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Localization of the Motor Area in the Brain

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CONTENTS

		Page
I.	Introduction Three theories of brain function	1
II.	Localization of sense and motor area	2
III.	Motor area (general)	3
IV.	Experimental methods and localization of motor area	5
V.	Experiments on monkeys - five motor areas	5-12
VI.	Results of experiments on apes	12
VII.	Conclusion	14

LOCALIZATION OF THE MOTOR AREA IN THE BRAIN

In 1830 the belief in precise localization of brain functions, under the name of Phrenology, was very prevalent. The idea was that of so-called "bumps"--that numerous divisions of the cerebrum must exist, each determining a mental characteristic. Thirty years later this school had fallen wholly into disrepute and another teaching came to the fore, namely, that all parts of the brain had the same function. It was compared with the liver, the various lobes not having a single service but rather participating in all the work of the organ as a whole. The cerebral functions were not thought of as local, but diffuse; to destroy part of it would not suppress any one power but weaken it all. This theory, however, finally gave way before the results of the remarkable experiments on the dog by Fritsch and Hitzig, performed during the latter part of the nineteenth century. These called forth a doctrine of specilization of function in different parts of the brain, known as the doctrine of cortical localization. Localization of a particular mental process in any part of the brain means simply that the part in question must be active whenever that mental process occurs. It does not mean that other parts of the brain never co-operate with the centre in which a given function is said to be localized.

Investigation has now localized all senses in some part of the cortex,-for instance, the centre for vision has been discovered in the rearmost part of the cortex in the occipital lobe, thru experiments by Munk, which proved that removal of both occipital lobes in the monkey caused complete blindness. Hearing has been definitely located in the temporal lobes of the cortex, lying just within the temple. Moreover, it has been found that certain regions could be stimulated artificially, so that particular muscles contract, on the opposite side of the body, and that prolonged stimulation produces local convulsive movements of the same parts. Removal of these localized parts of the brain area is followed by paralytic symptoms in the limbs or portions of the body which had before responded to their stimulation. These regions have been classified under the term "motor area", which includes the entire length as well as the free width of the precentral or ascending frontal convolution, and dips down to the bottom of the central sulcus, termed "Fissure of

Rolando" in man, but does not extend behind the sulcus. This fissure extends nearly at right angles to the longitudinal fissure of each hemisphere. The localization of the sense and motor areas in the brain cortex has been unquestionably established and serves valuably as a forward step in modern science.

It was thru experimentation upon the motor area of a dog's brain that scientists were able to isolate several distinct areas, whose stimulation caused,respectively, movements of the head, face, neck, hind legs, fore legs. This created a starting point for a long series of researches by Ferrier, Munk, Horsley, Schäfer and others--researches which have formed the basis of an exact cortical localization in the brain of man, and have given to surgery an entirely new and broad field of operation.

Histological study of the brain shows that the surface gray matter of the motor region contains many large nerve cells of pyramidal type, from which axons of nerve cells pass inward. Fibres originating here become condensed into well defined bundles which can be recognized at each successive level in the brain stem. In the medulla most of these fibres sweep across into the opposite half of the nervous system and descend the spinal cord to connect with motor cells in its gray core. This accounts for the fact that muscular responses occur chiefly on that side of the body opposite the excited brain area. A fibre from the cortex, however, never reaches a muscle, but plays upon a cluster of cells which, in turn, governs the contractile forces.

The degree of localization of function in the cortex has been found to go hand in hand with the general development of the brain. In man and monkey, motor localization is more elaborate than in the dog, that is--a greater number of movements can be associated with definite cortical areas. In the rabbit, whose motor centers have been particularly studied in recent years, localization is not so advanced as in the dog. Toward the bottom of the mammalian group certain motor areas can still be demonstrated, altho they are poorly defined, as in the hedge-hog and opossum. - No evidence of the existence of such an area in birds has been found. Areas of the same name and homologous regions in the different groups of animals do not necessarily have the same function--i.e., in the case of motor areas--that they do not have to be associated with the same movements.

A great deal of study along this line has been carried on

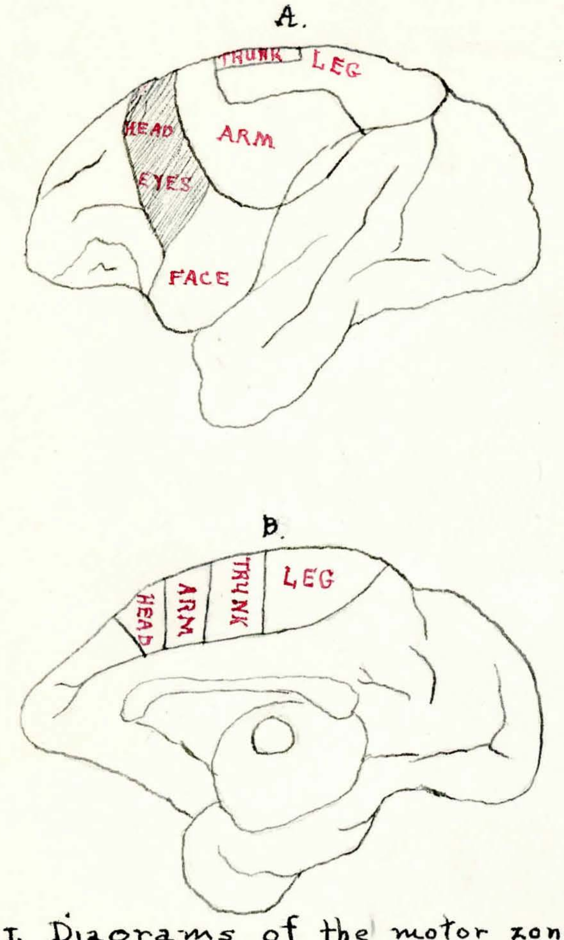


Fig. I. Diagrams of the motor zone of the monkey's brain,- it's five areas. A-external surface B-mesial surface.

upon the lower animals. The dog, jackal, a few rodents, insectivora, marsupials have proved available and useful material. These investigations have been of vast importance in starting out to solve this great problem, but the initial stage has passed. Experiments must now be made upon material which gives results directly comparable and applicable to man's life.

The methods employed in experimentation of this nature have been of two kinds: by excitation or stimulation of the various areas by electricity; and, by actual removal of portions or even of the entire area.

Exhaustive and exceedingly important, on account of the simularity to the human brain, experiments have been made upon the brains of various species of monkeys. The resulting evidence has been very far-reaching in its applications. Five areas of the motor cortex in the monkey's brain, outlined in Figure 1, have been distinguished--the area connected with the movements of (1) the head and eyes, (2) the face, including those of the mouth, throat and larynx, (3) the upper limbs, (4) the trunk muscles, including those of the tail, (5) the lower limbs. These areas have no definite boundaries, nor are they marked off from one another in any way, yet their limits, as shown by excitation, are distinct, and altho, when the stimulus is brought to bear exactly upon the boundary of any two areas, movements of both parts may result, a slight shifting of the electrodes to either side of the boundary will limit the movement to one part only, if the excitation be of weak intensity. Should the intensity be too strong or too prolonged, a noticeable spread of the effect immediately follows.

Varieties of movements are obtained by stimulation within the limits of the designated areas, which indicate a still further differentiation, or intra-areal localizations. Naturally, the larger areas and those concerned with the more complex movements are expected to have the best differentiation. Thus, localization of particular movements is rather connected with small areas of cortex than with mere points on the surface of the cerebrum. It is very unusual to find that a movement which is effected is simple or unaccompanied by other movements. Just as, by stimulation of a certain point, so-called because its area is so limited in size (on the middle of the ascending parietal convolution), a simple bending of the fingers occurs, or, at a point a trifle lower, that of the thumb; but, much more often, the bending of the fingers is accompanied by the extention of the wrist.

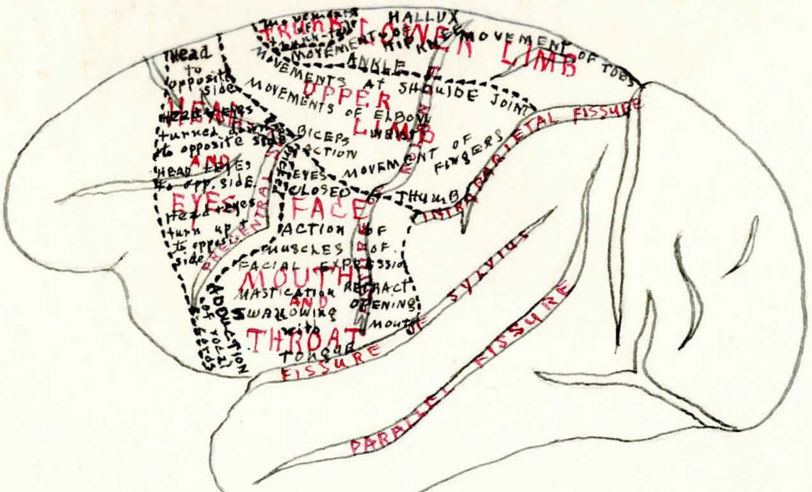
These movements may succeed one another, or may be simultaneous.

By stimulation and localized lesion within the limits of the motor sphere of the cortex, many detailed results were obtained. The surface area connected with movements of the head and eyes and of the ear, outlined in Figure 2, is most excitable in its middle and posterior parts, and becomes less excitable as the prefrontal region is neared. The action is bilateral--a movement of the head and both eyes toward the opposite side, simultaneous lateral deviation, having been produced, which may be simple, or combined with an upward or downward inclination. Mott and Schaeffer have made this area the subject of special investigation in the monkey and are able to show that excitation of the upper part of the area usually leads to downward and lateral deviation of the eyes and head;-of the lower part, to upward and lateral deviation--while excitation of a middle, narrow part produces simple, lateral deviation. Stimulation of the posterior boundary of the area invariably causes a pricking or drawing back of the opposite ear, or both ears, the former by that of the upper part of the boundary, the latter by that of the lower part. If the area on one side of the brain is removed, the head and eyes turn directly toward the side of the lesion, which is supposed to be due to paralysis of the muscles.

However, the effect passes off in a few days, and no permanent paralysis is noticeable, even if the area on both sides were removed. Other areas of the cortex, the occipital and temporal, each connected, to some extent, with the movements of the head and eyes, no doubt take over the work.

The area connected with movements of the face, mouth, throat and larynx, outlined in Figure 2, was found by Ferrier to contain a great amount of differentiation. When the upper part of the area over the ascending frontal gyrus is stimulated, retraction and elevation of the opposite angle of the mouth occurs; if the part just below this--an elevation of the opposite side of the nose and upper lip, together with a depression of the lower lip follows. Were these movements to be made on both sides, a snarl, exposing the canine teeth would be produced, which is a frequent and characteristic expression of monkeys when alarmed. If the portion below the centres mentioned were stimulated, the mouth would open, and the tongue would be protruded, by more anterior excitation, and drawn back again by more posterior excitation. Other experimentors have added to Ferrier's results. Both eyes close, but especially the opposite one, when the upper part of the (2) area near the margin is stimulated. Cheek, together

A.



B.

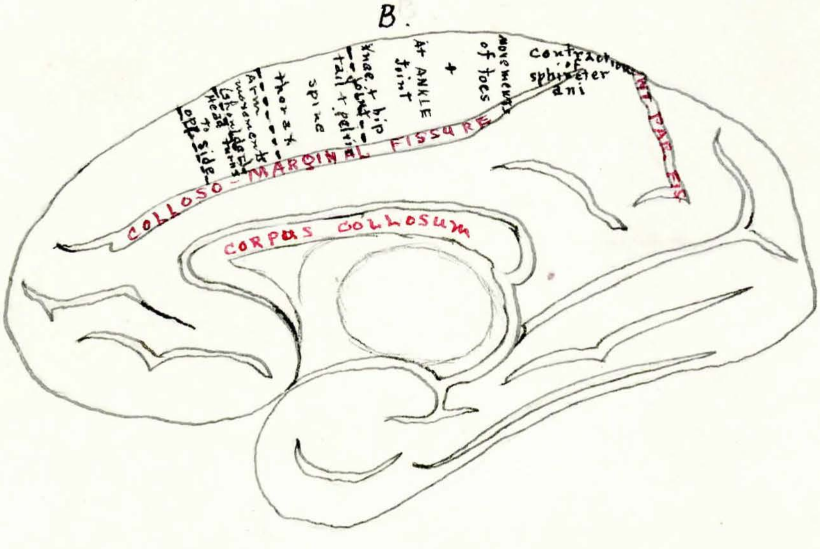


Fig. 2. Diagrams of the lateral and mesial surfaces of the monkey's brain, showing the effects obtained from stimulation of the excitable areas. A-external surface. B-mesial surface.

with chewing movements of the tongue and lower jaw, and the movements of the throat in swallowing, are obtained thru the lower part of the area. Stimulation of the front part of the lower end produces a strong drawing together or adduction of the vocal cords.

Paralysis of the opposite cheek pouch follows the removal or destruction of the facial area. It fills with food, but, by pressure of the hand upon the outside, is usually emptied. In time, however, the paralysis disappears and the pouch empties by its own muscular wall. If the corresponding area on the other side of the brain is also removed the pouch retains its regained ability. A two-sided lesion causes difficulty in swallowing and chewing, but the voice is not lost. The muscles recover their activity.

The area connected with movements of the upper limb, outlined in Figure 2, has also been studied by Ferrier. He described various complex movements of the arm and hand, by stimulation of this portion. The opposite hand was struck backwards, the arm being brought forward, extended and drawn back, when the upper part extending over both central gyri was affected. By stimulation more to the front, the arm was brought forward from the shoulder as if trying to reach or touch something before it; stimulated along the posterior part, the clenching of the fist, beginning with the thumb and index finger, associated with the action of the wrist; in front of this, flexing and unflexing the forearm was produced. Over the whole of the upper and anterior part of the area, merging in front into the combined movements of the head and shoulder, is found the forward movement of the whole arm with the raising of the shoulder, combined secondarily with the extention of the elbow. Therefore, this portion is primarily concerned with shoulder movments, altho other parts of the limb may be set in action. The lowest limit of the area causes the most marked thumb movements, alone, or with that of the index finger.

The area connected with movements of the lower limb, outlined in Figure 2, merges gradually into the area immediately in front of it, that of the trunk and tail. Stimulation of the posterior part produces, primarily, movements of the opposite toes, which may be associated with other parts of the limb.Close to the Fissure of Rolando is the seat of the movements of the hallux. Thus it is seen that a large part of the leg area is concerned with toe movements, and that this is even true, tho not as a primary effect, in the most anterior part of the area. The hip, knee and ankle movements are not very distinctly differentiated from each other in the leg area; they

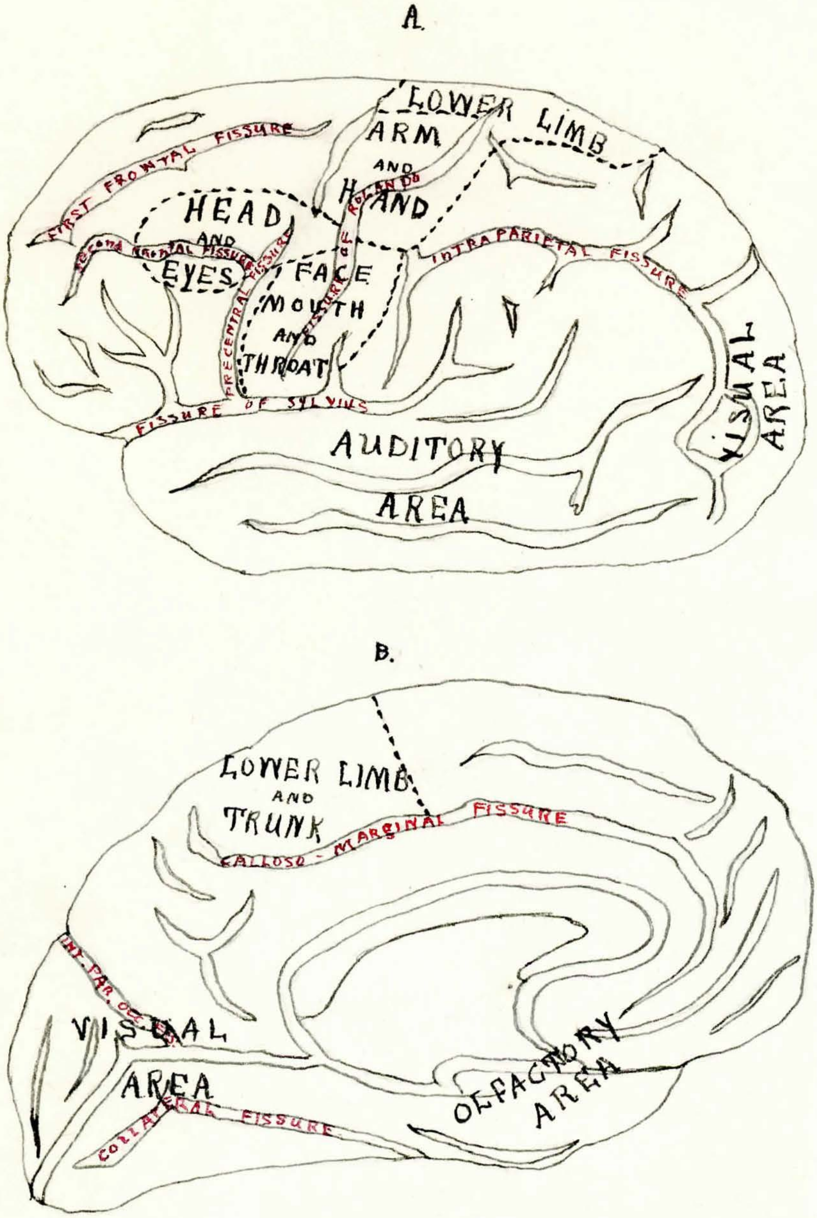


Fig. 3. Diagrams indicating probable localization of the chief motor (and sensory) areas of the cerebral cortex of man. A-lateral surface. B-mesial surface.

usually occur in association. Yet, generally, it is found that the hip movements are obtained from the anterior part, the toe movements from the posterior, and the knee and ankle movements from the middle part, the first often combining with the movements of the tail and pelvis. Sherrington has shown that, in the monkey, stimulation of the very posterior part causes contraction of the Sphincter ani. Removal of the leg area at first caused complete paralysis of the limb, which hangs limp in climbing, drags along in walking, and is thrust inertly forward in sitting. Improvement is noticeable at the end of one or two weeks; the movement returns, and after a few weeks have passed the animal runs and climbs again, apparently normal. It may be that the movements are associated now with those of the opposite side. However, if therecovered animal be held by the upper part of the body and suddenly lowered to the ground, or swung towards a cage, the limb that was paralyzed is never put down to reach the ground, or extended to catch at the cage, as any usual, unparalyzed leg would.

The area for movements of the trunk and tail, outlined in Figure 2, is too small to give any marked differentiation. A bending of the tail to the opposite side and a bending of the trunk follows when this area is excited. Gnerally, it may be stated that the posterior part is especially connected with the movement of the lower trunk and pelvis, associated with the hip and leg movements, and the anterior part with movements of the upper part of the spinal column, associated with the shoulder and arm movements. Removal of this area on one side alone produces very little effect. This is very difficult, however, for the surrounding areas are likely to be impaired by the operation. If both areas are removed together, the animal cannot sit erect for some time, since the control of the trunk muscles has been lost completely.

An experiment of very great interest and value was that carried out by two scientists--Beever and Horsley, some years ago, upon an orang-outang. The external form of the brain in the anthropoid ape resembles that of man still more closely than does that of a monkey. These researchers noted: that instead of a continuous excitable area of the cortex, there were small spaces here and there whose excitation gave no effect whatsoever. Furthermore, the orang-outang has a relatively smaller portion of cortex which may be stimulated than has the monkey. The first frontal gyrus, as well as most of the upper part of the ascending parietal was found to be inexcitable. The tendency to call forth a series of movements by a single stimulation so prevalent in the monkey, is very much diminished in the ape.

The motor areas of the gorilla and chimpanzee have been recently and carefully localized by those two great students along this line--Sherrington and Grünbaum--and there seems to be no doubt that the results, in their general outlines, at least, can be applied to the human brain.

It has been in the light of the results obtained from monkeys and apes, and by the aid of clinical, pathological and embryological observation, that the motor areas of man have, to a great extent, been mapped out. A few experimental observations have been made on man, in which the cortex, on several occasions, was stimulated over a limited area exposed in operation. The results, meagre as they are, conform with those made upon the monkeys and apes. In man and the orang-outang, a much greater strength of electric current was necessary to produce movements, which tends toward the conclusion that they are caused, not by mere superficial surface excitation but by a deep, cortical excitation. As a result of clinical observations made by two doctors--Charcot and Pitres--a number of useful diagrams have been made illustrating man's actual motor area. They show that this "zone" as it is called, includes only the convolutions adjacent to the Fissure of Rolando. Lesions of any of these gyri, even if quite small, always cause permanent paralysis in one or several of the muscle groups of the opposite side of the body and are followed by degeneration of the pyramidal tract. The outlines of the regions of the motor zone in man are clearly defined in Figure 3.

An extensive hemorrhage involving the Rolandic area of the cerebral cortex causes paralysis of the opposite side of the body. A tumor causes symptoms of motor irritation. For the surgeon to be able to localize lesions in the motor area of the cortex, to be able to operate for their cure, the exact position of the Fissure of Rolando becomes extremely important. Dr. Thane has found a simple method for determining this: "The point midway between the root of the nose and the occipital protuberance is fixed by measuring the distance with a tape. The upper end of the fissure of Rolando lies half an inch behind this middle point. The fissure makes an angle of 67 degrees with the longitudinal fissure."

Altho the definite localization of the motor area in man has led to innumerable miraculous surgical operations, as well as the untold minor, yet just as important, ones, which have saved millions of human lives, the field has comparatively few capable and sincere workers. They necessarily recognize how comparatively little is in reality understood about the subject, and are consequently devoting their lives to the furtherance of this vitalized study.

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