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GENERAL REVIEWS AND SUMMARIES

THE FUNCTIONS OF THE CEREBRUM¹

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The study, or science, of cerebral function is, like many other sciences, in a complex stage of its development. The relation of the brain to other parts of the body or to mental processes is no longer considered to be a mysterious matter, nor are the simple explanations of its functions believed to be entirely satisfactory. The collection of facts has proceeded to such a point that it is now generally recognized that even the relations of the cerebral cells to the production of movement are not to be explained in a simple manner. Many observations of motor, sensory and association disturbances accompanying cerebral lesions have been recorded which can not be explained by the older hypotheses, and which, in fact, negative them. Some have been insisting for a number of years that the cerebral relations are not simple, but because of certain practical needs and applications, the discrepancies have been largely disregarded. It must be understood that cerebral relations are not becoming complex in the sense that more areas with definite functions are being discovered, but in the sense that many functional variations are being recorded, that there are many so-called anomalous disturbances associated with cerebral lesions. For this reason the simple explanations or theories are no longer acceptable, and many which have hitherto been considered almost like statements of fact are undergoing radical modifications.

The general belief that aphasias in right-handed people are produced exclusively by lesions in the left hemisphere and in left-handed people by corresponding lesions in the right hemisphere is not borne out by a number of cases, and it is valuable to have the additional negative case which has been described by Long (6). On autopsy, Long discovered in this left-handed individual that

¹For last previous review see PSYCHOL. BULL., 1913, 10, 125-138.

the aphasia was associated with lesions of the second and third frontal convolutions, of the island of Reil, of the internal capsule, and of the surrounding regions in the left hemisphere. The reason for an association of such contralateral lesions (*i. e.*, not corresponding to the hemisphere of greater voluntary control) with the speech disturbances is not plain, but it is apparent that in this case, and probably in others, there may be an anomaly in the motor and sensory association functions of the cerebrum, or, which seems to the reviewer more probable, that we have in this case only an example of the normal variation in function in different individuals.

The symptom variations which are found in individuals with lesions in the occipital lobes are also very great. Certain cases have been described in which very extensive lesions have not been accompanied by a complete loss of vision, while in other cases comparatively small lesions resulted in almost complete loss. At other times it is found that even in apparently complete bilateral lesions some visual ability remains. In extensive calcarine lesions, and especially in those cases in which there are visual defects for special retinal segments, it is not unusual to find that patients still retain certain visual ideas and have visual experiences which are of the nature of hallucinations. In the case which has been described by Josefson (5), this was found. In this patient, in addition to the general mental changes associated with the pressure, etc., due to the cerebral lesion, which was produced by a glioma or a sarcoma in the left occipital lobe, there were found homonymous hemianopsia with optical aphasia and alexia, but the patient had marked visual hallucinations in the right visual field corresponding to the hemianopic area, and the hallucinatory figures were at times larger than normal. Such cases have more than the particular interest for the purpose of localization of cerebral function, for they indicate that even though there be large amounts of destruction of cells and fibres, the mental functions, supposedly connected with the activity of these cells and fibres, may still persist. They also indicate how little we know at present of the relations of cerebral cell activity and such mental things as ideas.

Minkowski (9), after extirpating the occipital regions of the cat's brain, and in certain cases the eyes, has determined the paths of degeneration, and especially the relation of the degenerations in the external corpus geniculatum due to lesions of the striate area (calcarine cortex). His results indicate that the external geniculate body is the only subcortical structure in which, following

an extirpation of the striate area, a degeneration of the ganglion cells is determinable, for neither in the pulvinar nor in the anterior quadrigeminal body was he able to determine accurately that there were pathological changes in the ganglion cells following such injuries. These latter structures, pulvinar and quadrigeminal body, do, however, show degenerations following the destruction of cortical areas near the striate area. Minkowski has also been able to demonstrate a finer anatomical relationship between the calcarine cortex and the geniculate body, for he has observed that the anterior portion of the striate area is connected largely with the anterior portion of the external geniculate body and the posterior portion of the visual cortex with the posterior part of that ganglion. A somewhat similar relationship is found to exist between the eyes and the corpora geniculata, and Minkowski has been able to show that there is a fair degree of correspondence, or anatomical relationship, of the retinal areas to parts of the geniculate bodies.

Boyd and Hopwood (3) have reported the autopsy findings and the clinical phenomena in an interesting case, which, by exclusion, gives valuable information regarding the more definite localization of the cerebral center for hearing. In their patient they discovered in the left temporal lobe of the cerebrum a large cyst which destroyed the superior and middle temporal gyri, with the exception of the anterior portions. In this patient no impairment of hearing was discovered by the clinical examinations, and the evidence appears to be conclusive that the portions of the temporal lobes which were destroyed are not primarily, or necessarily, concerned with the perception of sounds. It will be remembered that Campbell, on histological ground, has laid particular stress upon the anterior gyrus of Heschl as a special sensory center and as being closely associated with the function of hearing; in the patient described by Boyd and Hopwood this gyrus escaped involvement, and the authors conclude that the results tend to support Campbell's conclusion that only the anterior parts of the superior temporals are hearing centers.

It is well known that in certain animals, as the cat and dog, paralyzes due to cortical destructions are not permanent, the destruction of the motor area resulting in only a temporary paralysis which is followed by a subsequent practically complete recovery of control of voluntary movement in the involved segment. It has also been believed that after the destruction of part of the motor area in man and in the higher apes the paralysis resulting from the

lesion is permanent. In a chimpanzee, however, Brown and Sherrington (4) destroyed the left cerebral arm area, and although this area was completely destroyed, voluntary movements at the right elbow could be performed, and in a comparatively few months such a great amount of return of voluntary movements of the whole arm, took place that eventually there was no obvious difference in the control of the movements of this arm as compared with the left arm, which was normally innervated. The authors conclude that this return of function can not be due to a regeneration of the area which had been destroyed, nor to the assumption of this function by the corresponding portion of the right hemisphere, nor to the vicarious function of the left postcentral cortex. Following extensive precentral cortical lesions in man, there may be immediate extensive paralyses, even hemiplegias, which are expected to, and do, show a certain amount of improvement in the weeks succeeding the initial cerebral insult. Whether the partial restoration of functional control is due, as has been assumed by many, to a subsidence of the pressure, or to some conditions as yet unknown can not be definitely solved. The results of the experiments of Brown and Sherrington are, however, suggestive that even though there be a destruction of the cells, there may follow a functional amelioration. The possible ways in which this may be brought about are numerous, and we need only mention, by way of suggestion in this connection, the well-known efferent functions of the caudate and lenticular nuclei and of the cerebellum. In this connection also, it may not be amiss to call attention to the fact that the reverse condition has sometimes been met with, *viz.*, the appearance of organic-like paralyses without corresponding lesions of the cerebrum or of the other parts of the nervous system. Scientifically, it is neither satisfying nor exact to call these latter conditions hysterical or functional, for they tend to show that the cerebral relations are not as simple as they have been conceived to be, and the use of a special name is, in this case, only an indication of lack of knowledge.

Romagna-Manoia (12) has, in his book, collected very completely the phenomena associated with hemiplegia in its different stages, and has given us a careful account of minute experimental results on this matter, which are most interesting for the purpose of diagnosis, but which, in addition, are of value for the understanding of the relations of the cerebrum to other portions of the nervous system. The facts are too numerous to be detailed in the present

brief review, but it may be mentioned that the reflexes, the resulting contractures, and like phenomena accompanying the various paralyses have been carefully described and amply dealt with.

An interesting study of the stages of development of the cortex of an eighteen weeks' human embryo has been reported by Bolton and Moyes (2), who give us an account of the cell structure which, in its way, is a companion research to those of Flechsig on the myelinization of the brain. The embryo brain which is described contained only beginnings of the Rolandic, calcarine and parieto-occipital (temporary) fissures, the cingulum and the opening of the island of Reil. The Betz cell area was well marked and easily localized, although the authors say that the discovery of the Betz cells in a fetus of this age was a surprise to them. This area, probably on account of the lack of infolding of the central fissure, has a much wider extent than that in the brains of newborn children and adults, and in general a similar statement may be made regarding the calcarine type of cortex. Much of the cortex showed comparatively slight development, although the precentral and postcentral areas are remarkably well evolved in comparison with the remainder. They note, and in this there is support for Bolton's previous contentions, that the anterior frontal or prefrontal cortex is throughout its depth extremely embryonic in structure. No systematic attempt has been made, as did Flechsig, to correlate the findings with functional development, but it is apparent that the greater development of the precentral and postcentral areas, at this stage of its life, is to be correlated with the well-known activities of the embryo. It is believed, the authors conclude, that this development "bears a definite relation . . . to the already stable condition of the lower reflex mechanisms."

By histological methods Malone (7, 8) has attempted to differentiate the types of cells which are concerned with different types of function, and for this purpose he has examined a number of parts of the cerebrum and has applied his methods especially to the examination of definite cell groups. In the vagal nucleus, he shows, there are three types of cells which may be taken as correspondents of the three kinds of muscle (striated, the heart, and smooth), which are innervated by the cells in this nucleus. He reports that "there is no gradual transition in structure between the cells of the afferent and motor chains, and there is no indication of the beginning of motor structure in afferent cells. Those cells in the efferent chain whose function consists exclusively or primarily in conducting

impulses through the chain to cross striated muscle, or between motor centers, are characterized by a common structure, which differs according to the position of the cell in the motor series." He furthermore remarks that "an important field is open to students of the central nervous system in studying the cell structure of different cell groups, and in correlating a definite structure with a definite cell activity wherever this is possible"; and he concludes that "a definite type of cell structure corresponds to a definite cell function." If we consider this "conclusion" as a "point of view," we should be more nearly correct, for it has not been demonstrated that cells of different sizes and of slightly different appearances may not have similar function. If it could be shown that all kinds of histologically different cells in the cerebrum differ in function, and that each different combination of cells (cytoarchitecture) also represented a different function, the problem of the cerebral physiologist would become, if not less arduous, at least better defined. The connections of cortical cells with extra-cerebral parts and the interconnection of cortical cells must be investigated before we shall have definite knowledge of the function of special groups or groupings in the cerebrum, but for many it is more satisfying to speculate how things may be, rather than to investigate how they are. It is because of this failing that we possess many assumptions and hypotheses regarding the functions of individual cells. We should be more scientifically served if there were published fewer speculations and more serious attempts at anatomo-functional correlations, such as that of Malone.

During the past ten years the corpus callosum has been the object of numerous pathological and clinical studies. This has been due principally to the fact that lesions in this region have resulted in various types of apraxia and because it appears that by means of this structure the two hemispheres are closely connected. Our knowledge, however, of the course of the fibers which make up this structure has been rather inadequate, but van Valkenburg (13) has now compared the results of animal experiments and pathological human material, and although he has not been able to fix a definite relation for the callosal fibers for all portions of the brain, it is apparent that these fibers do pass from one hemisphere to the other and apparently bind corresponding or allied areas. In this work he shows that in certain parts the callosal fibers probably arise from the fifth and the sixth layers of cortical cells and that in proceeding to the opposite side they terminate in

the third and, possibly, the fourth cortical cell layer. He has pointed out another interesting fact, viz., that there is a connection between the precentral area of one side and the opposite postcentral area. The other extensive connections, between the corresponding occipital lobes, and between the corresponding frontal lobes, are better known, on account of the association of lesions in these tracts with the phenomena known as apraxia. The importance of a knowledge of these tracts is now being more appreciated, and we may hope to obtain in the not distant future more information of the corresponding areal connections of these tracts of the callosum and the processes or functions which are subserved.

Of a somewhat similar anatomical nature, and with similar physiological value, is the study of Besta (I), who has carefully worked over the paths of degenerations following various lesions in the brains of dogs and cats. By comparing the results of the degenerations of fibers by the Marchi method and those of cell atrophy, he has determined the paths of fibers and, consequently, of the impulses which normally pass between the cerebrum and cerebellum. One of the most interesting facts in his results is that, contrary to the contentions of von Monakow and others, he did not find, and because of this he denies that there are any cerebropetal fibers in the pedunculi cerebri.

In a general article, Pawlow (II) has reported his views of higher nervous function which have resulted from his experiments on psychic secretions. The psychic secretions which he has been mainly instrumental in demonstrating in animals he has termed "conditional reflexes," since, unlike the organic or the well-established reflexes which are carried out by the spinal cord and the medulla oblongata, they may be affected by and they depend upon a multitude of conditions. It is well known that when food is presented to an animal so that the animal sees the food, secretion by the digestive glands begins before the food is taken into the mouth. Pawlow has also shown that if, at the time food is presented, a stimulus which is extraneous to this food be also given to the animal, the combination of stimuli results in a secretion. After this combination, food plus an extra stimulus, has been used with an animal a number of times, it becomes sufficient for the production of the digestive secretions to present to the animal solely the extraneous stimulation which has been previously associated with the food. The non-food stimulus then gives rise to, or is accompanied by, the reflex activity. It has also been possible to show that even

though the character of the extraneous stimulus be changed, this non-food still results in secretion production. For example, if at the times that food be presented an electrical stimulus be given to the skin of the foot, the secretion of saliva becomes associated reflexly with this electrical stimulus. After the reflex has been well established, it is no longer necessary to present food to bring about the reflex, nor is it even necessary to stimulate the foot by electrical means; painful stimuli, such as cutting and burning, are also accompanied by the same sort of reflex activity, viz., secretion. Because of these and many other facts Pawlow points out, or concludes, that part of the function of the central nervous system, and especially that of the cerebrum, is that of dispersion, not only that of correlation or integration, of impulses, and that the cerebrum acts to a great extent, as the reviewer pointed out more than ten years ago, for the production of new types of activity and new reflexes, and, perhaps, anatomically for the purpose of making new connections.

The localization of functions in the cerebral cortex, or in the brain of man, von Monakow (10) writes, constitutes a complex problem, which is the goal of localization in the central nervous system in general. He points out, as others have previously done, that localization may be considered in three different ways: first, the localization in an anatomical sense, viz., groups of fibers and cytoarchitectonic; secondly, the localization according to symptoms and symptom groups, or the correlation of irritative or defect phenomena with localized injuries to the brain; and thirdly, the definite localization of mental functions. These three ways of looking at cerebral functions are frequently, perhaps usually, not differentiated. It is, however, important and necessary that they shall be kept clearly in mind if we are to draw a distinction between what may be called the "association of cerebral lesions with motor, sensory and association defects," and the "localization of mental processes." Every cerebral injury results in two stages or forms of symptoms, the initial and the residual. Both of these must be carefully noted and analyzed if we are to understand the complexity and the integration of cerebral activities. Among the most important of the general effects is that of diaschisis, which results in a cessation of impulses over the whole cortex and which is essentially a "reduction or cessation of the capacity for excitation." Widely separated areas are always involved even when only a very small portion of the cortex is affected. Some destructions may give rise

to perfectly obvious defects or exaggerations, others may give rise to effects which are to be determined only in an indirect manner by a process of exclusion, while others again appear to be of a "latent nature and only become manifest when there is added to the primary operation a second operation upon, or a pathological process in, another region of the cortex." At present we are only able to say that the motor and sense areas are roughly determinable; their functions are not circumscribed, or, as von Monakow says, "*inselförmig*," but they are parts of a mechanism, and concerning their finer organization and their temporal and spatial relations to psychic phenomena we know almost nothing. Our present knowledge regarding cerebral-mental relations is not much greater than that of the neurologists of a hundred years ago. The facts at hand, as was pointed out several years ago, may warrant the conclusion that there is a "close connection between the brain and mental processes," but at the same time they also permit only the general conclusion that "the mental processes are not due to the independent activities of individual parts of the brain, but to the activities of the brain as a whole."

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