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REMOVAL OF RIGHT OR LEFT FRONTAL LOBES IN MAN*

BY

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In the early days of the neurological renaissance that followed the discovery of localized function in the cerebral hemispheres the frontal lobes seemed to select themselves as the seats of the intelligence by a process of exclusion. Once the motor, the sensory, the visual, the auditory, and the olfactory areas had been roughed out upon the cortex and the tracts coming to and from them plotted with gradually increasing certainty (a task to this day uncompleted), it was but natural that speculation should be busy with those large areas still remaining which were unresponsive to stimulation and often, but not always, curiously "silent" to destructive or disease processes in man.

Those of us who "teethed" in study twenty-five years ago did so on the cortical maps of Flechsig, Elliot Smith, Campbell, Brodmann, and the Vogts, and learned that the grey matter consisted of numerous areas with different developmental histories and with different histological structures. This was true not only of the projection areas but also of the various association areas, and it was demonstrable that the frontal lobes, like other parts, had not one single homogeneous structure, but were subdivisible again into several cantonments, the most posterior of which formed the motor cortex. The work of Ferrier, of Horsley, and of Sherrington in particular, allotted definite functions to the different parts of that latter area, though our knowledge even of the apparently simple motor cortex is not yet complete (see, for example, the revival of interest excited by J. F. Fulton (1932), then by F. M. R. Walshe (1935), and more recently by D. E. Denny-Brown).

The Problem of Frontal Lobe Function

Since some areas of the whole patterned cortex were known from the early days of the newer knowledge to possess specific functions—functions evidently related to structure—it seemed to be only a question of time, and of opportunity of the right kind, before these would be allotted in a similar manner to the so far silent remainder. The deduction that distinctive histological structure portended distinctive and discoverable activities was, and still is, an irresistible one. But it remains to make these areas reveal their local secrets. We have become so deeply impressed with the importance of local areas, especially the motor, that we are almost certain to assume that function is equally local in the silent localities and that a small lesion of a frontal lobe will be likely to produce an equivalent paralysis, in this case of the intellect or in emotional control. But there is in such a conception something of the absurdity that we recognize so clearly in the earliest work on the localisms of cerebral

function, that of the phrenologists Gall and Spurzheim. Clinical observation has not succeeded in solving the problem of frontal lobe function, for whilst recognizable alterations of the expected kind are quite commonly present they are in some cases lacking. Moreover, paradoxical cases are met with in which there is intellectual deficit and a lesion is discovered at operation or necropsy in quite another part of the brain. The most useful evidence of the functions of the frontal lobes (since electrical stimulation has so far failed to yield anything informative) and the solution to some of these problems ought to come from cases in which one or both were removed in man. I have no personal knowledge of a bilateral removal, but reference will be made later to the only two cases which have been carefully studied and published.

Eight Case Histories

It is the purpose of this paper to present some examples of unilateral lobectomies, both left and right, and to set down as fairly as possible what the effects have been. There are eight cases in which one or the other frontal lobe was successfully removed. Two of these patients died subsequently, one of an intercurrent disease. Six are still alive, and, since three happen to be left-lobe removals and three right, they make an interesting group for comparison. The cases are of necessity described very briefly, and a great deal of negative evidence which might be demanded for scientific accuracy has been suppressed. It is hoped that at a later date some of these cases may be made the subject of closer psychological analysis by more competent hands than mine.

It is not my intention to enter into a long discussion of the symptomatology of frontal lobe tumours, for this is well enough illustrated by the cases themselves. It will be observed that the syndrome may vary with the type of lesion and a recognizable deficit be absent, so that fits and failing vision may be the only features to call attention to disease. Something will have to be said later about the reasons for the differences—why one case should show signs and others none; and especially we shall have to discuss the results of the operations.

Case 1

A female aged 22 was referred by the late Dr. Core to the Manchester Royal Infirmary, February 19, 1932. When seen in consultation the following note was made:

The patient sits propped up in bed and seems very cheerful and comfortable. She was pleasant and co-operative, but often slow in answering, though by no means always. She did not realize the seriousness of her state, and said she was very well. She declared that she had no headache at the time nor had she suffered from it. (This was untrue—she had suffered severely from headache and had had some bad crises; a few

* Based on a paper read before a joint meeting of Rochdale, Heywood, and Oldham Divisions of the British Medical Association on April 9, 1937.

days previously she had been really very ill with it.) Questioned on the onset of her illness she was very vague, but she knew how long she had been in the hospital, her full name, and where she lived. Often a striking point was the hesitation before she answered, as if she had not heard the question at all. She was not deaf. When the question was repeated she answered, but maybe after a brief pause. She spoke rapidly enough, and never made a mistake in the arrangement of her words or use of nouns or verbs. Another obtrusive feature was her lack of volition. She spoke without vivacity with very few movements, and in a long conversation scarcely changed her posture once. She volunteered no remarks. She was completely apathetic about food, never asked for it or showed any interest when meal-times came round. Her ideation was evidently limited, for she was unable, as it were, to weave any patterns on ideas suggested to her. She thought that she had only been ill since her admission to hospital, but in this she was inconsistent, for soon she dated her illness as far back as November. (The actual date of onset, so her mother informed me, was the previous spring, and she had had to give up work because of headache and failing vision in October. She had been treated for indigestion because of vomiting, and had seen an eye specialist, who gave her glasses.) Her headache was frontal and not lateralized. She had had several attacks of twitching in her left hand. Two very brief attacks while she was unconscious had been observed in hospital, both occurring when her headache was fierce. It was thought that her right arm was drawn up close to the body, unconvulsed, in these attacks, and that the left side was quite silent. She was incontinent the rest of the day after these attacks, although quite conscious. It was interesting to observe her lack of interest in her incontinence. She forgot about it between-whiles, and when it happened passed it off as none of her business, or another time said that she voided before she realized what was happening.

Clinical examination revealed high-grade choked disks, relative anosmia in the right nostril, slight hypertonia on the left side, but no loss of motor power, no grasp reflex, left abdominals easily exhausted, equivocal left plantar reflex, flexor right. There were no radiographic abnormalities. The diagnosis was: right frontal tumour, probably a glioma.

Operation (March 2, 1932).—A right frontal osteoplastic flap was turned down. On opening the dura the cortex was pale and the gyri flattened. A high posterior puncture was made to tap the anterior horn of the right lateral ventricle but struck a gliomatous cyst at a depth of three centimetres. The cannula was at once withdrawn and the cortex incised down to the cyst wall after underrunning the cortical vessels with silk. The cyst was deep, and near the midline there was an obvious neoplastic lining. It was thought that the best way of dealing with it would be to excise the frontal lobe with the tumour inside it. The slowness of the pyramidal signs denoted that the posterior end of the tumour lay definitely in front of the motor cortex. The frontal lobe was thereupon excised, but the line of section ran into gliomatous tissue, and it was seen that the tumour was too extensive for complete extirpation. The invaded area was very thoroughly diathermized. The line of section ran obliquely upwards and backwards from the lesser wing of the sphenoid, but a thin shell of the frontal lobe was left behind mesially and inferiorly.

The effects of this excision on the patient were remarkable. It might have been thought, since she was already slow and apathetic through harbouring a tumour in the frontal lobe, that frontal lobectomy would have made her worse by removing still more normal and functioning brain tissue. Exactly the opposite happened. Next day she was extremely well, and whereas she had never before spoken unless addressed, and not always then, she now spoke readily and at first rather excitedly but sensibly. She was worried about her personal appearance, for her right eye was closed by a temporary oedema. The incontinence of both urine and faeces which had been so troublesome a feature stopped within twenty-four hours of the operation. There was no trace of contralateral palsy. She professed herself at the end of a week

to be entirely well; she was able to give details as to where she worked and when she stopped work, as well as points in her earlier clinical history upon which she had before been very hazy. She moved about more readily in bed, and seemed to have an interest in life that had been lacking. She took her food well, and behaved very much as did the other patients in the ward.

The histological diagnosis in this case was astrocytoma with areas of malignant change. Probably the tumour should be regarded as a glioblastoma multiforme.

The patient was put on deep x-ray therapy and returned home. She remained to all intents and purposes normal for eight months, when she had a return of her previous symptoms and died fourteen months after her operation. As far as the frontal lobe removal was concerned the experience was encouraging, for it demonstrated that the mental disturbance associated with a frontal tumour could be relieved by lobectomy and not made worse, a very important point and one of which little was then known. It remained to apply the operation to a patient with a tumour not so far advanced as to transgress the limits of possible extirpation. No further opportunity arose until April, 1935.

Case 2

The next case can be very briefly reported because the patient died of an intercurrent disease seven weeks after operation. The case is useful only as a piece of evidence that the frontal lobectomy did not, so far as could be seen, seriously affect his mentality.

C. B., aged 44, was transferred on March 25, 1935, to the Neuro-Surgical Service from the medical wards of the Manchester Royal Infirmary by Dr. Fergus Ferguson with the diagnosis of right frontal tumour, probably astrocytoma. He had been admitted on account of his fourth series of severe convulsions, the first having been in 1928. In each of these series his fits had amounted to status epilepticus, but after a few days he had recovered completely and returned to his duties as a clerk almost at once. After the last series he had had much more headache, and had seemed rather slow in speaking and more drowsy than he should have been. Bilateral papilloedema was discovered, and the radiographs showed a calcifying tumour in the right frontal lobe, well forward. He had performed his duties perfectly well until the last outbreak of epileptic seizures that brought him into hospital.

On April 2, 1935, the voluminous right frontal lobe containing the tumour was removed, leaving the anterior fossa empty, the olfactory nerve being clearly seen in its floor; the falx was left bare on its anterior seven centimetres. The pericallosal vessels were exposed running round the genu of the corpus callosum. The mesial surface of the opposite frontal lobe was visible. The large cavity was filled with Ringer's solution and the flap replaced. The duration of the operation was five and a quarter hours. Next day the patient was relatively well and said he wanted to smoke. On the fourth post-operative day a conversation with him was taken down verbatim in shorthand. It was designed to test his memory, and disclosed no defects. He talked about his work, his children, and his home without difficulty. He lay rather quietly and did not move about the bed much, but he spoke rather loudly, and his manner was a little aggressive, though perfectly friendly and good-humoured. He complained of coldness of the feet, but made little effort to stir his limbs, though he could do so freely when requested. This lack of initiative was perhaps significant. On the other hand, he said that he would like to get up and sit in a chair as a change. His mouth and teeth, which had been very dirty, remained so, owing to keeping his tongue and lips very still. He was not incontinent. He smoked incessantly when allowed, but gradually he became more normal and quiet in manner, and was discharged to the convalescent hospital a month after operation. Two weeks later he contracted facial erysipelas and died of pneumonia in Monsall Fever Hospital.

At necropsy the operation wound was seen to be perfectly healed. There was no intracranial infection. The truncated anterior end of the right hemisphere was covered by dura firmly adherent to the cut surface. Histological diagnosis: astrocytoma.

This case is robbed of its full value by the short survival of the patient. During the first days after his operation his state was not entirely normal, although he was in possession of his faculties so far as they could be tested. After that he steadily improved, but unfortunately a really detailed inquiry into his later condition was postponed, and then was prevented by his unexpected death. I should have been left uncertain about frontal lobe function if this had been the only case in my experience, but Case 1 had already been observed, and those that follow leave no doubt at all. In the remaining six cases the patients are all alive still, and in three at least the removal of the lesion has been so complete that their continued survival is certain. The three right lobectomies will be taken first, then the three left, though that is not their chronological order. Since the technical steps involved in these operations are very similar in all cases they will be but briefly referred to.

Case 3

Right frontal oligodendroglioma. Removal of right frontal lobe. Recovery.

Mrs. L., aged 35, was referred by Dr. Carleton of Bristol on September 13, 1935. Twelve months previously she had commenced with intermittent attacks of headache and vomiting which were thought at first to be "bilious." In addition there were attacks of dizziness, during one of which she fell and hurt herself, and had to remain in bed for a week. Whilst recumbent she had another bad vertiginous episode. She vomited severely in all of these attacks. For the last few months she was no longer sick, but had headaches of great severity at intervals of about one month, commencing usually about 2 a.m. and lasting for one or two days. The pain was all over the head, but chiefly on the right side and at the back, with some stiffness of the neck. During these acute spasms of pain it seemed to relieve her if she could hold someone's hands and dig her nails into their palms; whilst doing this she stood with bent head, her face flushed, perspiring visibly, and breathing rapidly. On this account the case was for long regarded as one of migraine with a hysterical overlay. Latterly she had become touchy and irritable. Her memory was said to be bad, but very few useful illustrations of this were forthcoming. If she went to the cinema she could not remember when she got home what the film had been about (this struck her friends as remarkable). Vaguely, also, she felt that she could not concentrate. She consulted Dr. Carleton, who found bilateral papilloedema and an extensor left plantar response. She was referred to me. Acuity was normal and the fields were full; no other signs were elicited other than those recorded by Dr. Carleton: no anosmia, no hypertonus, no grasp reflexes. Stereoscopic radiographs by Dr. Twining brought to light scattered calcification low down in the right frontal lobe. Diagnosis: right frontal glioma, probably oligodendroglioma.

Her hypertensive attacks were peculiar and suggested a third ventricle tumour until the radiographs cleared the issue. She was bright and quite alert, except during or after her violent attacks of pain, but her husband was aware of an indefinable change in her. She was admitted to a nursing home, and on September 29, 1935, the right frontal lobe was removed. The line of section passed through the frontal horn of the lateral ventricle. The mesial surface of the left frontal lobe seemed to be superficially invaded by the tumour and the posterior line of section was not above suspicion. After a blood transfusion the wound was closed. She made an uninterrupted recovery. Forty-eight hours after the operation she was reading the newspaper and carried on a normal conversation with me. Her conversations were recorded verbatim, and they showed no defect whatever. She has been having deep x-ray therapy since, and has been seen from time to time.

Re-examined in March, 1937, eighteen months after operation, she says she is as well as ever in her life, and her husband privately agrees with this. Her memory, concentration, and demeanour are all normal. She does a great deal of housework, cooking and so forth, reads, sews, and listens to the wireless. All the frontal lobe signs which she had until her frontal lobe was removed have gone. I have interviewed the husband as well as the patient more than once, and have tried to get him to allow that something was amiss, but he will never admit to anything at all. She always had been a friendly sort of person, and he is sure she is not more so now; she was naturally good-tempered, but apt to lose her temper and regain it very quickly. These traits have not been modified. Histological diagnosis: oligodendroglioma.

Case 4

Mrs. E., aged 45, was admitted to the National Hospital, Queen Square, under Dr. Purdon Martin, on February 14, 1936.

Three years previously she had consulted an optician because her eyesight was failing. Four years ago she had begun to suffer from generalized headache, which sometimes wakened her in the night. Sudden jarring or sneezing greatly aggravated the headache, which was intermittent and, though not becoming more severe, was becoming more frequent. Eight months previously she discovered that her right eye was blind. Whilst in hospital in Southampton, a month before admission to the National Hospital, she had a convulsive seizure in the night about which she knew nothing. On examination there was primary atrophy of the right optic nerve, and two dioptres swelling of the left. Apart from diminution of the sense of smell in the right nostril there were no other neurological signs. Radiographs showed a localized hyperostosis over the right optic canal—an important point, the significance of which has been commented upon elsewhere (Jefferson, 1936). There were no mental and character changes, and she was perfectly orientated in time and place. She was operated upon by me on March 12, 1936. A right frontal osteoplastic flap was turned down and a large basal meningioma removed. The right frontal lobe had to be excised in order to get proper access. The operation was arduous, the duration being five and a half hours. Apart from pyrexia during the first week convalescence was smooth. Owing to this patient living at a distance contact has had to be maintained by letter. In March, 1936, she stated that she was better than she had been for years and had no disability, mental or physical, whatever, except for the blindness of her right eye. She works as a housekeeper.

The next case is too recent for any final assessment, but since it illustrates well the disappearance or at least amelioration of frontal lobe signs following removal of the lobe it is worthy of inclusion.

Case 5

Mrs. H., aged 49, was admitted to the National Hospital, Queen Square, under Dr. C. P. Symonds, on January 7, 1937. Her history as given by herself was unreliable and needed correction by her husband on many points.

Two or three years ago she began to suffer from occasional headaches and from peculiar fainting attacks in which she did not quite lose consciousness (minor epilepsy). Four months previously her husband returned home and found her in a peculiar dazed state. She was confused and unable to give any account of what had happened. She had vomited. She recovered in a few hours, and then had no recollection whatever of the incident. From that time her headache increased in severity, and was at times, especially during the night, almost unbearable for half an hour. She became very confused during the worst headaches. She tried to do her housework, but was incapable of either initiating or completing the simplest

task. She began to show definite forgetfulness and mental deterioration. She was well aware of the undependability of her memory, and would ask her friends not to tell her things, as she would be certain to forget them. On admission, questioned about an abdominal scar, she said she had had her appendix removed a good many years before. She did not know when or where. Pressed for an explanation, she said that she had not had an operation after all. She was a well-nourished healthy woman with a mild dementia. She could not remember the name of the present King. She resented physical examination in a playful, shallow way. There was bilateral papilloedema and no pyramidal signs. Radiographs disclosed a linear calcification in the right frontal lobe. Diagnosis: right frontal astrocytoma.

On February 11, 1937, the right frontal lobe was removed, the line of section running upwards and backwards from the lesser wing of the sphenoid and cutting through the lateral ventricle. There was no great alteration in cortical pattern, but puncture disclosed a tumour at a depth of three centimetres. On taking several readings it was found to come closest to the lower surface. There was no sign of tumour breaking through the mesial surface, as is so common in apparently unilateral frontal tumours, so a complete excision was carried out. There was a suspicious area to the inner side of the ventricle, seen after it had been cut across. The duration of the operation was two and a quarter hours. A month later this patient was greatly improved. Prior to the operation she was an aimless sort of being. The ward sister reported that she would sit for hours with a plate of food and not finish it, or if she went to the bath would have sat in it all day if she had not been got out (suggesting Flourens's decerebrate chickens). After removal of her frontal lobe she gave a different impression, seeming to have a purpose—to know what to do and to get on with it. In conversation she seemed nearly normal, and lost her facetious manner. She was never incontinent after her operation, though previously she had occasionally been so. There was a slight left-sided facial weakness for a time afterwards, but no weakness in the arm or leg, and there was no grasp weakness.

I am unwilling to accept this patient as entirely free from signs at the time of writing. Her powers of memory are not yet all they should be, but her alteration for the better is striking. She was up and about the ward at the end of two weeks. Her husband has written to say that she is normal mentally, and in reply to a detailed questionnaire he reports her, on all points, as having no abnormalities. But in June she had a convulsion and lost ground afterwards. Her future is uncertain, not because of the lobectomy but because of the likelihood of recurrence.

Removal of Left Frontal Lobe

The remaining three cases had the left frontal lobe removed; they also are presented in chronological order.

Case 6

Mrs. W., aged 32, was admitted to the National Hospital, under Dr. C. P. Symonds, complaining of blindness in the left eye, failing vision in the right, anosmia, severe headache, and "fainting turns."

The diagnosis of left frontal basal meningioma was made and, since she did not desire to run the risks of tumour removal at that time, a right-sided subtemporal decompression was performed. She was readmitted on March 19, 1936, because her fainting attacks were becoming more frequent and for a month past her headaches had returned. She also thought the sight of the right eye was declining again. The decompression had meanwhile varied, sometimes tight, sometimes slack, but always bulging to some extent. Neurological signs were as before: left optic atrophy, blind left eye; right papilloedema, field normal save for enlargement of the blind spot. She had anosmia, and protein increased in the cerebro-spinal fluid to 200 mg. On April 30, 1936, a left frontal osteoplastic flap

was turned down and a small meningioma was found growing from the falx. The superior longitudinal sinus and a section of the falx were removed, whereupon a second, much larger, meningioma was seen arising from the olfactory groove. The left frontal lobe was resected to give access to this tumour, which was removed in its entirety and its point of origin heavily endothermized. The duration of operation was five hours and forty minutes. One blood transfusion was given after four hours.

One hour after the close of the operation the patient spoke to the operator and said that she felt all right but was afraid of the ordeal which she thought she still had to undergo. Her convalescence was uneventful; at no time did she show any evidences of mental disturbance. She has been re-examined at intervals during the past eleven months, and was shown at the clinical meeting of the Neurological Section of the Royal Society of Medicine in February, 1937.

She does all the housework, shopping, and mending. She declares herself to be entirely normal in every way. She is never at a loss for a word; indeed, it was suggested that she was a trifle facile verbally. This patient has been in hospital for two long stretches, and great interest has been shown in her. She is naturally a friendly

FIG. 1.—Left frontal lobe, subtotal removal.

person, and I am not convinced that her demeanour is different from that of any other individual who has had the same comparable experience in a special environment. Her pursuits at home are those normal to her social class: she reads the papers, goes to the cinema, listens to the wireless, and so forth. She has no difficulty in writing. She does not need to make shopping lists because she remembers all she wants. She has no difficulty with prices or money, and easily knows what change should be given her after her purchases. She is neither especially good-tempered nor especially bad-tempered. Possibly she is a little lacking in reserve, but, if so, this is scarcely noticeable. Views on that point will differ with the amount of deference that the observer expects, but patients of course are very variable in that respect.

Case 7

Mrs. B., aged 39, was referred on October 9, 1936, to the Neuro-Surgical Service of the Manchester Royal Infirmary by Dr. Leslie Cunningham of Liverpool with the diagnosis of left frontal tumour.

She had had headaches for over four years, usually left frontal. Two years ago she had an epileptic seizure, and she had had three since. They were severe, generalized, with unconsciousness for two or three hours. Nine months prior to admission she found that she was blind in the left eye, and for six months she had had anosmia. During the last year her memory had seemed to go, so that she found it very difficult to give a proper account of her illness. She thought that she did not always understand what was said to her, that she failed to catch the meaning, so that sometimes she did not do things asked of her or reply in a sensible manner. She had good insight into this failure on her part (as was so in Case 5), and it worried her. She was co-operative, but was inclined to facetiousness. She was not taking a gloomy view of her condition, but when this was mentioned to her she replied that she found little to be cheerful about. She knew that at times she was extremely irritable and difficult. She was much less active than formerly, and was inclined to sit about, but this she attributed to her bad eyesight and her headaches. On examination no grasp reflex was present and she was blind in the left eye. Bilateral consecutive optic atrophy was present with papilloedema. This and the anosmia were the only positive signs. Diagnosis had already been arrived at by Dr. Cunningham by means of thorotrast ventriculograms, which showed the anterior horns of the ventricles displaced to the right. Radiographs of the skull showed a normal sella and a large abnormal diploic vein on the left side in the parietal area which could not be directly related to the tumour. The pre-operative diagnosis was an olfactory groove, at least an anterior fossa basal, meningioma. Perhaps sufficient weight had not been given to the fact that she had only noticed her anosmia recently, quite three years after the onset of her troubles. On October 24, 1936, a left frontal flap was turned down. On opening the dura a dark, reddish-blue, voluminous glioma was seen occupying the left frontal lobe. It was adherent to the dura anteriorly and to the falx mesially. The superior longitudinal sinus and falx were resected for a distance of six centimetres in order to allow of block removal of the frontal lobe with its contained tumour.

The operation proved to be long and tedious; 600 c.cm. of blood followed by 500 c.cm. of glucose-gum solution were given at the end of two and a half hours, and at the close, an hour later, a further 600 c.cm. of blood. The tumour-infiltrated lobe was soft, very vascular, and difficult to handle, its adhesion to the dura being exceptionally dense. The right hemisphere was not invaded. Such areas of dura as were not easily removable and showed evidences of invasion were heavily coagulated with the endothermy unit. The line of section was clear except deep in and mesially, where the tumour changed colour and became pale. Perhaps this region represented an area of astrocytic reaction.

The patient's recovery was smooth. Except for extreme thirst she said she felt well enough. On the tenth day she became very excited and noisy, declaring that her children were outside the ward and were being prevented from seeing her. She was at that time quite out of contact and would not listen to reassurances or react to persuasion. She quieted with chloral and bromide, and next day was better. Three days later she apologized for the trouble she had given. She remembered the incident perfectly, and said that she had been mistaken in the date, believing it to have been the regular midweek visiting day. Her memory was better, and with the disappearance of her headache and slight improvement of her vision she became very much more normal. The tumour was found to be an oligodendroglioma.

The patient was re-examined on April 17, 1937, six months after the operation. She said that her memory was now remarkably good, and she gave a lot of details about her earlier history that she could not give before. For example, she told of an unreasonable outburst that she had shown seven years ago, which makes the history much longer than she had led us to believe. Except for a slight freedom of manner which was in no way unpleasant she appeared to be quite normal.

Case 8

Mr. L., aged 42, was admitted to the National Hospital, Queen Square, under Dr. Purdon Martin.

For five years he had suffered from attacks of minor epilepsy which he found difficult to describe; these were of short duration. Three years ago he had a major fit and was unconscious for half an hour. Two years ago he began to suffer from a frequent dull pain in the left forehead and around the left eye. For eighteen months his memory had been somewhat impaired for some recent things, whilst remaining good for older events. He is a cabinet-maker in his father's firm, and sometimes made mistakes in his measurements and forgot names. For nine months he had had visual impairment, the print going blurred on reading. On examination he was found to be a well-looking spare man, very slow in his reactions but well-mannered and very co-operative. There was anosmia on the right, none on the left (a paradox as it turned out). There was early papilloedema on the left, the right fundus being normal; fields were normal. There were no other positive neurological signs. Radiographs of the skull disclosed a series of confluent calcified rings low on the left frontal lobe, the inner edge just crossing the midline, no doubt below the falx. No such picture had been seen before, and it was suggested they might be calcified hydatid cysts. Whatever the lesion, it was clearly well delimited and benign, whilst it was equally certain that it was the cause of his complaints over the last five years or even longer (two undiagnosed illnesses in which he was unconscious for a varying number of days at long intervals, the first thirty-five years ago, have been omitted). The cerebrospinal fluid protein was 75 mg.

On December 23, 1936, the left frontal lobe was removed after the calcified mass had been enucleated from its interior. When the dura was opened there was seen to be marked atrophy of the anterior frontal convolutions, which were stained a dirty yellow colour. The convolutions felt very firm, and on puncture the calcified tumour could be reached at a depth of 1.5 cm. The main mass was mesial in position, so the veins entering the superior longitudinal sinus were coagulated to allow of inspection of the inner surface of the hemisphere. The tumour was then seen, and was shelled out of the left frontal lobe by dissection with wet pledgets of lintine. It had to be followed across the midline and the inferior longitudinal sinus and free edge of the falx divided to allow of its delivery from the opposite side. The anterior cerebral artery was closely adherent to the tumour and had to be cut; it gave some trouble before it was secured with silver clips. After removal of the tumour mass the shell of the left lobe which remained was seen to be so blue that it was thought wise to resect it. The operator already had had experience of two left-lobe removals to encourage him to do this. Moreover, the left anterior cerebral artery had been clipped near its origin, so that the lobe would be not only useless functionally but a likely source of trouble during convalescence. The left olfactory nerve was seen lying in the floor of the anterior fossa untouched by the tumour. The duration of the operation was two hours and twenty-five minutes.

The patient spoke at the end of an hour after the operation and gave his full name correctly. However, next day he was moderately aphasic, and during the next three days became disorientated, though his speech was better. He was incontinent. A week after the operation his incontinence had disappeared, his speech had returned to normal, and he was much clearer mentally. He made a steady recovery.

Two months after the operation he travelled down from Northampton by himself and went on to Bournemouth to a convalescent home. There he played cards with the other patients and took part in the ordinary routine. He was shown at the clinical meeting of the Neurological Section of the Royal Society of Medicine, February, 1937. He declared then that he was quite himself again; indeed, better and clearer-headed than he had been for some years. He was still slow in his manner and diffident, but he is that sort of person. A word should be added on the subject of his aphasia. He

was the only one of three cases of left lobectomy to show aphasia post-operatively, though it was of very short duration. The posterior end of the cyst-agglomerate extended well backwards behind the level of the lesser wing of the sphenoid and must have compressed the subcortical pathways well back. The disturbance was purely of "nervous shock" or diaschisis from oedema, for he recovered his speech in four days. This patient wrote to the hospital in April specially to thank everyone concerned, because he felt better than he had ever done before.

Amount of Cerebral Tissue Removed

The anatomical frontal lobe is the largest of all. It extends from the frontal pole to the fissure of Rolando, and includes the pre-frontal, frontal, and motor areas. No surgeon would remove the whole lobe, and in the cases described the frontal association "area" rather than the frontal "lobe" has been extirpated (see Figs. 2 and 3).

The lines of section have always had the same starting-point below, immediately anterior to the Sylvian point and the lesser wing of the sphenoid in order to avoid the middle cerebral artery and the insula. The incision has been carried from there up to the midline either straight or curving a little backwards. The areas of brain removed correspond to Brodmann's areas 8, 9, 10, 11, 45, 46, and 47. Area 8 has probably not been entirely removed in any of them (see Fig. 4). None of the cases had purely anterior polar removals. Of course it may be that with neoplasms the normal brain tissue has been pushed backwards to some extent so that the line of section is actually further forward than it seems to be. The surgeon can only record the state as he sees it at the time. More functioning cortex is removed with the gliomas than when the compressed brain tissue over a meningioma is taken away, so that the amount extirpated was probably least in Cases 4, 6, and 8. As for the actual

technique, a lobectomy is by no means a difficult operation, and is often a preliminary to much more difficult procedures. The times taken over the various operations have been recorded, but they are only of passing interest. Some of the operations might well have been more expeditiously performed at the present time, though three were so difficult technically that saving time by cutting corners would have led to disaster.

FIG. 2.—(Five cases).

FIG. 3.—(Three cases).

Previously Recorded Cases

One of the earliest cases to focus attention on frontal lobe function was the famous "American crow-bar case" in 1848, which concerned a New England farm labourer, Phineas Gage by name. He was a popular hard-working man until his accident, in which a crow-bar 1½ inches thick was driven by a gunpowder explosion completely through his head to fall on the rock near him. He was not unconscious, and walked away with assistance from the scene of the accident. After a severe infection which must have increased the cerebral injury he recovered so far as to be able to work at different places for twelve years, dying then in convulsions. Meanwhile he had had the foresight to sell his skull to several universities. It lies now in the Warren Museum at Harvard. Phineas Gage was converted into a childish kind of crook (as Harvey Cushing has expressed it), was profane, obstinate, and given to outbursts of temper.

In view of the much more benign results of the frontal extirpations in the present series I have been at some

pains to review this case. The crow-bar passed through the rostral end of the left temporal lobe, the left frontal lobe, the falx and superior longitudinal sinus, and the mesial surface of the right frontal lobe (see both Harlow's (1869) and Bigelow's (1850) descriptions and the skull itself). Such an extensive lesion is more in keeping with what follows and what has gone before than a sharply localized unilateral lesion would have been. However,

evidence drawn purely from traumatic material is apt to be fallacious, as we see next in Phelps's assertion (1897) that mental changes nearly always follow an injury of the left frontal lobe, rarely one of the right. In more recent times frontal lobe function has been studied by many writers. Grainger Stewart (1906) from his clinical observations denied the dominance of the left frontal lobe, and stated that mental changes were much commoner with bilateral frontal, and especially callosal, lesions than with those of one lobe alone. The present series

FIG. 4.—Diagram of frontal areas, Brodmann.

confirms that view. Animal experiments from the days of Goltz (1879) to Bianchi (1922), and on to Lashley, Franz, and Fulton and Jacobsen, have all pointed in varying degree in one direction—that unilateral removal of areas corresponding to those removed in my own cases led to no discoverable loss, whilst bilateral ablations did so (Fulton and Jacobsen, 1935). These two authors' ability to produce an "experimental hysteria" in anthropoids by giving them problems that were increasingly difficult to solve, and their inability to produce it after both frontal association areas had been removed because the animals were too easy-going to bother themselves when they failed, was an interesting side-light on the part played by these zones. It seems to be quite certain in experimental field work that anthropoids which have been largely trained beforehand are still quite able, after a single (either) frontal lobe has been taken out, to resume and solve the problems that they have learned, and even to add new ones to their repertory. Section of the corpus callosum on anthropoids has little or no untoward effect (Kennard and Walter, 1934), but clean section is quite another matter from callosal gliomas, which damage the lobes on the two sides.

Turning now to observations on removal of these frontal association areas in man, Dandy in 1922 described the operation of unilateral frontal lobectomy, and reaffirmed it in 1928 as a harmless procedure. He has not published analyses of the mental status of his cases, and detailed reports from whatever source are rare in the literature. In 1935 Penfield and Evans recorded three cases in detail, a fourth very briefly. One was of great validity, because the operator had known the patient intimately for forty years. All these patients showed surprisingly little deficiency after the operation; one was bad at mental arithmetic (but it may be doubted how far this can be widely applied as a psychological test), and one patient, the best-known case, was a little lacking in initiative, though able to do her housework and look after her family. In this patient, however, some growing tumour had been perforce left behind at operation, and she died subsequently of recurrence. German and Fox (1934) reported three cases with results much the same as Penfield's. Glen Spurling (1934) removed the right frontal lobe in the attack on an olfactory groove meningioma which crossed the midline, operating twice from the right side. Not only was the right frontal lobe

removed, but the left was reduced to a fringe by the compression of the tumour. The actual degree of left-lobe destruction cannot be accurately estimated (see comment above on brain compression by non-invasive tumours). Spurling's patient made an excellent recovery, and psychometric tests by S. Ackerly (1935) showed her to be eventually near normal.

So much for unilateral and partial bilateral extirpations. One case only is on record in which both left and right frontal lobes have been excised in man—Brickner's case (1936). This is unique in the completeness of the post-operative analysis, only made possible by special circumstances. The record, though most instructive and exceedingly important, makes depressing reading, and no one surely will remove both frontal lobes widely again. A few remarks must be made about this case. A year and onwards after the operation he became a boastful, joking individual, with at the same time a certain amount of both voluntary inhibition, control, and synthesis of ideas. But in general he behaved like a child given to outbursts of naughtiness and difficulty, in which a sexual element was sometimes, but not always, present. Brickner states that his powers of evasion, when cornered on some point in argument, were little short of masterly. Studying this case, not alone in terms of brain removed but in the Jacksonian way, we come upon the question, With what parts of his brain were those jokes, those excuses, those mental side-slips, elaborated? Clearly with the more posterior portions of his brain. And Brickner, after exhaustive tests, concluded that there was no specific function in the frontal lobes which was not present in some degree elsewhere.

Discussion

Two points of great interest arise out of my own cases: first, that those who showed no mental alteration before the operation were unaffected by partial removal of the anatomical frontal lobe; secondly, that those who had mental symptoms were much better after the lobe had been excised. It can be concluded that removal of one frontal association area has left these patients with sufficient volume of neural tissue to ensure their being able to carry on their lives unaided afterwards (unless vision has been too badly interfered with by papilloedema beforehand). It appears to be quantity, volume, that matters most, even in man and not alone in the lower animals, as Lashley's work had suggested. No one will deny that the frontal lobes are deeply concerned in intellectual processes and emotional control, but they are not the only parts of the cerebral mass involved in these activities. It is clear that in a single frontal lobe mental activities have no closely packed, essential, or solitary locus the withdrawal of which leads to a state of dementia, partial or complete, and that the brain must function intellectually and emotionally as a whole, in the sense of Hughlings Jackson rather than in the departmental way that anatomical research once suggested. The frontal lobes cannot be regarded, either singly or together, as the "organ of mind." Pavlov proved the cortex to be a mosaic of function in which nothing was fixed except the motor and various sensory areas; it was a kaleidoscope of infinite possibilities of inhibition, adaptation, or substitution in mental and emotional processes. So that it can be concluded, from my own cases and those of others, that the reason why we have not known the exact localization of the higher cerebral functions is because they are not localized to any one small area.

Left-sided Dominance.—Many have thought the left frontal lobe to be more important than the right, and that

whilst right-sided lesions produced no great change left-sided ones did so. The evidence in favour of this is very tenuous, and my own cases go directly against such a view, for the patients were equally little affected, whichever side was operated upon. It must be conceded that once a lesion on the left side begins to go back behind the limit of the association area on the left there is a likelihood of damage to the speech centres, and no doubt it is on this account that the doctrine of left frontal dominance has grown up. An analysis of clinical material by Hyland and Botterell (1937) shows no essential difference between the two lobes apart from the aphasic element, and their conclusions on frontal lobe activities appear to be similar to those expressed here.

Cause of "Frontal" Changes

If a patient, one of whose frontal areas has been removed, has no severe frontal signs afterwards, it can be assumed that it was not purely one-sided frontal damage which was the cause of his previous disabilities. This is a very important point, but it seems to be established. In searching for another explanation two suggest themselves. The first is that it is the rise in general intracranial pressure occasioned by the tumour which is the additional agent that adds volume to the local lesion by producing widespread cerebral anaemia or oedema and interferes with the irradiation of impulses, compensation, inhibition, and so forth. Many cases are on record in which mental confusion has disappeared after a plain decompression without removal of a tumour. It must be that the successful operative management of such cases, with the consequent fall in intracranial tension and better cortical vascular irrigation, allows a resumption of normal powers by the uninjured parts of the brain. Conversely, frontal signs often appear in a high-pressure case even when the tumour is not frontal in situation. Gordon Holmes (1931) has expressed the opinion that mental symptoms are often due to high pressure irrespective of the site of the lesion. This is unquestionably true, and there is little doubt that many ill patients are psychologically abnormal not only because their suffering alters their reactions, but because their cerebral functions are impaired by anaemia. High pressure alone disturbs the mental activities of a patient more than does a local frontal tumour, because it interferes with the brain more widely than the tumour itself does; on the basis of Pavlov's view of cortical function in an integrated manner this can occasion no surprise. However, in the present series, in two cases the pressure was high and the patient had a frontal tumour as well, yet frontal signs were at a minimum. It is noteworthy that in both of these the tumour was non-invasive. This brings up the second possible factor already foreshadowed, the possibility of the tumour itself inducing some of the changes. We know that tumours which involve the primary receptor or effector apparatus often stimulate those areas to produce Jacksonian, motor or visual, or very often olfactory fits. Something of the same kind may occur in the frontal lobes; there may be some excitatory factor at the nature of which we can at the moment only guess. Such an idea was put forward long ago by Dupré and Devaux, who believed that the tumour exerts a toxic influence; but there is no clear evidence of it, and I, along with A. D. Macdonald, have failed so far to find histamine in gliomas in a few trials. I believe that the general circulatory basis plays a considerable part in the production of mental and emotional changes, but I am impressed by the differences shown by patients with invasive and non-invasive lesions. It should follow that

"frontal" changes will be most pronounced when the lesion is bilateral (as in callosal tumours), or when it is invasive, or when pressure is high, or in combinations of these conditions. Moreover, it is now easier to understand the delirium of toxic conditions, general and local, and suggest new ideas in the interpretation of the various states arising out of head injuries.

It would be unwise to conclude that removal of a frontal association area will always be a benign procedure. The patients in this series were not of any considerable mental stature; their occupations were not such as would easily bring to light faults in the higher synthesis of ideas. Whilst, therefore, a considerable amount of caution must be exercised in drawing conclusions from them which would tend to the formulation of a dogma, they illustrate the more plastic conception of cortical activities current to-day. In none was the operation carried out except in the face of necessity.

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ENURESIS*

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It may be said of enuresis, as Bacon said of medicine in general, that it is a subject which has been "much laboured but little advanced," for in spite of all the attention that has been devoted to it we are still very ignorant of its causes and mechanism, and largely helpless in its treatment.

For the purposes of this discussion it will be well to define enuresis as "bed-wetting," although it is true that diurnal incontinence is often present as well. On certain points we shall probably all be agreed: that enuresis should not be regarded as abnormal until the child has reached the age of 3; that it is commoner in boys than in girls; that most cases date from birth, although occasionally bladder control is lost after it has once been acquired; that it is worse in cold weather. We shall agree also, I think, that the term "enuresis" should be reserved for functional cases and that examples of incontinence associated with diabetes mellitus or insipidus, with chronic nephritis, with stone in the bladder, and with congenital lower urinary tract obstructions should be excluded, as well as incontinence occurring in cases of epilepsy or mental deficiency.

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