Part First.

ORIGINAL COMMUNICATIONS.

ARTICLE I.—*The Morisonian Lectures, delivered before the Royal College of Physicians of Edinburgh: Session* 1874. By J. BATTY TUKE, F.R.C.P.E., F.R.S.E.

LECTURE II. (*delivered 20th March.*)

Blood Supply.

WE now pass to the important and interesting study of the blood supply of the convolutions, taking it up at the point where it is left in systematic books on anatomy. Such works state generally, that the minute branches of the anterior, middle, and posterior cerebral arteries, after ramifying in the pia mater, pass into the brain substance; but we will now inquire in what manner and form they pass in and terminate.

This diagram but feebly represents the appearances shown by the brilliant preparation which stands on the table. It is one made by Dr Carter from the brain of a rabbit, into the arteries of which he injected a coloured solution of gelatine. The portion of this specimen, which is figured in the diagram,[1] magnified × 100, is the bottom of a sulcus. The eye will appreciate at a glance the fact, that there is a most manifest difference between the quantity of vessels supplied to the gray and the white matter; and closer observation will show that this is due to their size, length, and distribution.

This preparation (one of many hundreds that Dr Carter has made) demonstrates two anatomical facts:—

1st, That there are three distinct series of cerebral capillaries.

2d, That the ultimate distribution of these capillaries varies in the gray and white matter.

You will observe the transverse section of an artery at the bottom of the sulcus, from which spring branches to the right and left, which course round the periphery of the convolution external to its substance. From these smaller branches are given off, which enter the brain substance at right angles to the plane of the

[1] See Bucknill and Tuke's Psychological Medicine, Plate IX., Fig. 1, p. 614.

convolution. These arteries are various in size and distribution, and may be divided into the *large* or *medullary arteries*, and the *medium* and *small cortical* arteries; the first supplying the white substance, the two latter the gray. The large or medullary arteries run right through the cortical substance, rarely, if ever, supplying to it more than one small twig; as soon as they reach the white substance, they divide dichotomously to the right and left in the plane of the inner horizontal fibres—of course at right angles to the direction of the parent vessel. In the white matter they form a comparatively coarse capillary meshwork; this is due to the large divergent branches being connected by short annectant vessels at somewhat wide intervals. The mesh may be stated to be five times longer than it is broad. This appears to be the general arrangement of the capillaries of the white substance.

It will next be observed that there are medium-sized vessels, about twice as numerous as the large. These run directly (giving off a few twigs in their course) to the *inner* layers of gray matter, where they branch off in every direction and at *acute* angles, and then we have the smaller and most numerous arteries, whose duty seems to be the nutrition of the outer layers of gray matter. The cortical arterioles anastomose most freely with each other, but *they are terminal vessels in the gray matter.* Their anastomosis is procured by a much less definite arrangement than that of the white matter arterioles, as they simply divide and subdivide, casting off branchlets upwards and outwards—in fact, in every direction but downwards. I think the arrangement of these three sets of vessels can best be compared to that of a close forest. We have first the straight undergrowth, the branchlets of which mix with the branches of the half-grown trees; the branches of which again are overtopped by the lower ones of the giants of the forest.

The anastomosis of the cerebral arteries is most intimate. In the pia mater we have one anastomotic system, which is continued as the branches from its vessels penetrate the actual brain substance. In the pia mater lobe is connected with lobe, in the gray matter convolution with convolution, in the medullary substance all the inner aspects of the brain maintain mutual relations. The close anastomosis which is so evident to the naked eye between the external arteries becomes increased as they reach their ultimate ramification—in fact, it may be said that there is no ultimate ramification of a cerebral artery, in that it meets its fellow somewhere or other, until they conjointly merge into the venous capillary. Where the artery ends and the vein begins, we are in the same doubt as in other organs of the body.

Along with Dr M'Kendrick I have endeavoured, by simultaneous injection of artery and vein, under equal pressure, to elucidate this point in anatomy. At the present moment we do not feel justified in generalizing on the results of our experiments, but I trust that next session something definite may be laid before you.

I ask you to remark for one moment the difference between the *direction* of the supplies of blood to the white and gray matter. To the white it is by ever-recurring right angles:—the original vessel of the pia mater sends off its branch at a right angle, which again at the same degree transmits its branches to the brain substance, which, thirdly, decussate in a similar manner, which, fourthly, communicate with each other by annectant capillaries at an angle of 90°. The arteries of the gray matter, on the other hand, proceed, after the first rectangular branching, directly to the parts to be supplied, throwing off branches at acute angles, and in every possible direction.

This explains the immensely greater blood supply to the gray matter as compared with the white, which may be roughly stated to be as five to one. Although physicists are agreed that direction does not retard the amount or rapidity of the flow of fluids in *rigid* tubes, I am not aware that they have come to the same conclusion as regards elastic ones. The hypothesis may therefore be thrown out, that the constant recurrence of right angles on the arteries of the white matter *may* have an influence in modifying the amount of blood supplied to that part. However that may be, we have an absolute certainty of the greater vascularity of the gray over the medullary matter; and, arguing from all analogy, what better argument could we have that its functions are of the higher order?

It has been for long taught that the vessels which enter the convolutions are accompanied or supported by the pia mater, or, to speak more accurately, by projection of its inner flocculent surface, the *tomentum cerebri*. But it appears to me, that this teaching is more the result of argument by analogy than of actual demonstration. In fact, in none of the British standard works on anatomy is the pia mater, which is said to accompany the vessels, enumerated amongst their coats, or spoken of as a sheath, the reader being left to the belief that the outer fibrous coat of the artery and the cerebral substance are in direct apposition. In Germany it seems to be admitted that there is a coat outside the outer fibrous coat. Rindfleisch says "that although the arteries of the brain are usually said to enter naked, it would be inexcusable in any one familiar with the morbid anatomy of that organ to overlook the sheath of connective tissue, which, however slender, surrounds its arteries."

I present to you now a series of preparations which seem to me to demonstrate the existence of a coat intervening between the outer fibrous coat and the cerebral substance. Three of these are taken from the brain of one person who had been the subject of senile insanity, and who died from exhaustion and old age. On post-mortem examination no disease of heart or kidneys was found to exist. The pia mater was thickened and adherent. The other morbid appearances need not be alluded to, as they have no bearing on the point at issue. Specimens of the brain

were hardened in chromic acid, and the sections were cleared with turpentine and set up in Canada balsam diluted with turpentine; glycerine or acetic acid were not used. The first of the three is a transverse section of the lower part of the medulla, near the decussation of the pyramids. In the anterior median fissure a vessel of considerable size can be seen entering, accompanied by pia mater; at a certain point, the vessel, the muscular coats of which are much thickened, is cut off short, but the empty sheath runs inwards for a considerable distance, becoming thinner and thinner, less and less fibrous in appearance, until it is lost in the substance of the medulla as a fine translucent hyaline membrane, shrivelled longitudinally, and therefore apparently somewhat fibroid. In the second section,[1] which is taken from one of the convolutions bounding the fissure of Rolando at the vertex, a similar vessel and membrane are visible, the latter distinctly pronounced in the degree to which it had arrived at its innermost portion in the first section, viz., the hyaline condition. It is $\frac{1}{150}$th of an inch thick, and is traceable almost through the cortical substance and beyond the inner cut end of the vessel. In the third preparation, taken from the same convolution, there exists in a longitudinal section of a vascular canal, in which no trace of ordinary vascular tissue can be detected, a very fine, somewhat puckered, translucent membrane, non-fibrous and non-fenestrated, filling up the space almost from side to side and from end to end; its edges are well defined; it is not coloured by carmine. I could have produced many more preparations illustrative of this condition of the vessels, but prefer to take my stand on those made from this individual case for the following reasons:—1st, That the sections were not prepared with glycerine or acetic acid. 2d, That the same appearances are noticeable in different portions of the same brain. 3d, That the external pia mater was much thickened. 4th, Because the thickened conditions of the other coats of the vessels was such as to render their demonstration peculiarly easy; and therefore enabling the eye to determine their relation.

I present to you one other preparation. It has been taken from the fresh brain, and is unprepared by any chemical agent, except cold water. The vessel was carefully dissected out from the centrum ovale, and cleaned with camel's-hair brushes, water only being used. Around it you will see a loosely enveloping sheath apart from the outer fibrous coat, forming at the bifurcations a triangular sac.[2]

Judging from my own experience, and from the study of that of others, I can see no reason why we should not regard this membrane as the extension inwards of the pia mater, and therefore as a normal investment of the minute cerebral arteries. I would not

[1] See Bucknill and Tuke's Psychological Medicine (3d edition), Plate IX., Fig. 3.

[2] Loc. cit., Fig. 2.

have dwelt so long on this pia-matral investment were it not that the fact of its absence or presence has very important bearings on the next question at issue, viz., the cerebral lymphatics.

When we consider the immense vascularity of the brain, the multiplicity and activity of its functions, its consequent constantly called-for supply of nutrient plasm, and its consequent rapid waste of tissue, we will at once see of what paramount importance it is to the study of its pathology that we should arrive at some conclusion as to the means it possesses for relieving itself of superabundant material and the products of waste. I believe that on this one point hinges the explanation of the causation of the majority of cases of insanity, and that it has important bearings on the pathology of coma, convulsions, and other allied cerebral symptoms. At present, I will confine myself to the anatomical question of the locality of the cerebral lymphatics, as its physiological and pathological bearings fall to be considered under the head of the influences inducing and producing insanity.

Fohmann and Arnold first described the pia mater as possessing an extensive system of lymphatics—an opinion which has been endorsed by subsequent observers. These lymphatics are said to be in direct communication with what is called the *great epicerebral lymph space* or cavity, which is stated to lie below the pia mater, between that membrane and the brain. It is said to have been proved that such a communication exists, as the epicerebral lymph space has been filled by injection from the true lymphatics of the pia mater. Up to the time of Robin, no communication had been shown between the interior of the brain and this space. He, in 1853, subsequently in 1855, and in full detail in 1859, demonstrated that this communication was established by means of lymphatics which followed in the course of the bloodvessels; which, shortly after, His believed he succeeded in injecting from the lymphatics of the neck; according to Eberth, however, he has lately resiled from this position. The subject has been well worked at since by Obersteiner, Roth, and Boll, from whose papers and those of the authors already mentioned this description is mainly taken. These lymph spaces not only follow the course of the vessels, but they actually surround them, and were at first in consequence called perivascular *canals*. The term canal is now abandoned, and perivascular *space* adopted, for reasons which will presently be mentioned. In most sections of cerebral tissue cut transversely to the direction of its vessels, their cut ends will be seen surrounded by a clear ring of unoccupied space, and occasionally fine trabeculæ will be found running between the outer apparent coat and the brain substance. This clear space is, to some extent, due to retraction of the cerebral tissues, consequent on the use of hardening agents; but in diseased brains, as we will see further on in the course, it is also the result of hyperæmic dilatation during life. Considerable confusion has arisen from these clear rings, *which are*

not the lymph canals of the brain. I trust I have demonstrated to your satisfaction that there exists a sacculated coat outside the outer fibrous coat, which separates it from the brain substance; for between it, the so-called hyaline membrane or sheath of pia mater, and the outer fibrous coat is the space which is held to be a lymph space by the German authors. This sheath can be traced for a long distance loosely enveloping the vessels until (according to certain German observers) it debouches along with them into the epicerebral cavity by funnel-shaped mouths. According to Boll, the inner surface of the sheath is quite smooth, the outer rough or shaggy (zottig), holding connective-tissue, or, as they are called, after their first describer, Deiter's cells, their rough or shaggy projections communicating with the cerebral substance as if for the support of the sheath. It is believed that the superabundant plasm of the blood exudes into these lymph spaces by a process of exosmosis in the case of the arteries, and that the waste products are got rid of in a similar manner by the veins, at least to a considerable extent; for Obersteiner goes still further, for he holds that by certain "spur-like" processes there is maintained a lymphatic communication between spaces surrounding each nerve-cell and the perivascular lymph spaces.[1] This most careful observer states that he has actually thrown injections into spaces surrounding the cells; and, moreover, that he has seen lymph corpuscles in these spaces. In my own preparations of diseased brains, I have frequently found large clear spaces around the cells, and also in healthy animals, such as the ape; but I am not able to substantiate his position further than this. Obersteiner's theory is a most attractive one, for it gives us a passage by which the products of the waste of very active structures can be got rid of, and passed into the waste-pipe. I am not aware, however, of any confirmation of his observations.

I need not remind you that the brain is not singular in possessing perivascular lymphatics; for, according to Macgillivray, they exist around certain of the vessels of the liver; according to E. B. Kiber and Tomsa, around those of the spleen; and according to Dr Goodfellow, a similar relation exists in the cornea.

It is obvious of what vast importance it is to the pathology of the brain to establish the existence of a lymphatic system in it. In this country, little or nothing has been done in this direction, but in Germany it is held to be an absolutely proved anatomical fact. I propose, during the coming summer, to endeavour to inject these spaces from the lymphatics of the neck; for it appears to me that the method adopted by German authors, with the exception of His, who, as I have said, has resiled from the position, is not entirely satisfactory; they use the "einstick methode," which consists of driving injections under the pia mater, or into the substance of the brain, and allowing them to flow in every and any direction. Doubtless this method has served to demonstrate

[1] "Wien Stzb. d. k. Akad. Wissener," Bd. LXI., 1 Abth., Jan. 1871.

perivascular lymphatics in other organs, and as the results obtained from it are fully accepted by such authorities as Stricker, Rindfleisch, and Von Recklinghausen, we are justified in generalizing on the probable pathological results of cerebral conditions interfering with the action of these lymph spaces.

But I must confess to not understanding how these lymph spaces can communicate by funnel-like openings with the epicerebral lymph space which is said to lie between the pia mater and the brain matter. This to my idea is simply impossible. I have never seen any indication of the existence of an epicerebral space, and when we reflect that the surface of the pia mater is flocculent as it is applied to the convolutions, it would seem that its attachment must be intimate. On the other hand, I have frequently seen in morbid brains strong indications that there is a space between the two fibrous layers of pia mater; that, in fact, that membrane should be described as consisting of three layers,—an outer and inner fibrous, and a middle or vascular and possibly lymphatic layer. In the preparation, of which this diagram is a representation, such an arrangement can be seen most distinctly; and in this we see the funnel-like opening debouching actually into the middle, not into a space subjacent to the inner layer. If these spaces surrounding the vessels, between their outer fibrous coat and their sheath, are lymphatics, which I think is highly probable, they *must* communicate with the actual lymph passages of the pia mater. How can we believe in a space corresponding to the so-called epicerebral space in connexion with the spinal cord, where the pia mater is so very closely adherent to its substance, dipping into it, and holding it firmly together? It is only in disease that it becomes separated, and that its supporting influence on the entering arteries becomes impaired. Demonstration, analogy, and argument are all opposed to the existence of an epicerebral lymph space, as existing between the naked convolution and the pia mater; on the contrary, they converge to the establishment of the proper lymphatics of that membrane being the receptacles and conduits for the removal of the products of waste.

Interstitial Matter.

Maintaining and supporting the nerve fibres and cells and the bloodvessels in their position, holding all together as a matrix, we have a plasm called the neuroglia, or nerve glue or cement. There exists a difference of opinion as to whether this neuroglia is to be regarded as the connective tissue of the brain or a nervous structure. It would take up too much time to enter here fully upon this discussion; I will only say that the weight of argument bears upon the theory of Virchow and Kölliker, that the neuroglia is connective tissue. It consists of an intensely fine reticulated tissue, holding a clear homogeneous protoplasm (which after death becomes slightly molecular) and numerous nucleated bodies. In

certain positions, and more especially in diseased brains, connective tissue cells can be demonstrated; they are spider-like in form, and are called, after Deiter, Deiter's cells—why, I can hardly understand, for their presence was indicated by Virchow in the first edition of his Cellular Pathology. Scattered in considerable quantity throughout the substance of the neuroglia are nucleated bodies, the nuclei of the neuroglia; these are finely granular, with nucleoli, and present the appearance shown in this diagram, which is an enlarged copy of a plate in Paget's Pathology.[1]

I will not dwell longer on this brain element, all-important as it is; I will only ask you to regard it as the jelly-like matrix which holds *in situ* all the other more highly organized structures. Like all connective tissues, it plays a most important part in morbid processes, being subject to changes in quantity and quality, and to pathological alterations of its cells and nuclei.

As the cerebro-spinal fluid will claim especial attention when we come to the pathological conditions of the brain, I only allude to it now as an important item amongst the brain elements.

And now, Gentlemen, I trust you will not think that I have been too prolix on the anatomical part of my subject. Detail was inevitable, for if there had not been laid before you facts connected with the normal histology of the brain, it would have been impossible to demonstrate the changes which take place in the several tissues. Before leaving the subject, allow me to lay before you Bucknill's theorem: *that we have a right to presuppose that, in the brain as in the other organs of the body, the normal exercise of function is dependent on a perfect maintenance of the anatomical relations of the component structures.* And this is most especially true in the case of the brain, for two reasons. The first is, the extremely intricate relations which its various structures maintain one with the other; we have three systems of fibres, the radiating, the horizontal, and the commissural, keeping up communication between convolution and convolution, between lobe and lobe, and between hemisphere and hemisphere—we have cell communicating with cell, cell connected with fibre, and vessel with vessel;[2] in a word, it is the organ of the body which, in its histological associations, forms the most perfect whole. It is a perfect dual organ. The second reason is that it is, so to speak, self-contained. It cannot, like the lungs or liver, cast any of its functions on other organs; it can gain no relief in disease from vicarious aid; it must do its own work, rid itself of its effete matter, and of the products of injury or disease, and provide within itself for the resumption of functions, the exercise of which have become impaired from whatever cause. The bearing which these

[1] Page 113.

[2] It is not maintained that the anastomosis of vessels extends to a direct communication between the hemispheres; only as regards the lobes of each hemisphere.

facts have on the pathological position is—1st, *That circumscribed lesions may affect the whole encephalon temporarily or permanently;* and, 2dly, *That permanent loss of function of one hemisphere may be supplemented by the action of the opposite hemisphere.*

This latter consideration leads us naturally to the question: What are the functions of the hemispherical ganglia, and what light has modern research thrown upon it?

We were all educated in the faith, founded on the observations of such physiologists as Majendie, Longet, and Matteucci, that the cortical substance was the organ through which the highest manifestations of intelligence were alone produced, that it possessed no sensibility, and in no manner subserved the inferior functions of nerve force. Brown-Séquard even could not evolve from his extensive experiments that in it were seats of definitely localized function. But within the last few years a new school has sprung up, the apostles of which are Broca, Hughlings Jackson, Fritsch, and Hitzig, Nothnagel, Gudden, and last, though by no means least, David Ferrier. The theory of this school is, that in the cortical substance of the gray matter of certain convolutions, and in certain parts of convolutions, exist psycho-motor centres —that is to say, that in certain circumscribed tracts ideas are stimulated which prompt, or produce, or excite certain definite and distinct sets of muscles to action.

Fritsch and Hitzig were the first to demonstrate the fact that the gray matter *is* susceptible to irritation—the only wonder is that this fact lay so long in obscurity. They also showed that irritation gave rise to muscular action on the side of the body opposite to that of the hemisphere irritated, and they likewise were able to produce certain of their movements definitely. These physiologists, however, stopped short at this point. But Ferrier, independently of them, and with other objects in view, took up the investigation, and by a long series of experiments, conducted in the highest scientific spirit, has evolved results which will make his name historical in the annals of physiology.

As the accuracy of Ferrier's observations has been lately impugned by a former pupil of Brown-Séquard, Dr Eugène Dupuy, I think it advisable to narrate shortly what I and other Fellows of this College have seen of them.

Early in August of last year I accompanied Dr Ferrier to the Brown Institute at Lambeth, in order to see him prepare two animals, a monkey and a cat, for demonstration to an audience, amongst whom were Virchow, Liebreich, and Burdon Sanderson. With the rapid skill of an experienced surgeon, he reflected the scalp and removed the calvarium of both the animals, arresting the hæmorrhage by pledgets of cotton-wool steeped in perchloride of iron (the animals were fully under the influence of chloroform). The dura mater was removed, and the subjects were left for two hours to overcome the shock of the operation. The monkey very soon

recovered, and showed no indications of *malaise;* on the contrary, within an hour and a half of the operation he partook of milk and bread-and-butter from the hand of the operator, jumped on his shoulder, and played with him. The cat could not be trusted.

At the appointed hour a considerable audience was assembled, and Dr Ferrier, without any previous experimentation, proceeded to his demonstration; and in this wise: Holding the monkey in his left arm, utterly unrestrained, he said to the assembled crowd of observers:—"Gentlemen, I am going to touch with the electrode this portion of the brain of this monkey, on which he will open his mouth and protrude his tongue:"—the electrode was applied, the mouth opened, and the tongue was protruded. Next, Dr Ferrier indicated the spots which, when stimulated, would be followed by extension or retraction of the paws on the opposite side of the body, retraction of the ear, rotation of the head, movements of the eyes, clutching movements of the paws, and so on. Each prediction was made with the utmost confidence, and with good reason; for in every instance the result followed with the utmost exactitude, until stimulation became complicated, and epilepsy was produced; but a short interval of rest sufficed for the renewal of the demonstration. Dr Dupuy states that he has failed in obtaining the same results as Ferrier: this must be due to some imperfection in his method. For instance, he says that he has never succeeded in procuring opening of the mouth and protrusion of the tongue: now this very result Ferrier produced with the utmost certainty more than a dozen times on the occasion alluded to. Although by no means at one with Ferrier as to the explanation of the phenomena he has demonstrated, I can vouch for the absolute accuracy of his statements *as to fact* in every particular.

One important fact elucidated by these experiments is, that functional hyperæmia is produced on the application of the stimulus. I ask you to bear this in mind, as bearing on future remarks.

I must refer you to the original paper for full details, and will enumerate now only such as have special bearing on our subject. These are:—

1. The anterior portions of the cerebral hemispheres are the chief centres of voluntary motion, and the active outward manifestation of intelligence.

2. The individual convolutions are separate and distinct centres; and in certain definite groups are localized the centres for the various movements of the eyelids, the face, the mouth, tongue, ear, neck, hand, and foot.

3. Action of the hemisphere is generally crossed; but certain movements of the mouth, tongue, and neck, are bilaterally co-ordinated from each cerebral hemisphere.

4. The cerebellum is the co-ordinating centre for the muscles of the eyeball. Each separate lobule is a distinct centre for special alteration of the optic axes. The cerebellum is the organ on the

integrity of which depends the maintenance of the equilibrium of the body.

5. That Dr Hughlings Jackson's views as to the causation of epilepsies and chorea by discharging lesions of the different centres in the cerebral hemispheres is correct.[1]

Nothnagel's system of experimentation, which consists in the production of limited lesions of the gray matter by means of the injection of a concentrated solution of chromic acid, tends to support Ferrier's views; as it is found that the destruction of the ascending parietal convolution results in loss of muscular sense in the fore-leg of the opposite side of the body. Nothnagel also records other confirmatory observations.

Gudden likewise reports some most important results having a similar tendency. He has removed portions of the hemispheres from newly-born rabbits, and from observations made months after the operation, comes to the conclusion that "there is reason to locate the organic conditions of voluntary movements in the cortical substance of the brain, and that they are situated in the frontal lobe."

As opposed to the views of this school of physiologists, we have the experiments and opinions of Dupuy. That he has failed in obtaining the same results as Ferrier is no argument, as, as I have already said, those of the latter are too regular and sequential to admit of doubt; but he asserts that the same results can be obtained by irritating different parts of the gray matter, and even the stimulation of the dura mater produces cross action in the fore-legs. This observer believes that the electrical current must be propagated to the base of the brain in order to excite movement, and he has repeated the experiment of Flourens of removing the entire cerebral hemispheres without any resulting loss of muscular action; and he has further supported his theory of the propagation of stimulus, by showing that a galvanoscopic frog is thrown into a state of contraction when its nerve touches a part of the cerebral mass far from the point of excitation.[2]

This latter observation is really of no value as against the theory of Ferrier; for it is well known that during the passage of nerve force along a nerve, the natural electro-motive force of the nerve is diminished, it is affected by what physiologists term a negative variation. This negative variation is sufficient to stimulate a second nerve laid upon it, in the same way as we see in Matteucci's induced contraction. In the same manner it is evident that, if a small area on the surface of the brain be stimulated by electrodes, other portions of the brain containing nerve fibre communicating

[1] In a paper lately read before the Royal Society of London, Dr Ferrier has reported further observations, but without altering the above-recounted results.

[2] Burdon Sanderson's experiments in connexion with this subject have been published since the delivery of this lecture.—*Proceedings of the Royal Society*, 1874.

with this area will suffer a negative variation sufficient to stimulate the nerve of the galvanoscopic frog. The contractions observed by Dupuy do not show a diffusion of the electrical stimulus, but simply negative variation of other portions of the brain.

The theory of the existence of psycho-motor centres in the brain is by no means definitely settled. My own observations on the morbid histology of the brains of the insane do not appear to me to support it; for, as we shall see further on in this course, *bilateral* disease of the cortical substance can exist in the regions indicated by Ferrier as psycho-motor centres without loss or impairment of muscular power, and the cerebellum can be utterly disorganized to the extent of five-sixths of its substance without any aberration of the motility of the eyes, or loss of co-ordination of muscular action. We will postpone, however, the consideration of this question until there have been laid before you the nature and distribution of the cerebral lesions.

It is needless, Gentlemen, to recapitulate the various theories which have been advanced as to the *modus operandi* of cells and fibre in the evolution of psychical phenomena; for in this matter no leading *fact* has been experimentally demonstrated. We know nothing of the direction of electrical currents in the brain; we only know that such exist. Mr Dewar and Dr M'Kendrick lately directed your attention to the all-important fact that the influence of light could be reduced to absolute demonstration in the case of the special sense of sight, and that modifications of these influences could be measured with perfect certainty. We cannot yet see whither this system of experimentation is to lead us. If it be possible to demonstrate the mechanical operativeness of the influences which act on the organs of special sense, why may we not hope that the activity of the forces which we call psychical may yet be recorded by the galvanometer? Are emotion, volition, and actuation one whit less palpable in their immediate effect on the individual than light and sound? We all know the immediate physical effect of emotions; we blush, we pale, we grow hot or cold under their influence, the organism standing in the position of an elaborate galvanometer. When we think of the vast strides made in the science of physics within the last few years, when we regard the concentration of experimentation and ratiocination on the conduct of metals under peculiar conditions, and the vast outcome which has resulted, may we not hope that, when the physicist and the physiologist are more thoroughly merged in one common observer than they are at present, physiology will be able to assert itself as a perfect science? Without a perfect physiology we cannot have a perfect pathology. Till this is established, we can only go on working for future ages, in the hope that our labour may tend to support the observations of the coming man.