SOME POINTS IN THE PHYSIOLOGY OF ATTENTION, BELIEF, AND WILL.

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"GIVE me a fulcrum," cried the ancient sage, "give me a fulcrum, and I shall move the world." "Grant me a few postulates," says the modern reasoner, "and I shall read you the riddle of the universe." An unchallengeable postulate, however, is almost as difficult to find as a stable extra-terrestrial fulcrum. The scientific "spirit of the age" walks by sight and not by faith. It revels in facts. It numbers and weighs and measures, it catalogues and describes, it compares and classifies. To make progress among the secrets of nature its highway is Experiment, and its watchword is Demonstration. For any interpretation of a natural phenomenon it demands proofs that can appeal to the senses, and it looks with wholesome suspicion, if not contempt, on mere "arm-chair" speculation.

The marvellous success in advancing knowledge, and in gaining power over the forces of nature that has resulted from its use, is convincing evidence that the scientific method of interrogation is sound, and that it should always be adopted wherever possible. But it is not always possible to apply the method. The nearer we approach the region of subjective phenomena, the more difficult it becomes to test particular interpretations by an appeal to experiment. The galvanometer may reveal agitation in a sensory surface, but it tells nothing about sensation. The convolutions of a dog's brain may be tampered with, but he will not describe to us his feelings. Consciousness alone can discriminate the facts of consciousness; and the character, or succession, or relation of these can only be described in terms of metaphysic. Theories of physical relationship here must at first be tentative, and at the best they will require to be stated in very general terms.

The argument must consist in the application of general principles; and, in choosing these, analogy balanced by common-sense must be our guide. In drawing our conclusions, we may be satisfied if these can be held with some moderate degree of probability.

In attempting to gain a closer view of the somatic relations of mind, my subsequent argument will rest on the assumed correctness of three postulates. The first of these is—That every manifestation of mind is correlated to a definite mode and sphere of brain activity. This may be emphatically insisted on, whatever be the view taken as to the nature of mind itself. For, to take the illustration so frequently made use of,—that of the relation of a musician to his instrument,—the volume and quality and harmony of musical sounds are immediately correlated not to the fingers of the player, but to the tremors within the instrument. So the outcome of mental action, even as revealed to one's own consciousness, is not simply the result of some ideal, self-acting energy asserting itself, but it depends also on the compass and quality and adjustment of a material organization. It, of course, follows, that if we approach the subject from the physiological side, it is simply impossible to avoid the phraseology of materialism, and therefore, for doing so, I shall make no further apology.

My next postulate is—That the activity of the brain is conditioned by the activity of its circulation. The blood is to the grey matter of the convolutions what atmospheric air is to burning fuel; it is at once a necessity and a stimulus. However favourable may be the arrangement of cell and fibre, the consciousness will fail to respond to any impression, and every cerebral function will be impaired or suspended, if the circulation be lowered below a certain amount.

It follows that, so far as physiological means are to enable us to understand how mind and brain mutually act on one another, a consideration of the laws that affect the distribution of blood, and the influence of local surroundings in modifying these, must be of the first importance. Yet this is what is very seldom attended to. Volumes have been written on the relationship of mind and brain with scarcely a single reference to this aspect of the subject. While considerable progress

has been made in defining the immediate sphere of activity, in certain mental acts, and especially in mapping the centres for voluntary motion, very little attention has been given to the influence which the many peculiarities of the encephalic circulation must have on the mode in which the brain may exercise its functions.

The principal general fact in regard to the local distribution of blood on which I have at present to lay stress is that, as a rule, the supply to every tissue and organ is in proportion to the demand for it. When function is quiescent, the need is slight in comparison with that of active exercise, and accordingly we find that the circulation of any organ contrasts remarkably in the two states.

Considerable difference of opinion has existed as to how this is immediately accomplished. By many writers the vaso-motor nerves seem to be regarded as veritable physiological demons, whose unsleeping vigilance foresees and provides for all local wants; and it is supposed that, while the whole motor force acting on the blood is supplied by the heart's action, these nerves so regulate the calibre of the smaller arteries, that they turn on or shut off the blood current as may seem to be necessary. While not disposed to question their great importance, a good deal might be said in favour of the notion, that the molecular agitation in the tissue itself has a direct influence not only in assisting movement by lessening friction, but by exerting positive energy in urging the current onwards.¹

¹ In recent works on physiology it has been the tendency to ignore, if not altogether to deny, the active influence of local molecular change on the capillary circulation. In the higher animals, however, we have what I would consider crucial evidence in favour of its existence. I allude to the portal circulation. Here we have a large mass of blood returned from the chylipoietic viscera, which, before it can reach the heart, has to traverse the ramifications of the portal system of vessels. It will be at once admitted that considerable force must be required for the purpose. Now, if a *vis a tergo* alone be employed in moving the blood onwards, the whole stress so occasioned must in this instance be borne by the mesenteric veins. The backward pressure within these vessels will be as great as what is required to transmit the blood onwards to the vena cava. Is it in the least probable that the thin walls of these veins could bear such a strain? I rather think we have here evidence that, while the general circulation may be sustained by the action of the heart, certain forces acting at the capillaries give indispensable aid in transmitting the blood through the latter.

Into the controversy on these points, however, I cannot enter here. For our present purpose it will be sufficient if the intimate relations between demand and supply be admitted as a matter of fact; if we can assume that functional activity involves a fuller volume and more rapid movement of blood in the capillaries of a part than does functional rest.

The last postulate I have to submit is the one on which my subsequent argument must mainly rest; but, unfortunately, it is the one whose soundness is most likely to be questioned. It is—That the mass of blood within the cranial cavity can be neither increased nor diminished directly, nor, indeed, to an appreciable extent within short periods of time.

A general statement of the argument in its support may lie in a nutshell. The available cubic space within the skull being a fixed quantity, the bulk of its contents must also continue uniform. These contents being the brain-tissue, the blood and the cerebro-spinal fluid, no one of these can be altered without an inverse change in one or both of the other contents. Thus, if a degenerative nutrition cause wasting of the brain-tissue, we must have an increase in one or both of the fluid contents, and thus evidence will be got of extreme congestion, or of serous effusion, or both. For any such change, however, time is required. Again, no amount of general depletion can reduce the intra-cranial circulation until time is afforded to allow effusion of serum to occur, because no mechanism exists for immediately raising any fluid from the spinal canal. Neither, on the other hand, can any increased force of the heart's action make the intra-cranial vessels fuller, for the cerebro-spinal fluid cannot be immediately displaced. It cannot be pressed into the spinal canal, for the latter cavity is already tensely full.

Referring to the classical essay of Dr. Kelly¹ for experimental proof of the difficulty of affecting the mass of intra-cranial blood, I content myself here with a single argument, looking at the subject from a common-sense point of view

Whatever opinion may be held as to the nature of nervous energy, the phraseology used when its discharge is spoken of implies a certain amount of stress in the nerve-centre. Thus,

¹ 'Transactions of the Medico-Chirurgical Society of Edinburgh,' vol. i.

"vibration" cannot occur without *tension*, and "explosion" implies previous *repression*. A chord will not give a clear tone when it is relaxed; and if the chamber in which a cartridge is exploded is not perfectly rigid, the effect on the bullet is weakened. If we are at liberty to reason from analogies like these, we must infer that no nerve-centre can have its energy economically liberated unless its structure is subjected to a certain amount of stress. Now, stress in a nerve-centre means stress in its circulation, and this involves pressure outwards and equally in every direction. If the energy is to be liberated with ease, and with exactness as to amount and direction, support to the structures immediately concerned must be as little yielding as possible. But if the cerebro-spinal fluid is at liberty to flow and ebb as readily as some writers assert, this steady support would be absent. The brain in such a case would resemble an instrument with slackened strings, and would refuse to give a clear response to impressions. Sudden, or powerful, or exact voluntary effort would then be simply impossible. For here, as everywhere, the discharge of pent-up energy will take place in the direction of least resistance. If the displacement of the organ's support occur more readily than the production of the intended result, such as the movement of a limb, the latter will not be successfully accomplished. Some of the energy would be wasted in the form of simple mechanical effect on the surroundings, and the result, whether mental or motor, will be less precise than would otherwise be the case.

The inference, then, is obvious. If time be an essential factor in the production of any change in the bulk of the brain-tissue, or in that of the cerebro-spinal fluid, then for the time being the mass of intra-cranial blood must also remain a stable quantity.

If we are allowed to assume the correctness of our last postulate, two corollaries require to be kept in view in applying it to encephalic physiology. In the first place, no change can take place in the circulation of one portion of the brain without that of some other part being inversely affected. In the abdomen, a determination of blood to one organ need not of necessity involve a diminished supply to the rest of the

cavity, but an analogous occurrence within the skull is impossible. If the anterior cerebral arteries, for example, have their supply augmented, then to an exactly corresponding extent a lessened amount can be present in the other encephalic vessels.

In the second place, no change can occur in its circulation without a change in the balance of active pressure through the brain. The stress through the whole cranial cavity must, of course, be equalised, from the amount of fluids present, but the displacement of solid particles must occur, and such displacement is not likely to be without physiological significance.

Assuming the approximate soundness of these principles, we have to consider how they may be applied in encephalic physiology. My immediate object will be to show, that they must be of essential importance in any study of the correlations of mind and brain.

The first subjective condition or faculty I have to notice on its somatic side is Attention. It is unnecessary to enlarge on the psychological importance of this function. It may be said to underlie every other mental faculty. It is the bringing of the consciousness to a focus in some special direction. It is required to convert sensation into that comprehensive grasp of particulars which constitutes perception; without it, meaningless reverie will take the place of coherent thought; nor can we conceive of any act being strictly voluntary apart from its guidance.

To study it in its physiological relation, we may for convenience take the well-known effect of attention in modifying the intensity of sensation. The mental effect produced by an impression on a sensory surface is stronger, and details about the impressing cause are more completely gathered in when the mind is concentrated on it. On the other hand, if the consciousness is engrossed in some other direction—if absorbed by an interesting occupation or train of thought—the impression which formerly produced so much effect is felt obscurely or not at all. To account for this difference we cannot be content with a merely metaphysical explanation. To say that the mind is so constituted that it cannot at one

and the same moment entertain with equal distinctness dissociated ideas, is only one half of the truth. There must be a cerebral correlative, and some notion as to the nature of this must be got if we are to come nearer the whole truth.

Two factors, at least, may be specified as bearing on this problem. In the first place, when the consciousness is engrossed by an immediate sensation, the sphere of encephalic activity is comparatively restricted. What that sphere may be in any particular instance it is for anatomy and experiment to determine. For receiving the impression, for quickening the consciousness, and for completing its course as a definite perception, the track involved may be wide and branching, but it does not include the whole brain.

In the second place, *the encephalic circulation will be focussed in the direction of activity*. The molecular agitation occasions a necessity and an attraction for more blood, and determination of this takes place all the more freely on account of the quiescence of the larger part of the brain. The latter has, as it were, loosened its hold on the circulation, and the impetus toward those parts which have an attraction for it is thus all the stronger. The increased activity of the circulation then reacts on the energies of the tissue, and the mental effect produced is therefore greater.

If now we turn the picture, we find the lights and shadows have changed places. Let the mind be intent on solving some problem, or be engaged on some work requiring close attention and nicety of handling, and the impression which formerly so completely took possession of the consciousness may now not in the least be felt. Here, too, physiological conditions are at work. The impression fails, not simply because the consciousness is otherwise engaged, but because the track along which it is to travel is not now in a fit condition for responding to the stimulus. It is out of focus. The momentum of the circulation is now directed toward the centres of ideation and voluntary motion, and this implies a derivation from, and consequent weakening of, functional vigour in the sensory ganglia.

If the above reasoning be legitimate—even approximately so—it becomes a matter of detail to apply the principle in

other directions. In speculating on any point in mental physiology, we have something more than the molecular action of the brain itself to consider. The capillary circulation, too, has its laws, and the encephalic circulation its peculiarities, and a certain balance in the latter must be maintained if cerebation is to be healthy and its outcome exact.

In perfectly normal action it is likely that the molecular changes are the dominant factor and keep the circulation under control; but not unfrequently the mass and velocity of the circulating fluid may determine the sphere as well as the character of the activity, and thus have effect on the outcome, whether muscular or mental.

If the cells of one centre or class of centres be too readily explosive, they may attract the blood so strongly as to inhibit the function of other parts of the brain by the comparatively anæmic condition these are thus left in. Of this we have an illustration in the phenomena of an epileptic seizure. Here we have the blood determined in such volume to the motor centres that those which are more immediately related to consciousness have not sufficient left to enable them to sustain function with. Some writers seem to insist that during the seizure the whole brain becomes almost bloodless; but it would be as philosophical to expect a water-wheel to revolve violently by its supply of water being cut off, as that the energy of the brain can be prodigally expended in defiance of ordinary physiological conditions.

On the other hand, if the attractive power of some centre is under the normal, this may allow a determination to other centres to be excessive, and in this way, again, the action of the whole encephalon may be modified.

The means usually adopted to induce the hypnotic state afford us an illustration of a mode by which this condition may be brought about. In the first place, the attention is so strained in one direction that fatigue of a motor and of a sensory centre has been induced. When this has happened, the molecular agitation that accompanies activity of function becomes more difficult. Repose is needed to restore its former fitness for work. The structures immediately involved

are reduced to a condition approaching that of sleep, and as a result they have relaxed their hold on the circulation. The forces which sustain its balance are therefore disturbed. The condition of the encephalic circulation may now be considered analogous to that of the atmosphere with a low barometric pressure; it is mobile and disposed to storms. If attracted in one direction, it is determined strongly. Then, the very momentum with which the blood surges in that special direction, reacts on and strengthens function. If it be toward an ideational centre, some particular idea may so monopolise the consciousness, that the judging faculty is almost as completely in abeyance as in ordinary dreaming. Thus, when something bitter is put into the mouth of a hypnotised subject, and he is told it is sweet, the notion of sweetness becomes dominant because the circulation is so strongly focussed toward an ideational centre that the gustatory centre or track cannot respond to its natural stimulus. Its function is suspended on account of the failure of a necessary condition.

In regard to volition, we need not here enlarge on the metaphysical subtleties its discussion has given rise to. We have now to do with it as a faculty subject to the tyranny of organic conditions, and our endeavour is, if possible, to catch at least a glimpse of its mechanism.

The Will is essentially a prospective faculty. It must have a goal in view, whether a muscular movement, or an effort of memory, or a process of reasoning be required to reach it. Some notion must precede action, and cerebration does its work without revealing to the consciousness anything of the mechanism employed.

Certain of the factors, however, may be specified with some precision. I, of course, must assume we have to do with an educated brain, in which co-ordination has been established among its various parts.

Ideation, then, the initiatory stage of volition, involves, within a limited area, molecular movement with corresponding vascular excitement. The function of that area becomes active, and *radiation of energy must take place in some direction*. Strands for the purpose of conduction branch off in innumerable

lines to other centres. What the immediate direction may be, will of course depend on the circumstances of the moment and the results of previous association:

In order that the outcome may correspond with the intention, the impulse itself must be sufficient in intensity; the "points," (in railway phraseology) must be "open," the line must be clear, and the circulation must be so balanced that it is ready to surge in the required direction. The outcome may be defective by the failure of any of these conditions, and an improved adjustment in some needed respect may at once enable a correct result to be got. Thus, a familiar name or word may escape the memory, and for a time every effort may fail to recall it. Then, for example, a more successful focussing of the circulation taking place in the ideational centre, the word comes up without apparent effort. From this point of view, "unconscious cerebration" means simply, "better adjustment."

If the radiation be toward a motor centre, we find in the latter all the conditions favourable for liberating its energy. In the waking state, and in the absence of fatigue or disease, the centre requires little more than *permission* to do its work. All the potential conditions for discharge are already there. With the stimulus communicated from another centre, we have simultaneously molecular agitation and vascular excitement. The latter acts in two ways. In the first place, by derivation, it removes the inhibitory action of other parts of the brain; and in the second place, it further directly stimulates the molecular movement. The immediate result is turgescence or orgasm in the centre itself. Then, the general law in physics, that action and reaction are equal and contrary, must here hold good. If the surroundings, therefore, be stable, natural relief will be got by the overflow or discharge of energy into a motor nerve, and contraction of a muscle will be the result. On the other hand, if the support afforded to the centre be insufficient, the vascular turgescence will to some extent spend itself in displacing the surrounding tissues, and the intended movement will either not take place, or it will fail in precision and strength.

My object in the present paper has been rather to give

prominence to what I consider a neglected factor in cerebral physiology, than to attempt its application to all possible instances. I shall be satisfied if I have said enough to show the importance of investigation in the direction I have indicated. Indeed, when one reflects on how much research is devoted to the minute structure of the brain itself, it seems surprising that so little attention is given to what may be called intra-cranial physics. We have here a field which is at least as likely to be fruitful in results as the attempt to measure and classify all the varieties of nerve-cell, or to unravel the complex network of nerve-fibres.

Within the skull we have an *imperium in imperio*, where, with loyal fealty to the interests and claims of Imperial unity, the rights of "Home Rule" are jealously conserved. As the speck of protoplasm requires the restraint of the cell-wall to enable it to develop and exercise some specific form of energy, so the brain-mass has its form moulded, and its development directed, and, especially, its energies exercised under the severe repression of membrane and bone. Then, in the approximately—if not for a time absolutely—stable mass of blood in the encephalic vessels as a whole; in the arrangement of the vessels themselves; and in the relation of their contents to the pressure of the atmosphere, we have conditions which contrast so remarkably with those we find in any other part of the body, that a consideration of their significance is surely deserving more attention from physiologists than it has yet received.