MOTOR CENTRES

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IN THE

CEREBRAL CONVOLUTIONS;

THEIR EXISTENCE AND LOCALIZATION.

REPORT ON THE ABOVE SUBJECT, PRESENTED DECEMBER 21, 1874, BY THE COMMITTEE APPOINTED BY THE NEW YORK SOCIETY OF NEUROLOGY AND ELECTROLOGY, CONSISTING OF

J. C. DALTON, M. D, J. W. S. ARNOLD, M. D.,
GEO. M. BEARD, M. D., A. FLINT, JR., M. D.,
J. J. MASON, M. D.

[*REPRINTED FROM THE NEW YORK MEDICAL JOURNAL, MAR.*, 1875.]

NEW YORK:
D. APPLETON AND COMPANY,
549 & 551 BROADWAY.
1875.

THE POPULAR SCIENCE MONTHLY,

(Established May, 1872,)

Conducted by Prof. E. L. YOUMANS.

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In pursuance of the subject referred to them, the Committee have experimented upon five dogs, weighing each from six to eleven kilogrammes. In each experiment the animal was etherized and kept more or less completely under the influence of the anæsthetic during the whole course of the experiment. A portion of the cranium and dura mater was removed on one or both sides, over the convexities of the cerebral hemispheres, for a space averaging five centimetres longitudinally by two centimetres transversely. The exposed cerebral surfaces were then subjected, at different points, to the stimulus of a galvanic current from a battery which consisted sometimes of eight, sometimes of sixteen cells; each cell being composed of a carbon and an amalgamated zinc plate, immersed in a solution of potassium bichromate, one part; sulphuric acid, one part; water, ten parts.

The electrodes were rounded platinum points, insulated by a coating of hard rubber to within a distance of one millimetre from their extremities, and were fixed usually at the distance of one millimetre apart. When in action the galvanic current thus produced was imperceptible on the tips of the fingers, very slightly perceptible on the cheeks, and distinctly

perceptible, though not at all painful, upon the tongue. The Committee have seen reason to believe that the results obtained by using currents of this slight degree of intensity are of greater precision than those obtained with a more powerful stimulus.

The electrodes were placed in contact with the cerebral surface in such a way as not to wound, but only to touch it. As a rule, they were held in contact with the brain, at each application, for about one second. On two occasions they were applied alternately to the surface of the dura mater and to that of the brain, and the difference in the effects noted. The applications at each of the different points were frequently repeated, in order to make sure that the effects produced were not accidental. Thus on seven different occasions, the contraction of certain muscles was obtained by applying the electrodes to a particular part ten times in succession, on one occasion twenty-five times, and on one occasion forty times, with a moderate interval between the applications. The spots on the cerebral surface separately examined were situated from two and a half to five or seven millimetres distant from each other. After a particular point had been found, where the application of the electrodes caused a distinct muscular contraction, the application was repeated until the galvanic current had produced a slight brownish discoloration sufficient to mark the spot; and at the end of the experiment the location of each spot was permanently fixed by the insertion of a round-headed steel needle into the cerebral substance. The animal was then killed, the encephalon removed and preserved in spirit, with the needles in place, for future reference. It is only by this means that the points stimulated in different experiments can be compared with each other, since particular convolutions cannot be recognized with certainty until the whole brain is exposed.

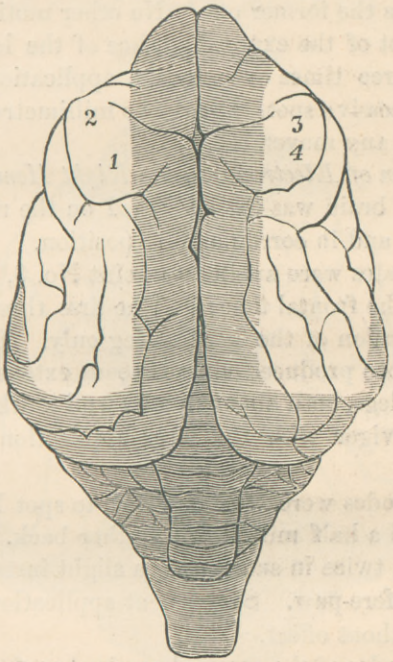
The following are the details of the experiments:

Experiment No. I., *June 18th.*—The skull and dura mater were removed on the left side, so as to expose a surface of the brain measuring four and a half centimetres longitudinally by two centimetres transversely; the inner edge of the ex-

posed portion being about one centimetre distant from the median line.

Application of Electrodes to the Left Hemisphere.—The electrodes were applied to a point situated about the middle of the post-frontal convolution, marked No. 1 in the diagram.

EXPERIMENT No. I.



1. Flexion and adduction of opposite hind-leg, ten times ; accompanied eight times with slight extension of opposite fore-leg.
2. Extension of opposite hind leg, eight times ; accompanied three times with slight flexion of opposite fore-leg ; three times, slight depression of shoulder on same side.
3. Simultaneous extension of opposite fore and hind legs, nine times. Extension of opposite fore-leg only, three times.
4. Flexion of opposite fore-paw only, twice.

The right hind-leg was at once drawn upward and inward. This was repeated ten times with a similar result. The contractions were immediate, perfectly distinct, and momentary in duration; rather increasing in vigor with the later applications. Eight times they were accompanied also by slight extension of the right fore-leg. No other movement.

The electrodes were then applied to point No. 2, situated about seven millimetres farther forward and outward, near

the outer extremity of the frontal fissure, producing eight times in succession extension of the right hind-leg, very marked, and increasing in vigor with successive applications. Three times this movement was accompanied by slight flexion of the right fore-leg, and three times by a depression of the left shoulder, neither of these actions being at any time so well marked as the former one. No other motion.

All the rest of the exposed surface of the left hemisphere was tested, three times over, by the application of the electrodes at successive spots about five millimetres apart, without producing any movement.

Application of Electrodes to the Right Hemisphere.—The surface of the brain was then exposed on the right side, to a similar extent and in corresponding position.

The electrodes were applied to point No. 3, near the outer extremity of the frontal fissure. The first three applications produced extension of the left fore-leg only. The subsequent nine applications produced simultaneous extension of the left fore and hind legs, both about equally well marked, and rather increasing in vigor with the later applications. No other movement.

The electrodes were then applied to spot No. 4, situated about two and a half millimetres farther back. The application produced, twice in succession, a slight instantaneous flexion of the left fore-paw. Subsequent applications at the same point were without effect.

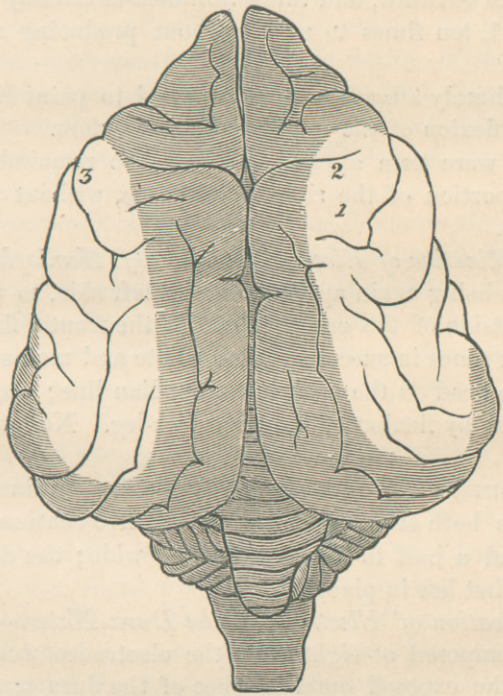
The remainder of the exposed cerebral surface on the right side was then tested by repeated applications, in the same manner as it had been done on the left, without producing any movement.

Experiment No. II., *June* 22*d*.—The dog being etherized, the surface of the left cerebral hemisphere was exposed for a space of about five centimetres longitudinally and two centimetres transversely. The same operation was at once done on the right side, except that, in order to avoid a too long exposure of the brain, the dura mater was left in place until the time for examination arrived. There was an unusually abundant hæmorrhage from the diploë of the skull on the left side,

which continued a long time before it could be permanently stopped, causing a considerable loss of blood.

Application of Electrodes to the Left Hemisphere.—With only eight cells of the battery in action, the electrodes were applied over the whole exposed surface of the left hemisphere, at intervals of three to five millimetres, without producing any movement. The strength of the battery was then increased

EXPERIMENT No. II.



1. Flexion of opposite fore-paw only, ten times.
2. Flexion of opposite fore paw, accompanied by incomplete flexion of whole of opposite fore-limb.
3. Flexion of head on neck, six times; accompanied three times by flexion of opposite fore-leg.

to sixteen cells, and the electrodes were again applied all over the exposed surface, as before, without producing any movement.

Application of Electrodes to the Right Hemisphere.—The electrodes, applied to point No. 1, in the back part of the post-frontal convolution, produced, ten times in succession,

distinct momentary flexion of the left fore-paw, without any other movement.

Applied to point No. 2, about three millimetres in front of the last, they produced repeatedly similar flexion of the left fore-paw, but accompanied by incomplete flexion of the whole limb.

The electrodes were then applied in succession to three points, situated respectively three millimetres inward, three millimetres outward, and three millimetres directly backward from No. 1, ten times to each, without producing any movement.

Immediately afterward again applied to point No. 2, they produced flexion of the left fore-limb, as before.

They were then applied all over the remainder of the exposed portion of the right hemisphere, without producing any effect.

Reapplication of Electrodes to the Left Hemisphere.—The electrodes being again applied, on the left side, to point No. 3, just outside of the external end of the frontal fissure, produced, six times in succession, immediate and momentary flexion of the head on the neck in the median line; accompanied three times by flexion of the right fore-leg. No other movement.

Experiment No. III., *June 26th.*—The cranium was removed, on both sides, for a space about five centimetres long by one and a half to two centimetres wide; the dura mater being at first left in place.

Application of Electrodes to the Dura Mater.—With the battery composed of eight cells the electrodes were applied all over the exposed outer surface of the dura mater on the left side, at intervals of three millimetres, without producing any visible effect. But, on increasing the battery to sixteen cells and again applying the electrodes at a point in the posterior part and close to the outer edge of the exposed surface, there was produced, ten times in succession, distinct twitching of the subcutaneous muscles on the same side of the head, between the ear and the eye. No effect elsewhere.

The battery being reduced to eight cells and the electrodes applied to the dura mater on the right side, in the posterior

part of the exposed surface, the application produced, eleven times in succession, twitching of the orbicularis oculi on the same side. No other motion. The same effect was produced, three times in succession, by applying the electrodes to a point in the anterior part of the exposed surface of the dura mater. No effect elsewhere.

The battery being again increased to sixteen cells, application of the electrodes at a point in the anterior and lateral part of the exposed surface of the dura mater, on the right side, produced very slight flexion of the head on the neck in the median line, with simultaneous slight flexion of the opposite (left) fore-leg. As nearly as could be judged, this point was situated immediately over that part of the brain where similar motions are produced by direct application of the electrodes to the cerebral surface.

Application of Electrodes to the Brain on the Left Side. —The dura mater was then removed on the left side. With the battery composed of eight cells, application of the electrodes to point No. 1, at the most anterior visible part of the præ-frontal convolution, produced ten times, distinct flexion of the head on the neck in the median line, without any other motion.

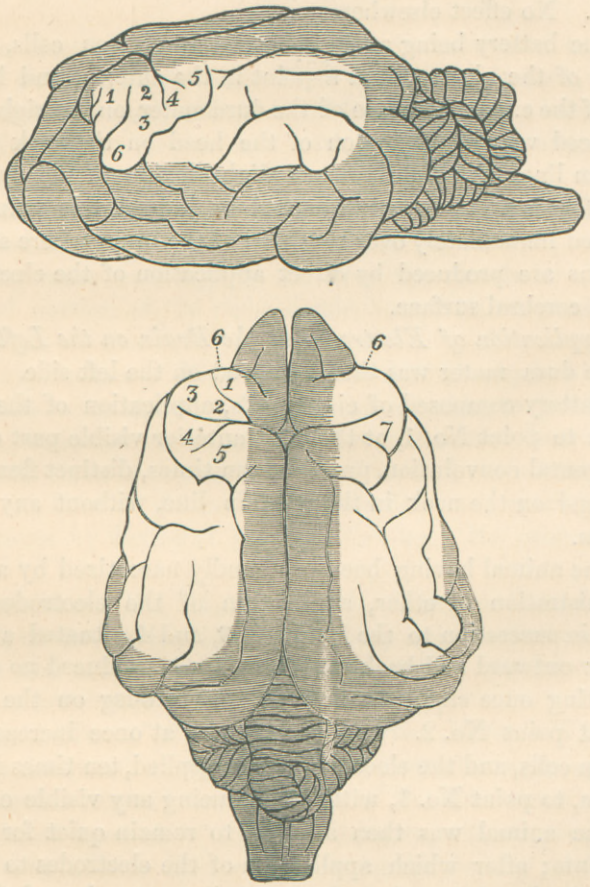
The animal having been profoundly narcotized by a fresh administration of ether, application of the electrodes, ten times in succession to the points 2, 3, and 4, situated a little farther outward and backward from No. 1, produced no effect, excepting once slight extension of the fore-leg on the same side at point No. 2. The battery was at once increased to sixteen cells, and the electrodes again applied, ten times in succession, to point No. 1, without producing any visible effect.

The animal was then allowed to remain quiet for a few moments; after which application of the electrodes to point No. 4 produced, ten times in succession, extension of the opposite fore-leg, accompanied once by simultaneous extension of the opposite hind-leg. No other movement.

The battery was reduced to eight cells, the animal having become less deeply narcotized. Application of the electrodes to point No. 5, in the back part of the post-frontal convolution, produced eight times flexion of opposite hind-leg only; but

on increasing the battery to sixteen cells, application of the electrodes to the same spot produced again flexion of the opposite hind-leg, with a confused movement of all the other limbs.

EXPERIMENT No. III.



1. Flexion of head on neck, in the median line, ten times.
2. Slight extension of fore-leg, on the same side, once.
3. No effect.
4. Extension of opposite fore-leg, ten times; accompanied once by extension of opposite hind-leg. Flexion of opposite hind-paw only, five times.
6, 6. Flexion of head on neck, with rotation toward the side of the stimulus.
7. Flexion of opposite hind-paw only, ten times.

The animal was again thoroughly etherized, and the electrodes applied, ten times in succession, to point No. 5, without any effect. Then the application made at point No. 4

produced, five times in succession, distinct momentary flexion of the opposite hind-paw alone.

The electrodes were then applied to all the remaining posterior and lateral exposed surface of the brain, on the left side, without visible effect.

Effect of Galvanization on the Dura Mater as compared with that on the Brain.—A small triangular portion of the dura mater having been accidentally left in place, at the posterior and inner angle of the opening in the skull, the electrodes were applied to its outer surface. The application produced a shrinking movement of depression of the shoulder on the same side, without any other motion. But, when the application was made to the exposed surface of the brain, immediately beside the cut edge of this part of the dura mater, it produced no effect. The applications were thus made alternately, to the dura mater and to the brain, ten times to each, in immediate succession, always with the foregoing result.

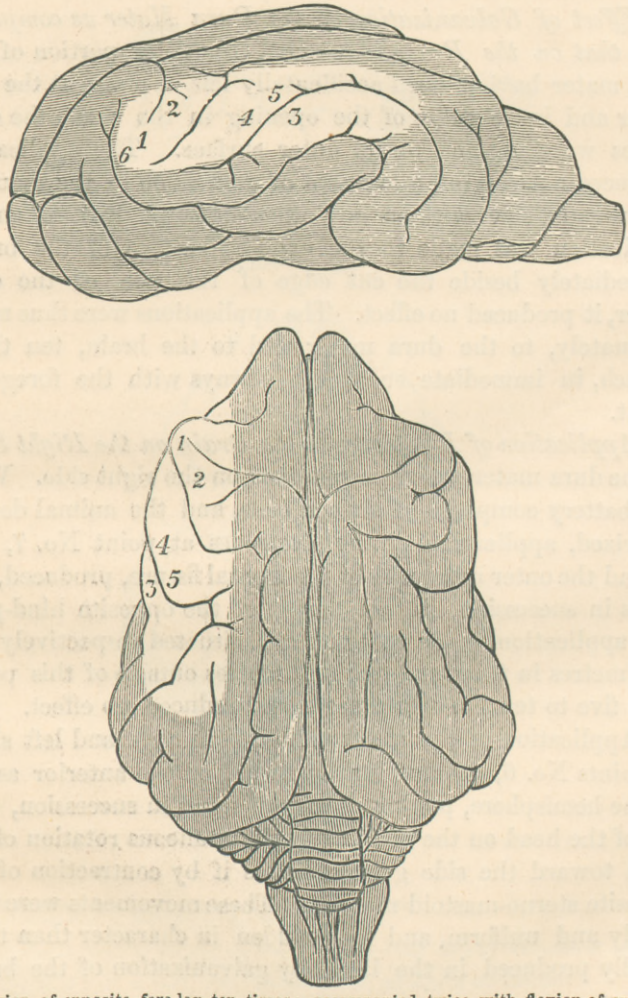
Application of Electrodes to the Brain on the Right Side.—The dura mater was then removed on the right side. With the battery composed of sixteen cells, and the animal deeply etherized, application of the electrodes at point No. 7, just behind the outer extremity of the frontal fissure, produced, ten times in succession, distinct flexion of the opposite hind-paw. The application, made to two spots, situated respectively five millimetres in front and five millimetres outside of this point, from five to ten times in succession, produced no effect.

Application of the electrodes on both right and left sides, to points No. 6, situated far downward on the anterior aspect of the hemisphere, produced, several times in succession, flexion of the head on the neck, with simultaneous rotation of the head toward the side galvanized, as if by contraction of the opposite sterno-mastoid muscles. These movements were very steady and uniform, and less sudden in character than those usually produced in the limbs by galvanization of the brain-surface.

Experiment No. IV., *July 7th.*—In this experiment, the brain was exposed on the left side only. The exposed portion occupied a space about five and a half centimetres long by one and three-quarters centimetre wide.

Application of Electrodes to the Left Side of the Brain.—With the battery composed of eight cells, and the animal deeply etherized, the electrodes were applied all over the exposed cerebral surface, without effect.

EXPERIMENT No. IV.



1. Flexion of opposite fore-leg, ten times; accompanied twice with flexion of opposite hind-leg.
2. Flexion of opposite hind-leg only.
3, 4, 5. Contraction of orbicularis oculi on the opposite side, twenty-five times.

The battery was then increased to sixteen cells, when application of the electrodes to point No. 6, situated as in the

preceding experiment, produced twice slight flexion of the head on the neck; but three subsequent applications to the same spot, immediately afterward, produced no effect.

A few moments later, application of the electrodes to point No. 1, just beyond the outer extremity of the frontal fissure, produced, ten times in succession, flexion of the opposite fore-leg, accompanied twice with flexion of the opposite hind-leg. No other motion. Application of the electrodes to point No. 2, situated about five millimetres farther backward and inward, produced, several times in succession, distinct and sometimes forcible flexion of the opposite hind-leg only.

The electrodes were then applied to a region on the lateral surface of the brain, near to and on both sides of the supra-Sylvian fissure, at points Nos. 3, 4, and 5. The application produced, twenty-five times in succession, well-marked contraction of the orbicularis oculi, and drawing of the external angle of the eye downward and outward, on the opposite side of the head. No other motion.

The electrodes were then applied all over the remainder of the exposed cerebral surface, without producing any effect outside the points designated.

Experiment No. V., *July 9th.*—The left side of the brain was exposed for a space about four and a half centimetres long by one and a half to two centimetres wide.

Application of Electrodes to the Left Side of the Brain.—With the battery composed of eight cells, and the animal deeply etherized, the electrodes were applied all over the exposed cerebral surface without visible effect.

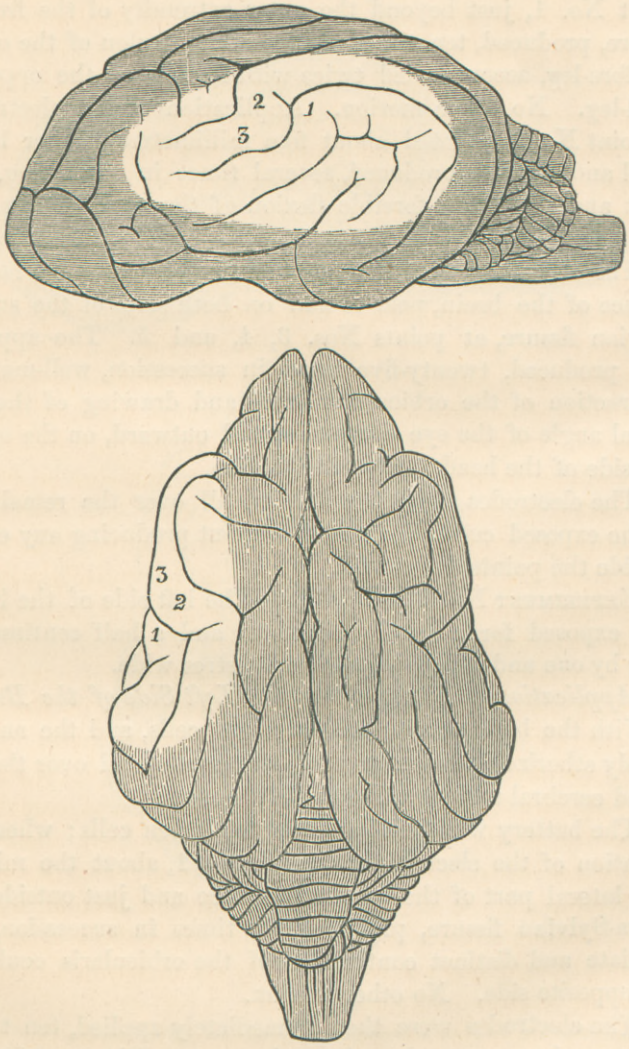
The battery was then increased to sixteen cells; when application of the electrodes to point No. 1, about the middle and lateral part of the exposed surface and just outside the supra-Sylvian fissure, produced, ten times in succession, immediate and distinct contraction of the orbicularis oculi on the opposite side. No other motion.

The electrodes were then immediately applied, ten times in succession, to a point situated seven millimetres farther outward, without producing any effect.

Then they were reapplied, ten times in succession, to point No. 1, each time with the former result.

They were then applied to a point situated seven millimetres directly backward from No. 1, ten times in succession, without any visible effect.

EXPERIMENT No. V.



1. Contraction of orbicularis oculi on opposite side, forty times.
2, 3. Same effect as at point No. 1, but less frequently repeated; sometimes two similar contractions produced in quick succession.

Then again immediately reapplied to point No. 1, ten times, each time with the former result.

Then they were applied to points Nos. 2 and 3, situated five to seven millimetres farther forward and inward, on the other side of the supra-Sylvian fissure, ten times to each, nearly always producing contraction of the orbicularis oculi on the opposite side, sometimes with a rapid double contraction for each application. No other movement.

Then they were applied all over the remainder of the exposed cerebral surface without visible effect.

Finally, they were again reapplied, ten times, to point No. 1, each time with the former result, namely, contraction of the orbicularis oculi on the opposite side.

It will be seen that the observations of the Committee confirm the most important of the results obtained by Hitzig and those who have followed him in this line of experiment. There is no doubt that there are certain limited spots upon the surface of the cerebral convolutions which, when subjected, in the etherized animal, to a weak galvanic current, will cause distinct momentary contraction of separate muscles, or groups of muscles, on the opposite side of the body.

The same galvanic stimulus, applied to other points, not more than five millimetres distant, will be entirely without effect; and, when reapplied to the former spot, will again produce the same contractions as before.

The number of the repetitions of particular contractions following galvanization of particular points leaves no question as to the reality of the connection between them.

In repeated instances, corresponding points upon the right and left sides of the brain act experimentally as centres of motion for similar groups of muscles on the left and right sides of the body. We cannot say that in all cases this bilateral correspondence of the cerebral centres of motion is complete; although it may be so in reality, since the two sides of the brain in the dog are never exactly symmetrical, as regards either the fissures or the convolutions.

The action of the cerebral convolutions in producing muscular contraction, when this contraction is definite and limited, is always a crossed action; galvanization of the convolutions on either side of the brain exciting movement in the muscles, both of the limbs and face, on the opposite side of the body.

Galvanization of the dura mater, or other sensitive parts, produces on the contrary, by reflex action, muscular twitching on the same side of the body.

This is especially illustrated in Experiment No. III., where the dura mater being exposed but unopened, application of the electrodes to its exterior surface produced, twenty-four times, muscular twitchings on the corresponding sides only; namely, ten times on the left, and fourteen times on the right.

But, after the dura mater had been removed, application of the electrodes to the surface of the convolutions, in the same experiment, produced, thirty-two times, distinct muscular contraction on the opposite side of the body alone; while once only it was followed by a slight contraction on the same side.

In the same experiment, application of the electrodes to a small part of the dura mater left at a corner of the wound produced a distinct depression of the shoulder on the same side, while their application to the cerebral surface immediately adjacent was without effect; this result being obtained invariably in twenty applications, made alternately to the dura mater and to the brain.

If we compare the total results of all the experiments, the preponderance of crossed action in galvanization of the brain becomes very manifest. Fifteen different points of the cerebral surface, when galvanized, excited distinct movement on the opposite side of the body one hundred and sixty-nine times; two points excited slight movements on the same side with themselves four times only.

Among these instances is not counted that of a special point which usually excited a flexion of the head and neck in the median line; both sets of the muscles, right and left, being either called into action harmoniously, or else each one having the power to flex the head without deviating it toward the opposite side.

All the centres of motion for the anterior and posterior limbs are situated in the convolution immediately surrounding the frontal fissure. This fissure, which is well marked in the dog and other carnivorous animals, is a nearly transverse furrow running outward from the great longitudinal fissure, and situated at about the junction of the middle and anterior

thirds of the brain, as viewed from above. The centres for flexion and extension of the anterior and posterior limbs the Committee have always found in the external part of the præ-frontal convolution, just anterior to this fissure, and in the post-frontal convolution just behind it. In a majority of cases those for the anterior limbs were situated more in front, near the outer extremity of the frontal fissure, and those for the posterior limbs more posteriorly and inward, but their exact position varied somewhat in different cases. The centre for flexion of the head and neck in the median line is in the lateral and anterior part of the præ-frontal convolution, where it bends downward and outward; that for flexion of the head with rotation toward the side of the stimulus is in a part of the convolution situated still farther toward the front and downward, so as to be invisible in a view of the brain taken from above. The centre for the facial muscles is in a region situated on the lateral part of the hemisphere, immediately about the supra-Sylvian fissure.

These localities, as found by the Committee, correspond in nearly all essential particulars with those given by Hitzig, and in some instances their identity was complete. This fact is of much value as testifying to the genuineness of the results in both cases—since the spots experimentally found to be centres of motion were all marked, as above stated, by the insertion of needles before killing the animal; but their location upon the hemispheres, and consequently their correspondence with those discovered by Hitzig, could never be seen until after the brain had been removed from the cranium.

With regard to the separate points for flexion and extension of the anterior and posterior limbs respectively, the Committee are unable to fix these points more precisely from the results of their experiments. In some cases they varied in position more or less in different animals; and in some a single application of the electrodes would produce movement in more than one set of muscles. It is not possible, therefore, for the Committee to indicate an exact or invariable locality for the centres of motion, by reference to the fissures or convolutions; but they are led to the conclusion that these centres exist, and that, when the galvanization happens to be applied

only to the spot which they occupy, they will produce movements peculiar to themselves.

Thus, in the experiments detailed above, sixty-four applications of the electrodes produced flexion in one limb only, and fourteen applications produced extension in one limb only; making seventy-eight isolated movements. In twelve cases there was flexion or extension of both limbs simultaneously, and in eleven cases flexion of one limb, accompanied by extension of the other; making in all twenty-three double movements of the limbs. That is, more than three-quarters of all these movements were isolated movements of flexion or extension of a single limb.

It is evident that a variety of circumstances influence the results of galvanizing the cerebral convolutions. On several occasions the contractions produced in an opposite limb seemed to increase in intensity with the repetition of the stimulus at short intervals. A deeply etherized condition of the animal, on the other hand, will sometimes suspend altogether the phenomena of movement, which were well marked a short time before; and these phenomena may reappear after an interval of repose.

A weak galvanic current from eight cells, applied to a particular spot, may cause distinct movement in one of the opposite limbs only; while a stronger current from sixteen cells, applied to the same spot, may produce a confused motion in all the limbs at once.

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