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CEREBRAL LOCALIZATION.*

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It is well in our specialty, from time to time to review the immediate past history of each of its branches, so constant is the progress in the study of mental diseases. It is almost, I might say, quite impossible for the busy superintendent of an insane hospital to keep *au courant* of all the recent advances in his department, and yet it is of the greatest importance to do so.

Perhaps at the present moment, no subject demands more careful study of all the details of investigation up to the date of writing, than that of cerebral localization. This implies a fair general knowledge of cerebral anatomy, physiology and pathology as related to insanity, and a knowledge of the latest results of special research into the functions of the cortex of the brain, by means of physiological experiment and clinical observation. The practical side of the question, includes the latest studies of cranio-cerebral topography, and the results of the recent wonderful development of brain surgery. The discovery of the feasibility of locating and removing tumors, and diseased portions of the brain, with consequent recovery in many cases, is one of the greatest advances of modern surgery. The brilliancy of this discovery shines with at least a reflected light on the department of medicine to which we are devoted.

What is that morbid condition which forms the basis of insanity, and what part of the brain does it affect? This obscure question requires some attempt to explain the normal functions of the brain. We know the cerebral functions include the sensory, motor, and mental manifestations, because in injury or disease, or under toxic influences, these functions are impaired or obliterated. Much has

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been learned of late years, to render less obscure and perplexing, the complicated cerebro-spinal apparatus. The structure and functions of white and gray matter, of nerve cells and fibres, of ganglia and centres, of the many-layered cortex and its numerous convolutions, have come to be quite well understood by the expert microscopist and specialist in this branch of anatomical science.

A minute detailed knowledge of cerebral anatomy is however, beyond the reach of most alienists and even the anatomical specialist can only confess how little he knows, compared with what remains undiscovered. We are certain however, that the cerebral cortex in some way, subserves the purposes of mental operations. Many abortive attempts have been made from the time of Gall and Spurzheim to that of Fritzsche, Hitzig, Ferrier and their followers, to localize some of the mental faculties in their corresponding cerebral convolutions. The experiments of Longuet, Dalton and others long ago demonstrated that the cerebral hemispheres exclusive of the ganglia form a centre not directly essential to animal life, but devoted to a still higher class of functions.

Numerous systems of fibres have been demonstrated in the cerebral hemispheres, of which the more important are as follows:

(1) The Corona radiata; (2) The expansion of the corpus callosum; (3) The fibres of the anterior commissure; (4) The expansion of the nerves of sense, especially the optic nerve; (5) special systems, which pass from one convolution to another and arciform fibres, which connect different parts of the same hemisphere.

Without going into detail, it may be stated, that these fibres spreading out, are distributed to the convolutions along certain main lines; they do not enter each convolution and form an axial plane, as there are extensive tracts of convolutions which receive no central fibres at all. These tracts are connected with these lines, and with each other, by fibres running for the most part longitudinally in the brain. The fibres connecting one gyrus with another do not cross transversely under the sulci, but run longitudinally in the convolutions seeming to imply independence of function—more or less perfect in these portions of the cortex.

The cortex, consisting of dark and white matter in layers, varying in number from four to eight, presents a nervous apparatus of the utmost delicacy and complexity. It is in general composed of fibres, ganglionic cells and granules suspended in the homogeneous tissue of the neuroglia. The nerve cells vary in shape and size, being oval, fusiform, angular and pyriform, so disposed in layers as to give evidence of the highest elaboration of function. Vir-

chow compares these characteristic apparatuses to the layers of the retina. Maudsley says "the general result of research is the fact that an infinite number of communications exist in all directions between an infinite number of cells of all varieties of shape." Van der Kolk states that "wherever there are differences of structure and relation, differences of function exist."

We find in the cerebral cortex, a nervous apparatus similar to, but vastly more extensive and complex than the lower ganglia, and therefore suited to the highest conceivable sensori-motor functions. Is it not equally well suited to the so-called functions of the mind?

We may take what has been called a diagrammatic view of the cerebro-mental functions, and for this purpose we must divide the nervous apparatus into four sections, or spheres of action, viz.: organic, reflex, sensori-motor and ideo-motor. The organic centres have an independent action, originating in the sympathetic ganglia, although modified and controlled by their connection with the spinal cord. Their operations are carried on outside the spheres of consciousness. Their functions, though simple, powerfully affect and are powerfully affected by the higher centres.

The spinal cord and medulla, are the chief centres of reflex action, though this mode of reaction pervades the entire nervous system. Here originate those motor impulses which respond directly to excitation. In man, they are for the most part primarily under voluntary control, and are only secondarily automatic. Examples of secondary automatic action, make up a large part of our daily life.

This independent action of the reflex centres, is liable at any moment to become subject to the centres next above, viz.: the sensori-motor centres.

Dr. H. P. Bowditch is at present making an elaborate series of experiments on the patella tendon reflex, which will show how sensitive this phenomenon is to sensory and emotional reinforcement, by action of the higher centres—also how diversion of muscular energy into other channels retards it.

Sensori-motor action may be voluntary, and it may be unconsciously performed, the mind taking no note of the guiding sensation. Dancing, marching, walking, singing, and many other complicated sensori-motor acts, may under some conditions become automatic. The phenomena of somnambulism, hypnotism and insanity furnish abundant proof of the extent to which automatic

action may go when the supra-sensory centres are asleep or pre-occupied.

The ideational centres form the fourth division of our diagrammatic system. They are brought into relation with the outer world through the sensorium. These centres are referred, by general consent to the cerebral cortex.

Here in one portion of its extent, or throughout the whole of it we have an ideatorium capable of education through sensory channels. Simple ideas here become established, organized, grouped and associated in great variety, according to individual experience and capacity. The ideational centres react more or less directly through an extensive and complicated system of motor fibres, basal ganglia, medulla and cord. Ideo-motor action may be involuntary, a sudden thought exciting instant reaction. It may be unconscious, the train of ideas following certain laws of association, and producing certain results which the mind perceives without having been aware of the process.

The best results of ideation are of this spontaneous character, self-consciousness serving often to retard the mental operations. The ideational centres have no immediate connection with the action of individual muscles. The will can only control, and the mind is only conscious of movement in the mass.

Ideation deals with movements as well as sensations in the abstract. As there is a sensorium where sensations are combined and coördinated, there is a motorium, containing the organized residua of all past actions, ready to respond to adequate stimulus in any direction.

How do we know that the ideational centres, in other words, the material substratum of the mind, is to be found in the cerebral cortex? Pathology ought to throw much light on this subject. As the one symptom peculiar to all forms of insanity is a tendency to dementia, so the pathological condition common to all advanced stages of mental disease is atrophy of the cortex. In only six out of sixty-eight autopsies made at the Boston Lunatic Hospital by Dr. W. W. Gannett, and tabulated in my report for 1888, was there lack of evidence in some degree of atrophy of the cortex. In these six cases the patients died of fatal organic diseases intercurrent with the insanity. In two of them there was extensive pachymeningitis; in one, external exostosis of the skull; in one, great anæmia of the brain; in one, tubercle of the brain; and in the last, general tuberculosis. In each case the patient died before insanity was fully developed, and no doubt atrophy would have

occurred sooner or later. In five of the six cases there was a lesion which affected the cortex generally. In only one case, then, out of sixty-eight, was there an apparent exception to the rule, of some general lesion of the cortex in all cases of mental disease. I am unable fully to explain this exceptional case, and yet I am satisfied it does not disprove the theory which locates the ideational centres in the cortex.

It was a case of decidedly insane heredity; the patient's father was a dipsomaniac, and the patient an inebriate. He was insane a year before admission at the age of thirty-three, and remained three years in hospital before he died. His mental symptoms were of a most pronounced type, beginning with melancholia, with hallucinations of sight and hearing. He soon became maniacal and violent, and at times had cataleptoid attacks, and anomalous muscular movements and tonic spasms, followed by real or apparent dementia. The diagnosis of katatonia was made at the time. His lungs, liver and intestines gave evidence of extensive tuberculosis, but the brain was apparently perfectly healthy, and no microscopic changes were noted in sections from seven different localities.

Whether we regard cerebral atrophy as the cause or result of insanity, senility and general paralysis, it is equally good evidence of the location of the mental functions in the cortex. It is probable that morbid changes in the nerve cells of the cortex proceed to decided atrophy step by step with the slow progress of acute insanity to complete dementia.

During a rather short period, in most cases a few months or a year, the morbid deterioration may be arrested, and the cells of the cortex restored to healthy activity. In other words, insanity, in the early stages, is often curable, and the disease may be termed functional in the sense that no lesion of the cortex or disease of the cells may be apparent to our imperfect methods of examination. It is probable that any great change in the cerebral blood supply constituting either anæmia or hyperæmia, may sometimes suffice to produce an attack of mental disease.

The continued presence of some toxic element in the blood, either the result of morbid organic processes of some kind or introduced from without may suffice to produce insanity. These causes are of exceeding frequency in the production of mental disease, and of a curable kind, up to a certain point, if the morbid matter can be removed from the blood.

But however caused, there is a strong tendency in all forms of

insanity to become chronic and to progress more or less swiftly to dementia. In all old cases of insanity, however caused, are found similar changes affecting the cortex and meninges over a large extent of the surface of the brain.

In the sixty-eight autopsies already quoted, the following lesions were present: œdema of the pia, 55 times; chronic ependymitis, 30; chronic leptomeningitis, 29; atrophy of cortex, 26; various forms of pachymeningitis, 14; chronic endarteritis of basal and other vessels, 11; anæmia, 8; hyperostosis of skull, 8; chronic internal hydrocephalus, 7. These were the lesions most frequently found, and it will be seen they all involve the superficies of the brain, including the cortex more or less directly.

There were nineteen cases of general paralysis in the sixty-eight autopsies. In addition to the above lesions were a large number of accidental gross lesions of the brain occurring one or more times; such as tumors, softening, hemorrhages, aneurisms, and the like.

The microscopic appearances were equally significant of cortical lesion, and support the same theory of the location of mental functions equally well. The most frequent changes observed were increase of the fibrous element in the pia and cortex, round cell infiltration, pigmentation of ganglion cells of cortex and sheaths of vessels, fatty degeneration of the capillaries of cortex, effusion, hemorrhage or dilation around vessels of pia and cortex, spider cells, corpora amylacea, granular corpuscles, and other changes more or less significant of chronic degeneration of the cortex.

Having shown that the seat of the lesion in insanity is in the cerebral cortex, let us see if any of the functions or faculties of mind have been more definitely located. The honor of discovering that the motor centres concerned in speech are located in the posterior third of the third left frontal convolution, undoubtedly belongs to M. Broca. He published two cases supporting this theory in 1861, and this first successful attempt at localization has been the fruitful parent of many observations and experiments, until more than half the cortex has been definitely mapped out with a score or more of centers of movement or sensation.

In 1870 (*Boston Medical and Surgical Journal*) I reported thirty-eight cases of aphasia, giving the prominent symptoms and lesions, and including all the cases at that time sufficiently well described to be available. Among other conclusions, I find the following:

“IV. Theoretically, the lesion in aphasia may impair the power

of speech by producing disorders of ideation, loss of memory for words, interruption of voluntary transmission, interference with auditory impressions, defects of coördination and paralysis of the muscular apparatus. Practically the lesion gives rise to two or more of these forms of aphasia at once."

"V. As a rule, the lesion in aphasia will be found in the anterior lobes, and on the left side, in the proportion of about fifteen times to one. The evidence for the more limited location of M. Broca is conflicting."

The experiments of Ferrier and others, have since located the motor centre of speech definitely in the place assigned to it by M. Broca, while sensory aphasia in the forms of word deafness and word blindness, depends on the lesion of centres situated at some distance in the temporal and occipital lobes.

Ferrier, improving on the methods of Fritzsche and Hitzig in 1870, continued their researches by experiments on dogs and monkeys. By stimulating small portions of the cortex by a very mild galvanic current, definite muscular contractions were excited. The cortical centres so determined, were referred to the corresponding convolutions in man. Fortunately the convolutions in the higher apes, correspond very well to their homologous gyri in man.

It is an undoubted fact, that physiological experiment has been more useful in locating the cerebral centres, than has a study of lesions affecting the cortex. It is so seldom that a strictly limited lesion produces a definite and diagnostic symptom.

The nature of the representation of movements in the cortex has been misunderstood by many of the opponents of Ferrier's views. Because single muscles have not been moved by electrical stimulation of the cortex, the whole theory of such representation, has been scouted. It is a fact, that the mildest stimulation of the smallest possible area of the cortex, produces not movement of a single muscle, but the simplest coördinated movement proper to some segment of a limb, for instance. Greater stimulation of the same spot calls out more extended and complicated movements of the same limb. This shows that movements and not muscles are represented in the cortex. It also shows how closely related are the centres of movement for the same segment of the body. This is what we might expect when we remember that we cannot voluntarily contract any single muscle of the body.

Although Ferrier's conclusions were disputed by some for a long time, they have now been in the main, accepted and confirmed.

A reference to the writings of Horsley, Roswell Park, Seguin, Dana, Bramwell, Wells, Starr, Weir Mitchell and others, will show the present state of the discussion. I have transferred to a rough diagram of the convolutions conveniently enlarged, the cortical motor centres as at present located, from a small diagram of Dana's, and another chart from the same source shows, that the sensory cortical centres as at present located, are nearly coincident with the motor region. (See Figs. 1 and 2.*) It will be further

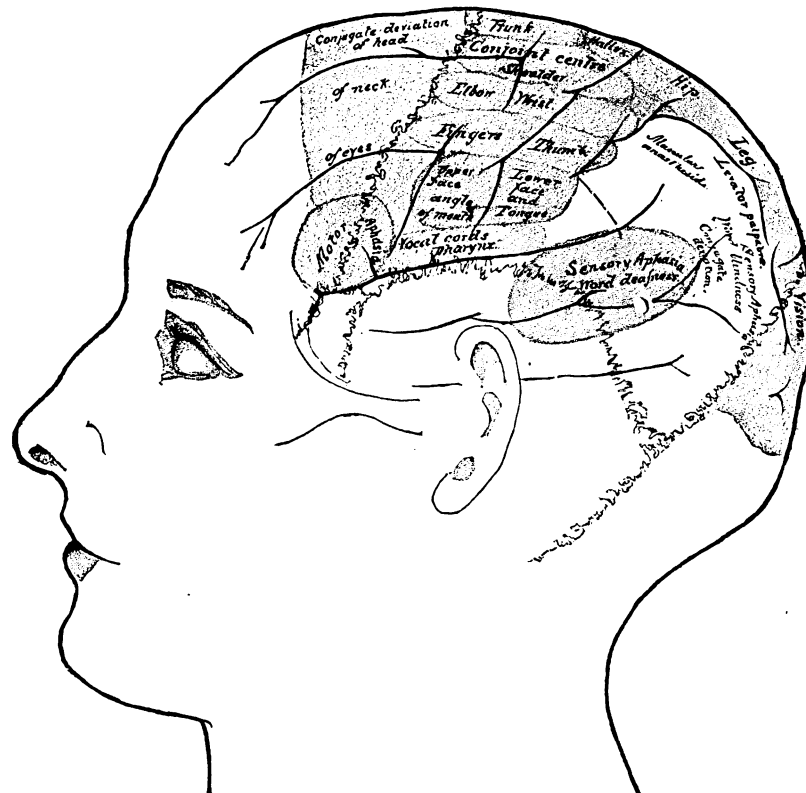


FIG. 1. Diagram showing cerebral fissures and cortical centres mapped out on the scalp.

noticed that all portions of the body, if not all possible movements and sensations, are represented in the region enclosed. We call these localizations, motor and sensory centres, but they are really centres of ideation. The greater part of our mental operations

* Messrs. Wm. Wood & Co., publishers of the *N. Y. Medical Record*, have courteously placed these wood-cuts at the disposal of the JOURNAL.—ED.

are directly connected with sensory and motor phenomena, and are so completely represented in the region described that it is hard to imagine just what functions the unassigned portions of the cortex can represent.

Stimulation of the region outside of this enclosure is negative in its results. Generally speaking, the anterior half of the frontal lobes, the posterior portion of the occipital lobes, the basal surface of the brain, and the inner surfaces of the two hemispheres, constitute the true *terra incognita* of the cortex. Here is certainly room enough for the location of the higher centres concerned in

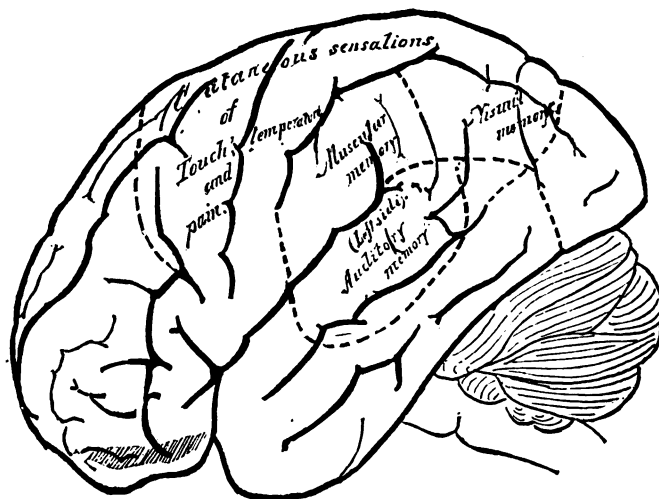


FIG. 2. Sensory cortical localizations.

mental action. Speculations concerning a more definite subdivision and localization of the mental functions would be unprofitable at present.

Dana's article (*N. Y. Med. Rec.*, January 12, 1889,) is a most excellent one, giving very precise rules for the location of the principal fissures and convolutions on the cranial surface; minute and exact measurements are of the first importance in connection with brain surgery, and I learn from Dr. Knapp's (*Boston Med. and Surg. Journal* 1889,) experiments that the rules of Broca are very misleading.

In examining the skull, some allowance must be made for variations due to deformities, accidents, perversions of growth and disease, especially in the insane. In 1871, it occurred to me to

compare a large number of adult male heads, both among the sane and insane by means of the hatter's *formateur*. I found by comparing numerous areas and diameters of the small outline figure obtained by the *formateur* in one hundred sane heads and eighty-five insane ones, that there was a uniform and decided deficiency in the averages of all of these dimensions among the insane. It was shown not only that the insane head was smaller, but that it was oftener deformed, asymmetric and misshapen. The relations of fissures and convolutions to the sutures, might be somewhat affected by these abnormalities of the insane head.

The first chart referred to (Fig. 1) agrees fairly well with that of Ferrier. The centres of muscular movement are arranged, roughly speaking, in order from front to rear, as the several portions of the body would be if a man went on all fours. We have a patient at the Boston Lunatic Hospital, whose case confirms in one or two points, the accuracy of this chart. Twenty-five years ago he fell fourteen feet and struck his head, making a depression in the right middle parietal region, about one and a half inches in diameter. Thane's method was used for finding the fissure of Rolando. This method places its upper extremity at 55.7 per cent of the distance from the glabella to the occipital protuberance. A line drawn two and one-quarter inches from this point at an angle of sixty-seven degrees and one and one-eighth inches more vertically will indicate the course of the fissure. The depression is directly over the lower extremity of this fissure, covering the centre for certain movements of the vocal chord and pharynx. Just in front on the left would be the centre for motor aphasia and just behind the centre for certain movements of the tongue.

This patient was treated at the Massachusetts General Hospital after the accident, but was not trephined. He soon developed *petit mal*, and also became an habitual drunkard. He however was able to marry, and has an insane daughter. He has supported himself all these years by carpenter work, and at the hospital works regularly and well on nice work in the hospital shop. He is not much demented, but is cranky and irritable and suspicious merely. He was committed as an habitual drunkard, and not as an epileptic. He has had for years certain symptoms probably due to the original injury.

There is a slight ptosis of the left eyelid; his tongue turns persistently and decidedly to the left, so much so as to impair his speech. The records at the Massachusetts General Hospital mention paralysis of the left side of the face and tongue as the chief

symptom, and it has continued to the present time. There is now some fibrillary tremor of the tongue. His voice is raucous and changed since the accident. Dr. Craigin, interne at the Boston Lunatic Hospital, examined his throat with the laryngoscope, and found general relaxation of palate, uvula and vocal chords, but could not discover any uni-lateral paralysis of those organs. The strength of his hands by the dynamometer is rather subnormal being 110° in each. There is increased kneejerk and ankle clonus on both sides. There was no sensory impairment discovered by the æsthesiometer in his hands and arms. Most of these symptoms might have been predicted, knowing the part affected.

The foregoing case opens the question of the advantages of brain surgery in similar cases of traumatism and tumor. The article of Horsley (*Journal of Medical Science*, April, 1887,) is an important one in this connection. His personal experience in the removal of tumors of the brain, depressions of skull, etc., at this time amounted to ten cases. He says that the value of the sulci in separating areas of the cortex with different functions, is not absolute and definitive. The arm for instance, is represented on both sides the fissure of Rolando; this fact however does not militate against the general principle of localization. The true value of the sulci, has still to be determined. They are useful as landmarks, but not always as boundaries. It is necessary of course in any study of cranio-cerebral topography, to determine the location of the sulci, and by their means of the convolutions.

The localities in which the different functions are located are not separated by hard and fast lines, but they occupy absolutely constant focal positions. The sense centres, he says, are not accurately located yet.

He further says there is a greater difference of function between the top and bottom of the motor region, than between the front and rear of it, and this corresponds to the decrease in size of the motor corpuscles from above downwards. These are constant in size at the same horizontal level. One should imagine the upper and lower frontal sulci, carried horizontally backwards, and a line drawn parallel to the fissure of Sylvius from the lower end of the intra-parietal sulcus. These will separate important levels of function. In apes, the convolutions run longitudinally. In man the fissure of Rolando is an interloper, but of course, has its meaning, if we only knew it.

Horsley gives diagrams locating most of the motor centres, his own researches confirming generally the experiments and experi-

ence of others. He also gives the results of some of his operations on the brain.

Since it has been repeatedly shown that opening the cavity of the skull and removing a tumor superficially located or excising a portion of the cortex is a comparatively safe operation, it has been much in vogue. Occasional brilliant successes have stimulated surgeons in all the great centres of medical knowledge, to operations of this kind. The hopeless or fatal nature of the diseases requiring this operation is an added excuse for its performance. As in the early days of ovariectomy many useless operations have been made, ending at once or later, in death; but each operation adds its share to our knowledge of the cortical centres, and of the probabilities of relieving or curing disease in this locality.

In hospitals for the insane, cases where surgical interference would be warranted are rare, and cases where the consent of the patient and his friends can be obtained, are rarer. The patient is often insane or demented, beyond the power of giving assent. We have had one case only in which trephining was done for an injury to the brain, resulting in dementia, before his admission to the hospital.

The patient, a boy of fourteen, a year before admission, fell and struck his head against a curbstone, making a scalp wound in the right parietal region. There were signs of concussion, followed by gradual loss of memory. Three months after he began to lose power in his legs, and later in his hands. Nine months after, at the City Hospital, he was very forgetful and weak-minded, with weakness of limbs, most marked in left hand. "Speech was slow and indistinct, and tongue, three weeks after injury, rolled about in right side of mouth. Had at one time clonic spasm of left side of face and left arm; sensation generally diminished; knee reflexes alike exaggerated; double neuro retinitis." He was trephined April 27, at the Carney Hospital, by Dr. W. N. Bullard, over seat of injury. Nothing abnormal was detected, there being no adhesion of membranes, and the button of bone was replaced. He lost the power of speech immediately after the operation, and gradually became more demented and helpless, until November 15th, when he was admitted to the Boston Lunatic Hospital. November 20th had slight convulsions of right side of face, and left side of body. He died of exhaustion December 13th.

The autopsy of Dr. W. W. Gannett, pathologist to the hospital, showed no lesion at seat of injury, but general œdema of pia and

atrophy of brain, chronic leptomeningitis, chronic internal hydrocephalus and ependymitis of fourth ventricle. The microscopic appearances were those common to degenerative disease of the cortex. The whole train of symptoms in short, were due to concussion, and not to a local lesion. The trephining, though unsuccessful, was a proper and harmless expedient.

I have tabulated forty-one cases of brain surgery, the result of a very brief research. Many of them were not fully described, some important element being lacking. Recovery was claimed in fifteen cases; death occurred sooner or later in eight cases, and eighteen cases were relieved, or the result not given.

Operations for tumor, traumatic epilepsy, and cerebral abscess, were about equal in number. In the great majority of cases the localizing symptoms were sufficient to accurately determine the place of the lesion, and the operations were quite uniformly successful in finding the desired portion of the cortex.

Dr. P. C. Knapp, of Boston, has recently written a paper of much importance on this subject (*Med. and Surg. Jour.*, 1889.) He gives a summary of twenty-three cases of cerebral tumors and cysts removed, or where removal was attempted. Of these, thirteen recovered and ten died. As most of these operations are of a very recent date, it is too soon to pronounce upon the mental condition of some of them, and the permanence of recovery in some of the cases is open to doubt. Dr. Knapp deserves great credit for the very skillful manner in which he located a tumor recently removed by Dr. Bradford.

The number of alleged recoveries in the two tables referred to being about 40 per cent of the cases reported, fully justifies, I think, this method of attempted relief for a most intractable and fatal class of diseases. The positive value and reliability of the localizing symptoms in the cases reported, shows how great an advance has been made in this direction. The next decade will no doubt show still greater progress in cerebral physiology as a consequence of the general interest in brain surgery.