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THE

INTRACRANIAL CIRCULATION:

AN ESSAY

TO WHICH WAS AWARDED THE FIRST PRIZE OF THE BOYLSTON MEDICAL SOCIETY IN 1867.

BY

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"In this work, attempts will exceed performances."
BROWN'S VULGAR ERROURS.

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PART FIRST.

The circulation within the cranium, its derangements and variations, are subjects of such interest and importance, considered from either an anatomical, a physiological, or a pathological point of view, that it is not surprising that for many years they have been investigated by many able observers, the diversity of whose conclusions shows how much obscurity still exists.

The distribution of the blood-vessels in the different viscera, varies with the function of each, and the anatomical and physiological peculiarities of each organ modify its circulation in various ways. That of the brain presents marked peculiarities, the study of which will tend to elucidate many obscure points of physiology and pathology. This subject is also of interest as the cause of one of the most remarkable controversies of medical literature.

As the blood distributed to the brain comes directly from the heart, by the internal carotid and vertebral arteries, a strong bend in each of these vessels as it enters the skull both preserves the cerebral substance from undue violence, and some-

what retards the current. On the base of the skull the arteries form the beautiful system of anastomoses known as the Circle of Willis, from which large branches are given off to the lobes of the cerebrum; the pons Varolii, cerebellum, and medulla oblongata being supplied by branches of the basilar and vertebrals. The dura mater is chiefly supplied by the meningeal arteries, the largest and most regular of which are the anterior, from the internal carotid, the posterior, from the vertebral, and the middle, from the internal maxillary, which enters at the foramen spinosum and is the only branch from the external carotid distributed to the interior of the cranium. The cerebral arteries as a rule, do not penetrate the cerebral substance till they are of almost capillary minuteness, but run between the lobes and convolutions, giving off small twigs from their sides. This arrangement is evidently to permit the arteries to dilate without compressing the brain or interfering with the strands of nerve fibres.

The Circle of Willis further retards the current, but its main object, as is well known, is to insure an uninterrupted circulation to the different parts of the brain. The readiness with which the obstruction of any of the vessels composing this circle can be remedied, is too obvious to be dwelt upon. But this great outwork for the defence of the brain once passed, the citadel falls; or, dropping metaphor, if a clot passes the Circle of Willis, softening must follow, for all its branches diverge like rays, and no anastomoses occur between them till they are but

little removed from capillaries, so that, in case of need, the collateral circulation cannot be established before irreparable damage has been done. It is, I believe, admitted that the middle cerebral is more frequently the seat of embolism than any other artery of the brain. .It is, perhaps, not out of my province to inquire the reason. As the clot rises, forcibly carried upward by the blood from the heart, the chances are greatly in favor of its entering one of the carotids; if it does not, it can reach the brain only by the vertebrals; these are much smaller, and so situated that the clot is more likely to pass by than to enter them.* The middle cerebral arteries are almost direct continuations of the internal carotids, so that the same reasons which render the passage of the clot through one of the latter probable, render its final arrest in one of the former almost certain. Another point of interest in cerebral diseases depending on the circulation is, the greater frequency of their occurrence in the left than in the right side of the brain. M. Fleury stated, in 1865, that in "l'Hôpital des Vieillards et des Incurables," at Bordeaux, out of sixteen patients affected with hemiplegia, eleven were paralyzed on the right side.† This, perhaps, is greater than the usual proportion. The following ingenious theory is received with favor by French physiologists. When fluid passes suddenly from a tube of large

* See diagram at the end.

† Gazette Hebdomadaire. Mémoir sur la pathogénie du langage articulé. 1865. p. 250. Fleury.

to one of small calibre, its velocity is increased. The right carotid is separated from the aorta by the innominata, so that the blood flows through a vessel of gradually decreasing size, but the left carotid rises directly from the arch, so that, by this law the blood moves more rapidly, and the activity of the left cerebral circulation is increased, thus accounting for the greater force and dexterity of the right half of the body.* What happens in the case of left-handed persons is not mentioned.

From these various arteries the blood passes through the delicate capillaries to the veins, which are destitute of the middle coat and of valves; thence it goes to the sinuses, which discharge it from the skull. It is to be remarked that the veins which open into the superior longitudinal sinus, run in a direction contrary to that of the current in the latter, evidently to prevent too rapid a circulation. The sinuses act as reservoirs, and, together with the valve at the lower end of the internal jugular vein, preserve the brain from the injurious effects of any possible regurgitation.

The proportion of venous to arterial blood is greater within the cranium than in the body at large. Dalton estimates the capacity of the venous system to be double that of the arterial, and the quantity of blood in the veins to be as three to two to that in the arteries.† Now, according to Hirsch-

* Gazette Hebdomadaire, p. 280. Baillager.

† Dalton's Treatise on Human Physiology. Venous Circulation. p. 254.

feld,* the veins of the pia mater will contain six times as much as the arteries, and when we take into consideration the great capacity of the sinuses and the veins of the diploë opening into them, it seems probable that about the same proportion is preserved throughout the cranial cavity.

Though, in the ordinary state of the circulation, almost all the blood escapes by the internal jugular veins, it must not be forgotten that in case of need a very considerable amount may find exit through the following veins, — the two ophthalmic, the two mastoid, the two posterior condyloid (when open), the two middle meningeal, those of the diploë, and the posterior occipital sinuses which communicate with the posterior spinal veins. This, of course, occurs only under exceptional circumstances, as the usual direction of the current through these veins is from without, inwards.

The foramina giving passage to these veins are, excepting, perhaps, the posterior condyloid, very constant. In the skull of childhood, the foramina parietalia, and the foramen cæcum are also patent, but they generally are closed in adult life.†

The posterior occipital sinuses, though small and but two in number, can give passage to much blood, for their continuations, the spinal veins, form a great plexus with numerous inosculations lining the entire spinal canal, and it is evident that when the

* Quoted by Flint in his Physiology of Man, p. 302.

† Mr. Hilton's Lectures on the Cranium. Guy's Hospital Reports. 1853. p. 374.

blood is forcibly expelled from the great reservoirs of the skull, it must flow with great rapidity through the narrow tubes connecting them with the great reservoirs of the spine.

The blood in the arterial and capillary systems of the cranial cavity moves in accordance with the same laws that govern it elsewhere; but in the venous system, though there is no new force called into play, various circumstances combine to modify the action of the ordinary motive powers. The causes of the venous circulation in the body at large, are, —

First. The vis a tergo.

Second. Muscular Contractions.

Third. The force of Respiration, which, however, acts powerfully only in the neighborhood of the thorax.

Fourth. The pulsation of arteries accompanying veins.*

Fifth. The possible contraction of the coats of the veins.†

Sixth. The force of gravity.

Seventh. The slight suction force exerted on the contents of a small vein opening into a large one.‡

The first of these causes is probably neither greater nor less in the brain than elsewhere.

* Mr. Hilton's Lectures on the Cranium. Guy's Hospital Reports. 1853. p. 391.

† Flint's Physiology. Causes of the Venous Circulation. p. 316.

‡ Ibid.

The second cause evidently cannot exist in the interior of the cranium.

The third deserves special attention. Respiration has a more marked influence on the circulation under consideration than on that of any other part of the system. Almost all the blood discharged from the inside of the skull is conveyed by the internal jugulars in a nearly straight line to the heart, so that every inspiration acts upon it with the greatest mechanical advantage. The size, as well as the direction of the jugular veins renders the suction power of the heart — the so-called "vis a fronte" — doubly strong, for as the right side of the heart empties itself, the superior vena cava depends, in no slight degree, upon the blood from the interior of the cranium to fill its vacuum. All this is of easy demonstration: in emaciated children, especially, it is common to observe the jugulars become distended during expiration, and empty themselves during inspiration. A valve at or near the junction of the internal jugular and subclavian veins prevents regurgitation.

Fourth cause. The pulsation of the arteries throughout the body gives a certain impulse to the blood in their venæ comites, the valves of which necessitate its passage towards the heart. In the closely packed cranium none of this force can be lost: every beat of each artery not only communicates itself to the adjacent veins, but, so to speak, reverberates through the skull. This force is exerted to the greatest advantage where the carotid

passes through the cavernous sinus. There are no valves to prevent reflux, but the vis a tergo, and more particularly the vis a fronte, render it almost impossible for the current to be in the wrong direction. In order, however, that the jugular vein may under no circumstances be interfered with, the carotid canal opens into the skull at some distance from the foramen lacerum posterius.

It should be noticed that arterial pulsation acts also upon the cerebro-spinal fluid, and, in short, assists in keeping the fluids of the cranium in perpetual motion.

The fifth cause of the venous circulation — "the possible contraction of the coats of the veins" — is of doubtful existence anywhere, but must be wanting in the cranium, as the veins have no middle coat, and the sinuses are evidently incapable of contraction.

The sixth cause is gravitation. This, of course, can act in parts above the heart only. Its effect on the cerebral circulation is most marked.

The arguments, supported by experiments, for and against this proposition, will be more fully considered in another connection; it will be sufficient here to refer to the cases of patients who, though inclined to sleep when sitting or standing, lose the inclination and ability the instant they lie down,* which, if Dr. Hammond's well-proved theory concerning the cause of sleep be correct, can only be

* Hammond on Wakefulness, p. 70.

accounted for by supposing a variation in the circulation. The fact that more acute impressions are conveyed to the organs of sight and hearing when the head is hanging downwards, points in the same direction.

The seventh cause of venous circulation is the slight suction force exerted on the contents of a small vein opening into a large one. This force must be very active where the veins of the brain, its membranes and the diploë, open into the sinuses. Indeed, the peculiar manner, already alluded to, in which the veins open into the superior longitudinal sinus, appears to imply that this force would otherwise be in excess.

To recapitulate very briefly, of the seven forces which cause and assist the venous circulation, one is the same within the brain as elsewhere, two are absent, and the remaining four, if at all changed, are increased.

The cranium has been often described as a complete sphere, protecting its contents from atmospheric pressure. It is important to consider how far this definition is correct. It will be understood that there is question of the adult head only. The various veins which pass through its walls have already been enumerated; there are also several foramina for the passage of arteries and nerves. A glance, however, at the inside of a fresh head will convince any one that if any pressure upon its contents can be caused by the atmosphere, it must be through the volume of the blood as it passes from

the skull; for the vessels and nerves, together with the membranes and areolar tissue, fill the openings so exactly, that it is impossible for it to occur in any other manner. The pressure transmitted through the blood must moreover be reduced to a minimum, for the carotid and vertebral arteries enter, and the jugular, posterior-coronoid, and posterior-spinal veins issue through the base of the skull, and are deeply placed when outside of it. The veins of the diploë are very tortuous, they expand into lacunæ, and the passage through them is extremely long and indirect. The same, though in a less degree, is true of the mastoid veins, which pass through the bone very obliquely. The middle meningeal artery and vein are deeply situated, and lastly, the ophthalmic veins are thoroughly protected by the contents of the well-filled orbits in which they rise.

In infancy, before the closure of the fontanelle, and in adults who have been trephined, there are only the integument and the membranes between the air and the brain; and though, under certain circumstances, the coverings of the aperture are raised, and under others, depressed, there is no reason to believe that the circulation in these cases is materially different from that of the normal adult head. From this we should argue, not that the skull affords no better protection to its contents from atmospheric pressure than integument, like that of the rest of the body, but that, in the cases just mentioned, the scalp, the arachnoid, and especially the dura mater, have sufficient strength nearly to take the place of bone.

It is universally admitted that the amount of blood in the cranial cavity is subject to variation. Should any evidence in support of this be wanted, the experiment of trephining an animal and covering the opening with a watch-glass will give conclusive proof, though the testimony of post-mortem rooms is sufficient. The dilatation of vessels following section of the sympathetic also shows that their contents must be increased.

This being admitted, the next question is, what makes room for the blood when it is increased, or takes its place when it is diminished? There are but three agents to consider, — the cerebral substance, the fluid of the arachnoid, and the cerebro-spinal fluid.

Can it be the cerebral substance?

Much has been said about the non-compressibility of the nervous tissue. This gratuitous and probably false proposition, has been taken for granted by many prominent observers. Strange as it may appear, there is much uncertainty as to the meaning of the word. Dr. J. Hughes Bennett writes as follows: — "We must draw a distinction between pressure on, and compression of, an organ. By compression must be understood, that a substance occupies less space from the application of external force; as when we squeeze a sponge, or compress a bladder filled with air. Fluids generally are not incompressible, yet it requires the weight of one atmosphere, or fifteen pounds on the square inch, to produce a diminution equal to one twenty-thou-

sandth part of the whole. Now this is so exceedingly small a change upon a mass equal in bulk to the brain, as not to be appreciable to our senses. Besides, the pressure on the internal surface of the blood-vessels never exceeds ten or twelve pounds on the square inch during the most violent exertion, so that, under no possible circumstances, can the contents of the cranium be diminished even the one twenty-thousandth part." * The relevancy of this reasoning is not obvious, for though eighty per cent of it is water, the brain is by no means fluid. The following appears to me a more correct view of the subject: "Neither can it be said that the brain is incompressible. That only is incompressible, the particles of which will not admit of being more closely packed together under the influence of pressure. That the brain is not a substance of this kind is proved by the fact, that, while it is always undergoing a certain degree of pressure, as essential to the integrity of its functions, a slight increase of pressure is sufficient to produce such an amount of physical change in it as at once to interfere with its healthy action." †

In confirmation of the above, the phenomena of hernia cerebri following severe fractures of the skull, may be alluded to, for though they are partly due to vascular and serous pressure, the removal of pressure also has a share in their production. Cases in

* Bennett's Practice of Medicine, p. 149.

† Todd and Bowman's Physiological Anatomy, p. 268.

which the brain protrudes, shortly after injury, are, of course, the only ones referred to.

The brain, then, is compressible, but not sufficiently so to compensate for the variations of the circulation.

Is it the fluid of the arachnoid? No. It is not probable that in health a drop more of this fluid is secreted than is necessary to lubricate the opposed serous surfaces. Neither experiment nor analogy gives weight to any other opinion.

Is it the cerebro-spinal fluid? Yes. This fluid is situated between the pia mater of the brain and cord and the visceral layer of the arachnoid, and passes, by an opening at the inferior extremity of the fourth ventricle, into the general ventricular cavity.* Dr. Todd believed this opening to be the result of manipulation, and that there is no interchange between the fluid of the base of the skull and that of the ventricles, except by osmosis through the pia mater.† But I am led to attach little importance to Dr. Todd's theory, by the high authorities, Hilton and others, who agree with Magendie, by the motions simultaneous with that of the extra ventricular cerebro-spinal fluid, to be observed in the fluid of the ventricles when their roofs have been removed and by the rapid passage to the subarachnoid space, even after death of coloring matters placed in the ventricles.

* Magendie. Quoted in the Cyclopædia of Anatomy and Physiology, Art. "Nervous Centres," Vol. III. p. 640.

† Ibid., p. 641.

Indeed, unless the existence of such a communication be admitted, it is impossible to explain how the equilibrium of the fluids of the brain can be maintained when the amount of the blood is suddenly altered. This fluid varies in amount from two to eight ounces, and is in inverse ratio to that of the blood, and in direct ratio to the age of the subject. It is in the most intimate relation with the blood-vessels, which, in certain places, — the choroid plexuses for example, — are bathed in it; an arrangement eminently calculated to promote osmosis. When from any cause the other contents of the cranium are increased this fluid is diminished. In atrophy of the brain, or when it is very anæmic, the reverse takes place. The way in which it varies with the amount of blood, is well shown in cases of spina bifida; the tumor swells during expiration and sinks during inspiration.

Ecker's description of the movements of the cerebro-spinal fluid is so clear and satisfactory, that I cannot forbear giving it. "At the moment of expiration, the vertebral sinuses, which are numerous and ramifying exterior to the theca, are distended with blood. This distension must cause an approximation of the theca towards the spinal cord, and this inward or centripetal movement will create a pressure upon the fluid within the theca. This contained fluid seeks an outlet which it finds more readily towards the inside of the cranium than elsewhere. The cerebral veins are, indeed, distended at the same period, but the unyielding sinuses within the cranium

are not dilated in proportion: the spinal fluid can thus partly escape in this upward direction; it flows in part into the ventricles, and a part probably beneath the arachnoid on the surface of the encephalon. At inspiration, the vertebral sinuses empty themselves, the fluid returns to the vertebral canal, and again occupies the vacated space." *

There are some cases which appear to disprove the statement that the cerebro-spinal fluid is in inverse ratio to the blood within the cranium. These exceptions, however, are only apparent. I allude to cases in which great cerebral congestion and effusion have been found to coexist. Dr. John Sims, in a paper on "Serous Effusion," gave many statistics and cases from which much information on this subject may be gathered.†

Table I. contains "fifty cases of persons who died of various diseases, not cerebral, and who manifested no symptoms referable to the brain, but on dissection, effusion of fluid and other morbid appearances were found in the brain or membranes." Of these fifty cases there are six in which there was much effusion and congestion together. (There are others in which the same condition existed, to some extent, but I have taken only those in which it was

* Quoted in Disorders of the Cerebral Circulation, by Dr. Burrows, p. 53.

† John Sims on Serous Effusion from the Membranes and into the Ventricles of the Brain; and its connection with Apoplexy and other diseases of the Brain. April 28, 1835. Medico-Chirurgical Transactions, Vol. XIX. p. 265.

well-marked, and unequivocally stated.) Now the average age of the patients in these six cases was sixty-four years and six months, the youngest being fifty, and the oldest seventy-six, at which time of life a certain atrophy of the brain and consequent increase of serous fluid is the normal state. This being granted, it is plain that if the blood-vessels become gorged, some fluid will be displaced, and yet enough remain to cause the appearances described. Dr. Sims also relates five "cases of serous effusion into the ventricles or membranes, of old standing, with loaded, dilated, or diseased blood-vessels, frequently termed serous apoplexy, but more probably referable to simple sanguineous apoplexy." Of these five cases, the weight of the brain is given in four, in none of which it reaches the average weight; the same explanation therefore holds good for this and the preceding class.

The experiments of Durham in England,* and Hammond in America,† on the physiology of sleep, have shown that a great variation in the amount of the blood in the brain may occur, and indicate also the usual time of its occurrence. When the cerebral tissue requires renovation, the amount and velocity of the blood sent to the brain are diminished, whereby exosmosis from the vessels is favored, and the repair of the brain effected. In the mean time, as Mr. Durham has pointed out, the surplus of blood is

* The Physiology of Sleep, by Arthur E. Durham. Guy's Hospital Reports, 1860. p. 149.

† Hammond on Wakefulness, Chap. I.

distributed to the digestive and excretory systems. The instant the brain resumes its duties, some of its tissue is destroyed, and the effete matter carried off by the circulation, the increased rapidity of which promotes endosmosis into the vessels. To reason by analogy, it is but fair to suppose that the cerebral circulation is undergoing perpetual variations. When the mind is active and intent upon any subject, the force of the circulation is increased, to subside again as the attention or the blood is called elsewhere.

Indeed, it is well known that intense mental exertion interferes with the healthy action of the various organs, and, on the other hand, that when the blood is in the latter in large amount, it is difficult, if not impossible, to use the brain to advantage. During sleep, similar though slighter changes probably take place. Dreams can occur only in imperfect sleep, and doubtless require the presence of more blood in the brain than is consistent with quiet repose. The slight feeling of fatigue often experienced after a night of dreams, is probably due to the interruption of the repair of the brain after the waste of the preceding day.

There are many other causes of variation of the cerebral circulation; some purely mechanical, others depending on the state of the system.

I do not propose to discuss the phenomena attending the exhibition of certain drugs; nor the effect of disease of the several organs; it is sufficient to say that the congestion of any one of them

will, of course, leave less blood for the brain. Congestion of the lungs furnishes an exception to this rule, for it is liable to cause regurgitation through the tricuspid, — the safety valve of the heart, — and thus to produce congestion of the brain. Mitral regurgitation, for similar reasons, has often the same effect.

The changes in the constituent parts of the blood during its passage through the brain, have not received the attention they deserve. The blood of the jugular vein has indeed been analyzed, but, as far as I know, no very thorough and satisfactory treatise on this subject is to be found. Lehman* has compared the blood of the jugular with that of the portal vein, but as the latter is not a fair specimen of venous blood this is of no value in the present inquiry. Prof. Austin Flint, Jr. has made some observations on the quantity of cholesterine.† He examined the blood of the carotid artery and the internal jugular and femoral veins, and found, in one case, that the percentage of increase of this fat in the jugular over the carotid was 59.772, and over the femoral vein 6.308, and in another, that the blood in passing through the brain gained 23.307 per cent of cholesterine. I do not give the results obtained from experiments on a dog to whom ether had been administered, because, as Professor Flint ob-

* Lehman. Physiological Chemistry, Vol. II. p. 249.

† Experimental Researches into a new Excretory Function of the Liver, &c., by Austin Flint, Jr. American Journal of Medical Sciences, October, 1862. p. 305.

serves, the anæsthetic very probably modified the cerebral circulation. It is clear, then, that more cholesterine is discharged from the brain than from the other parts of the body.

Omitting the doubtful, and considering only the proved, from among many conclusions to be obtained we may select the following: —

1st. That the circulation within the cranium varies according to the wants of the system or accidental circumstances.

2d. That, though it is regulated by the same forces that govern the general circulation, their action is modified by many peculiar arrangements of surrounding media.

3d. That the cerebro-spinal fluid maintains the plenitude of the skull and spinal canal, the cranium being very nearly a closed case, and the brain almost incompressible.

4th. That the blood returned from the brain differs in its composition from the rest of the venous blood.

PART SECOND.

It is astonishing, when such simple and satisfactory conclusions as the preceding can be so easily reached, how much time, paper, and blood also, have been wasted in the discussion of a very plain question. The only obscurity was caused by the disputants themselves, each of whom started on different premises, and considered but one side of the subject.

The dispute began as follows: Monro taught that the skull was an air-tight case, and the brain incompressible, thus: — "As the substance of the brain, like that of the other solids of our body, is incompressible, the quantity of blood within the head must be the same, or very nearly the same, at all times, whether in health or disease, in life or after death; those cases only excepted, in which water or other matter is effused or secreted from the blood-vessels; for in these, a quantity of blood, equal in bulk to the effused matter, will be pressed out of the cranium."* Dr. Kellie accepted these statements,

* Observations on the Structure and Functions of the Nervous System, by Alexander Monro. 1783. Chap. I. Sect. 4.

but greatly underrated the functions and value of the cerebro-spinal fluid, and so argued very logically that the quantity of fluid within the cranium is invariable. Some of his most important conclusions are: —

1st. "That a state of bloodlessness is not discovered in the brains of animals who have died by hemorrhage, but, on the contrary, very commonly a state of venous congestion."

2d. "That the quantity of blood in the cerebral vessels is not affected by gravitation or the posture of the head."

3d. "That congestion of the cerebral vessels is not found in those instances where it might be most expected; as in persons who die by hanging, strangulation, suffocation, &c."

4th. "That if there be repletion or depletion of one set of vessels (arteries or veins) in the cranium, there will be an opposite condition of the other set of vessels." *

Dr. Kellie's experiments are so well known and often quoted, that it is unnecessary to enter into any detailed account of them. Simple as they are, however, they have apparently been often misunderstood; for instance, he is constantly made to say that bleeding cannot diminish the amount of blood in the brain, though his experiments show most plainly that there was less blood in the brains of animals bled to death than in those killed by prussic acid.

* Dr. Kellie on Death from Cold, and Congestion of the Brain. Transactions of the Medico-Chirurgical Society of Edinburgh, Vol. I.

This quotation is from Dr. Burrows on Disorders of the Cerebral Circulation, p. 8.

The most conclusive experiment he performed is one which proves incontrovertibly that the skull is very nearly a closed case. After bleeding a rabbit to death, and finding the brain by no means exsanguined, he did the same to another which he had trephined, and the brain of this one was indeed bloodless. The conclusion to be drawn is too evident to require further comment. Dr. Kellie's views were accepted almost without question, till Dr. Burrows attacked them, in a course of lectures delivered in 1843 and 1844, and in his work on "Disorders of the Cerebral Circulation," published in 1846. While Dr. Burrows gained advantages over Dr. Kellie, on some side issues, he also misunderstood the latter's dictum, — that the amount of *fluid* within the *cranium* must be always the same, — and occupied much time in discussing the effect of blood-letting, posture, and strangulation on the *blood* in the *brain*. "By thus confounding blood with fluid, and brain with cranium," says Professor Bennett,* "he has only overthrown a doctrine of his own creation." The chief point concerning which it is impossible to reconcile in any way the opinions of Drs. Kellie and Burrows, is, the effect of position on the blood. Each of the observers having killed two animals (the former chose dogs, the latter, rabbits) with prussic acid, suspended one (A) by the ears, and the other (B) by the hind legs, and, after allowing them to hang a sufficient length of time, exam-

* Bennett's Practice of Medicine, p. 150.

ined their heads. Dr. Kellie * states that in A the outside of the head was pale and bloodless; the brain, however, was well colored, and the sinuses moderately filled. There was a slight effusion of serum. In B the external vessels of the head were loaded with blood, but inside, the dura mater exhibited no increase of vascularity; the veins of the pia mater and the sinuses, however, contained decidedly more blood than in A. He adds that within the head the contrast between the two was but trifling.

Dr. Burrows † found that the head of A was very anæmic both within and without, while that of B was, in the highest degree, congested in every part. The contrast was most striking. It is to be regretted that he made no record of the amount of serum found in either case.

As Dr. Burrows gives two excellent plates, showing the appearance of the brains, as Dr. Kellie admits that he found *some* difference between the interior of the two heads which he examined, and as Prof. Bennett,‡ though opposed to Dr. Burrows's theory, confirms his results, we may conclude that position has a decided influence on the amount of blood within the cranium. Dr. Kellie's experiments go to strengthen the doctrine that when the blood in the head is diminished its place is taken by serum.

* Dr. Kellie's paper, Part II. Transactions of the Medico-Chirurgical Society of Edinburgh, Vol. I. p. 139.

† Disorders of the Cerebral Circulation, p. 117.

‡ Practice of Medicine, p. 150.

The appearances found after death by hanging have been much quoted by both parties, which is unfortunate, for they tend to prove nothing whatever.

The cause of death, and consequently the post-mortem appearances, are by no means the same in all cases.

The position of the cord varies, and so do the lesions. Not unfrequently it happens that one of the jugular veins remains pervious, and in other cases, pressure on one or all of the pneumogastric or phrenic nerves must derange the last vital actions. The brain may be congested, normal, anæmic, or with apoplectic effusions. No lesion whatever may be found to account for the fatal result; as in the case of Probst, executed at Philadelphia in 1866.* Casper of Berlin writes as follows: — "But far more frequently than is generally supposed, as I must again repeat, far more frequently than hyperæmiæ of the head or chest, or of both together, the appearances found in those strangled are of that perfectly negative character which betoken death from neuroparalysis, in which not one single organ in the whole body displays any unusual alteration." †

In short, though particular cases may be instructive, the entire class is useless for argument.

Dr. Kellie's proposition, that, when the arterial blood is increased, the venous must be diminished

* Boston Med. and Surg. Journal, Vol. LXXIV. p. 401.

† Casper's Forensic Medicine, Vol. II. p. 183. New Sydenham Society.

to an equal extent, and vice versa, is, to say the least, not proved. If the amount of blood within the cranium were invariable, this would necessarily be true, but as it is not, the question may be considered at rest. It is known that the proportion of the two kinds of blood is not always preserved, but that in certain pathological conditions it is liable to great variation. The effect of opium on the cerebral circulation is well shown by Dr. Hammond's experiments on animals.*

A little reflection will show that the opinions of Drs. Kellie and Burrows are by no means so opposite as one would imagine from the discussions they have caused. They both agree that the blood in the cranium is variable in quantity; Dr. Burrows, however, will not admit that the circulation is subject to other laws here than elsewhere; — in short, he will not admit that the cranial contents are almost removed from atmospheric pressure; while Dr. Kellie holds that they are entirely so.

On this point the whole argument turns. If this pressure be the same as on other parts, why is it that the place of blood withdrawn from the head is taken by the cerebro-spinal fluid? Dr. Burrows distinctly says that it is so, but does not explain why it *must* be so.

After the publication of Dr. Burrows's book, almost all physiologists, except those who prudently avoided the subject, followed his views, and rejected

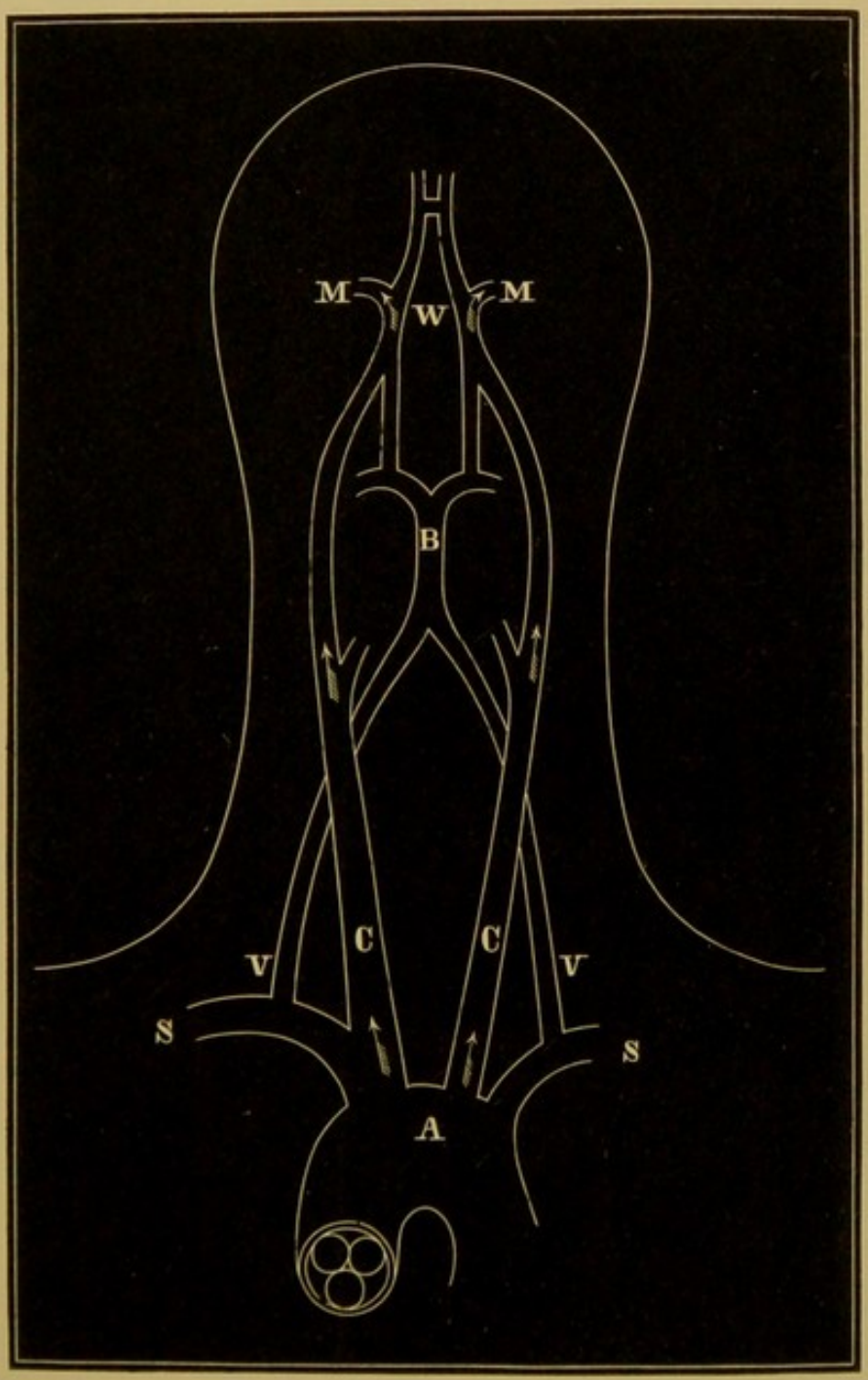
* Hammond on Wakefulness, p. 19.

those of Monro, Abercrombie, and Kellie, without considering that on many points there was only a "distinction without a difference," till Prof. Bennett of Edinburgh declared for the doctrine of the latter. There is no need of reviewing their statements in detail, — perhaps Flint's résumé is the best.*

It is hoped that the conclusions given at the end of Part First will be found to comprise, in a condensed form, all that is true and nothing that is false in the views of the eminent observers so often quoted.

* Physiology of Man. Flint, p. 332.

A ROUGH DIAGRAM TO SHOW THE MOST PROBABLE COURSES OF A CLOT OR VEGETATION FROM THE HEART.



A — Aorta.
S — Subclavian.
C — Carotid.
V — Vertebral.
B — Basilar.
M — Middle Cerebral.
W — Circle of Willis.