on the fact, "that fevers in India, taking one year with another, destroy twice as many lives as small-pox and cholera, and all other epidemic diseases, put together". This being so, the cause of such fevers becomes a question, not merely of interesting and curious speculation to medical men, but one of the gravest importance to a teeming population and to the nation that has assumed the responsibility of governing them. The Government of India has at this moment a task imposed on it requiring the aid of statesmen, engineers, and sanitarians in the first rank of their respective sciences. It is nothing less than to contrive well considered measures to prevent the recurrence of famines, and to stay the progress of those fevers, the destructive agency of which Dr. Cornish has so forcibly described. I repeat, "well considered efforts", for such they would need to be; for hitherto some of the irrigation works directed to prevent the first evil have not only failed, but have, by interfering with the natural drainage of certain districts, left them so saturated with moisture as to develop malaria to an extent that threatens to depopulate them. Let us speculate as much as we please on medical questions; but let such of us as are in a position in any, the smallest degree to influence, or distract, or embarrass the Government in the work they have to do, pause before we put forth theories, which, if acted on, may indefinitely delay the progress of sanitation. If the Government of India be tempted to embrace a theory that we in this country know would be very captivating to the minds of money-saving vestrymen, that fevers are the outcome of "chill" or "certain electrical conditions" of which we know nothing, and which lie out of the domain of human control, it would obviously follow that it is vain to contend with them.

Whether it be true or false that out of the soil, under certain conditions long recognised, a poison issues, which, for mere convenience sake, we call malaria, the belief has at least been fraught with good to mankind; for, just in proportion, in all places and in all climates, as we have carried out the measures believed to be antagonistic to the genesis of this poison, so have we diminished disease and death, and promoted human happiness and progress.

[To be continued.]

ON THE LOCALISATION OF THE FUNCTIONS OF THE BRAIN.*

By DAVID FERRIER, M.D.,

Professor of Forensic Medicine in King's College, and Assistant-Physician to King's College Hospital.

IN the short time allowed to me it is not my intention to read to you any elaborate paper on the localisation of function in the brain. I only wish to make a very few remarks, in order to bring before you more objectively, than by mere written description, some of the facts which I have published elsewhere, in the *West Riding Lunatic Asylum Reports*, and in a recent paper communicated to the Royal Society; and also to point out to you some of the bearings of the results of experiments on the lower animals in regard to the pathology and diagnosis of certain forms of brain disease. I presume you are all aware of the method of experimentation which was first introduced and applied by Fritsch and Hitzig, two German physiologists who experimented on dogs, and also of a similar method which I followed on a more extensive scale, not only on dogs but on several other of the lower animals, especially monkeys. It is chiefly with regard to the experiments on monkeys that I wish to speak to-day.

The experiments which Fritsch and Hitzig commenced, and those which I have made, have been repeated in this country and abroad by several experimenters; and I think that the main facts which are elicited by galvanisation of the brain are admitted by all. The interpretation of those facts, however, is a matter on which very considerable difference of opinion exists. Both Fritsch and Hitzig differ from the explanation which I give, as also M. Dupuy, M. Carville, Brown-Séquard, and Schiff of Florence. On the application of a galvanic or electric stimulus to certain regions of the brain, certain definite motor phenomena result. Hitzig and myself attribute these movements to excitation of the cortical substance of the hemispheres. Dupuy, who has repeated the experiments, and others who follow him, admit the definiteness of the movements which are caused, but they deny that they are dependent upon excitation of the cortical centres, asserting that the cur-

rents are conducted from the cortex of the hemispheres to the basal ganglia, the corpora striata, and motor tracts. Hitzig also makes a similar objection to my method.

In reference to this, I wish to make a short criticism. It is said by Dupuy, that when you place an animal fully under the influence of chloroform, you may stimulate the brain, but no action at all is produced; but when you stimulate the motor centres as well as the corpora striata or the motor nerves, then you get movements produced as before, notwithstanding the anaesthesia; therefore, he argues, the cortex of the brain cannot be motor, because it is not affected in the same way as the other motor centres. This seems to me to bear directly against himself, and to prove more conclusively the facts which I have brought forward and the theory I hold with regard to them. I have myself shown that the cortex of the hemispheres and the motor ganglia are differently influenced by anaesthetics. If you place an animal deeply under chloroform, you may irritate the cortex of the brain and no movement is produced; but if you expose the corpus striatum, you may excite movements, and when the corpus striatum is no longer excitable, movements may still be produced by stimulation of the corpora quadrigemina. This shows that the motor centres differ in their excitability under the influence of chloroform; and, unless it be proved that chloroform destroys the conductivity of brain-tissue, these facts rather favour the idea that the movements are dependent upon the excitation of centres in the hemispheres, which now have lost a function which they formerly possessed. It is said, on the other hand, that these movements are due to conduction; that the currents used are too strong; that they are conducted down through the substance of the brain to the motor ganglia. In answer to this, I will here refer to the brain of the monkey. In the first place, there are certain regions of the brain of the monkey which do not react to any stimulus, however strongly applied; as, for instance, the antero-frontal regions and the whole of the occipital lobes, which proves that conduction, if such exist, is only within certain limited regions. On the other hand, when the fissure of Sylvius is separated, and electrodes are placed on the island of Reil, which covers the corpus striatum, no movement results under the influence of a stimulus which excites movements in regions more distant from the great motor ganglia. Therefore, conduction cannot be the explanation of these facts. Still further, the phenomena which are produced by the application of a stimulus to points closely related to each other, are so different that they can hardly be explained by conduction. Conduction ought, if it be the explanation, to call forth all these movements in a mixed manner. Instead of this, they are so definite and predictable, that I undertake, on exposing the brain of an animal, to say, on the application of the electrodes, that the animal will now do this and now do the other. These results have always followed whenever I have given any demonstration. So that, taking into consideration the definiteness of the results, their predictability and uniformity, haphazard conduction is out of the question. For instance, if I place electrodes on this part of the brain of the monkey—the upper part of the superior temporo-sphenoidal convolution—the animal pricks up its opposite ear, turns the head to the other side, opening the eyes widely, and dilating the pupils. That is invariably the action produced. If I apply the electrodes just across the fissure of Sylvius, a point not further distant than the fraction of an inch from the previously stimulated region, the animal retracts the angle of its mouth.

Let me point out some of the chief centres, stimulation of which gives definite results. I may state generally that I regard the whole of the brain as divided into a sensory and a motor portion. Roughly, a line drawn up through the fissure of Sylvius, and carried through the parieto-occipital fissure to its extreme termination, cuts off the whole motor region, while all behind and below is sensory; and the external phenomena which result from the stimulation of the brain are to be regarded as an excitation of voluntary motor centres, or of the centres of sensation. With the aid of this diagram I indicate at the upper part of the ascending parietal convolution the leg centre; movements of the leg being produced on the opposite side of the body. In the upper part of the ascending frontal or the posterior part of the superior frontal there is a centre for certain movements of the arm and the leg, chiefly those for grasping. In the lower division of the ascending parietal, we have a centre for the movements of the fist. In the ascending frontal, behind the superior frontal sulcus, is a region the stimulation of which causes the action of the biceps, the animal raising its hand to its mouth and closing the fist. A little lower down, behind the posterior extremity of the middle frontal convolution, is the centre of action of the facial muscles, the zygomatics, and those which elevate the angle of the upper lip and the ala of the nose. At the posterior extremity of the inferior frontal, corresponding to what in the human brain is conventionally termed Broca's convolution, is a centre for the various movements of articulation. The stimulation of a corresponding

* Delivered before the Medical Section at the Annual Meeting of the British Medical Association in Norwich, August 1874.

region in dogs, which is situated also at the anterior extremity of the lower external convolution, produces exactly similar movements, the animal opening its mouth, putting out its tongue, and often barking loudly. The stimulation of no other part of the brain produces the same result. In cats there is a similar region, the stimulation of which causes them to mew, spit, and make all the signs corresponding to speech. This is the region which is usually destroyed in the disease known as aphasia. In the frontal convolutions in advance of the hand-centres, corresponding to the posterior half of the superior and middle frontal, we have a region connected with certain movements of the head; when it is stimulated, the animal always turns its head on the opposite side, and its eyes also and the pupils dilate. From the phenomena which result from stimulation of the region situated behind those which I have pointed out, I am inclined to regard these as being the cerebral centres of the sensory nerves; that is, there are special regions for sight, special regions for hearing, special regions for smell, and for taste, and touch.

As to the signification of these movements, I regard the motor centres as centres of voluntary motion; that is, the centres by which what we term the will acts downwardly upon the motor apparatus. Dr. Burdon Sanderson has recently communicated a paper to the Royal Society, in which he rather controverts the opinions which I have expressed in regard to the signification of these centres. Owing, perhaps, to some ambiguity in the terms which have been employed, he has mistaken my meaning; he has supposed that I regard the motor nerves connected with the individual muscles which are set in action as being directly carried upwards to the surface of the brain and there co-ordinated and combined. That is not the view I hold. A simple diagram will explain more clearly the signification which I attach to the term motor centre. [Here the lecturer drew a diagram, in which he represented the cortical centre, the corpus striatum, the spinal nuclei, and the motor nerves passing to the combination of muscles concerned in the production of a definite movement. Pointing to the cortical centre, he explained that the functional activity of this part caused the act through the medium of the lower co-ordinated ganglia in the corpus striatum and the spinal cord. The cortical centre he regarded as that which was concerned in the first instance in the effort of will.] In the corpus striatum, all the movements are integrated which are differentiated in the hemispheres. The stimulation of the corpus striatum usually produces all the movements which are induced or caused individually by stimulation of localised regions in the hemispheres. Dr. Sanderson, by stimulating the medullary cone of fibres which pass from the corpus striatum to the hemispheres, causes the same localised movements which result from the stimulation of the cortex itself. This, however, is entirely in accordance with my own views. The stimulation of the medullary fibres by electricity is essentially the same as that caused by any functional activity of the grey matter of the hemispheres corresponding to these fibres; so that, in reality, there is no essential difference between the interpretation given by myself and the facts which Dr. Sanderson has demonstrated.

Let me say a word in regard to the bearing of some of these results on pathology and the phenomena of paralysis arising from brain-lesion. The destruction of a motor centre in the brain of a monkey causes loss of voluntary power over the movements elicited by stimulation of the respective centre. The paralysis, however, differs in degree, according as the movements are independent or associated with those of the opposite side. I have shown very definitely that in monkeys and in the dog, and other four-footed animals, you have certain differences which have led to what I regard as errors on the part of Fritsch and Hitzig in reference to the signification of the results following the destruction of those centres. If you destroy the centre for certain complex movements of the fingers in monkeys, you produce an almost complete paralysis; but if you destroy the centres which cause the movements of the paw in dogs, you rarely obtain the same amount of paralysis, but often a mere degree of weakness. The facts of my experiments bear out the hypothesis of Dr. Broadbent, that the movements which are associated together on both sides of the body are bilaterally co-ordinated through communicating fibres between internal spinal nuclei or some higher centre, and through the influence of the sound hemisphere the lower ganglia are enabled to carry out the movements which have been associated together. They also afford a very distinct explanation of the symptom in hemiplegia which has been often described, but of which I think no very definite explanation has been given before, namely, the fact that in hemiplegia there is a temporary deviation of the head and eyes to the sound side; e.g., in left hemiplegia you will have the head and eyes directed to the right side of the body. The explanation is this. There exists in the hemisphere a centre which causes the movements of the head and eyes to the opposite side, and when this centre is destroyed by lesions which cause paralysis, the influence of the corresponding centre in the sound hemisphere,

causes the head and eyes to be directed to the sound side, because it is no longer counterbalanced; so that turning the head and eyes to the opposite side is simply an example of the same kind of lateral distortion which we observe in facial paralysis.

Results of great importance are revealed by destruction of the part which I call the centre for the mouth. The excitation of the brain produces usually a cross action, that is to say, the excitation of the centre of one hemisphere causes action of the opposite side of the body; but, in regard to the opening of the mouth, the movements of the tongue, and all the movements concerned in articulation, the action is not cross but bilateral. When destructive lesions occur in the corresponding part of the brain of man on one particular side, we have, as a rule, or in a great majority of instances, a condition of aphasia, that is, a condition in which the individual is unable to express himself in articulate speech. In this case there is no paralysis of the function of articulation. In discussing the pathology of aphasia, I think we ought to exclude all cases of congenital defects, such as deaf-mutism, and all cases where the function of the brain generally is interrupted, where persons have not only lost their speech but their other faculties. We ought to leave out of the account all cases where there is an interruption of the mechanical apparatus, or where the individual may have a will to speak but the way is interrupted, or generally all cases of paralysis of the muscles or interference with the mere apparatus of articulation. It is an established fact, that lesions of this region of the left hemisphere usually cause aphasia. We must allow that there are instances in which aphasia is not caused; and Dr. Bateman of Norwich, in his work on Aphasia, has brought forward numerous arguments against the localisation of speech, and so far as clinical observation and morbid anatomy alone went, I think he succeeded in casting a doubt on the localisation of a speech centre in one hemisphere at least. But granting that, we have a great number of instances of aphasia resulting from very limited lesions, and how are we to account for this? I think that some further light is thrown on the subject by the results which I have laid before you. These centres, besides being centres of voluntary motion, have a psychical signification, and form, as it were, the motor substrata of mind. The mouth-centre is the centre, not only for the movements of articulation, but also for the memory of articulation. What are words? Words are merely certain articulations effected under the guidance of the ear. The memory of words is the memory merely of certain articulations so affected. Words, themselves, are merely symbols of ideas, and the memory of words need have no necessary connection except by associating fibres with the organic seat of the ideas that they represent. When you destroy the organic seat of the memory of articulations on both sides of the brain, you cut out the whole memory of words, but you do not necessarily affect the memory of the ideas of which these words are the symbols.

On destruction of this part of the brain, there results a loss of speech while the ideas still remain, so that, when you pronounce a word to an individual who is aphasic, he knows what it means; he cannot find the word himself; the ideas are excited, though he has lost the power of expressing them. In a great majority of instances, the lesions in aphasia have been on the left side; in some instances, a lesion on the left side has not produced it. It must be remembered that the brain is a double organ, and that the centres of articulation are symmetrically situated on both sides. It has, however, been sufficiently demonstrated, that the two sides of the brain have an unequal preponderance in the initiation of voluntary movements. Just as the right side of the body is the most used, so the left side of the brain is chiefly concerned in the initiation of voluntary acts. When you destroy the speech centre on the left side, you, as it were, cut off a man's right arm; you destroy not the memory of words, because that exists in the right hemisphere, but you destroy the power of getting at the words by an act of will, an essential distinction which has been drawn by Dr. Hughlings Jackson; but there is no reason, except, perhaps, the facts of heredity and education, why persons may not use the right side of the brain in speech instead of the usually employed left.

There are several cases of aphasia with left hemiplegia; one such case has been lately reported in the *Medical Times and Gazette* by Dr. Russell of Birmingham; but, as a general rule, one observes right-sided development in all animals. Aphasia is usually associated with hemiplegia, the effect being more marked in the arm than in the leg. The explanation of this I have alluded to above. The destructive lesion which causes aphasia usually extends into the centres which are concerned with the movements of the arm and of the leg. The centres for the arm are in more immediate relation to the speech-centre than the centres for the leg; hence in lesions affecting merely the cortex, the arm may be paralysed while the leg may entirely escape.