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EXPERIMENTAL AND PATHOLOGICAL INQUIRY

INTO THE

FUNCTIONS OF THE CEREBELLUM.

BY

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ON THE FUNCTIONS OF THE CEREBELLUM.

Ever since anatomists learned to distinguish the several parts of the encephalon from each other, the function of the cerebellum has been the subject of speculation. Their conjectures are various and contradictory.

Galen thought that the cerebellum must be the source of a large amount of vital force, since it was the origin of all the nerves distributed through the whole body. After his time the belief seems to have prevailed that the ventricles, not the substance, were the active part of the brain. According, however, to the statements of later writers, it had been customary for the early anatomists to regard the cerebellum as the seat of memory. "To show that memory is placed in the cerebellum, they plead that the substance of the part, being harder, is best qualified to retain impressions; and that we are apt to scratch the hinder part of the head when we are eager upon calling anything to mind." (Pierre Dionis.)

Varolius claims to have been the first to teach that the cerebellum is the seat of the faculty of hearing.

Our own countryman, Willis, writing in the year 1664, thus speaks of the organ: "Some affirm this to be another brain, and to perform the same actions with it; but if any one should have a soft and foolish brain I greatly doubt if he should become wise, though he should obtain perhaps a more hard and solid cerebel." He finally argues that this part of the brain is the source of involuntary motion, instancing the action of the heart, the movements of the bowels and respiration. He dwells upon the voluntary character of cerebral operations, but maintains that "the spirits inhabiting the cerebel perform unperceivedly and silently their works of nature without our knowledge or care."

Henry Ridley, towards the end of the same century, endorses the opinion of Willis as regards the heart and the alimentary canal, but refines upon the question of respiration, holding that a "sensitive faculty" resides in the cerebellum, which receives impressions from the lungs through the pneumogastric nerves, and transmits them to other parts which are the true source of the respiratory movements.

Boerhaave was of opinion that the heart and the muscles of respiration derived their power from the cerebellum; and his commentator, Van Swieten, more than half a century later, adopts the view, though at the same time he states some objections which would appear fatal to the theory.

Haller considered the preceding views to be amply confuted by the fact of the cerebellum giving origin to the fifth cranial nerve, and as a necessary consequence being a seat of sensation, as well as a source of voluntary muscular power.

Rolando, after many experiments on living animals, came to the conclusion that the cerebellum was the cause of all muscular movements. Gall, and after him Broussais, and many others, maintained that the sole function of the organ was to preside over the act of reproduction. Flourens, reasoning from the effects of the partial removal of this portion of the nervous system in birds and mammalia, argued, from the muscular disturbance which resulted, that the office of this large portion of the brain was to regulate or "coördinate" voluntary movements. The muscles, according to this view, derive their nervous supply from some other source, while the cerebellum merely regulates and directs its distribution.

Serres, who shortly afterwards made experiments in which lateral injuries were inflicted upon the organ in horses and dogs, states that loss of power in the side opposite to the wound was a constant result. Bouillaud, four years later, who made a wider series of observations bearing upon the same question, denies that paralysis was occasioned by such partial removals as he practised, and concludes that the only office of the cerebellum in vertebrate animals is to maintain such equilibrium between the two sides as is necessary for the performance of locomotion. Thus he limits the co-ordination theory to the harmonizing of the movements of the right and left limbs. The theory of Flourens has since been supported by Longet, Hertwig, Budge, and Carpenter.

Magendie relates experiments and cases to prove that a power resides in the cerebellum which continually impels to forward movement; which, in a natural condition, is balanced by forces generated in other parts of the brain, which tend to produce retrogression.

Foville holds that the organ is a seat of sensation. Wagner, while yielding a partial assent to the doctrine of Flourens, revives the theory of Willis as to the influence of the organ upon the involuntary muscles. Finally, a physiologist no less distinguished than Brown-Séquard, holds that clinical observation and vivisection agree in showing that the cerebellum has not any of the functions with which it has hitherto been credited.

This diversity of opinion as to the use of the cerebellum has suggested a further inquiry; and it may be well to say a word in starting upon the principles on which it has been pursued.

In all the vertebrate animals the brain is divided into the same great divisions—the medulla, the hemispheres, the optic and olfactory lobes, and the cerebellum; and it may be inferred that the function of each of these grand components is invariable. It is not necessary to justify this assumption.

As to the cerebellum in particular, not only does it always hold the same position and maintain the same connexions, but it has a peculiar microscopic structure which is different from that of any other part of the brain, and which is essentially the same in whatever part of the animal kingdom it may be examined. There can, then, be no doubt

as to the identity of this organ throughout the vertebrate class; and it may be fairly assumed that its function, whatever that may be, is actually the same everywhere.

Under these circumstances, observations made upon the lower animals will supply deductions which will be equally applicable to the higher; and experiments of a conclusive kind will be possible, such as mammals and birds have not sufficient tenacity of life to survive.

Commencing with those animals in whom the cerebellum is least developed, it will be first ascertained what are the capabilities of the subject of the experiment when left with the medulla oblongata as the only remnant of the encephalon. In a similar animal, if an operation then be performed in all respects the same, except that the cerebellum is left in attachment to the medulla, a comparison may be made which will display, in the powers or susceptibilities which the one has more than the other, the functions of the organ of which the possession constitutes the only difference. Finally, it will be ascertained what is the effect in each species of the removal of the cerebellum by itself.

By this system it will be easy to ascertain what powers belong to the medulla with the spinal cord; and what additional faculties are proper to the cerebrum on one hand, and the cerebellum on the other. The properties of the cerebellum can thus be estimated in two ways. We may measure the gain to the animal which this organ makes, as an addition to the medulla; and conversely, we may find what is the loss when this alone is subtracted from the nervous system.

The positive results of the experiments made on this system have been entered into a table, in which the species have been arranged in an ascending scale, according to the weight of the cerebellum, compared to that of the central nervous system.

Some of the experiments will be also given in detail. All observations of a merely negative character will be omitted, both in the table and in the detailed accounts, and given together subsequently.

The accuracy of every experiment has been verified by examination of the parts after hardening in spirit.

Some of the observations will now be more fully given, commencing with those which display the effect of the additions of the cerebellum to the medulla.

ADDITION OF CEREBELLUM TO MEDULLA.

Common Snake.—Two snakes were taken, and the hinder part of the skull was cut away in each—a work of some difficulty, owing to the great hardness of the bone. In both of these the cerebrum was separated from the medulla by a transverse section close behind the optic tubercles, and the cerebellum was then taken away from the medulla with cutting forceps, so that in each case only the medulla oblongata was kept in connexion with the cord. Subsequent examination proved that this centre was left unhurt, and that the separation was complete.

In both there was a moderate loss of blood. The animals became collapsed, and apparently lifeless. They were closely watched, and no further signs of life were noticed, excepting trifling movements of the body, under irritation, evidently of a reflex character; mere wriggling

TABLE *showing the capabilities of some of the Lower Animals when deprived of definite portions of the Encephalon; arranged in an Ascending Scale, according to the Proportionate Weight of the Cerebellum compared to that of the Central Nervous System.*

(The figures in brackets refer to the number of times the operation has been successfully performed.)

Subject of experiment.	Proportionate weight of cerebellum to central nervous system.	Whole encephalon removed or isolated excepting medulla oblongata.	Possessing medulla oblongata and cerebellum.	Possessing medulla oblongata and cerebrum.
Common Snake	1 to 200	Immediate collapse; no further sign of life except a few weak wriggling movements on irritation; no evidence of consciousness. (2.)	Feeble locomotion; head and neck pushed passively along by motion of trunk; resists manipulation, with every appearance of consciousness. (2.)	Active when irritated, but at other times unusually sluggish; movements sudden and emotional; apt to roll over in water and on land. (4.)
Frog	1 to 160	Temporary collapse; feeble, irregular progression, by means chiefly of hinder limbs; head depressed. (4.)	Temporary prostration; vigorous walking; movements general and regular; head depressed; no hopping. (2.)	No evident loss of activity or of power of co-ordination. (3.)
Salamander ...	1 to 112	The animal which suffered least walked regularly, naturally, and for considerable distances; it made regular swimming movements, which were wanting in vigour; all the limbs were used as before. (3.)	Walked well, and swam vigorously and steadily; all the limbs used naturally; more quiet than natural. (1.)	Walked in an irregular manner and rolled over and over in water with much rapidity; made efforts to steady itself.—*Note.* Not possible to be quite certain of amount of injury. (2.)
Common Toad.	1 to 101	Shuffled about on the belly with irregular movement, which could scarcely be called walking; hind legs used most; appeared sensitive; tried to remove irritation from any part of the skin. (2.)	Holds the head down; walks about freely, regularly, and well; swam naturally, but feebly; hind legs used most. (3.)	Fore legs rather straighter than natural; walking and swimming with natural regularity and activity. (2.)
Land Tortoise.	1 to 42	For several hours walked about slowly for short distances, in curves; excited to more active movement by putting in water; movements ceased two days before death. (2.)	Walked about as well and as actively as before operation. (1).	Great loss of activity; in 2 cases remained without motion for 4 days; movements then few and sluggish and stilted. (3)

Eel	1 to 40	Wriggled the fore part of the body, and made a few half turns over without rotating ; no movement produced by irritation ; became motionless, and died in a few hours. (1.)	Turned over many times in both directions ; jerked and wriggled when touched ; lived 12 hours. (1.)	Rolled over and over in water and swam backwards, and often belly upwards ; motor power scarcely diminished. (2.)
Water Tortoise	1 to 33	Walked about slowly with stilted limbs ; swam regularly ; hind legs most used ; often walked backwards. (1.)	Walked in a natural, even, and rapid manner ; swam naturally ; became torpid, and moved little except when irritated. (3.)	Walked and swam actively, though less disposed to move than natural ; always raised itself on tiptoe to utmost extent of limbs. (2.)
Perch..... ...	1 to 16	Lay motionless, with occasional gasp ; no locomotion or posture ; frequent spasmodic twitching of anterior part of trunk. (1.)	Lay on side nearly motionless, but breathing regularly ; now and then slight lateral movements of body; occasional convulsive start ; no locomotion or posture. (2.)	Swam about a great deal, with continued rotation, using all the fins ; movements sudden ; when at rest trunk bent ; gradually became prostrate and died in 6 hours. (1.)
Pike	1 to 15	Immediate collapse and apparent death ; breathing at once ceased ; in an hour became stiff. (1.)	Great collapse, but after a few minutes partially recovered and swam about on its back with the use only of the tail ; motions continuous ; anterior fins flat against the side. (1.)	Lay on side motionless, but breathing ; did not swim, but jumped about actively when out of the water, and bit at a thermometer put into its mouth. (2.)
Dace	1 to 12	As if dead ; a little irregular gasping for a short time, and scarcely perceptible twitching of tail ; in half an hour all evidence of life ceased. (1.)	Swam about for a few minutes, lying belly upwards, using only the tail, while the anterior fins were motionless ; steadily preserved the same posture, but movements became fewer, and in an hour it died. (2.)	Swam rapidly, with rapid and continuous rotation ; often lay motionless, but sprang quickly away if touched. (1.)
Tench.....	1 to 12	Floated on side perfectly motionless ; breathing reduced to an occasional gasp ; 8 hours after the operation a convulsive movement took place when it was grasped. (1.)	Lay on side, breathing regularly, with now and then a little flexion of trunk and movement of tail ; struggled when grasped ; no posture or locomotion. (1.)	Swam about with rotation or oscillation ; fins and tail used ; sprang away when touched ; agitated by sound ; in one case 15 revolutions, on long axis, in a minute. (2.)
Common Carp..	1 to 10	No further movements except an occasional slight jerk when touched ; breathing continued ; lay on side.	Remained for some time in normal posture ; bent trunk when taken hold of ; swam in a feeble manner, not using anterior fins. (5.)	Lay motionless, and appeared as if dead, but respiration continued for 3 days. (1.)

Subject of experiment.	Proportionate weight of cerebellum to central nervous system.	Whole encephalon removed or isolated excepting medulla oblongata.	Possessing medulla oblongata and cerebellum.	Possessing medulla oblongata and cerebrum.
Golden Carp ...	1 to 10 (?)	Immediate collapse and death. (1.)	Much collapse; very trifling movements; speedy death (much loss of blood). (1.)	Swam about actively, using tail and fins, but with continued oscillation, like a ship at sea; sprang away actively when touched, and was agitated by sound. (2.)
Pigeon	1 to 9	.. ..	Tremulous convulsions; animal made progress along the ground by flapping the wings in an irregular manner; in 5 minutes expired. (1.)	Bird lay as if dead, except that breathing went on regularly; the eyes remained wide open, but were not sensitive; the body was very flexible, but retained any posture it was placed in; 2 convulsive attacks; death after 5 minutes. (2.)
Guinea Pig ...	1 to 9 (?)	... ...	Slight convulsive action, which subsided, leaving him as if dead, but with heart beating and respiration active; convulsive start and a cry on pinching any of the limbs. (1.)	Giddiness, staggering, loss of power in hind legs; rolled in both directions; scratched nose when it was irritated; pawed, chiefly with fore legs; convulsion; lived 24 hours. (1.)
Stone Loach ...	1 to 9	No sign of life, except that when the tail was pinched a little flexion of the trunk was produced. (1.)	Swam about steadily, but for short distances, using only trunk and tail; anterior fins motionless. (1.)	Posture normal but quiet, except when irritated; then made sudden, impulsive movements, with rapid rotation; all the members used. (1.)
Rudd	?	Lay on side, giving only one feeble flexion of tail; no posture or locomotion; breathed for about half an hour. (2.)	Swam steadily, but in unusual positions, without the use of the anterior fins. (2.)	After irregular movements swam actively, with oscillation, using tail and fins; occasional sudden movement, as if from convulsion. (2.)
Gudgeon	1 to 5	Lay as if dead, irregular gasping for about half an hour, and a scarcely perceptible twitching of tail. (1.)	After collapse had passed off made feeble progression by means only of trunk and tail; soon became motionless and expired. (2.)	Rotated and oscillated, all members used; often quiet, but sprang away suddenly when disturbed by sound or touch. (1.)

of the trunk when touched. On the following day they were both unmistakeably dead.

Two others underwent the same injury, as far as the cranium was concerned. In one the cerebellum was left attached to the medulla, while the whole of the cerebrum was removed. He now coiled himself up, and so remained for about an hour, he then recovered some power of movement. When held suspended by the tail he assumed a corkscrew shape, and revolved quickly in this position. On the ground it shuffled along in a peculiar manner, not using the head upraised and alert, as is the habit of snakes, but pushing it along by the motion of the trunk, while it and the neck remained passive. When a thermometer was put down its throat, it coiled its tail round a support and pulled steadily against it. When the parts came to be examined, it was found that the cerebrum had been completely separated, as intended, and that the cerebellum was left, but one side of the latter organ had been slightly injured.

In the other the section was made a trifle in front of the junction of the optic tubercles with the medulla, so as to ensure the integrity of the cerebellum. The same peculiarity of movement was noted regarding the head and neck, but no rotation took place. The animal was sluggish, but locomotion took place to a considerable extent when the animal was disturbed.

Hence it appears that the possession of the cerebellum gives a power of movement limited to the trunk, enough to produce locomotion, and that this is of a kind to be adapted to external circumstances. It further appears that a lateral injury to the cerebellum gives a lateral inequality to the movements.

Frog.—Two similar frogs were taken, and the same opening was made in the skull of each. A vertical transverse section was then made scrupulously in the same position in both, so as to separate the optic lobes from the cerebellum and medulla. In one the cerebellum was afterwards removed from the medulla, while in the other it was left.

The frogs were placed together for the sake of comparison.

The animal which retained only the medulla had immediately after the operation a transient convulsion, which was followed by a minute or so of prostration. It then walked slowly and with difficulty, as if the limbs were heavy. The fore-legs were peculiarly motionless. It continued very sluggish. It could not be stimulated to change its place, though when a limb was pinched, it wriggled with a perseverance suggestive of pain. In water the movements were few, irregular, and restricted to the hind legs. During the night following the experiment it died. The medulla was found quite separated from everything else, and unhurt.

The companion, who still possessed the cerebellum, after a temporary prostration, began to walk with considerable vigour. The head was depressed, though it was sometimes raised as the animal stepped. It continued to walk in a tolerably rapid and active manner when disturbed, though it did not hop. It swam in water with general and regular movements. It lived two days. The medulla and cerebellum were uninjured, and separate from the cerebrum.

In another frog, the cerebrum was cut away from the rest of the encephalon, leaving the cerebellum in its normal relation, as already described. After collapse of the duration of a minute or two, the animal began to walk about, and continued to do so much as before the operation. It however did not hop. Excepting in the last particular, no loss of motive power could be made out. On the following day the cerebellum was taken away also. The animal then was able to make only few and feeble movements, scarcely enough to produce locomotion. When put on its back it made ineffectual efforts to turn over. It remained in much the same condition for two days, and then expired. The medulla was uninjured. The cerebellum had entirely disappeared, and the cerebrum had been completely cut away.

In order to limit with more certainty the motive power which belongs to the medulla, another experiment may be quoted. A transverse section was made across the brain, close behind the attachment of the cerebellum, so that the medulla oblongata only remained in connexion with the cord and limbs. The animal was no longer able to walk except in a peculiar manner; it shuffled along with the belly upon the ground and the head depressed. There was more power in the hind than in the fore legs. The hinder parts of the animal were, in consequence, often pushed underneath the head, so that the creature fell over backwards. It was unable to turn over when on its back, though it made attempts to do so. The pupils were contracted; the eyes half shut. Ammonia to the nostrils caused great agitation. The section was afterwards found to have exactly separated the medulla from the cerebrum and cerebellum.

The proceeding was repeated in another animal with closely similar results.

It hence appears that the movements which depend upon the medulla and cord are feeble, irregular, and almost restricted to the posterior members. The limited amount of locomotion which is possible has not the regularity proper to walking or swimming. The addition of the cerebellum gives a distinct increase to the motive power of the trunk and limbs; regular and combined movements become possible, so that walking and swimming, though weak, are scarcely unnatural.

Toad.—By a proceeding such as has been described, the cerebrum and cerebellum were detached. At first attempts to move were made, which were unsuccessful, because the fore legs did not second the hind; afterwards, however, all the limbs were used, the anteriors very feebly. The result was a little progression, which could scarcely be called walking. The creature shuffled along on its belly, and on one occasion was found to have moved several yards from a marked position. In water irregular movements were made, chiefly of the hind legs. A drop of ammonia was laboriously scratched off its body by the hind legs. It attempted, but in vain, to turn over when put on its back. When after six days it died, the operation proved to have been performed as intended.

In a successful repetition of the experiment, the animal walked a

foot or so after the operation, but soon became quiet, only moving when irritated, and then but for a short distance, with a feeble and irregular action. It shuffled along with the head depressed, and the belly upon the ground. In water, it either fell to the bottom motionless, or made swimming movements of a very feeble and irregular character. It made efforts to remove ammonia from its skin, first with the hind leg of the same side, and when this was held, with the corresponding fore leg.

The same injury to the cranium was now inflicted in a similar animal, and the cerebrum only separated. The animal carried the head depressed, but walked much, regularly, and naturally. In water it was sluggish, but swam in a normal manner on the surface. Both on land and in water the hinder limbs were used more than the anterior.

The results of two successful repetitions of the experiment may be shortly given. In the first, after a very temporary prostration, the creature walked for a considerable distance with the nose upon the ground. It used the limbs naturally, with even and continuous motion. It did not hop, and was apt to remain without movement until disturbed. It then walked nearly as well as before the operation. The hinder limbs evidently retained more freedom of movement than the anterior, and the creature was particularly prone to go backwards. It swam when placed in water, using chiefly the posterior limbs. The attitude was natural when at rest.

The second walked off with much rapidity immediately after the section. It went considerable distances with a persevering and not unnatural walk. It made attempts to hop, but not with enough force to raise it off the ground.

It must appear from these experiments that the possession of the cerebellum is followed by a gain in the power of moving the limbs, and of a certain regularity in their action which did not before exist. It is obvious that these acquisitions were due simply to the possession of the cerebellum, since in the two classes of experiments the cerebrum was cut away scrupulously in the same situation, the external injury was the same in both, and the only difference between them was in the possession of the organ in question.

It further appears that the cerebrum has a greater control over the anterior than over the posterior members.

Water Tortoise.—In a small animal of this species the cerebrum and cerebellum were taken out of the skull, so that only the medulla oblongata remained, which on subsequent examination was found to have escaped injury. The severance had taken place close behind the optic lobes.

At first, no movements were made excepting frequent opening and shutting of the mouth. The limbs were pulled in on irritation. In the course of an hour it walked six or seven inches, in a very peculiar way, with the limbs straightened and the body lifted as high as possible. When put on its back it made unsuccessful attempts to turn over. In water tardy swimming movements were made, the hind legs being used in chief. At times the movements seemed regular, while some-

times the limbs of one side were used without those of the other. On the second day after the operation, it walked more than a yard backwards with much rapidity. Irritation caused much agitation of the limbs, and occasionally a cry. The peculjar stilted gait remained, but the movements became feebler, and death took place nine days after the operation.

In a similar animal, the cerebrum was separated from the rest of the encephalon by a transverse section. It was found by several failures that it was very difficult to cut exactly between the optic lobes and the cerebellum without injuring the attachments of the latter to the medulla. In this case, therefore, the incision was commenced in the substance of the optic lobes, and then carried downwards and backwards so as to isolate all their inferior part, with the rest of the cerebrum, while some of their upper part was left as a protection to the cerebellar attachments. Eventually the medulla was found in normal connexion with the cerebellum, and attached by a slender isthmus to a remnant of the optic lobes.

Immediately after the operation the animal walked with much rapidity for several yards, in a perfectly natural and even manner. In a few minutes it became quiet, but always walked naturally, and with considerable vigour when irritated. When put in water it always remained motionless for a short time, and then swam in a perfectly natural manner. Excepting in its sedentary habits, it was not different from an uninjured animal. The evenness of its gait was a marked contrast with the kind of movements which followed the removal of the cerebellum.

In one instance, the section appeared to have passed exactly between the optic lobes and the cerebellum without injuring either. The animal walked about freely afterwards, and swam well. The movements were as before the operation, with the single exception that the right limbs were rather less active than the left. On dissection, a trifling injury was found upon the left cerebellar attachment.

In another experiment, the right attachment was unintentionally injured. The animal walked and swam, but with only three legs. The left hind leg was always kept within the shell, and offered more resistance than its fellows to being pulled out, so that its power of resistance was inverse to its freedom of motion.

The gain in the power of walking and swimming which follows the addition of the cerebellum is sufficiently evident. If the cerebellum maintains its perfect connexion with one side only, the limbs on the opposite side will acquire more freedom of movement than those on the same. The lateral inequality is more evident in the hind legs. Beside this, movements which with the medulla only were stilted and irregular, with the cerebellum became even and well adjusted. Since in these experiments the cerebrum has been previously taken away, it follows that the "co-ordinating" action is not a modification of impulses which arise in that part of the encephalon.

Pike.—A small fish of this species was removed from water, the back part of the skull rapidly cut away, the cerebrum separated by a

transverse section behind the optic lobes, and the cerebellum detached from the medulla oblongata. The loss of blood was small. The animal became at once collapsed and motionless. It lay on its side in the water, without breathing or any other sign of life. In an hour it was rigid and evidently dead. The portions intended had been cleanly separated, while the medulla was uninjured.

In a similar animal the proceeding was repeated, save that the cerebellum was left in connexion with the medulla. It immediately became prostrate and motionless, but in a few minutes it had so far recovered that it swam, but in a continuous automatic manner, with the belly upwards. The tail only was used, while the anterior fins remained flat against the body. It so continued for about half an hour, when it sunk to the bottom and ceased to breathe. Three hours after the operation it was stiff.

The only difference, on comparison of the parts, proved to be in its possession of the cerebellum; and this, it appears, enabled the second animal to execute regular locomotion by means of the tail; though the anterior members were as incapable of use as in the former case. The movements did not appear to be influenced by external circumstances.

Dace.—A dace suffered the removal of both cerebrum and cerebellum. It then lay as if dead. Carefully watched, a little irregular gasping was observed, and a scarcely perceptible twitching of the tail. It never moved from its position, and in half an hour all evidence of life had ceased. The medulla proved to have escaped injury.

When in the corresponding experiment the cerebellum was allowed to remain, the animal swam about for a few minutes by means only of the tail. It moved quite steadily, but with the belly uppermost. The movements became fewer, and in an hour it was dead. The operation had been performed as intended. It was repeated with similar results.

The power of using the tail so as to produce locomotion is seen here, as in other experiments, to depend upon the possession of the cerebellum. The influence of this organ appears to stop short of the anterior fins.

Carp.—In the manner already indicated, the cerebrum and cerebellum were both separated from the medulla oblongata of a moderate-sized gold fish. It became immediately prostrate, and no further sign of life was observed. The operation proved to have been done as intended.

The effect of the removal of the cerebrum by itself will be seen in the following example. The cerebrum was isolated by a transverse section, so that when subsequently examined, the cerebellum only was found to be in connexion with the medulla, which, like itself, was perfectly uninjured.

After the operation the fish swam for a short distance without the use of the anterior fins. It then became still, and lay on the top of the water breathing regularly. It soon discharged air and sunk to the bottom, where it lay on its side. When touched it responded by

a movement of the trunk. In about twenty minutes the creature began to use the tail, and by its means raised itself gradually into an upright posture, which it retained for a minute or so, and then fell over on the opposite side. This was repeated a good many times, and afterwards the animal swam forwards by a few strokes of the tail. All this time no use had been made of the anterior fins. They were generally flat against the side, but were floated out by disturbance of the water; and it was noticed that on touching the side of the body the corresponding fin jerked, as if by a reflex action. The animal remained in the same state until it died two days after the experiment.

A repetition of the same proceeding might have been described in almost the same words. In this case it was noticed that for a time the anterior fins jerked with the inspiration. They swayed with the water, as in the first case, and were not used to effect the movements of the fish.

The same experiment was performed upon two other fish of the same species with similar results. In another, in which the cerebrum had been taken out of the cranium, the loss of blood was very great, and death almost immediate. The power of using the tail and trunk so as to maintain a posture, and even to produce a certain amount of locomotion, is here seen to depend upon the possession of the cerebellum. The total prostration and speedy death which followed the removal of both cerebrum and cerebellum were so accordant with what has always been found in fish under the same circumstances, that it was not judged necessary to repeat the experiment.

From the preceding experiments the effect of the addition of the cerebellum to the medulla may be thus stated as regards reptiles.

The snake with the medulla only is incapable of locomotion, or of any movement directed to a purpose. On the addition of the cerebellum it acquires a power of regular locomotion, which depends entirely on the muscles of the trunk; the head remaining passive.

The salamander, with only the medulla oblongata, is only able to make feeble and irregular movements, though it will make attempts to get rid of an irritation. With the cerebellum it becomes able to walk and swim in a natural manner.

Frogs, toads, and both kinds of tortoises, are able with only the medulla to make progression in a feeble, awkward, and irregular way; and will execute certain actions called for by external circumstances. Their fore legs retain much less power than the posterior. With the cerebellum added, these creatures are enabled to walk and swim in a regular and natural manner; the anterior limbs, however, wanting in motor power.

With regard to fish, it appears that the medulla oblongata, in every species experimented upon, is insufficient to give rise to any locomotion, to the maintenance of posture, or to any act not obviously involuntary. The great prostration and speedy death of some individuals, particularly perch and tench, after the removal of the cerebrum, made it impossible to draw positive conclusions from all the experiments.

The following results were obtained :—With the addition of the cerebellum, eels became able to turn about with some freedom; pike, dace, carp, roach, rudd, and gudgeon are enabled to preserve a steady though not always an erect posture, and to move along in the water with the aid of the tail and trunk, while the anterior fins remain motionless. These movements are of a continuous kind, and appear little influenced by external causes.

Hence it appears that in those animals where the movements which belong to the cord and medulla are few and insignificant, where they are insufficient to produce locomotion or to maintain an unstable posture, the addition of the cerebellum generally gives both these capabilities.

In certain reptiles where feeble and irregular locomotion can be produced by means of the cord and medulla, the addition of the cerebellum gives a marked increase in the motor power of the limbs, and so adjusts their action that most of the movements of the animal are naturally executed.

Furthermore, it is a necessary conclusion that since the removal of the cerebrum in reptiles weakens, and in fish paralyses, the anterior extremities, that these members derive thence a large proportion of their motor power; while, since the hinder limbs and the trunk are not thus affected, it must appear that the cerebellum with the medulla and cord are the main centres by which these parts of the body are moved. The preceding deductions must show how much of this power is due to the cerebellum, and how much to the cord and medulla.

REMOVAL OR PARTIAL DETACHMENT OF CEREBELLUM.

Snake.—In three of the animals of this species which were experimented on, the cerebellum, as appeared by subsequent dissection, was completely removed without any further injury.

One never recovered from the immediate prostration, and died in a few hours; the others soon began to move about pretty freely. They were ready to take alarm when approached, and one of them escaped from a basket in which it was kept. The head was carried upraised and on the alert, and the tongue was used with its ordinary vivacity. It was noted, however, that on land, and more particularly in water, there was a tendency to move with the belly uppermost; but there was no rotation. There appeared to be in each case a loss of habitual activity; they lay motionless for long periods unless disturbed; but it was not possible to say that this deficiency was more than must be ascribed to the wound in the cranium.

The only effect that must necessarily be ascribed to the loss of the nervous centre is the failure in lateral balance.

In another experiment, similar in all respects, excepting that the cerebellum retained an attachment on one side, the same general stillness was observed, and the same rapid and irregular movements on agitation or in water. But a striking peculiarity was noticed. Whenever it was held up by the tail, which was done repeatedly, it twisted into a corkscrew shape and rapidly revolved in this position,

so that the tail became twisted until it was in danger of breaking, which it eventually did. The rotation took place in both directions. An experiment has been already recorded in which the same rotation followed a lateral injury to the cerebellum, the cerebrum having been previously taken away.

Frog.—After the removal of the cerebellum the animal hopped about so briskly as to be difficult to catch, and, as far as could be made out, in a perfectly natural manner. It sprang vigorously and fell with proper elasticity. In water it was as active as ever, and perfectly steady, using the legs regularly, and with the ordinary swimming movement. It attempted to elude capture; and though closely watched, it was not possible to detect any difference from the natural state, in the amount of activity or in the character of its actions. It however had, after putting in water, one or two attacks of transient loss of consciousness, resembling fainting fits. The animal was killed on the day after the operation, and the parts examined. No trace of the cerebellum remained. The ventricle was uncovered, but its edges were quite smooth, and the medulla and optic tubercles were unhurt.

In one repetition of the experiment the same absence of result was noted, with the exception that in hopping the animal fell flat and awkwardly. The first experiment, however, is conclusive, and proves that in cases where further effects may have been observed, some injury must have been inflicted beyond the mere removal of the organ.

In another animal the left attachment of the cerebellum was cut with perfect exactness; the only effect that could be detected was that the right limbs seemed slightly weaker than the left. In its ordinary posture the animal bent down on that side. It however walked, swam, and hopped without any noticeable inequality.

Hence it is clear that, in these animals, the power of co-ordinating voluntary movements depends so little upon the cerebellum, that the organ may be lost without any failure in this respect being apparent. Secondly, it appears that the effect which it has upon voluntary movement itself is not enough to make its loss evident.

It would be, of course, impossible to appreciate a very slight deficiency in this particular.

Toad.—A large, strong toad underwent the loss of the cerebellum; directly afterwards it hopped about with much activity, springing away from a touch; it struggled vigorously when taken hold of. In water it swam steadily, rapidly, and in all respects naturally. It walked quickly and steadily; in all its actions it would have passed for an uninjured animal, and it required close comparison, side by side, with a fresh toad, to render any peculiarity evident. It then appeared that the fore legs were a little straighter than natural, and the shoulders consequently higher; and it seemed that though the creature was as active as ever when disturbed, it was less apt to move of its own accord. There was no diminution of power in any limb, and in its various movements there was certainly evidence of "co-ordination."

It was watched for two days, during which it underwent no

change. It was then decapitated, and the brain examined: the cerebellum was found to have been completely removed; the medulla was smooth and unhurt, and the optic tubercles in the same condition.

In a repetition of the experiment, where, to appearance, the neighbouring parts had equally escaped injury, a decided amount of collapse followed the operation; and when the creature began to walk about it was with a very marked peculiarity of gait: the fore legs were extended, and the head and shoulders raised so high that the animal occasionally fell over on one or the other side; swimming was irregularly performed, chiefly with the fore legs. It was generally without movement save when irritated.

Though the first experiment is necessarily the more conclusive, the greater results in the second must not be disregarded, insomuch as they closely correspond with what takes place in animals where the cerebellum is more developed.

In a similar animal a section was made, with fine scissors, of the left attachment of the cerebellum to the medulla. This afterwards proved to have been done completely and without injury to any other part of the brain. No peculiarity could afterwards be discovered, excepting that the right shoulder was rather higher than the left, more especially as it stepped. It walked perfectly naturally in every other respect, and in swimming no peculiarity of any kind could be seen.

It must be inferred that the loss of the cerebellum in the toad does not entail any necessary loss of regularity of movement or of motor power; the only obvious result is a peculiar stilted manner of using the legs, which, when the organ is cut away on one side only, is productive of a lateral inequality. When the power of using the limbs is unequally affected the posterior suffer most.

It will be seen by reference to the table that all the removals of the cerebellum hitherto reported have been upon animals in which it forms less than one-hundredth part of the central nervous system. The loss of the organ is accordingly little felt.

Tortoises.—In consequence of their more active habits, water tortoises were found to be more adapted for these experiments than their relations of the land.

In one of these creatures the cerebellum was completely taken away, and, as it proved, neither the cerebrum nor the medulla hurt. The animal remained quiet for a short time, and then began to move about, but in a very remarkable manner: it raised itself as high as the limbs would extend, and often came down rather suddenly as it stepped forward. It swam with steadiness and activity, and without any observed peculiarity. All the limbs were used. When excited by the contact of water it was always active, though unusually sluggish on land and prone to remain motionless for long periods. It lived for nearly five weeks, and retained for the whole time the peculiarities that have been noticed.

The experiment was repeated several times with precisely the same results—the loss of activity and the remarkable stilted gait.

Land tortoises were found to display exactly the same peculiarities. In them the immobility was more conspicuous, insomuch that two of them, deprived of the cerebellum, remained in the same position each for four days.

The effects of lateral injuries to the cerebellum were ascertained in both varieties. In a large, strong water tortoise all the connexions of the cerebellum to the right of the median line were severed. On dissection, it was found that this had been accurately done. The organ was a little displaced, so as to uncover the fourth ventricle, but it was not damaged itself, and the left attachments were entire. The medulla had escaped injury. The peculiarity of the walk was striking; when stimulated to move, it raised itself high on all the limbs except the right posterior, which remained little protruded, while the other three were extended to the uttermost, as if its cerebellum had been entirely removed. This was calculated to give an erroneous impression that the right posterior limb was used less than the others; while, on the contrary, its freedom of movement was greater. In water, the peculiar gait was no longer evident, but the right members were used more freely than the left, and the anterior more freely than the posterior. These observations were placed beyond doubt by two successful repetitions of the operation. The superior freedom of movement in the limb which was least extended was very evident.

Hence it appears that in the tortoise the loss of the whole cerebellum alters the muscular condition of the limbs, and lessens the habitual activity of the animal. And that if the attachment on one side remain undivided, the hind leg of the opposite side will retain its normal muscular state and its normal activity, while the three other limbs are affected as if the whole organ had been removed.

Perch.—Two similar perch were taken for the sake of comparison, and exactly the same injury inflicted upon each by removing the vault of the skull and exposing the encephalon. One was now restored to the water without further mutilation, while, from the other, the cerebellum was removed, which was done with great ease and celerity. The former swam swiftly, and with perfect steadiness; its behaviour seemed natural in all respects. The second swam with continued rotation on its long axis, to the right or the left indifferently. All the fins and the tail were used. The movements were apt to be sudden, and the speed of the animal was decidedly less than that of its companion. The trunk was bent to one side or the other when the creature was at rest. It gradually moved less, and in six hours was dead. The cerebellum proved to have been removed as intended, without injury to the medulla.

Dace.—It is needless to repeat accounts of the removal of the cerebellum in fish, since the results are the same in all who survive the operation long enough.

After the removal of this organ from a dace, some splashing irregular movements at once took place. It then progressed a little on its back or sides, and as the collapse passed off it swam rapidly, with

rapid and continuous rotations. It was apt to be motionless, but at a touch would dart away rapidly. The tail and fins were alike used. Seven hours after the operation, which proved to have been accurately performed, it was found dead, having jumped out of the vessel in which it was kept.

Gold Fish.—Two gold fish were deprived of the cerebellum in the manner already described. The details of one experiment will suffice for both. Immediately after the removal of the organ the movements of the animal became a little irregular, and it rolled over once or twice on its long axis. It soon recovered so far as to swim about with some activity, but it rolled from side to side like a ship at sea. This unsteadiness was particularly manifested upon any disturbance of the water, or upon the slightest touch on its own body. It did not rotate. When grasped it sprang away with activity, and was agitated by sound. All the fins and the tail were used, as appeared, naturally. It died on the fifth day after the operation.

In fish, the results of the removal of the cerebellum present a great uniformity. The most obvious effect is a loss of lateral balance. No member appears to lose its power of movement, though, so far as possible to judge, the habitual activity of the creature is diminished.

Birds and Mammalia.—The effects of cutting away part of the cerebellum in some of the higher animals have been made well known by Flourens and his imitators. It is also known that after such partial removals as he executed, the loss of "co-ordination" is only temporary. I have made many such experiments as he relates, upon pigeons, and the smaller rodentia, with results similar to those he describes. As an instance of the loss of the whole organ, the following experiment may be cited.

In a guinea-pig the cerebellum was so far removed that only a small crumb of nervous matter hung on to each lateral peduncle. No other part of the brain was damaged.

The animal supported itself on the fore legs, with the head and shoulders elevated, and swayed from side to side. The hinder limbs were spread out flat along the table. He scrambled about a good deal, chiefly from the action of the anterior limbs, though all retained some power of movement. He could not walk, nor stand otherwise than as described. One or two attacks of convulsion occurred. The creature lived about thirty-six hours. He scratched ammonia from his nose with his front paws.

Many other experiments have been made, in which an extensive mutilation of the cerebellum in birds and quadrupeds has been followed by total loss of motor power and speedy death, but from the fact that in other cases like that recorded voluntary acts have been performed where no cerebellum existed, it is clear that the total paralysis is owing to the approach of death.

In such experiments as I have made, involving only a partial removal of the organ, it was proved that with guinea pigs and rabbits there was an invariable loss of the power of walking, while motor action remained more in the fore than the hind limbs. Appa-

rent giddiness, or loss of balance, was conspicuous in some of the cases, the more so the more of the organ had been removed.

In a guinea pig, where a piece had been cut from the left side of the cerebellum, the right posterior limb became spasmodically contracted, while the other hind leg and the right fore leg were affected with continual tremor.

In pigeons the results were very uniform. Staggering with a peculiar drunken manner and wild stare; falling over frequently, backwards or sidewards; finally, as successive slices were taken away, total loss of motor power, the bird lying flaccid and inanimate, but with the heart beating and the respiration active; then death.

It will be observed that these observations upon the higher animals, though less complete, and therefore less conclusive, give much the same results as have been obtained lower in the scale of creation.

As to the negative results of these experiments, it appeared that in no case was the possession of sensation interfered with by the removal of the cerebellum. It was also found that with copulating frogs, the male grasped the female with as much fervour without as with that organ. Fish deprived of it were found not to have lost the activity of their alimentary canal, insomuch as shot introduced into the œsophagus, made the passage of the bowels as if no mutilation had been performed. Observations were made with a delicate thermometer, constructed for the purpose, which proved that the temperature in the œsophagus was not invariably altered by the removal of the cerebellum; and in cases where it was reduced by the operation, it was to so small an extent that it was believed to be no more than the loss of muscular activity in the animal easily accounted for. Finally, abundant secretion was found in the gall bladder, and on the mucous membranes, in animals which had lived for some time without the organ in question. It may, therefore, be inferred that the cerebellum is not concerned as the seat of sensation, nor as a channel for its passage; that it is not the instigator of the sexual propensity; that it is not the source of power for the involuntary muscles; that it has no function which is directly concerned in the maintenance of animal heat; and that it is not the excitor of secretion.

The consequences of the removal of the entire cerebellum may now be summed up.

No faculty is lessened excepting such as concerns the voluntary muscles.

With snakes, where the organ is at a minimum, it is not possible to be sure of any loss consequent upon its removal, excepting a want of lateral equilibrium.

With frogs the consequences are almost inappreciable.

In the salamander, the smallness of the parts renders it difficult to limit the injury with accuracy. A tendency to rotation in water appears to follow the removal of the organ, though it is clear that in the absence of both cerebrum and cerebellum, the animal can walk in a natural manner.

With toads the only effect which is well marked and constant is a

peculiarity in the use of the limbs, which are more than usually extended.

Tortoises, of both kinds, display in a more marked degree the stilted manner of walking. They also lose much of their habitual activity. This loss has been noticed in the previous cases, but it was not possible to state with certainty that it was more than followed from the external injury.

Of fish, eels swim backwards, roll over and over, and appear to possess diminished activity. Perch, dace, tench, carp, loach, rudd, and gudgeon, manifest a remarkable tendency to rotate or oscillate upon their long axes, and on comparison, their swiftness and habitual tendency to motion are found to be diminished. All the members are used.

Pike become prostrate, and die too soon to allow of any trustworthy estimation of the effects of the injury.

Pigeons scarcely survive the removal of the whole organ long enough to display the characteristic effects.

Guinea pigs manifest a loss of lateral balance, and of motor power in the posterior limbs.

The effects of detachment of the cerebellum from one side only may be thus stated:

In snakes there is a remarkable rotation when the creature is suspended by the tail. Frogs lose, under similar circumstances, a slight amount of power on the side opposite to the injury, and toads present a lateral unevenness of gait. In tortoises there is the same uncalled-for extensions of the limbs, and loss of freedom of movement, as take place in the total absence of the organ, with the exception that the posterior limb on the side of the injury completely escapes in both particulars. In the guinea pig, an injury on one side of the organ was found to produce a spasmodic constriction and loss of mobility in the hind leg of the opposite side.

Thus it may be generally said that, when the cerebellum is very small, its removal is scarcely productive of any effects. As it increases in size, a want of adjustment in the muscles of each limb is noticeable, and there is a want of co-operation between the two sides of the body. There also becomes evident an absolute loss of motor power, with a diminished tendency to spontaneous movement. A lateral inequality of action is produced by a lateral injury to the cerebellum, the deficiency being on the contrary side to the mischief. Lastly, when the power of movement is unequally affected in the anterior and posterior extremities, the posterior lose most.

A series of experiments was made upon the water tortoise, with a view of defining the action of the cerebellum upon the voluntary muscles.

The natural posture of these creatures, when quiet, is with the limbs hidden in the shell. If a limb be pulled out the animal will try to withdraw it; and if the limb be irritated by pinching, the efforts will be increased as far as the strength of the member allows. The weight that a limb is able to raise under these circumstances is a measure of its strength.

It was found in this way, by many trials which need not be given in detail, that—

1. The removal of the cerebellum is followed by no loss of lifting power in any limb, or by so slight a loss, equally distributed, that it may fairly be assigned to the loss of blood and general effects of the wound.

2. The cutting of the cerebellar attachments on one side does not produce any inequality in the lifting power of the right and left limbs.

3. The removal of the cerebrum, or decapitation, has little or no effect upon the lifting power of the hind legs, but diminishes by about one-third that of the upper limbs.

From these facts it may be concluded that in the tortoise the cerebellum has no share in such movements of the limbs as are directly in answer to a local stimulus. It appears that such movements in the hind legs depend entirely, in the fore legs chiefly, upon the cord. It is probable that actions of this nature are such as must be termed instinctive or reflex; and hence it appears that whatever the cerebellum may have to do with voluntary, it has no part in the production of reflex actions.

DEDUCTIONS FROM HUMAN PATHOLOGY.

It is necessary to use caution in applying the facts of clinical medicine as a guide to the functions of the cerebellum. This organ is so enclosed and connected that an addition to its bulk must often compress adjoining structures; and it is believed that the question of its functions will be much simplified by leaving out of consideration all cases where the disease has been a morbid growth, an abscess or an extravasation of blood. In each of these conditions there may be an uncertainty how far the results are due to the loss of cerebellar structure, and how far to pressure on the medulla oblongata.

It will remain to examine cases of congenital deficiency of the cerebellum, and cases of morbid alteration pervading its tissue.

In collecting the examples, great care has been taken to exclude those in which disease of any other part of the nervous system may lead to uncertainty as to the origin of the symptoms.

There are but two instances of congenital deficiency:

1. Alexandrine Labrosse died at the age of ten years in the Saint Antoine hospital. The details are very fully given in Magendie's 'Journal of Physiology;' and as to the post-mortem appearances, we have the evidence of Majendie himself, who dissected the brain, and of Cruveilhier, in whose great work it is represented.

The cerebellum was entirely absent, as also were the pons Varolii and the cerebellar peduncles. The occipital fossæ were occupied by serous fluid, and a semicircular band of areolar tissue lay across the medulla in the place of the absent organ.

The child had been generally slow in development, especially in the lower limbs. She could not stand until she was five years of age. When nine she was apparently paraplegic. Subsequently the legs, although very weak, allowed of her standing, though she often fell.

She then took to her bed, where it was observed that she could hardly move her legs, which, however, were not wanting in sensibility. The hands and upper limbs appeared always to have been used naturally. She was addicted to masturbation. She eventually died of a disorder of the bowels. She had been epileptic and nearly idiotic.

This conclusive case affords a confirmation of the deductions which have followed from other evidence. No special sense suffered, nor was ordinary sensibility impaired. Voluntary motion was diminished but not destroyed, and the loss was mainly evinced in the lower limbs. "Co-ordination" was executed naturally. The epileptic fits and the feebleness of intellect may be presumed to depend upon some alterations in the remaining parts of the encephalon.

2. A man, forty-four years of age, died in the Guernsey Hospital. His brain was exhibited at the Pathological Society by Dr. Salter, and Dr. Cockburn supplies the details of the case. The left hemisphere of the cerebellum, as well as the central parts of the organ, were altogether absent. The right lobe only remained. The various peduncles on the left side were absent, while those on the right were perfect. A condition of chronic hydrocephalus also existed. The patient from whom these parts had been taken was a deformed idiot. "Taste, sight, hearing, smell, and touch were all perfect. He never walked, but could use his arms as far as his deformity allowed him." He was epileptic, and was addicted to masturbation.[1]

It is to be regretted that this patient had not been more minutely observed during life, but as far as the record goes it appears that the same loss of power in the lower extremities took place here as in the preceding case. Both legs appear to have been equally affected. The epilepsy and the want of intellect may be ascribed to the morbid state of the cerebrum.

In the tables are the details of thirteen cases of softening of the cerebellum and three of active congestion.

TABLE I.—SOFTENING.

Reference.	Post-mortem appearances.	Symptoms.
1. Arch. Gén., Dec. 19, 1862.	Softening of entire cerebellum.	For a long time trembling in the lower limbs, which gradually became weakened. In a man 65 years old.
2. Jour. de Physiol., Magendie's, vol. vi. p. 162.	Cerebellum entirely disorganized and transformed into a white "bouillie."	A soldier, who was struck on the back of the head. Peculiar condition of vision; no absolute paralysis, but an inability to walk except backwards, and for a few feet only; head always supported by hands; sudden death 13 days after accident.

[1] Pathological Transactions, vol. iv.

Reference.	Post-mortem appearances.	Symptoms.
3. Lancet, 1855, p. 210.	Cerebellum universally softened; disease of lung, liver, and kidneys.	For 15 years gradual loss of power in lower extremities; able to walk by means of a stick, but when hurried fell down. When spoken to quickly, legs thrown into a state of convulsive agitation; addicted to masturbation, and extremely fond of women; incontinence of urine; sudden death.
4. Lallemand, vol. ii. p. 39.	Membranes of cerebellum depressed and wrinkled, and containing only half an egg-shell-full of brown, fœtid, sero-purulent fluid.	Man 49 years of age. Dull pain in the head; for one year vertigo and vomiting; staggering on the legs, and inclined to fall forwards.
5. Jour. de Physiol., Magendie's, vol. iii. p. 137.	Circumscribed softening, 9 lines long, 5 wide, in the right lobe, opposite to attachment of the peduncle; the rest of the lobe harder than the left; ulceration of bowels.	Man 68 years old. After drinking turned round repeatedly from right to left; loss of consciousness; hemiplegia of left side—this remained permanently in the leg, while the arm partially recovered, so that he could work as a shoemaker; no loss of sensation; death from diarrhœa.
6. Ibid., p. 139. (Serres.)	Left lobe softened from the upper to the lower vermiform process, also the left peduncle; left side of pons harder than right; lungs and bowels diseased.	A journalist, 66 years old. Sudden and complete loss of use of right leg, without any loss of feeling; the limb became shrunk. Stammering for 8 months before death, which was apparently chiefly due to disease of chest and bowels.
7. Amer. Journal of Medical Sciences, Feb. 1839.	Left lobe collapsed to $\frac{1}{5}$th the size of the right; the whole interior destroyed from the cores downwards; a shell only left, a line or two in thickness; the cavity occupied by a delicate, brownish tissue and some serum; a minute coagulum in crus.	Man 72 years of age. Four years before death severe pain in left side of head, dizziness, and appearance of objects whirling round from left to right. Two years before death hemiplegia of right side; revival of sexual feeling to the extent of a "morbid salacity," which decreased before death; latterly no emission; imbecility, epilepsy, delirium, stupor, death.
8. Medico-Chir. Trans., 1849, p. 107. (Mr. Dunn.)	Whole inside of right lobe softened and pulpy, small clot in its centre; median lobe also softened; convolutions of brain and optic nerves shrunken; mesocephale unhealthy in appearance.	Enfeeblement of mind; impairment of sight; constant desire for sexual intercourse; latterly loss of virile power; weakness and stiffness of left leg and foot; unsteadiness of gait; apoplectic attack—death four hours afterwards.
9. Lallemand, vol. i. p. 134.	White substance of left lobe reduced to pulp; membranes and substance of brain slightly injected.	Man 56 years of age. Loss of consciousness and paralysis of right side, which remained immovable; commissure of lips drawn to left; loss of sensibility in eye and lid of right side; death in 8 days.

Reference.	Post-mortem appearances.	Symptoms.
10. Andral, vol. v. sec. 2, Case 1.	Mass of softening occupying ⅔rds of the right lobe of the cerebellum, which somewhat affected the crura; pia mater generally injected; ventricles distended with clear serum.	Woman 31 years old. Gradual accession of hemiplegia of left side, commencing with the arm; amaurosis; pain in the head; intelligence unaffected; no loss of sensation; convulsive movements in paralysed limbs; coma.
11. Ibid., Case 2.	Yellow softening as large as a nut in the centre of the left lobe; large recent effusion of blood in the left hemisphere of the cerebrum.	Man 53 years of age. For two months pain at the back of the head; gradual loss of power in the extremities of the right side, latterly with contraction; no loss of sensibility; sudden attack of apoplexy, which proved fatal in a few hours.
12. Ibid., Case 3.	Two-thirds of right hemisphere of cerebellum only existed in form of "bouillie;" no other change.	Shopkeeper, 29 years old. While in apparent health, sudden cry, apoplectic fit, convulsive agitation of the four limbs; return of consciousness in less than an hour, but complete hemiplegia of left side, with loss of sensibility. After 7 days, seizure exactly similar to the first, after which coma and death.
13. Ibid., Case 4.	Membranes injected; reddish softening of left lobe of cerebellum, its posterior and inferior half.	Groom, 39. Pain in head, after a time concentrated in occiput; giddiness; vision weakened on right side; no loss of power or of sensibility in limbs, but all four were convulsively agitated; muscles of respiration similarly affected; intelligence dull, but no loss of consciousness; death from apnœa.

Table II.—Congestion.

Reference.	Post-mortem appearances.	Symptoms.
14. Jour. de Physiol., Magendie's, vol. ii. p. 173. (Serres.)	Lobes of cerebellum greatly injected, as also were the superior and inferior peduncles, in which were points of extravasation; tuberculæ quad. slightly injected; genital organs congested.	Man 32 years old. Attack of apoplexy while in the act of intercourse; unconsciousness; from time to time seized with convulsive movements and tetanic rigidity, which lasted several minutes; erection of penis and heat of genital organs, contrasting strongly with coldness of extremities.
15. Ibid., p. 179. (Serres.)	Volume of cerebellum increased, and of a red colour; medullary substance of a bright red; little extravasations on surface and in substance; tuberculæ quad. and processes and testes reddened.	Man 46 years old. Apoplectic attack; somnolency; general spasmodic and convulsive movements; respiration slow and irregular; erection and congestion of penis, with much ejaculation of serum; heat of genital organs; limbs stiff; increased satyriasis; death day after attack.

Reference.	Post-mortem appearances.	Symptoms.
16. Jour. de Physiol., Magendie's, vol. ii. p. 262.	Induration and redness of superior and inferior vermiform appendices, in front of which is some softening; cerebellar arteries enlarged, as also are those of the pelvic organs.	An irreclaimable prostitute, 33 years of age. For last 4 years violently given to masturbation; became imbecile, and died of phthisis.

Softening.—The whole organ was softened in four cases. In none was any loss of sensation reported. In each there was a loss or alteration of the power of using the lower extremities, and not the upper. In one, the patient could only walk a few feet, and that backwards. In another, he staggered in walking and frequently fell forwards. In the two others, the lower limbs gradually became weakened, and were affected with convulsive or tremulous movements. A peculiar condition of sight in one case, and genital excitement in another, complete the symptoms ascribed to softening of the entire organ.

Nine cases are reported where one lobe of the cerebellum was softened while the other remained natural.

In one, in which the affection was limited to a part of the lobe, there was comvulsive action of the four limbs, without any apparent loss of power. In the rest, the limbs on the side opposite to the mischief were enfeebled. The loss of power was in every case either equally distributed between the upper and lower limbs, or was chiefly marked in the lower. The latter condition was observed in three instances. Once, where the paralysis was observed to have commenced in the arm, the crura cerebelli were included in the morbid change.

The only other symptoms which occur often enough to suggest any pathological connexion, are impairment of vision, which was noted in three cases, and genital excitement, which took place early in the history of two, while later in their course the virile powers were impaired. Common sensation and intelligence were generally noted as unaffected.

Cases in which the cerebellum is simply softened furnish probably the best physiological experiments which nature is capable of making. There is no product which can occasion pressure upon neighbouring organs, or affect them in any injurious manner. Such symptoms as arise, then, may be fairly attributed to the deficiency of the cerebellar tissue, and this deficiency is generally extensive, since no limiting membrane or abrupt boundary preserves to use any part of the lobe which is the seat of the disease.

The loss of power in the voluntary muscles, which was the prominent symptom in every case, was confined to the trunk and limbs with so much consistency, that we must necessarily conclude that the cranial nerves derived none of their influence from the organ to which the change has been confined.

The more marked effect upon the lower than upon the upper limbs accords with what has been deduced from experiments on animals.

The next table contains three cases in which the organ, without any limitation to one lobe or the other, was the seat of active con-

gestion. A prominent symptom in all was genital excitement. In one, there were frequent attacks of convulsive movement, with tetanic rigidity; in another, there were convulsive or spasmodic movements, with stiffness of the limbs; while in the third case, in which the morbid condition was not general, no disorder of the motor powers was noticed.

Drawing such conclusions relating to the function of the organ as follow from the foregoing details, it must appear that the only faculty which constantly suffers in consequence of destruction of the cerebellum is the power of voluntary movement.

In the two cases where it was absent or defective as a congenital state, there was want of action in the muscles of the lower extremities. Where the entire structure was changed by disease there was always loss of voluntary motor power, either general throughout the trunk or limited to the lower limbs. Where the whole organ was softened, there was in every case loss of power confined to the lower extremities. Where it was generally congested, tremulous or convulsive movements affected all the limbs. Unlike what takes place in cerebral disease, the faculty of superficial sensation was always unimpaired.

Of the cases where a morbid change was limited to one lobe, there was one where all the limbs were affected with convulsive movements, while in the others, eight in number, the loss of power was only in the limbs of the opposite side. In three of them it was most marked in or confined to the leg.

We are thus warranted in concluding that in the human being the cerebellum is an especial source of motor power to the lower limbs, each lobe mainly effecting the leg of the opposite side. It further appears that the organ has a more remote influence of the same sort upon the upper limbs. It is certain that it has no effect upon the mobility of the parts supplied by the cranial nerves.

It is scarcely needful to review the effects upon the genital organs, and upon the visual power, which are recorded in some of the cases of cerebellar disease. It is manifest that, since the entire organ may be congenitally absent, without any impairment of the sexual appetite, the cerebellum is not the excitor of that propensity. Similarly, since in the case of congenital absence, and in cases where the whole structure has been destroyed by disease, the eyesight has remained unaffected, it is evident that none of the capacity for vision depends thereon. Both those coincident affections must be ascribed to the conveyance of an influence to parts connected with, but distinct from, the organ in question.

Summary.

Drawing together the deductions from the several divisions of the inquiry, it will be seen that:

1. The addition of the cerebellum to the medulla oblongata gives an increase of voluntary motor power in the four limbs; to the posterior in a greater degree than to the anterior. The power thus obtained is distributed in such a way as to produce even and balanced movements, and appears to be exercised in a continuous and automatic manner.

2. The removal of the cerebellum has an effect upon the muscles of

the limbs, which increases in proportion as the organ increases in size. It consists in a diminution of voluntary power and of muscular adjustment. When an inequality of effect can be noticed, the loss is greater in the posterior limbs. There is a loss of habitual activity. From the effect of lateral injuries, it must be assumed that each lateral half of the organ has an influence upon both sides of the body, but to a greater extent upon that opposite to itself.

3. The removal of the cerebellum has no effect upon superficial sensation, on any special sense, on the action of the involuntary muscles, or on reflex movements.

4. In the human being it appears that there is no constant effect from loss or alteration of the cerebellum, but failure of voluntary muscular power.

Disease or deficiency of the whole organ invariably lessens voluntary power in the limbs especially in the lower. The loss of one lobe produces its effect more particularly on the opposite side. Disease confined to the cerebellum has no effect upon superficial sensation, on the intellectual powers, or on the action of the muscles supplied by the cranial nerves.

Hence it must be believed that the function of the cerebellum is to supply the voluntary muscles of the body and limbs with self-regulating motor power. This is distributed in an inverse manner to the influence of the cerebrum. The latter has the sole control over the parts supplied by the cranial nerves, and the chief control over the anterior limbs. The cerebellum has its greatest effect upon the posterior limbs, less upon the anterior. Thus the muscles of the trunk and limbs are under a double rule. The influence of the cerebellum is apt to produce continuous, and probably habitual movements, which are subservient to the cerebrum, but not dependent upon it.

It is hardly needful to point out that the foregoing conclusions differ materially from those of Flourens. Flourens held that the cerebellum "co-ordinates" voluntary movements. In other words, that the cerebellum regulates the distribution of nervous force derived from elsewhere. He did not assign to that organ any power of originating muscular action. From this inquiry it appears that the cerebellum is the source of voluntary motor power, which it distributes in a regular manner. It harmonizes its own movements, and none others. Movements which spring from the cerebrum owe nothing to the cerebellum. This is proved by the fact, that in the absence of the cerebellum there is no necessary want of co-ordination. Cerebral movements are impulsive, and often irregular, for they are under the direct influence of the mental faculty. Those that belong to the cerebellum are instinctive and habitual, only controlled by the mind indirectly.

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THE END.