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ART. I.—*Experimental Investigations into the Functions of the Human Brain.* By ROBERTS BARTHOLOW, M.D., Professor of Materia Medica and Therapeutics and of Clinical Medicine in the Medical College of Ohio; Physician to the Good Samaritan Hospital, etc. (With a woodcut.)

THE researches recently made in animals on the functions of the brain, although of great importance, need to be complemented by similar investigations, or by corresponding pathological alterations, in the human brain. Notwithstanding the general similarity in the conformation of the brain of man and that of the highest animals of the order—Primates, special differences of great importance are very apparent. The same remark is true of the Orang and of animals in the scale below him. The brain of man differs still more remarkably from that of the inferior animals, in the extent and variety of its functional manifestations. It is obvious that it is exceedingly desirable to ascertain how far the results of experiment on the brain of animals may be employed to elucidate the functions of the human brain. Before proceeding to narrate my own observations, it may be desirable to make a preliminary statement of the results thus far achieved by experiments on animals.

Nasse and Rosenthal, but especially Leyden, had a few years ago studied the effects of pressure and agitation on the functions of the brain mass. (*Ueber Hirndruck und Hirnbewegungen—Virchow's Archiv*, Band 37.) Leyden injected a solution of sodium chloride between the skull and dura mater. A more extended series of experimental investigations was subsequently undertaken by Dr. F. Pagenstecher (*Experimente und Studien über Gehirndruck*, Heidelberg, 1871). Pagenstecher injected

a mixture of white wax and tallow heated to 50° C. (p. 12) between the skull and dura mater of dogs.

As regards the sensibility of the dura mater, Leyden and Pagenstecher differ, the former holding that it has not, and the latter that it has to a slight extent (p. 45). Pagenstecher notes, as the result of his experiments, derangement and loss of the psychical functions, stupor, somnolence, sopor, and coma; also, disorders of motility, convulsions, paralysis, movements of rotation; alterations of the pupils, and deviations from the normal of the pulse, respiration, and temperature.

Similar to the above as regards results, but more definite in aim, are the experimental studies of Nothnagel (*Virchow's Archiv. f. path. Anat. u. f. klin. Medicin*, 1873), and of Foornie (*Recherches Exper. sur la Fonctionnement du Cerveau*, Paris, 1873). These experimentalists, having made a small opening in the cranium, injected into the substance of the brain, at various points, corrosive substances (chromic acid and chloride of zinc coloured with carmine). Abolition of a function could be thus distinctly associated with the destruction of certain districts of cerebral matter. Injections into the gray matter caused alteration of the psychical functions, and affected the movements of distinct groups of muscles. Injury of the outer portion of the last frontal convolution caused, according to Nothnagel, loss of the muscular sense in the opposite fore-leg. Destruction of a portion of gray matter of the outer lateral portion of the hemisphere was followed by paralysis of the opposite side of the body. Injury of the white substance, also, caused paralysis of the opposite side of the body. When the injections were made into the corpus striatum, convulsions and paralysis on the opposite side ensued. Injury of the optic thalamus paralyzed sensibility.

The most important results as regards localization of functions, have been obtained by faradization of limited parts of the brain. The demonstrations recently made in this way by Fritsch and Hitzig (*Archiv f. Annt. Physiol. u. Wissenschaftliche Medicin*, 3, 1870), and by Ferrier (*West Riding Lunatic Asylum Reports*, vol. 3) are entirely opposed to the well-known experiments of Magendie, Longet, Flourens, Vulpian, and others, which had apparently shown the excitability of the cerebral hemispheres.

Fritsch and Hitzig employed in their researches the galvanic current. They confirmed by their investigations the opinion of Meynert that the anterior lobes are the chief centres of the motor functions. Electric irritation of these lobes, if feeble, caused contractions in limited groups of muscles on the opposite side; if strong, combined action of the muscles on the opposite side. Certain convulsions were thus ascertained to have definite functions, with regard to the movements of the extremities.

The method of experimentation pursued by Fritsch and Hitzig has since been very successfully applied by Ferrier, who has used, however, an induc-

tion apparatus. Ferrier's method (p. 32-3) consists in cutting away the skull and the dura mater and applying blunted electrodes to the surface of the brain. Proceeding in this way he has apparently succeeded in defining the functions of different parts of the cerebral mass. All parts of the brain in front of the fissure of Sylvius—the anterior lobe—have to do with certain motor actions, of the paws, legs, tail, the facial muscles, and the muscles of the tongue. The convolutions of the middle lobe—behind the fissure of Sylvius—seem to be devoted to the special senses of sight, hearing, taste, and smell. The corpora striata are motor in function, and electric excitation of them causes muscular movements of the opposite side of the body. The corpora quadrigemina are concerned in vision, and strangely preside over the extensor muscles. The cerebellum appears to be the centre for the movements of the ocular muscles, and for those co-ordinated muscular acts which require for their accurate performance the aid of vision. This is a confirmation of the views of Broadbent regarding the special function of the cerebellum.

Faradization of a hemisphere of the brain caused violent epileptiform convulsions of the opposite side—a fact which indicates the correctness of the theory of epilepsy propounded by Dr. Hughlings Jackson, viz., that unilateral epilepsy is a result of irritative lesions in the convolutions grouped about the corpus striatum.

The accuracy of the conclusions of Ferrier have been called in question by Fritsch and Hitzig, who maintain that by using strong faradic currents the central ganglia of the base are called into action. The most damaging opposition to the views of Ferrier has come from Dogny and Carville (*Gazette Médicale de Paris*, Nos. 2, 3, and 4, 1874). In his inaugural thesis Dupoy has presented the results which he has obtained by a course of experimentation made in the laboratory of Volpino. He has shown that Ferrier's observations must be regarded as inconclusive, because the faradic current which he has used cannot be localized to the cortical layer, and that the apparent excitation of this layer is due to the diffusion of the current through the white matter to the central ganglia. Moreover, when the animal operated upon is *completely anesthetized*, electric irritation confined to the gray matter of the convolutions does not cause muscular movements, although electric excitation of the sciatic at the same time induces brisk contractions of the muscles to which it is distributed.

M. Carville has pursued the same line of investigation, and has arrived at identical results.

The following are his conclusions:—

"The peripheric layer of the hemispheres is not excitable, and is insensible, and does not contain special motor centres.

"The effects obtained by faradization due to the penetration of the current to the striated bodies and to the peduncles, are those of direct excitation of these organs.

"The effects are not due to reflex action.

"Complete anesthesia which hinders the effects [of Ferrier] does not change any of the conditions of the peripheric layer of the hemispheres, and does not effect the excitability of those parts of the encephalon known to react under stimuli."

It is obvious that further observations will be needed to decide the important question of the electric excitability of the cerebral hemispheres.

Nothing has hitherto been done to subject the human brain to a course of experiment in order to determine the nature of its functions. It is true lesions have occurred so exactly limited to special parts as to throw great light on their uses. In this way the faculty of language has been associated with the anterior part of the left hemisphere, the corpora striata with motility, the optic thalamus with sensation, etc. The influence of pressure has been studied in cases of injury, hemorrhagic extravasation, effusion, etc. The brain when exposed by injury has experienced such a degree of concussion or damage to its structure, that any exact observations of the functions of its parts cannot be made. Having had a case recently in which a considerable portion of the posterior lobes of the brain was exposed by disease without any interruption of its functions, I ventured to make some experiments on the plan pursued by Fritsch and Hitzig and Ferrier. I beg to submit the results to the readers of the Journal.

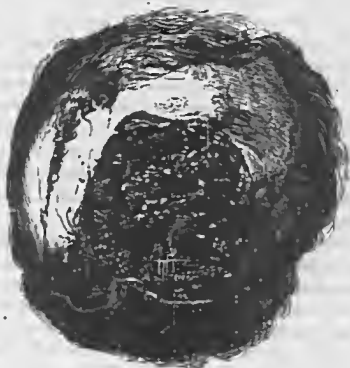
Epithelioma of the Scalp of Thirteen Months' Duration. Exposure of the Dura Mater. Experiments on the Functions of the Posterior Lobes. (Details of the case by Dr. Steeley, House Physician.)

Mary Rafferty, æt. 30; born in Ireland; present residence, Cincinnati; occupation domestic. Admitted to the Good Samaritan Hospital, January 26, 1874.

Mary is a woman of medium height, is not very well nourished, and is rather feeble-minded. She is one of five children, all of whom are in good health. Her father died of an unknown acute disease, but her mother is living in good health. Mary's health has always been good until thirteen months ago, when a small ulcer appeared on the scalp, produced as she supposed by the friction of a piece of whalebone in her wig. When an infant, she had fallen into the fire, her scalp was badly burned, and the hair was never reproduced. There is no history of syphilitic infection. She has never had falling sickness or attacks of unconsciousness.

She presents on admission an appearance of moderate health, although not strong. There is an open ulcer on the posterior and superior border of both parietal bones, nearly circular in shape, the margin on the left side being four inches from the left meatus auditorius externus, and three and a half inches on the right side from the right meatus auditorius externus. The most anterior portion of the ulcer is four inches from the root of the nose and posteriorly it extends to within two and a quarter inches of the occipital protuberance. The skull is eroded and has disappeared over a space two inches in diameter, where the pulsations of the brain are plainly seen. The edge of the ulcer is thickened and hard; the

excavation secretes a great quantity of pus; pain is experienced, but it is not very acute.



Although rather feeble-minded, Mary returns correct replies to all questions. The history which she gave of her case has since been confirmed at all points by her sister and cousin. She does not hesitate for words. She is cheerful in manner, and smiles easily and frequently. The pupils are normal. She does not complain of headache or vertigo. The tactile sensibility is about normal on the left side of the face; on the right it appears to be lower, for both points of the æsthesiometer are only felt at a distance of one inch. Both points of the compass are felt at a distance of one inch and a quarter on the dorsal surface of the hands. There is no impairment of her sensibility to pain or of her appreciation of temperature. The muscles of the extremities react normally to the faradic current. The muscular sensibility, also, is normal.

Apparatus and Method of Experiment.—Galvanic current from a 60 Siemens and Helske cup battery. Faradic current, primary, from Galvano-Faradic company's double cell battery. Insulated needle electrodes of various lengths.

As portions of brain-substance have been lost by injury or by the surgeon's knife, and as the brain has been deeply penetrated by incisions made for the escape of pus, it was supposed that fine needles could be introduced without material injury to the cerebral matter. The needles being insulated to near their points, it was believed that diffusion of the current could be as restricted as in the experiments of Fritsch and Hitzig and Ferrier. The method of procedure was proposed to consist in tentative experiments with both currents on different parts of the brain, proceeding cautiously; in careful thermometric observations to note varia-

tions of temperature; in sphygmographic observations to ascertain the effects on the blood pressure and arterial tension. Unfortunately, owing to a rapid extension of disease to the left hemisphere, these details were not fully carried out.

Observation 1. To test the sensibility of the dura mater and brain.—Needles were inserted at various points into the dura mater and into the brain. When the irritable granulations of the surface of the ulcer were touched, pain was experienced; but when the needle points were engaged in the dura mater, Mary declared, in answer to repeated questions, that she felt no pain, and certainly did not indicate any by her conduct. No pain whatever was experienced in the brain-substance proper. Mechanical irritation of the cerebral matter produced no results on motility or sensibility of the extremities.

Observation 2. To test faradic reaction of the surface of the dura mater.—Two needles insulated were introduced into left side until their points were well engaged in the dura mater. When the circuit was closed, distinct muscular contractions occurred in the right arm and leg. The arm was thrown out, the fingers extended, and the leg was projected forward. The muscles of the neck were thrown into action, and the head was strongly deflected to the right. These effects were produced by the current from one cup, the wooden cylinder entirely inclosing the bobbin. (Current of least volume and intensity from one cup.)

The same phenomenon precisely occurred when the right posterior lobe was acted upon by a current of the same strength. The head was deflected strongly to the left, and the extensors of the left arm and leg were thrown into action.

Observation 3. To test faradic reaction of the posterior lobes.—Passed an insulated needle into the left posterior lobe so that the non-insulated portion rested entirely in the substance of the brain. The other insulated needle was placed in contact with the dura mater, within one-fourth of an inch of the first. When the circuit was closed, muscular contraction of the right upper and lower extremities ensued, as in the preceding observations. Faint but visible contraction of the left orbicularis palpebrarum, and dilatation of the pupils, also ensued. Mary complained of a very strong and unpleasant feeling of tingling in both right extremities, especially in the right arm, which she seized with the opposite hand and rubbed vigorously. Notwithstanding the very evident pain from which she suffered, she smiled as if much amused.

The needle was now withdrawn from the left lobe and passed in the same way into the substance of the right. When the current passed, precisely the same phenomena ensued in the left extremities and in the right orbicularis palpebrarum and pupils. When the needle entered the brain-substance, she complained of acute pain in the neck. In order to develop more decided reactions, the strength of the current was increased by draw-

ing out the wooden cylinder one inch. When communication was made with the needles, her countenance exhibited great distress, and she began to cry. Very soon the left hand was extended as if in the act of taking hold of some object in front of her; the arm presently was agitated with clonic spasms; her eyes became fixed, with pupils widely dilated; lips were blue, and she frothed at the mouth; her breathing became stertorous; she lost consciousness, and was violently convulsed on the left side. The convulsion lasted five minutes, and was succeeded by coma. She returned to consciousness in twenty minutes from the beginning of the attack, and complained of some weakness and vertigo.

Observation 4. In test faradic reaction of posterior lobes.—These observations were the same in character as the preceding, except the strength of the current was not sufficient to produce the epileptiform attack. On both sides the results observed were precisely the same as those indicated in previous observations, viz.: Muscular contractions of the extensors on the side opposite the lobe acted upon; pain and tingling in the extremities, especially in the hands.

Observation 5. In test galvanic reaction of posterior lobes.—Two days subsequent to observation 4, Mary was brought down into the electrical room with the intention to subject the posterior lobes to galvanic excitation. The proposed experiment was abandoned. She was pale and depressed; her lips were blue; and she had evident difficulty in locomotion. She complained greatly of numbness and tingling in the right arm, shoulder, and foot. She used the right arm very awkwardly, and on further examination there was found to be decided paresis and rigidity of the muscles of the right side of the body. She explained the difficulty in walking by saying that she was extremely dizzy. As she sat in the chair answering my questions, I observed rhythmical movements of alternate contraction and relaxation of the muscles of the right arm. These soon extended to the shoulder and neck, so that the head moved synchronously with the arm. She became very pale, her eyes closed, and she was about to pass into unconsciousness, when we placed her in the recumbent posture, and Dr. Steeley gave her, at my request, chloroform by inhalation. The movements soon ceased.

Observation 6.—The day after observation 5 was made, Mary was decidedly worse. She remained in bed, was stupid and incoherent. In the evening she had a convulsive seizure, lasting about five minutes, confined to the right side. After this attack she lapsed into profound unconsciousness, and was found to be completely paralyzed on the right side. This paralysis involved both motion and sensation, for no movements of any kind could be excited by strong irritation of the skin of the paralyzed side. There was convergent strabismus and the pupils were dilated and motionless.

Autopsy.—The brain only was examined. There were no unusual ad-

hesions of dura mater to the skull. The superficial veins were deeply gorged with blood. A thick layer of greenish-yellow pus extended over the whole of the left hemisphere, and an intense degree of vascularity existed over the whole brain. There was a thick layer of yellowish-white exudation, corresponding to that part of the ulcer overlying the left posterior lobe, and extending downward on the left side of the falx. There were no products of this kind on the right side. No special appearances were observed about the points at which the needles were inserted, and the vascularity and the exudation on the left side were not apparently increased at these places.

Before making an inspection of the needle wounds, the brain was placed for twenty-four hours in a solution of chromic acid. When sufficiently hardened, careful horizontal sections were made of the upper part of the hemisphere to ascertain what injury, if any, had been done to the cerebral matter. The track made by the needles could be distinctly traced on both sides. On the left side the needle had entered the upper parietal lobule of Ecker (*The Cerebral Convulsions of Man*, p. 38), the gyrus centralis posterior of Henle (*Handbuch der Nervenlehre des Menschen*, p. 149, *et seq.*, Braunschweig, 1871), the postero-parietal lobule of Turner, one inch from the longitudinal fissure, and had penetrated a depth of one inch. The track of the needle was marked by some diffused cerebral matter two lines in diameter.

On the right side the needle had entered the same convolution, but more posteriorly, and one inch and a half from the great longitudinal fissure. The needle on the right side had also penetrated to a greater depth—one and a half inch—and its track through the lobe was marked, as on the other side, by a line of diffused cerebral matter. The surrounding brain-substance was perfectly unaffected by the injury in the track of the needle. Beside the intense vascular congestion, there was no other lesion, except that immediately produced by the needles.

The principal factor determining the marked engorgement of the superficial cerebral veins was a thrombus of the great longitudinal sinus, which lay nearly in the centre of the rodent ulcer, and which was reached by the ulcerative process through continuity of structure. The most marked evidences of inflammatory action were immediately adjacent to the great longitudinal sinus and on the falx, points which were not touched at all by the needles. Although it is obvious that even fine needles cannot be introduced into the cerebral substance of man without doing mischief, yet the fatal result in this case must be attributed to the extension of the epitheliomatous ulceration to the sinuses, and the formation of a thrombus, and to the inflammation of the arachnoid set up through the invasion of the dura mater by the epithelioma at its point of greatest depth—the centre of the ulcer.

The convolutions subjected to electric irritation are anatomically most

intimately connected with the commissural fibres of the posterior and middle lobes of the hemispheres and with the posterior portion of the optic thalami (Luys, *Recherches sur le Sys'tème Nerveux, Cérébro-Spinal, etc.*, p. 175, and *Atlas de Planches*, Pl. xxii., xxiii., xxiv., and xxv.)

It has seemed to me most desirable to present the facts as I observed them, without comment.

ART. II.—*Remarks on Embolism.* By ED. G. LORING, M.D., of New York. (With five wood-cuts.)

ALTHOUGH cases of so-called embolism are still, from their rarity and from the uncertainty of their origin, objects of interest, I doubt whether I should have felt authorized in giving a detailed account of the following cases, had not their further development been attended with some interesting phenomena; which have served to raise a doubt as to the correctness of the diagnosis of embolism, which had previously been applied to them, as well by some of my colleagues who had examined them, as by myself; a doubt which has served also to raise the inquiry whether similar cases have not already been classified in a category to which they did not belong.

CASE I.¹—A. O., aged 62, presented herself in December, 1869, with the complaint that she was "blind in one eye." She had always been remarkably healthy, and had never had any previous trouble with her eyes. Three weeks before this, while standing perfectly still, sight in both eyes became suddenly obscured by a dense cloud which, as she expressed it, had a "quivering motion." This was unaccompanied by any pain, and the sensations which the patient experienced at the time were exactly those which she had previously felt when about to faint, which had occasionally happened to her in former years. The cloud passed away from the left eye almost immediately, vision becoming at once as clear as ever. The vision in the right eye remained so much diminished that the patient could only tell light from darkness.

During the three weeks between the occurrence of the trouble and her visit to us, vision improved a little at times, but the improvement was only occasional and then very transient.

Externally the eyes presented nothing abnormal. The ophthalmoscopic examination showed that the media were perfectly clear. The optic disk rather injected than pale, but not markedly so. The arteries were not much reduced in size, while the veins on the contrary were enormously distended, and were without any double contour from their very commencement up to their exit from the globe. There were three hemorrhages, all of which were venous (see Fig. 1), one of which was evidently of recent origin, the other two manifestly of longer standing, as the hæmatin had been absorbed from them; they were, however, of no great date, as could be told by their colour. The hemorrhage of recent date was, as

¹ This case was reported before the N. Y. Ophthalmic Society, January, 1870.