everywhere agreed that harsh measures are justifiable, the Governments are, in my opinion, well advised in not making the attempt. Law-abiding though they be, British subjects do not tamely submit to what they may regard, rightly or wrongly, as unnecessary coercion.

Where the lepers are comparatively few, and the public in general desirous of their seclusion—as in New South Wales, for instance—such measures may be to a large extent feasible; but where the lepers are numerous, and the lepers' friends still more numerous, and not acquiescent in their separation, it seems to me that harsh measures can only lead to the concealment of cases—as has been well exemplified, for example, in South Africa and in Hawaii.

If difficulties be raised among an ignorant people by the enforcement of common sense sanitary precautions against such an acute and virulent disease as a rapidly spreading plague, how much more difficult might it not be to insist on rigorous measures in the case of a disease of such slow and insidious progress as leprosy?

With regard to India, moreover, even if the complete isolation—in spite of the above considerations—were possible, the question of "ways and means" must come in. The segregation and maintenance of upwards of 100,000 souls is, to say the least, a large undertaking.

We must not forget that our knowledge of the etiology of leprosy is still far from complete; and although we may form theories and impressions from the imperfect data which are before us, we are not justified in dogmatically insisting upon conclusions which are practically only based upon such mere theories.

In an Appendix were given the various Laws and Acts bearing upon the subject of leprosy, which have been passed within recent years by the Governments of:

1. India.	9. Jamaica.
2. The Straits Settlements.	10. Barbadoes.
3. Cape of Good Hope.	11. St. Kitts and Nevis.
4. Natal.	12. Antigua.
5. British Bechuanaland.	13. Trinidad and Tobago.
6. The Seychelles.	14. British Guiana.
7. New South Wales.	15. Malta.
8. Queensland.	16. Cyprus.

THE INTRACRANIAL CIRCULATION IN SOME OF ITS ASPECTS.*

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Few subjects have given rise to so much discussion as the question regarding the differences existing between the circulation as observed in the brain with an opening in the cranium and that carried on when the skull is intact. For nearly 150 years a vast amount of work, and still greater amount of theorising, has been done on this subject. Schlichting¹ in 1750 made the first real step towards the elucidation of the cerebral circulation when he showed that movements of the brain corresponded with respiratory movements, expansion of the brain occurring with expiration and retraction of the brain with inspiration. De la Mure² and also Haller³ a few years afterwards showed that these movements of the brain were due to the mechanical effect of the respiratory movements of the chest on the large veins entering the thorax, and the latter demonstrated that in addition to the movements of the brain with respiration there were pulsations synchronous with the arterial pulsation elsewhere. Little advance was made in our knowledge of the intracranial circulation in the open skull till Mosso⁴ wrote his important monograph about twenty years ago on the circulation of the brain in man, derived largely from tracings taken from the brains of men with gaps in the skull. A considerable number of writers have used this method since then in similar conditions, and two years ago Dr. Hutchison⁵ and the writer showed that much information could be got in this

direction from the movements of the fontanelle in children when a delicate apparatus is used. It is not my intention at present to deal with this aspect of the question at any length, but it is necessary in order to discuss the relationship of this to the circulation in the closed skull to state the chief facts which have been observed in connection with the circulation in the unclosed skull.

There is in an unclosed skull a double cerebral pulsation—(1) synchronous with arterial pulsation, and due to distension of the arteries by the cardiac systole; and (2) with respiration, retraction of the brain from aspiration of the venous sinuses with the inspiratory movement, and distension of the brain with the expiratory movement. The amount of blood in the brain therefore varies very greatly with the respiratory movements from the fact that when the venous pressure is reduced in inspiration the small vessels in the brain are compressed by the atmospheric pressure. The greater the extent of the respiratory movements the greater of course the movements of the brain. The arterial pulse wave as taken by various instruments is nearly always found to be anacrotic in character, though at times, as we shall see, it may become katectotic. No satisfactory explanation has yet been given of the cause of this anacrotism.

When we come to the consideration of the circulation inside the closed skull the subject becomes much more difficult, and it is this aspect of the intracranial circulation which has led to so much discussion. So long ago as 1760, Lorry⁶ put forward the idea that the pulsation of the arteries with cardiac systole might lead to a compression of the venous sinuses, and to a more rapid return of blood to the heart. Monro Secundus⁷ taught that as the skull was a closed box the quantity of blood inside it could not vary except under certain pathological conditions, when its place was taken by effusions. This view was strongly supported by his pupil, Dr. George Kellie,⁸ of Leith, as the result of his experimental and pathological experience, and the theory of the unvarying quantity of blood in the skull has therefore been named the Monro-Kellie doctrine. It must be remembered that at this time the constant presence of cerebro-spinal fluid in the central nervous system was not known, for although it had been described before this by Cotugno, the discovery had been lost sight of. Not till Majendie in 1825 carefully described the presence of this fluid was the Monro doctrine much questioned. Majendie⁹ put forward the theory that with distension and contraction of the vessels of the brain, the cerebro-spinal fluid flowed backwards and forwards between the cranial and the spinal cavities, and this theory with some modifications has practically up to the present been the one generally accepted. Burrows¹⁰ also, in 1846, strongly combated Kellie's views, by experimenting in a somewhat similar direction, and came to the conclusion that the amount of blood inside the cranium could vary to a very considerable extent. This work of Burrows was pretty generally recognised, especially in this country, as having completely refuted the old doctrine of the Edinburgh School, but the results of the magnificent recent work of Leonard Hill tend to show that in its essential points the Monro-Kellie doctrine was fairly correct.

We have seen in speaking of the circulation in the open skull that there are two forms of cerebral pulsation (1) the arterial, and (2) the respiratory. Do such pulsations occur in the closed skull, and, if so, by what means is accommodation made inside the closed cavity for them? It is obvious that with each cardiac systole blood is forced into the arteries of the brain. The cranium is practically a closed cavity, and there must be some provision to accommodate this increased quantity of blood. It has been proved that the brain tissue is incompressible, and therefore there are only two possible means apparently by which the necessary space for the increased arterial blood can be got (1) by displacement of cerebro-spinal fluid, and (2) by displacement of venous blood. As we have seen, the former explanation has been hitherto pretty generally accepted. It has been argued that although the cranium is a closed cavity the spinal column is not; that as the cerebro-spinal spaces of the one cavity are continuous with those of the other, fluid passes from the cranial into the spinal cavity when arterial pulsation occurs, and *vice versa* between the beats. It must be remembered, however, that although the dura mater hangs loose inside the spinal column

*This was incorporated in a thesis for which the degree of M.D. was given by Edinburgh University. The experimental work was done in the laboratory of the Royal College of Physicians, Edinburgh. Towards the expenses of this research a grant was made by the British Medical Association, on the recommendation of the Scientific Grants Committee of the Association.

it is surrounded by fat and venous sinuses, whilst the spinal ligaments covered by thick layers of muscles and strong aponeuroses are rendered practically non-distensible. Pulsation of the ligaments of the cord, especially in the upper part, has been seen in animals when the spinal column has been exposed, but that is no proof that such pulsation occurs when the thick layers of muscles and the aponeuroses are in position. If, then, the ligaments are in the natural condition non-distensible, the spinal column seems to be in much the same position as the closed cranium, for although the spinal cord does not fill up the whole of the cavity, the extradural fat is incompressible, and the extradural veins are comparable to the large intracranial veins and sinuses.

If, now, we consider the effects of respiration on the intracranial circulation, we find that there is an aspiration of blood from the large veins with inspiration. In the open skull—as in infants where the fontanelle has not yet closed—this is shown by recession of the brain, due to compression of the vessels by the atmospheric pressure. But in the closed skull this does not come into play, and therefore the space which was occupied by venous blood must be taken by something; and here, again, it has generally been supposed that there is a flow of cerebro-spinal fluid from the one cavity to the other—in this case from the spinal to the cranial cavity during inspiration. But one must remember that during inspiration there is also an emptying of the venous sinuses in the spinal column, and if, as we have argued, the spinal column is closed, the conditions in the two cavities are much the same.

Looked at, then, theoretically, there does not seem to be any very strong reason in favour of this to-and-fro movement of cerebro-spinal fluid with arterial pulsation or respiratory movements which has been postulated. Donders¹¹ long ago tried to settle the question of whether cerebral pulsation occurred in the closed skull by making a trephine opening in the cranium and fixing a glass window in the place of the bone removed so as thoroughly to close the opening. He noticed that the pulsation of the brain ceased with respiration, whilst variation in the size of the arteries continued with each heart beat. This experiment of Donders has been repeated with similar results. It has been argued, however, that, if any pulsation with movement of cerebro-spinal fluid occurred, it would not be seen on the surface of the brain, but rather at the base of the brain and in the spinal column.

EXPERIMENT I.—A large retriever dog was first put under the influence of morphine, then etherised, and an incision was made in the upper dorsal region. The muscles were carefully reflected so as to avoid hemorrhage—which is apt to be troublesome unless one keeps close to the bone—and when the spinal column was laid bare a trephine opening was made in it. A thread was put on the edge of the trephine hole, and a window, fixed in a metal ring, was screwed tightly into the opening without pressing on the tissues beneath. Before the window was screwed in movements with respiration and with arterial pulsation were seen; but as soon as the window was airtight no movements were seen with respiration, although, of course, pulsation in the arteries was still visible.

The results of this experiment, so far as they go, are opposed to the movement of fluid from the cranial to the spinal cavity. Of course it might be argued that as soon as the window was inserted this part of the column was rendered non-distensible, and the movement of the fluid would be towards a part of the column which was distensible. One would be inclined to think, however, that if there was movement of any great extent this would be perceptible by the window.

It seemed to the writer that much information might be got in this connection from the injection of finely-coloured granules in suspension into the cerebro-spinal arachnoid space, noting what movement of the granules, if any, occurred. A considerable number of experiments were therefore carried out in dogs and rabbits, the former being more satisfactory from the larger size of their spaces. Most of the experiments were made on the spinal cord, pretty high up. As the important point was to determine the state of affairs in normal conditions, it was important not to allow the atmospheric pressure to come into play by opening the cranium or spinal column. The experiments were therefore conducted thus: After the animal had been anaesthetised an incision was made over the spines of the spinal column and the muscles carefully reflected from the spines and laminae. The needle of a syringe containing normal salt solution with fine granules

of Prussian blue in suspension was pushed through the ligaments into the spinal cord, and as the needle was gradually withdrawn the fluid was gently expressed, so that some of the granules were left in the arachnoid space. The wound was closed by deep and surface stitches, and everything was done as far as possible under antiseptic precautions. The animals were allowed to live for varying lengths of time, from a few hours up to three or four days. They were then killed by chloroform, put in ice, and frozen sections of the brain and spinal cord made.

EXPERIMENT II.—Large rabbit: An incision was made in the middle line in lower cervical region, muscles reflected from several vertebrae, then about 3 minims of Prussian blue in suspension injected. The animal lived about ten minutes, taking deep respirations, and was then killed, frozen, and sections made. There had been no diffusion of the granules in the arachnoid space further than $\frac{1}{8}$ to $\frac{1}{4}$ inch from the point of injection.

EXPERIMENT III.—A control experiment carried out on a dead rabbit showed that by the injection of 3 or 4 minims of the fluid, granules were carried as far from the point of injection as in the previous experiment.

EXPERIMENT IV.—Large rabbit: Incision was made in lower cervical region, and after the spinal column had been exposed, a very small opening was made in the column, and 4 to 5 minims of Prussian blue in suspension injected. The animal was kept alive amongst wool, and with a hot bottle. It was quite lively, and eating an hour or two after the operation, although there was considerable loss of power in the hind legs. After fifty-four hours it was killed by chloroform, and frozen sections made. On examination it was found that above the point of injection the granules did not reach more than $\frac{1}{4}$ inch, whilst below the point of injection they reached $\frac{1}{2}$ to 2 inches.

This experiment seems to be very valuable. Had there been movement of the cerebro-spinal fluid with the respiratory movements or with the arterial pulsation, the diffusion of the granules would have been both above and below the point of injection. On the contrary, there had been no flow upwards, whilst the diffusion downwards is much too slight to have been the result of respiratory movement during fully two days, and is probably the result of the natural flow of the cerebro-spinal fluid, which, being secreted in the choroid plexus, passes partly down the cord. The sheaths of the nerves from the cord near the injection were examined for granules, but with negative results, showing that there had been no flow of cerebro-spinal fluid along the sheaths of the nerves with the respiratory movements.

EXPERIMENT V.—Dog: Incision made in upper cervical region, and injection made of Prussian blue in suspension. The dog was allowed to live for three days, then killed by chloroform, put in ice, and frozen sections made. The examination showed that only a small quantity of injection had gone into the arachnoid space, and there had been no diffusion of granules beyond three-quarters of an inch or so.

EXPERIMENT VI.—Medium-sized dog. Incision made down on spinal column in lower cervical region, and injection of granules in suspension made in two different places. Killed by chloroform in twenty hours, and frozen sections made. On examination, no granules were found beyond three-quarters of an inch or so from the points of injection. Along the nerves arising close to the points of injection no granules were found beyond the ganglion on the posterior root.

Some other similar experiments gave practically the same results.

Some experiments were also performed on the cranium in rabbits. Here, after a flap had been reflected, and the cranium laid bare, a hole just large enough to admit the needle of a hypodermic syringe was made with a very fine drill, and then some minims of Prussian blue in suspension were injected into the arachnoid space. No diffusion of the granules beyond half an inch or so was observed.

It was only after these experiments had been carried out that the writer found that Quincke¹² had long ago used the injection of coloured granules to determine the flow of cerebro-spinal fluid. He experimented on dogs chiefly, and found that wide diffusion of the granules occurred. How are his results to be explained? In many of his cases weeks or months elapsed before the animals were killed, and then of course wide movement of the granules was to be expected. In others, however, which were killed or died in twenty-four to seventy-two hours, there was also wide diffusion. It must be noted, however, that he used a considerable amount of fluid in his injections. There is a great difference in injecting into the comparatively small arachnoid space 15 minims as compared with 2 or 3 minims, and if the injection be made with force the fluid travels to a very considerable extent. This is shown by the following experiment of the writer.

EXPERIMENT VII.—A rabbit was etherised; a semilunar flap made over the vertex, and a fine hole drilled in the skull, as already described, large enough to admit the nozzle of a hypodermic syringe. Twenty minims of carmine-coloured gelatine was then injected with force into the arachnoid

space, and the animal then killed with chloroform, and frozen sections made. It was found that the gelatine had passed down about two-thirds of the length of the cord, as well as through the aqueduct of Sylvius, into the lateral ventricles.

Quinke does not describe how he extracted the brain and spinal columns of the animals experimented on; but evidently they were not frozen, and there is no doubt that very considerable diffusion of granules could occur in the removal. The quantity of fluid injected, then, and the method of removal, would appear to be sufficient to account for the results got by Quinke in his experiments.

Having seen, then, that in all probability no movement of the cerebro-spinal fluid occurs with respiratory movement or with arterial pulsation, we must consider what happens in the cranial cavity during these events. Taking the respiratory movements first, we have seen that blood is aspirated from the veins with inspiration; as its place is not taken by cerebro-spinal fluid, it must either be taken by venous blood from the spinal column or by arterial blood. With inspiration the veins of the spinal column are also depleted, and so the only alternative left is distension of the arteries inside the cranium. This is what we should expect to occur when we consider the condition of affairs. The cerebro-spinal pressure has been shown by Hill to be the same as the venous pressure; with the inspiratory movement it falls, whilst the intra-arterial pressure throughout the body rises during inspiration, and this would naturally lead in the physical conditions present in the closed skull to a distension of the arteries. As the veins filled again during expiration, the cerebro-spinal pressure would rise to a corresponding extent, and the arteries would become smaller. This see-saw movement on the part of veins and arteries might of course quite readily occur without interfering with a constant flow through the capillaries. With the inspiratory movement the veins which collapse are probably chiefly the large veins which open into the cranial sinuses, the walls of the sinuses themselves being incompressible. With the dilatation of the intracranial arteries during the inspiratory movement and the decreased intracranial pressure, it is probable that there is at this time, as compared with the subclavian for instance, increased flow along the carotid artery, which as regards the direct effects of respiration is under similar conditions.

What occurs in the cranial cavity with the arterial pulsation? Obviously room must be made for it either by displacement of cerebro-spinal fluid from the cranial to the spinal cavity, or accommodation must be got by displacement of venous blood.

The injection experiments already mentioned seem to show that there can be no displacement of the fluid worth speaking of, else there would have been some considerable diffusion of the granules. François-Franck and Pitres,¹³ in a very valuable contribution to the physiology of the cerebral circulation, thought that they had proved by experiment that such displacement of fluid does occur. They exposed the occipito-atlantal membrane in the dog, and inserted through it a fine hæmodromometer into the arachnoid space. Movements were seen with each arterial pulsation. But it is obvious that if the instrument happens to come in contact with an artery similar movements would be communicated to it, and so the experiment is very far from conclusive.

Much more important is the fact that no movement of the hæmodromometer, was seen with the phases of respiration, which is further proof of the conclusion we have already come to that no movement of fluid occurs with respiration. If then no movement of cerebro-spinal fluid occurs from the cranial cavity with arterial pulsation, blood must be pressed from the veins. So long ago as 1824 Carson,¹⁴ one of the supporters of the old Edinburgh doctrine, insisted that blood must be pressed from the skull with each heart beat, but as we have seen, at that time it had not been shown that cerebro-spinal fluid was always present in the cranium, and there seemed to be no alternative to his proposition, except that of the compressibility of the brain tissue. What proof is there of this "lateral" pressure by the arterial pulsation on the veins? In a boy aged 8, who was operated on for symptoms of mastoid disease following otitis media, the lateral sinus, which was found to be quite healthy, was laid bare, and in addition to the pulsation of the sinus with the respiratory movements, pulsation of the sinus with each heart beat was also seen. Mosso, after inserting a cannula into an

intracranial sinus through a trephine hole, and covering the trephine hole with a rigid plate, found that there were present pulsations synchronous with the arterial pulsations.

There seems then to be considerable evidence that the arteries inside the cranium, in addition to the ordinary *vis a tergo* action, cause a "lateral" pressure on the intracranial veins so leading to increased flow of blood from the skull during the beat. This compression of the veins will probably occur in the largest veins whose walls are compressible—that is, in the large veins opening into the venous sinuses. The sinuses, because of their firm walls, are themselves incompressible. In the spinal column a similar compression of the large veins probably occurs, but as in this case the large sinuses have not rigid walls, the compression will occur in them.

All that has been already said refers, of course, to the circulation inside the skull under ordinary physiological conditions. When there is a pathological rise of pressure inside the skull, however, there will of course be a flow of fluid from the cranial into the spinal cavity, where, as the two cavities are now no longer under the same influence, the cerebro-spinal pressure will be less.

EXPERIMENT VIII.—A rabbit was etherised, an incision made over the upper dorsal region, the muscles reflected, then through the ligament about 3 minims of Prussian blue in suspension injected into the arachnoid space. A semilunar incision was then made over the skull, a flap reflected, a fine hole drilled in the skull large enough to admit the needle of a syringe, and 20 minims of gelatine slowly and gently injected on the surface of the brain; the animal was then killed by chloroform and frozen sections made. On examination it was found that granules of Prussian blue had passed down almost to the lowest point of the spinal cord, and in addition granules were seen along the sheaths of the nerves near the point of injection.

This shows that under conditions closely resembling an effusion of blood inside the cranium there is a flow of cerebro-spinal fluid from the cranium into the spinal column. Bayliss and Hill¹⁵ have shown, however, that, although such a flow occurs, it is by no means great, because when the intracranial pressure rises much, the cerebellum and base of the brain sink into the foramen magnum and cut off the connection between the cranial and spinal cavities, and therefore that because of this, although at first rises of intracranial pressure are accompanied by similar rises of intraspinal pressure, the latter rise soon ceases, whilst the former goes on increasing. This plugging of the foramen magnum would probably only occur, however, in sudden rises of intracranial pressure. This would seem to be a reason, apart altogether from alterations in the rate of secretion and absorption of cerebro-spinal fluid, why sudden rises of intracranial pressure are followed by evidences of circulatory disturbance to the brain much more readily than more gradual rises. In the latter cases there would be respite for the circulation for a certain length of time. The effect of such an increase of intracranial pressure would be compression of the walls of the veins. This, if great, would lead to interference with the flow of blood through the capillaries, (what Geigel¹⁶ has suggested to name *adiæmorrhysis*), and if the pressure still rose, to obliteration of the capillaries and a true condition of cerebral anæmia.

THE REGULATION OF THE BLOOD SUPPLY TO THE BRAIN.

One of the most remarkable features about the intracranial circulation is the readiness with which it responds to changes in the circulation of the rest of the body, or of part of the body. Mosso¹ showed this in his able work published twenty years ago, and more recent researches have only tended to further accentuate it. When one takes tracings of the brain movements in the unclosed skull, one finds that increased intracranial pressure occurs with all movements of the body (which, of course, raise the general venous pressure), and particularly with any movements which interfere with the return of blood by the jugular veins. This is readily understood, as we have seen already the powerful influence which the respiratory movements exert on the circulation to the brain through the great veins of the neck and the venous sinuses inside the skull. Anything which interferes with the calibre of the great veins of the neck will, of course, lessen this aspiratory action of the expansion of the chest. It has also been shown, however, that all conditions which lead to a stimulation of the vasomotor centre lead to an increase of intracranial pressure—that is, to an expansion of the brain, and this in a manner quite unlike any other organ in the

body. Thus, in the condition of the circulation when the so-called Traube-Hering waves are produced, when there is a diminution in the size of all the other organs of the body from contraction of the arterial walls, there is expansion of the brain.

Further, Roy and Sherrington,¹⁷ and more recently Bayliss and Hill¹⁸ in their extremely valuable work already referred to, have come to the conclusion, after a vast amount of careful experiment, that there are no vasomotor nerves to the brain. Roy and Sherrington believed, from the results of some of their experiments, that the calibre of vessels in the brain might be directly influenced by the chemical composition of the fluid surrounding them; but Hill could find no evidence whatever to support this theory. He showed that the intracranial pressure could be affected by alterations in the general arterial pressure, or by changes in the general venous pressure, but it more readily followed the latter than the former. He could, however, find no evidence of any vasomotor nerves to the cerebral circulation. Considering the very comprehensive character of Hill's experiments, there would appear to be little doubt that the cerebral circulation is not directly governed by the general vasomotor centre.

If now we examine tracings of the brain pulsation, we find that in most cases of increased intracranial pressure, along with the rise in the general level of the tracing, the height of the individual pulse wave is lessened, whilst the wave retains its anacrotic character. In 2 kinds of increase of pressure, however, the writer has noticed a difference in the form of the wave from that commonly seen. (1) With mental work the individual pulse waves are higher and tend to become katarctic instead of anacrotic, whilst the general level of the tracing rises. This is beautifully seen in some of Mosso's tracings. It is natural to suppose that with the activity of a part of the brain there will be a greater supply of blood to that part, and if so, it would necessitate a mechanism of some kind to bring it about. That such localised increases in the circulation do occur has been shown by the observation of congestion in parts of the motor areas in patients who have been liable to epileptic attacks, and whose brains have been exposed. It is true that Mosso showed that along with the expansion of the brain during mental activity there is also diminution of the size of the limbs, probably from contraction of the arterioles, but it has been recently proved that this diminution in the size of the limbs does not correspond either in time or in extent with the expansion of the brain; therefore the expansion of the brain is not the passive result of the activity of the vasomotor centre acting on the other arteries of the body. (2) The other condition in which the writer has noticed, along with rise of intracranial pressure, increased height of the pulse waves and tendency to katarctism is after the inhalation of nitrite of amyl. This is well seen in the accompanying tracing taken from a deaf

Fontanelle Nitrite of Amyl Given
Respiratory movement

and dumb girl with a persistent fontanelle. She began to inhale nitrite of amyl, and with the rise of the tracing the alteration of the pulse waves already mentioned is observed. Most conditions which lead to dilatation of the peripheral vessels lead to a fall in the intracranial blood pressure, for as we have seen, the intracranial pressure is very largely dependent on the general circulation. Here, however, with the dilatation of the peripheral vessels there is an expansion of the brain, probably due to the direct action of the nitrite on the muscular wall of the vessels, for nitrite of amyl can cause dilatation of the vessels of a part when all connections with the vasomotor centre have been cut off.

It is sufficiently interesting to be worth noting, that in one of these two conditions (where expansion of the brain is accompanied by increased height and change in the form of the pulse wave) the change in the intracranial circulation is almost certainly independent of the condition of the general circulation, whilst in the other it is probably independent of it.

While, therefore, the circulation of the brain may be said to be usually at the mercy of the general circulation in the rest

of the body, and whilst there is probably no direct influence of the general vasomotor centre on the intracranial vessels, there must of necessity be some means of regulating the circulation in different parts of the brain.

CONCLUSIONS.

In this paper the cerebral circulation has, of course, been considered in only a few of its aspects. It may be advisable to place in a short summary the conclusions which have been drawn in our consideration of the subject:

1. In the unenclosed skull there are two very evident forms of pulsation of the brain: (a) the arterial, (b) the respiratory; the former produced in the arteries, the latter in the veins.

2. In the closed skull the venous side of the circulation is of the greatest importance, and respiration acting through the veins takes an important rôle in the intracranial circulation.

3. During inspiration in the open skull the aspiration of blood from the cranial veins is accompanied by compression of the vessels and retraction of the brain.

4. In the closed skull a similar withdrawal of blood from the veins occurs, accompanied by decrease in the intracranial pressure.

5. There is no flow of cerebro-spinal fluid from the spinal cavity to the intracranial cavity, either with respiratory movement or with arterial pulsation, as has usually been supposed.

6. In all probability, accompanying the emptying of the large veins during inspiration, there is dilatation of the arteries. (This may be accompanied by an increased rate of flow in the carotid artery as compared with the other arteries in the body above the level of the diaphragm, which are otherwise under somewhat similar conditions.) So during expiration the dilatation of the intracranial veins will be accompanied by narrowing of the arteries. The flow of blood through the capillaries will remain constant.

7. With arterial pulsation lateral pressure is exerted on the intracranial veins leading to an increased flow of blood from the skull.

8. These movements of the veins, with respiratory movements and with arterial pulsation, will occur in the large veins leading into the intracranial venous sinuses, the walls of which are themselves incompressible.

9. Similar movements of alternating compression and dilatation of the arteries and veins probably occur also in the spinal column, the cavity of which is to be looked on as being practically closed, just as the cranial cavity is.

10. In all cases of sudden increase of pressure affecting both cranial and spinal cavities there will practically be no variation in the quantity of blood present in the cavities. There will only be either (a) a variation in the amount of blood in one side of the circulation as compared with the other, arterial at the expense of venous, or *vice versa*; or (b) an alteration in the rate of flow through the capillaries. In rises of pressure lasting some time there may be alteration of the quantity of blood inside the cavities resulting from alteration in the rate of secretion or of absorption of cerebro-spinal fluid.

11. The point of importance in alterations of pressure inside the skull is the rate of flow through the capillaries. Steady flow through the capillaries—"adiæmorrhysis," as it has been called by Geigel—may go on under very low intracranial pressure or under comparatively high (Hill).

12. Increased intracranial pressure from an effusion into the cranium—for example, a hæmorrhage—leads first of all to flow of cerebro-spinal fluid from the cranial to the spinal cavity, so giving a respite for a certain length of time to the intracranial circulation. If the effusion goes on, there is, first, compression of the larger veins, which leads, after it has taken place to a certain extent, to interference with the flow of blood through the capillaries—adiæmorrhysis—and if the pressure still rises, to actual compression of the capillaries and true anæmia of the brain.

13. When tracings are taken of the pulsations of the brain, with rise of pressure two forms of pulse wave may be seen (1) Where wave is less ample and still anacrotic, as it is under normal conditions; (2) where wave is higher and tends to become katarctic. The former occurs much more frequently

than the latter, and seems to be present in what may be termed "passive" increase of intracranial pressure—that is, where the intracranial pressure is increased from alteration of the circulation in the rest of the body.

14. In some conditions the intracranial circulation seems to vary independently of the circulation elsewhere. This would tend to show that, although the blood vessels of the brain are not directly controlled from the general vasomotor centre, there must be some local mechanism for altering their calibre.

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ON THE IMPORTANCE OF REST IN THE TREATMENT OF ACUTE PHTHISIS.

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THE great importance of attempting, in so far as it lies in our power, to give local rest to the diseased lung is, I think, sometimes overlooked in the treatment of acute phthisis. The deficient movement of the affected side, the tendency of the whole chest to fall into, and as far as possible to maintain, a position of expiration, the onset of unexpectedly severe dyspnoea on slight exertion, the pain induced so frequently when a deep inspiration is forcibly taken, and the consequent disinclination to make the attempt, and the tendency to persist with an irritable slight cough rather than to force a more violent one, and thus cause the chest to expand and the sputum to be dislodged in the way that occurs in bronchitis and other chest affections, all point to the fact that in acute phthisis there is a continuous flow of inhibitory impulses to the respiratory muscles which prevents them from making strong contractions; in other words, there is a continuous unconscious effort on the part of the body to keep the diseased part as much at rest as is compatible with a sufficient aëration of the blood. Arguing from the above only, one would be inclined to suggest that in all cases of phthisis an attempt ought to be made by every means in our power to limit the movements of the affected side; experience, however, has abundantly shown that this is inadvisable. For instance, the fact that phthisical patients, in whom the disease is not acute, derive marked benefit from residence at a high altitude, both in the early and later stages—under which circumstances, of course, the amplitude of the respirations is increased—in itself plainly shows that the diminution in the movement of the lung, and its consequent partial rest, are by no means always a necessity for recovery.

The cases in which the best results are to be looked for from the local rest treatment, that is to say, from limiting the movements of the affected side, are undoubtedly those of acute and progressive disease, where the temperature is materially raised, where wasting is rapid, and where all the signs of a severe toxic infection are well marked. Further, this local rest is especially beneficial when the mischief is not only active but early, and where there is reason to believe that the wide area over which physical signs can be made out does not correspond with the actual area of tuberculous dissemination, but rather with a tolerably wide area of consolidated lung, the result of a broncho-pneumonia in the neighbourhood of one or more tuberculous foci. It must have been within the experience of everyone to have seen cases where, in spite of the brief history of ill health, the

physical signs have been so marked and so widely diffused as to have suggested the rapid breaking down of a whole lobe, but yet which, after a brief period of complete rest, have improved to such an extent as to have become almost quiescent. These are the cases in which great good results from limiting the movements of the affected side. The notes of the following case, seen in consultation with Drs. Metcalfe and Crocker, afford a fair example of what may be frequently expected from rest.

A. A., aged 28. Cough and slight wasting for some months. Acutely ill, with high temperature for ten days. Has not been resting, though feeling ill. Only consulted a doctor a few days ago. *Râles* down to the root on the left side, and in the second space in front and in the supraspinous region on the right. Impaired note at both apices in front and behind. The patient was from this time on kept strictly at rest in bed. Small doses of creasote and quinine were given, and he was moved into a nursing home. A week later the general condition had much improved; the catarrhal signs in the lungs were much less marked, and the patient stated that he felt nearly well. The temperature still, however, went up to 102° at night. The sputum was still profuse, and contained tubercle bacilli in considerable numbers. I did not see the patient again for a month, by which time the lung signs had become almost quiescent; the temperature had been normal for a week, and the general health was in every way better. The patient now exerted himself somewhat more, and at the same time had a good deal of worry, the result being that the temperature again rose, and he had for about a week signs of some recrudescence. He was again kept strictly at rest, and the adverse symptoms slowly disappeared. Tubercle bacilli could still be found in the sputum in considerable numbers. Finally, after another period of rest, the temperature again became normal. The patient was then taken by easy stages to Falkenstein, where he remained for some months undergoing the rest, over-feeding, and air cure, the result being that his general condition so much improved that he was able to return to his ordinary mode of life. A year later I heard that he was still going on well.

Perhaps, however, the strongest proof of the importance of local rest is furnished by those cases in which a pleural effusion has occurred on the affected side. A most instructive case bearing upon this point has been put on record in the Hunterian Society's *Transactions* for 1895-6 by Dr. Arnold Chaplin, and the views therein expressed by Dr. Chaplin as to the advisability of not interfering with a moderate amount of fluid in cases of acute phthisis are abundantly borne out by experience.

In these acute cases as soon as the temperature has become normal, the greatest benefit may be expected to result from a stay in one of the health resorts, such as Falkenstein in the Taunus, or Nordrach in the Black Forest, where the so-called "air cure" is carried out. Lately the same method of treatment has been advocated and adopted in some of the health resorts at high altitudes, but the climatic conditions in these places appear to me to be quite unsuitable for this method of cure, and I have heard of many cases in which the patient has not only not improved, but has rapidly lost ground under this treatment. After a somewhat prolonged stay at Falkenstein, when the lung condition is no longer acute, and when the patient is able to take exercise without risk, a winter spent at Davos or St. Moritz Dorf is, however, of the greatest advantage.

BRONCHIAL AND VESICULAR BREATHING.

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To make students easily understand the mechanism by which the chief varieties of breathing to be heard over the lung are produced it is necessary to begin, and to insist by frequent repetition, with the postulate that the sounds are primarily produced in the glottis by the vibration of the currents of air as they rush past the vocal cords in inspiration and expiration; that these sounds are modified and diminished by the progressive narrowing and increase in total sectional area of the bronchi and bronchioles, and, finally, by the spongy tissue of the lung itself. The sounds