cerebri Anatome" on which his reputation principally depends. This work was followed eight years later by his "De animali Quintasum", in which he regards the soul of beasts to be the same
with the vital principle in man—corporeal in its nature and dispensing with the body.

He speaks of the animal spirits as constituting part of a corporeal soul and the nervous phenomena exhibited by man and the higher animals are due to its activity. Much of his work is concerned with the features and mode of action of the corporeal soul.

"The corporeal soul," he says, "common to man and the higher animals, while it extends over the whole organic body and vivifies, actuates, and irradiates every part, both tissues and humours, yet seems more eminently to subsist in two of these, and to hold them as its imperial seats as it were. These subjects of the soul are, on the one hand, the vital fluid, the blood, circulated in a perpetual round in the heart, arteries and veins; and on the other, the animal fluid or nervous juice streaming gently through the brain and its belongings. Both these provinces the soul inhabits and adorns with its presence, but since the whole soul cannot be in both provinces at the same time,
it is, as it were, divided; it activates each province by its appropriate half. One of its halves, in its nature of fluid, glides into the blood after the fashion of a lighted flame, while the other half seems diffused through the animal fluid after the manner of light, like the rays of light emanating from that flame, rays which, taken up by the brain and the nerves as by dioptric glasses and manifoldly reflected or refracted, form various figures according to the workings of the animal faculties. The animal soul, therefore, corresponding to its dual functions in the animal body, consists of two distinct parts, namely: flame and light; for as regards the functions called "natural", these are in truth only involuntary animal functions, and are carried out by the aid of "animal spirits". Following this, Willis maintains that the active properties of the nervous system, the animal spirits, were of the nature of light, but when he comes to explain nervous phenomena, he misuses up the property of light with other physical phenomena, indeed the physical
Phenomena of fluids. Nervous action he explains thus: "The internal and immediate efficient cause, both of sense and movement is furnished by the basis of the sensitive soul, that is to say, by the animal spirits instilled into the brain from the blood which is alight, and thence diffused into the nervous system. These being distributed by the brain, as from a fountain, along the nerves over the whole body, inducing in each a certain tensioness. So that, the ducts of the nervous system, like cords slightly stringed, are extended from the brain and its appendages in every direction to all peripheral parts. And these are so stringed and so actuated by a certain continuity of the soul (composed soul), that if either extremity be struck, the blow is forthwith felt throughout the whole. Hence any intention conceived within the brain immediately carries out the purposed work in the proper member or part; and vice versa, any impulse or blow which is inflicted from without on any member or sensitive organ, is communicated to the brain. When the impression or impulse passes outwards from the brain along the nerves to motor structures, movement is produced."
...on the other hand, the impression, started from without, is carried upwards towards the brain. Sensation is the result. In the same animal spirits being about both movement and sensation, by their own opposite and inverse disposition, and effect. When Willis comes to explain the functions of the several cerebral structures, he has recourse to his hypothesis of the nervous action being light. He was indeed the first to clearly enunciate the localisation of function to distinct parts of the nervous system. In his "Canonii Anatomia" he attempted to establish the cerebrum as the organ of voluntary motion and the cerebellum that of involuntary motion, as it will be remembered, William of Salicetian had also imagined, four centuries before the time of Willis. Circulation, respiration and digestion he maintained were dependent on the cerebellum, which was the seat of the vital property. He placed the animal faculty in the cerebrum, imagination in the "Corpus Callosum", perception in the "Corpora Striata", and memory in the convolutions of the cerebrum. Explaining the reason why the
Cortex of the brain is thrown into convolutions he writes thus: "For as the animal spirits for the various acts of imagination and memory ought to be moved within certain and distinct limits or bounded places, and those motions be often iterated or repeated through the same tracts or paths, for that reason these manifold convolutions and in-foldings of the brain are required for these diverse manners of ordinings of the animal spirits — in that, that in these cells or storehouses severally placed, might be kept the species of fluente things, and as occasion serves, may be taken from them." Following on this new theory, he showed that the cortex or superficial part of the brain was the seat of the origin of the ideas, and maneuver, that under excitation an impulse was started therein which travelled from the cortex into the brain substance and so into the spinal cord and nerves. His medical experience, together with his anatomical knowledge enabled him to connect disease in certain regions of the cerebral cortex with symptoms of palsy or.

According to Willis, "external impressions," or
As we would now say, sensory impulses, were transmitted to the common seat of sensation — the corpora striata — and then passed on to the corpus callosum, and finally to the cortex and the same path was taken in a reverse direction by the motor impulses started in the cortex.

That he had conceived the doctrine of reflex action is very evident from many passages throughout his writings from which may be taken the following quotations to illustrate. "We may admit that the impression of an object, draining the animal spirits inwards, and modifying them in a certain peculiar manner, gives rise to sensation, and that the same animal spirits, in that they return from within outwards in a reflected wave as it were, call forth local movements"; and again, "and so sensation preceding movement is in some manner the cause of it."

Often, indeed, accepting an illustrative analogy as the proof of his argument, Willis made many false contributions to the knowledge of the brain and its functions: yet his views
The 18th Century

Paccioni
in their physiological accuracy were a long way ahead of those of Descartes and his statement contained much truth which subsequent investigation revealed.

A long period intervened before anyone took up again the problems which had occupied the mind of Willis. Just as Harvey's great discovery of the circulation of blood had had the effect, during the Seventeenth Century, of diverting scientific thought along certain definite paths connected with it, so in the Eighteenth Century the discovery of the lymphatic circulation by William Hunter again turned physiological enquiry away from the nervous system.

The work of Antonio Pacioli, published in 1721, concerning the supposed muscular nature and action of the dura mater, contained opinions maintained with considerable ingenuity and the investigations to which the controversy led contributed greatly to produce a more intimate acquaintance with the structure and functions of the brain. One remarkable advancement of knowledge was made in the
Eighteenth Century, which although it concerned not the functions proper of the brain, but the relations of the functions of nerves to those of muscle, yet had a remarkable influence over the whole of neuro-muscular physiology. This was the chief work of Haller on the doctrine of irritability.

Haller in his "Elements," which tested of his views of the nervous system and its relation to muscular contraction, discovered this property of irritability. The chief objective manifestation of life, and he showed that it was not only independent of sensibility, but survived for a time the death of the body. This power, he maintained, was inherent in the muscle and could be brought into action spontaneously or through the instrumentality of the nerves. In the light of his discovery, he proceeded to deal in a truly scientific manner with many of the difficult problems of the nervous system. His experiments confirmed his views that the nerves were the only instruments of sensation, just as they were the only instruments of movement.
He was opposed to the doctrine of Willis that various faculties of the mind were placed in different portions of the brain and cerebellum, and concluded, from the numerous cases of the fatal effect of injuries, that sensation resided in the cerebrum and volition in the cerebellum — opinions, it will be recalled, again contrary to those of Willis. In dealing with the physiology of the nervous system, Haller carefully describes the structure, the physical properties, and the chemical composition as far as those were then known; then having stated the observations that have been made, and the several views which have been put forward having been explained, he carefully delivers a reasoned judgment — his own views and conclusions. The example he 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 importance; because there seemed a great tendency in his day to build up Physiology, particularly that of the nervous system,
on theory only, without substantiating the arguments with experimental investigation. Haller's work on the nervous system was of great value, not so much, indeed, because he made any sweeping changes in the Physiology regarding it; but because he called into question many of the vague points that then existed—points which he showed still remained to be verified by experiment.

In refuting the ideas of Willis and others, as he did, Haller gave rise to much controversy which assisted greatly in forwarding, among other subjects, the Physiology of the brain.

His doctrines were strongly opposed by Whytt and Fosterfield, particularly the former. Whytt attributed vital motions to the operations of the sensitive principle, which he imagined 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. But Whytt is better known for his convincing proof that the central nervous system is the place of reflection in the phenomenon of reflex action. Earlier physiologists had thought that the reflex might occur in the anastomoses
The value of the microscope.

Reil
of the nerve trunks, but Whytt showed that, in a decapitated frog, the reflex movements were abolished if the spinal cord was destroyed.

It is important to notice at this stage the progress that was being made by the aid of the microscope. It has already been seen how it enabled Malpighi and Vieussens to examine the fibrous structure of the brain, and with its help, Reid in 1795, successfully prosecuted the same study. In a series of papers, 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 Cerebellum, and from thence through the Corpora striata to the convolutions. Moreover, he investigated the fibres of the Corpus callosum and anterior commissure, and followed their course into the hemispheres. The structure of the convolutions was also accurately described by him and he remarked that if one were to fix a point in the nervous system, such as the medulla oblongata, the system might be regarded as radiating from this point to the extremities of the fibres of the...
The 19th Century

Bichat
Cerebrum and cerebellum on the one hand, to the
extremities of the nerves, on the other: or that, in other
words, all these fibres might be considered
as converging from their extremities toward
the medulla oblongata.

A host of anatomists and physiologists
contemporary with Reid, were also investigating
the nervous system, and the most distinguished
for their researches were Moreau, Poche,ha,
Haeckel, Santorini, Weisberg, Virg d'Azur,
Cignus and Borden. Points of importance,
too numerous to detail, were accumulating fast
and adding new light to the subject.

Early in the Nineteenth Century, in the
year 1805, there appeared the work of
Bichat: "Recherches physiologiques sur la vie et
to mort", which, on account of the ingenuity
with which the opinions were expressed and
also of the eloquence with which they were
maintained, excited amongst physiologists the
greatest sensation. Bichat divided the nerves
into two distinct systems, animal and organic,
the one having for its centre the brain and
including those nerves intended to receive
Phenology
impressions as well as those subsequent to volition: The other had many centres existing in the ganglia, each ganglion being, as it were, a small brain and possessing a distinct source of nervous influence. The first according to Bichat, presided over sensation, voluntary movement and intellectual power: the second governed the operations of the animal economy over which the mind had no control, together with the passions. Bichat was a true revolutionist in Physiology, as his contemporaries of the Convention were in politics, and a criticism of his idea of dividing life into animal and organic existence may be found in the words of Charles Bell, whose wonderful work was soon to follow: "a bold and original notion, which proclaims Bichat a great genius, but anatomically incorrect."

A few years prior to Bichat's publication, there had appeared an altogether new doctrine, which was now the subject of great discussion. This was the system of "cranioscopy" or "phrenology", devised by
The system of Gall & Spurzheim

Its principles
Gall—and elaborated by his followers, especially Rochaert, indeed, may be
looked upon as the father of phrenology, as, in his work on the Nervous System, published
in Vienna in 1784, he had propounded views very similar to those which were later
formulated into a system by Gall.
His system was constructed by a method of pure
empiricism and embodied four principles:
1. The brain is the organ of the mind.
2. The mental powers of man can be analyzed
into a definite number of independent faculties.
3. These faculties are innate—and each has its
seat in a definite region of the brain.
4. The size of each of these regions is the measure
of the power of manifesting the faculty associated
with it.

The organs of the innate disposition,
as Gall calls the definite regions, are expressed
on the surface of the brain and form certain
proliferations on the external bony cover of the
skull, by means of which the existence and
degree of development of the organs can be
determined. The following examples extracted from
Blödl's account of Dr. Gall's lectures, will illustrate the means by which the so-called organs were established and at the same time will serve to show the very frail supports on which the whole system was built.

"No. 13. The Organ of Valour. By carefully examining the skulls of many chimney sweepers and street boys at Vienna, who are much inclined to fighting, Dr. Gall found in these, who were most apt to quarrel and fight, a hemispherical protuberance on the lower and hindmost angle of the Os trigonius behind and above the ear. Equally amusing is his eighteenth organ:

"No. 18. The organ of ambition and vanity.

By the side of the organ of height, in the angles of the area trigonius, which are formed by the Larger sagittalis and the artus angulares, there are sometimes seen two hemispheric protuberances, which Dr. Gall found more often distinctly expressed in women than in men, and observed that the persons so organised always were ambitious and vain." Although Phrenology was thus
a system of mental philosophy, it had the more popular aspect, in that it furnished a method whereby the character and disposition of an individual could be ascertained.

The arguments that were brought against this system and which ultimately were responsible for its downfall, were those of simple anatomical observation. It was shown that although the inner surface of the skull is moulded more or less accurately on the brain, and the outer surface approximates to parallelism with the inner surface, yet the correspondence is sufficiently variable as to render conclusions therefrom uncertain. Anatomists demonstrated that the spongy diploe which intervened between the two layers might vary to a conspicuous extent in different parts of the same skull. The frontal sinus, indeed, was found to be often so large that it might occupy the region of five of the organs. Further, it had been shown that premature syrinxes of the sinuses and artificial malformations altered the skull shape considerably, without affecting to any appreciable extent the relative
Monroe

Santorini and Weisberg

Prochaska and Ismenning
development of the brain. Physiology, psychology and experience alike contributed to discredit this system and to show how worthless further investigations on those lines would prove in advancing knowledge of that aspect of the Physiology of the Brain which was then beginning to excite general interest, namely, the localization of cerebral functions.

But, like many other false systems before it, it stirred up much controversy which served the useful purpose of stimulating physiologists to a nearer research regarding the structure and function of the brain.

Moro had discovered that the ganglia of the spinal nerves were formed on the posterior root and that the anterior root did not enter the ganglion: Santorini and Weisberg had observed that the fifth pair of nerves had two roots: Prochaska and Esmesnig had noted the resemblance between the spinal nerves and the fifth pair; yet, notwithstanding the progress attained by these celebrated anatomists, the physiological efforts which followed were undirected by any principle.
Sir Charles Bell.
"The multiplicity of anatomical facts" wrote Sir Charles Bell, "which the anatomists of Europe continued to discover, instead of increasing the light, only tended to throw obscurity over the subject." To Sir Charles Bell lay the difficult task of disentangling this accumulation of anatomical facts and of getting order out of what was apparent chaos.

Born in 1774 and educated in Edinburgh, Bell early associated himself with the study of the nervous system. Before dealing with his work it will be useful to epitomize here the main ideas concerning the physiology of the nervous system as received by him.

It was generally believed that:—The brain was a common senesovium: the nerves were organized such that each was fitted for a definite impression or that they were distinguished from each other only by a delicacy of structure and by a corresponding delicacy of sensation: impressions were carried along the nerves to the senesovium and presented to the mind: the mind, by the same nerves which received sensation, sent out the mandate of the will to
The moving parts of the body. "All appears sufficiently simple and consistent," writes Bell, "until we begin to examine anatomically the
structure of the brain and the course of the nerves. Then all is confusion: the divisions and sub-
divisions of the brain, the circuits, course of the nerves, their intricate connections, their
separation and reunion, are puzzling in the last degree and are indeed considered as things
inseparable." In opposition to
these opinions, given above, Bell gave his reasons in his "Idea of a New Anatomy of the
Brain" and in a series of papers to the
Royal Society, for believing that the cerebrum
and cerebellum differed in function: that
the nerves were distinct in function as they were
in origin from the brain; that the matter of
the nerves was adapted to receive certain
 impressions, while the corresponding organs of
the brain were put into activity by these
impressions. By demonstrating their
difference in function between the anterior and
posterior roots of the spinal nerves, and
thereby showing that the conducting channels
in the nervous system possessed differences in function, he discovered the experimental fact which established the great principle of localization of function. Once this was done, it was relatively an easy task for subsequent investigators to show that the nerve centres to which those channels led possessed also the differentiation of functional ability. Haller indeed had said: "But I know not a nerve which has sensation without also producing motion: the nerve that gives feeling to the little finger is the nerve which moves the muscles." Yet Bell's reasoning convinced him that this could not be so.

"In a word," he says, "the force which precedes muscular contraction runs along a nerve in one direction, and the force which causes sensation runs in another. Is it logical then to suppose that the two forces cross each other thus—that the same nerves, on the same portions of nervous centres, exercise two functions at a time?"

In a paper to the Royal Society he gives this account of his great discovery: "Next, considering that the spinal nerves have a double
root, and being of opinion that the properties of the nerves are from their connections with the parts of the brain, I thought I had an opportunity of putting my opinion to the test of experiment, and of proving at the same time that nerves of different endowments were in the same cord held together by the same sheath. On laying bare the roots of the spinal nerves, I found that I could cut across the posterior fasciculi of nerves which took its origin from the posterior portion of the spinal marrow, without convulsing the muscles of the back: but that, on touching the anterior fasciculi with the point of the knife, the muscles of the back were immediately convulsed. Such were my reasons for concluding that the cerebrum and cerebellum were parts distinct in functions and that every nerve possessing a double function obtained that, by having a double root. I now saw the meaning of the double connection of the nerves with the spinal marrow: and also the cause of that seeming intricacy in the connections of
nerves throughout their course, which were not double at their origins. The spinal
nerves being double and having their roots
in the spinal marrow, of which a portion
comes from the cerebrum and a portion
from the cerebellum, they convey the attributes
of both grand divisions of the brain to every
part, and therefore the distribution of such
nerves is simple, one nerve supplying its
destined part."

Strengthened in his
conviction that the whole anatomy of the nervous
system, if properly investigated, would bring
symmetry out of apparent confusion, he
examined the nerves of the brain and found
that the fifth nerve, having two roots similar
to the spinal nerves, was the only one which
could bestow upon the head those double
functions of sensation and movement.

He then selected the nerves of the face for experiment
and had the satisfaction of determining that "the
nerve with the ganglion on it was the nerve of
sensation."
The most importance of his
discovery threw at once a flood of light
upon Pathology; and in his papers to the
Royal Society he instances many cases of great interest in support of his arguments. Equally skillful with the pencil as he was with the dissecting scalpel, Bell executed many splendid drawings of his fine dissections of various nerves; drawings which were of great value for their anatomical accuracy.

It is not necessary to give a detailed analysis of Bell's other important contributions to the knowledge of the structure and functions of the nervous system, nor is it necessary to discourse on the controversy that arose owing to a claim of priority in this great discovery by Magendie. Historical evidence goes to show that whatever additional developments were made by Magendie, the original ideas belonged to Bell. Therefore, suffice it to say that this great anatomist and physiologist handed on to future enquirers the key that would unlock the gates that, hitherto, had barred all progress in the investigation of cerebral localization.

In the light of this great discovery, the anatomists and physiologists of England, France,
Germany, Russia, Austria and Italy, renewed their investigations with the greatest talent and diligence, endeavouring to discover those laws which govern the operations of the brain, and to establish the connection which exist between mind and matter.

The first two-thirds of the Nineteenth Century, as a result of this grand international combination of intellect, was an age of revelations and wonders. Patience had received its due reward; and the wonderful discoveries concerning the action of the nervous system upon all the organs and functions of the body, were scientific triumphs unparalleled in the previous history of physiological progress. It would indeed be a matter of great difficulty to enumerate here the many scientists who contributed in making this period such a brilliant one. Therefore, in what follows, mention will be made of the work of only the most renowned, at the expense of omitting many, whose contributions to our knowledge of the nervous system, were of direct though of minor importance.
The Study of the Reflexes.

Harald Hald and Johannes Müller.

Lassereau, Flamcan, Longat.
Claude Bernard, Pflüger.

Thaenberg.
It has already been seen how Wytel in 1751 had buried himself with the study of reflex actions and had conclusively demonstrated that the central nervous system was the place of reflection. The reflexes then received the attention of Legalais and Prochaska, and in the nineteenth century interest was again excited in the subject by the works of Marshall Hall, appearing in 1833, and those of Johannes Müller following soon after. This branch of study was then brought to a very high degree of perfection by quite a host of investigators, chief amongst whom were Lallemand, Flourens, Langest, Claude Bernard, and Pflüger—all of whom chronicled observations of the highest excellence.

Ehrenberg, in 1833, showed that the brain was composed of an immense number of tubular-like fibres; in the same year Remak described the ganglion cells with which Huxley in 1840 associated the nerve fibres, showing the latter to be prolongation processes of the cells.

The great improvement upon
The methods of prosecuting histological study brought to light new facts which were subsequently of the very greatest importance in aiding the investigation of the functions of the nervous system.

R. Stilling of Cassel, in 1842, showed that by the process of freezing, very fine sections of the cord and brain could be obtained. Later, an improvement upon this method was made by Haemauer and Seckhardt who demonstrated the value of Chromic acid as a hardening agent for these tissues. Gedack in 1858 introduced the method of staining sections with Carmin and some what later followed the more perfected processes of Golgi, Weigert and Ramon y Cajal. To such a degree of perfection was histology advanced that it was now generally believed that the nervous centres were formed of (1) nerve cells with (2) tube-like processes or fibres and (3) an intermediary ground substance—"Neuroglia". The tube-like fibres of the peripheral nerves were now believed to be constituted
Kompl.
Helmholtz, Schroeder van der Luek.
Jacobowitz.

Owejamihoff.

Walter.
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Geblach in 1858 introduced the method of staining sections with Carmine and some what later followed the more perfected processes of Golgi, Weigert and Ramón y Cajal. To such a degree of perfection was Histology advanced that it was now generally believed that the nervous centres were formed of (1) nerve cells with (2) tube-like processes or filaments and (3) an intermediary ground substance — "neuroglia." The tube-like filaments of the peripheral nerves were now believed to be constituted
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now generally believed that the nervous
centres were formed of (1) nerve-cells with
(2) tube-like processes or filiform and (3) an
intermediary ground substance—"Neuroglia".
The tube-like fibres of the peripheral
nerves were now believed to be constituted
Kronprinz
Helmholtz, Sachsens van der Fuch.
Johannes Peter
Oswajanni Kopf.
Waller
of an "axis cylinder" (Ramhage), surrounded by "myelin" and those two enclosed in a sheath "the sheath of Schwann."

In addition the cells were differentiated into unipolar, bipolar and multipolar, and the processes arising from these cells were of two kinds — "axons" and "dendrites." These processes were now studied for the first time by Remak and later received the careful observations of Helmholtz, Schroeder van der Fliet, and Jacobowski.

It was now shown by Jacobowski and O'wens and Koff that the grey substance of the cord contained two types of cells which differed anatomically and physiologically, one class being larger than the other and communicating with motor nerve fibres, while the smaller greyish-white cells communicated with sensory nerve fibres.

Waller in 1850 showed that when a nerve fibre was cut, the part distal to the point of section degenerated in a few days, and to this change which results in the severed fibres, has been given the name of
The Vaso-motor system

Weber

Budge

Claude Bernard

Ludwig and Kling
Wallerian Degeneration.

How it is true, are histological facts, yet it has seemed necessary to have made mention of them here for two reasons: first, because they show the immense revolution that had taken place in the conception of the finer anatomy of the nervous structures, and second, because of the great importance of these facts in furthering the knowledge of the Physiology of the Nervous System.

But by far the most important discoveries which were made during the first two thirds of the nineteenth Century, were those which treated of the wonderful action of the nervous system upon all the organs of the body. It was during this period that scientists revealed the hidden work of the vaso-motor nerves, and of those other nerves which obey not calls of the will, but perform their silent duties without awakening consciousness. Thus, Weber and Budge, then Claude Bernard demonstrated the inhibitory action of the vagus upon the heart; while Ludwig and They discovered...
Stilling Bernard

Ludwig

Dr Bois Raymond

Electricity as a means of investigation
The accelerator fibres which the same organ receives from the sympathetic system.

The vaso-motor nerves were described by P. Stilling in 1840 and in 1851 Claude Bernard showed that these nerves were governed through the Sympathetic System. Bernard's experiments showed conclusively the existence of vaso-dilator nerves and vaso-constrictor nerves, and in addition, that the vaso-dilatator excited an inhibitory action upon the vaso-constrictor. Ludwig and Bernard then investigated the action of the nervous system upon the glands, and in a series of remarkable experiments, found this action to be analogous to that exercised over the vascular system.

Moreover, the experimental genius of Dr. Bois-Reymond was responsible, at this time, for many contributions to neuro-muscular physiology, and in 1867, he demonstrated the great value of electricity as a tool of investigation. With the aid of electrical science which had now advanced to a remarkable degree, the last third of the Nineteenth Century was destined to unfold discoveries of the most
The last third of the 19th Century.

The Localisation of Function.
A Brief Summary of its Development.

Avicenna.

Albertus Magnus.
astounding character: yet of all the scientific
triumphe which in this period crowned the
labours of physiologists, surely the most beautiful
and the most wonderful were those which
concerned the localisation of function in the
Cerebrum.

Ever since the belief had been
established that the Cerebrum was the organ of
the higher psychical activities, these naturally
arose the question whether different provinces
of the brain had different functions. Correspon
ding to the various faculties of the mind, or whether the
Cerebrum was functionally equivalent throughout.
Antheagenus seems to have been the first to have
attempted to answer these questions by
venturing the hypothesis that imagination
resided in the anterior part of the brain,
memory in the posterior region and inter
mining lay the seat of the intellect.

This distribution however did not satisfy
the mind of Aricena, who assigns to
the ventricles the various faculties.

Equally fanciful was the conjecture of
Albertius Magnus, who flourished in the
Mondino di Luzzi

Montagnano

Tocco

Trecastelli
Nineteenth Century. To the frontal region he assigned judgment— to the middle, imagination, and to the posterior, memory.

Mondino di Luzzi, of the Fourteenth Century, was inclined to favour the theory of Princedo.

A century later Montanarius published a chart which indicated regions possessing the special powers of imagination, memory, and judgment. Fuchs, in the Sixteenth Century, was content to accept the views of Archigenes: “Quam enim imaginatio quam aliis sensum communem appellant, priore cerni partem occupet; cogitatis medium; memoriae vero posteriorum...” Tracatores has definite reasons for inclining to the same views, for, he says, that if one wishes to imagine anything, one Knits the brows and if it is the desire to remember something, one scratches the back of the head. “Si quinde bene volumus imaginari, natura ipsa docet; videamus frontem contraere et paratem illum acuere: posito laece in parte videntis et imaginationem laeti... Quod laecae, in parte quae medium respicit Capitis ubi
trigmu vocatum est Constat rationem deficient: postrema vero lacea non rationem sed
memoriam, reservationem specierum... cum volumus memorari nactus
nos docente, scapimo posteriorum partem
quae omnia manifeste monstrat non
intelliebunt. Sed reservationem specierum
postrema ventriculo fici.

Merricoli thought it more appropriate
to make the cerebral substance surrounding
the ventricles the principal seats of the faculties
and in support of the doctrine of localization
he cited an interesting case of sensory
aphasia, which he regarded as a partial
"loss of memory." "Wonderful to relate,"
he says, "this man can write, but is
unable to read what he has written!"

According to Descartes, the "pinna gland"
and the substance of the walls of the ventricles
were the all-important centres. Willis
it will be remembered, differentiated between
the functions of the cerebrum and cerebellum,
assigning the former to be the organ of voluntary
movement and the latter to be the organ of
Haller
involuntary movement. 

Imagination he had placed in the Corpus Callosum, perception in the Corpora Striata, and memory in the Convolution of the Cerebrum, while he believed the optic Thalamus to be especially connected with sight. Haller, however, repeated those assertions of Willis and was much more conservative regarding the question of localization. He admitted that some experiments and some of the phenomena of disease did give a certain support to the idea of cerebral localization, yet he was far from being satisfied with the knowledge of his day regarding this subject.

"Our present knowledge," he says, "does not permit us to speak with any show of truth about the more complicated functions of the mind, or to assign in the brain to imagination its seat, to common sense its seat, to memory its seat. Hypotheses of this kind have in great numbers reigned in the writings of Physiologists from all times. But all of them alike have been feeble, fleeting and of short life."

The question of the localization of function
Gall and Spurgeon

Francisco
involuntary movement. Imagination he had placed in the Corpus Callosum, perception in the Corpus Striatum and memory in the convolutions of the cerebrum; while he believed the optic thalamus to be especially connected with sight. Haller however, refuted those assertions of Willis and was much more conservative regarding the question of localisation. He admitted that some experiments and some of the phenomena of disease did give a certain support to the idea of cerebral localisation, yet he was far from being satisfied with the knowledge of his day regarding this subject.

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Gale and Spurzheim

Flaxman
in the cerebrum had therefore been much debated throughout the centuries, but the most interesting and, at the same time, the most important discussions upon the subject belong to the nineteenth century, and more particularly to the last third of the nineteenth century.

While the century was still young, Gall and Spurzheim began to teach publicly their system of phrenology, which created an immense sensation, but which, in the face of anatomical facts, soon fell into disrepute, its methods being exploited chiefly by frauds and charlatans. His new doctrine, however, had its beneficial results in that it stimulated a keener inquiry into the anatomy and physiology of the brain, and while Gall was teaching in Paris, Flourens began his celebrated work upon the functions of the brain—work which was mainly instrumental in convincing physiologists that the cerebrum was functionally equivalent in all its parts.
Bamillona

Marc Box

Broca
upon pigeons and in these birds he found that ablations of parts of the cerebrum produced mental impairment in proportion to the amount of cerebral tissue removed, and not with any relation to the locality from which removed. The choice of animals for these experiments was, perhaps, an unfortunate one, yet the results obtained were in part corroborated by a number of instances in human beings, who by accident or wounds in battle, had lost a part of the brain, without any apparent defect in their mental powers ensuing. Therefore, as a result of these experiments, the view was at once held that the brain was functionally equivalent in all its parts. Opposed to Flourens' doctrine were the observations of Bouillaud who in 1875 had called attention to the peculiarity of loss of articulate speech. Marc Dax, moreover, had in 1836 localized the seat of this symptom in the frontal lobe. While Broca in 1863 established a more precise localisation in the posterior part
Jitsch und Nitrig 1870.
of the third frontal convolution. Although still other observations contradicted Flourens, yet the majority of physiologists accepted his views for nearly half a Century, until the epoch-making experiments of Flitsch and Hitzig revolutionised these ideas in 1870.

By exposing the cortex cerebri in dogs and stimulating it electrically, these observers demonstrated, in direct contradiction of all previous experimenters, the following three important facts: (1) That a portion of the cerebral cortex is motor in function while another portion is non-motor. (2) The motor portion lies in the more anterior part of the cerebrum while the non-motor area lies more posteriorly. (3) Electrical stimulation of the motor area gives rise to muscular movements upon the opposite side of the body.

Experiments of a similar kind were then carried out by a host of other investigators; observations were made in which the cortex cerebri was stimulated in various animals and finally in man, and confirmation of the doctrine advanced by
Tuctch and Hilfig came from every quarter.
In addition the method of ablation was employed with subsequent study of the animal regarding the resulting motor or sensory defects; and these results were further extended by careful autopsies upon human beings in whom paralysis of various kinds and sensory defects were associated with more or less definite lesions of the cerebrum.

An extreme view of the localization of function required, and definite areas were circumscribed and separated from each other, thus making the cerebrum a plurality of organs. Subsequent investigations, however, modified these extreme views, showing that owing to the intimacy which exists anatomically between various parts of the cerebrum, an injury in one part might influence to some extent the functional value of other regions. The modern view is that the cerebrum is composed of a plurality of organs, not isolated from each other as taught by Gall, but intimately associated with one another and
Perric, Schäfer, Horsely, Beevor

Munt

The Location of the Centre of Vision
To a certain extent dependent upon one another for their full functional importance.

The motor area which Pritsch and Kitoz had disclosed was later investigated by Sverie, Schäfer, Horsley and Bemor and their observations showed that there were cortical areas lying within the whole motor zone which activated the musculature of each part of the body. Munk raised the question whether there was a possibility of the area designated as 'motor' also functioning as the termination of the sensory impulses. Physiological and clinical work however, has not tended to support this view.

In the delimitation of the sensory areas the results obtained have been most definite in the case of the higher senses, vision and hearing, since defects in these senses are most clearly recognised.

Anatomical, physiological and clinical evidence have all contributed to locate in the cortex the general area for vision. The method of ablation was followed by Munk, Ferrier and others, with the results that
The Location of the Auditory Centre

The centres for smell and taste.
it was determined that the visual centre embraced
the angular gyrus and occipital lobe.
Physiology and Pathology were now working
in complete harmony with one another.

The auditory centre was located
after investigations upon the same lines as
were followed for the visual centre.
Munk and Decker showed that entire ablation
of both temporal lobes was followed by
complete deafness.

Regarding the cortical centres for
taste and smell, the experimental evidence
has not been of entire satisfaction, owing to
the technical difficulties in operating upon
reced portions of the brain without involving
neighbouring areas. It has usually been
assumed, without much decisive proof, that
the cortical centre for taste sensations lay
in the hippocampal convolution; while the
centre for smell has been localized, in a
less doubtful manner, in the lesser of the
hippocampal convolution.

In conjunction with the investigation
of the Cerebrum, inquirers were also
The investigation of the Cerebellum.

Gaten, Mitchell, Luciani, Lewandowsky.
Russell.

L. Casti
experimenting upon the Cerebellum, and medulla oblongata.

As in the case of the work done upon the Cerebrum, Flourens also took the lead in the experimental observations upon the Cerebellum and, as before, availed himself of pigeons for the work. The striking results obtained by him led to his suggestion that the Cerebellum was an organ for the coordination of voluntary movements, particularly the more complex movements necessary in equilibrium and locomotion.

And though Dalton, Mitchell, Luciani, Lewandowsky, Russell and others, have all advanced modifications of this suggestion, little progress has been made since the investigations of Flourens.

The possibility of a localization of function was suggested at one time by the experiments of Penfield, in which definite movements of the eye were obtained upon electrical stimulation of the Cortex Cerebelli, but later observers, especially Hoodly and Clarke, have advanced reasons for discreditng
The investigation of the Medulla Oblongata
His idea of localization of function in the Cerebellum.

The Medulla Oblongata also came in for its share of investigation and it was ascertained that certain centres which control the activity of the circulatory and respiratory organs were to be located here—"the vasomotor" and "respiratory centres." In addition, it has been shown that other important reflex activities are affected through the medulla by means of the vagus nerve, such as the reflex control of the heart through the cardio-inhibitory centre, and of the movements and secretions of the alimentary canal.

Such then has been the past, and what has been written will show, even though very imperfectly, how far our knowledge of the brain and its high function has advanced—how far, indeed, it has been man's privilege to trace the hand of the Great Creator in the matchless beauty of His design of our frame.
And, as a traveller who stops awhile to contemplate the progress he has made, we, the Children of the Twentieth Century, look back upon the varied landscape of time, through which has flowed, with many windings and under changing skies, the Stream of Knowledge which bears us ever onwards. Stumbling lazily from the obscurity of a distant past, enshrouded in the mists of Superstition and Conjecture, it has slowly trended its onward way, and though at times it has lapsed into clouded periods of partial stagnation, yet it has emerged again into the sunlight that has shone so brilliantly upon its activity, until in recent years, it has broadened out into a mighty and stupendous flow.