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Contributors

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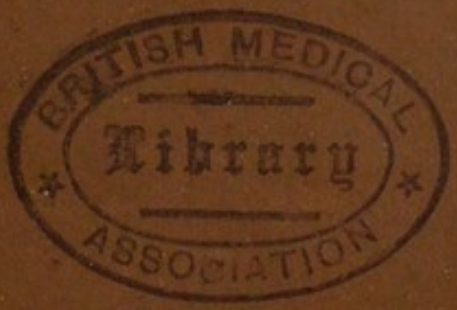

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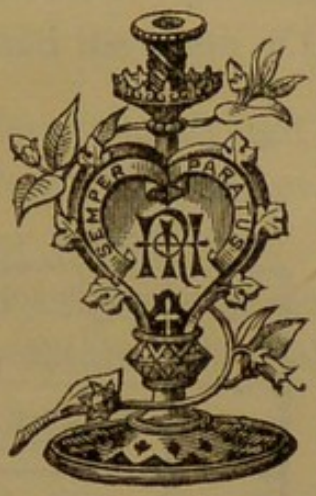

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TO

HENRY MONRO, M.D.,

PHYSICIAN TO ST. LUKE'S HOSPITAL;

AND TO

ALEXANDER PATRICK STEWART, M.D.,

LATE SENIOR PHYSICIAN TO THE MIDDLESEX HOSPITAL.

My dear Friends,

Allow me the pleasure of addressing to you this attempt to set forth the manner and the cause of Going to Sleep.

From the age when Morpheus, though Somnus's son, was held to be the producer of Sleep, there has ever been a veil over this strange transition in our mental state. The obscurity is now less dense, but it has not yet wholly cleared away; some difficulty still existing in the nature of the subject which disappoints, as often as it provokes, enquiry.

Whether this venture into somewhat new ground shall be deemed to have solved the difficulty, or not, I shall ever remember your counsel, and as much as I could have of your approval, as encouragements which lightened the task.

Believe me, faithfully yours,

CHARLES H. MOORE.

102, *Piccadilly, November*, 1868.

CONTENTS.

ON GOING TO SLEEP.

How do we go to sleep? We know something of sleep itself, and something also of dreaming or incomplete sleep; but the child's old question, "How do we go to sleep?" has never been answered. The difficulty of the question seems to lie in two things—in ignorance as to what part of our complex nature it concerns, and in the occurrence itself being such as to elude our own discernment of it.

In what element of our being should a reply to the question be sought? While we are awake, our attention is naturally engaged with the condition of the mind, but knowledge thus obtained is but the thought in which mental operations issue, not a knowledge of the manner in which that result is produced. The same is true of dreams: we attend to the strange and ill-assorted subjects of them, but have no perception of their source. The state of the mind in sound sleep is absolutely unknown. Thus limited in our acquaintance with the procedures of the mind during wakefulness, and in ignorance of its condition during sleep, we are necessarily, as we have always been, unable to discover by the mind alone the mode of transition from the one state to the other.

Respecting the condition of the brain in sleep we possess information which is less incomplete. Certain surgical accidents have disclosed to view variations in the state of that organ, according as we are awake, or lightly slumbering, or in sound repose. Our knowledge, in this respect, has been confirmed and extended by physiological experiments, which have, moreover, in part demonstrated certain chemical changes in the texture of the brain connected with wakefulness and sleep. Thus the only ascertained fact about sleep is a physical change, and the further study needed is such as shall enable us to connect the mental with the physical phenomena of it, and to discern the cause and manner of its accession.

It is the abeyance of mental power, the interruption even of the consciousness of existence, that makes sleep so strange to us. If thought were only continuous throughout it, as is the case in dreaming, it would appear less unintelligible, for we might seem to comprehend a merely subdued activity of the mind: but that we should lose proof of its existence altogether, almost gives colour to the fancy, that for the time and purpose of due repose our immaterial nature abandons the physical portion. Yet we are accustomed to recognise two functions of the brain; one of subordination to mind, the other of supremacy over the body. We understand quiescence, not to say palsy, of muscles on a withdrawal of the cerebral influence on which their action depends; and we expect the blunting of a sense, if the cerebral

root of the nerve which should awake the sense be not responsive to the impressions conveyed to it. Since, then, the manifestation of thought is cerebral, the abeyance of it also may arise out of stillness of its instrument. Not downward only, towards the grosser animal functions, does the brain display a periodical inaction, but upward also, in its higher relation to mental power. Both cerebral functions cease during sleep: on the one hand mind is shut out; on the other, the dependent body is quieted. In respect to both, sleep is a negation, a ceasing of the actions of wakefulness.

Could we contemplate mind apart from its manifestation through the brain, the time of abeyance of the functions of that organ would be our opportunity for a better acquaintance with it. But in sound sleep there are no indications whatever respecting mind, or of its separate qualities, whilst the vague thoughts of unsound sleep appear not to arise without partial awakings of the brain. It follows that, whatever elements of our nature take part in sleep, the production of it can be studied only so far as that is displayed in the structure of the organs concerned.

It is not to be expected that a physical cause of sleep, if such a mechanism actually exist, should ever be demonstrated in action. The sleeper himself loses sight of the problem of his change of state in the instant of its solution, and there are probably no circumstances, consistent at once with the life and necessary bodily tranquillity of the sleeper, in which the process of going

to sleep could become visible to an observer. Certainly such circumstances have never yet occurred to any one competent to use them.

Accordingly the following attempt to explain the production of sleep is not made with the pretence of being a demonstration. From the nature of the case that is impossible. It is rather an inference from divers facts. But these appear so consentaneous, and so many of the phenomena of sleeping, awaking, dreaming, and somnambulism, are brought into relation and explained by it, that it may be deemed to be some advance upon our present knowledge of the subject.

Manner of Going to Sleep.

What is going to sleep? There is a final moment of time in which wakefulness passes into sleep. By previous arrangements within and around us occasions of sensation are excluded, and the mind composes itself so far as to relinquish all activity of voluntary thought. A feeling of relaxation ensues, like that in the eye when giving up the effort to inspect a near object, and expanding its gaze afar; a feeling, the opposite of that cerebral action or movement in the forehead, of which we are sometimes conscious when resolutely concentrating attention on a purely mental object. In some moment of this gradually deepening calm, sleep suddenly arrives.

Looked upon as poets and our own feelings present

it, this change may seem to be a mere subsidence to inaction of body and mind; or it may be held to be a positive occurrence, some action producing inaction. There is truth in both of these notions. Sleep is inaction, but it is physically produced. The inaction supervenes most commonly and easily indeed upon a quiescence which is voluntary. But the inaction is more than the quiescence; it is a different fact, and it has wholly another cause. The conception perhaps is not easily apprehended that inaction, an even obliteration of the function, of any organ is the purposed issue of an active cause. Yet both must be taken account of in explaining sleep and the mode in which it is produced. Abolition of our faculties, both percipient and reflective, is the actual object and the result of providing a mechanism of sleep.

What is the unperceived yet powerful agency which produces so abrupt a change? Before this can be understood, or even the search for it rightly directed, it is necessary to define more precisely the range of sleep, the organs affected by the supposed mechanism of it, and the state into which those organs are brought while under its control.

State in Sleep.

From the nature of the case there is some uncertainty respecting the limitations of sleep, for the very means by which the sleeper might recognize them are withdrawn from him. There appears to be so far an unity in natural sleep that within its almost sudden embrace, thought, voluntary motion, and the senses are wholly and at once annulled. Does sleep, then, extend over and comprehend at once these several and widely-spread functions? Or is there some one organ which, by its own repose, secures the resting of the others? It may be that the cerebrum alone sleeps, while other organs wait passively upon its rest. The grey masses at the base of the brain, which are thought to preside over motion and feeling, might then not really sleep, but might simply owe a certain quietness to their loss of the influence of the brain above them. Or there may be methods and degrees of sleep adapted to the several parts of the nervous system, as well as to the special organs of motion and of sense. Now, there clearly occurs a suspension of the bodily functions of voluntary movement and the senses. But whether this suspension is merely inaction, or amounts to a deprivation of power, is not manifest at first view. The ability to resume actions of wakefulness immediately on the cessation of sound sleep appears to indicate that the muscles and sensory organs have been only unexercised, and not incapable of exertion. But, since without an interruption, or some

sufficient lightening, of sleep there occur none of the motions and feelings of the waking state, it is clear that the several organs of motion and sense are virtually functionless. They are either themselves out of gear, or are disturbed in their relation to the nervous centres from which they take their power.

That voluntary motor power in sleep is not merely unexercised, but lost, is shown by the fact that sleepers do not move without a proportionate cerebral awakening, and also by the dissociation of the will from the muscles in some dreams. The movement, in the former case, and the awaking may be the most transient and slight; as when a sleeping infant stirs, makes its readiest instinctive movement with its lips, perhaps even utters a gentle sound, but does not relapse into calm sleep again without a sigh. For even such slight exertion has not been that of the muscles primarily or alone, but has sprung from the brain, which manifests its light awakening by requiring oxygen at something more than the sleeping rate. So partially may the brain awake in this case, that the will, and even the consciousness, may have been scarcely, if at all, aroused. It is enough that the motor centre be in action, for in a decapitated frog, movements once performed through will, and afterwards become habitual, may be induced by the appropriate irritation. In the dreams referred to, however, whilst consciousness and will are certainly awake, the motor power is lost. The most strenuous efforts of the will cannot excite the muscles to action, and it is evident

that the will and the motor faculty are separate, that the one may sleep without the other, and that, in the dream in question, there is a break in the connection between them. In fact, the awaking of the brain appears to be incomplete. That portion which directs the muscles is still dormant, and the mechanism which can release it from the control of sleep is not in that segment of the brain which is awake, and at the moment engaged with will.

The interruption of sensation during sleep is scarcely less an abolition of it than that of motion. This appears from numerous facts, of which those perhaps are the most convincing in which we awake just sufficiently to perceive the loss of a particular sense. Thus, the abeyance of feeling may be shown by the inadequacy of moderate sounds and touches to impress a sleeper, or by our ignorance on untimely awaking as to the disturbed sensation through which we have been aroused (provided the disturbance be not prolonged into our fully restored consciousness). But it is yet more distinctly shown when we awake so partially as to miss our habitual sense of support against the attraction of gravitation, which constitutes the dream characterised by a sensation of falling; or again, when a somnambulist with open eyes appears devoid of sight.*

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* Could we be sure of the functions of the different parts of the brain, most dreams might be explained by sleep of one part of that organ, while the rest was awake. The two dreams, for instance,

The same view may be taken of the abeyance of the faculties of thought and will, and therefore of the con-

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that of wakeful will to move, but dormant motor power, and that of wakeful consciousness, limited to a sensation of falling, might thus illustrate the physical origin of partial sleep. The sense of falling appears to be the interpretation put by the wakeful mind upon the absence of those impressions from the sensory nerves of the body, to which it is constantly used in the waking state. The two dreams are therefore counterparts of one another, the mind being alert in both, but the motor faculty in one and the sensory faculty in the other being asleep. Now of the two masses of grey matter at the base of the brain, one, the corpus striatum, is held to preside over motion, the other, or optic thalamus, is the ultimate seat of sensation. From the former mandates descend along nerves and direct the actions of the muscles of the body; whilst the latter receives by other nerves the impressions ascending to it from the distant organs of sense. Supreme thought does not reside in either of these, but is supposed to be connected with that yet larger quantity of grey nervous matter, which is spread over the whole brain. This keeps up during wakefulness a ceaseless communication with the two great centres beneath it, exercising control over the motor "corpus" and deriving information from the sensory "thalamus." Hence sensation and thought about sensation occur in different parts of the brain; and again, the will to move, which is formed in the surface of the brain, is put into exercise by the motor centre beneath. Now in both the dreams referred to, the grey cerebral surface, as the chief seat of consciousness and will, appears to awake, but in the one dream the corpus striatum, in the other the optic thalamus, continues asleep. The effect in both is to disconnect the supreme wakeful grey surface from the peripheral nervous system. In the one dream, nerve currents descending from the surface of the brain meet with a dormant and therefore disobedient motor centre, and fail to reach the voluntary muscles. In the other dream, the attention of the wakeful grey surface to the feelings of distant parts is intercepted by the sensory centre, which, being asleep and therefore void of impressions from beneath, presents to the grey mass above it only a negation of sense. The mental interpretation of this negation

sciousness of existence. In so far as these depend upon a continuance of felt relationship to the external world, to time, to memory, or to the body itself, the mental faculty is virtually suspended. If we judge of sound sleep, indeed, by the characters of dreams, and by nights of broken rest, we may conclude that the mind retains some degree of activity; but, in fact, profound repose deprives us of all proof of its continuance. A sound sleeper carries with him on awaking no perception of even his recent mental existence. He is unaware of his waking, his sleeping, and his going to sleep; and even the thoughts which last occupied his mind are gone. It is only in weary waking that thoughts remain from overnight, and then they do not arise afresh in the mind, but are there already, as if (though even then the fact is not remembered) they had continued without interruption all night.

It thus appears that sleep arrests thought, will, and voluntary motion, in the most absolute sense in which they depend on the brain; and that it dulls the faculties of sight, hearing, taste, touch, and doubtless also of smell. None of these several functions, indeed, are put beyond recall by the influence of extraordinary stimuli; but they are not active, even in the degree in which,

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by the disappointed attention may very well be that the whole body, as to which it is appealing to the intervening sleeping sensory centre, is falling away from it. The start which breaks both dreams may answer to the gush of blood which suddenly restores function to the pallid segment of the brain.

when awaking partially or singly, they give rise to a bewildering dream. Accordingly, in natural sleep, respiration proceeds without yawning or sighing, sneezing or coughing; there are no incongruous memories uncorrected by the judgment, no misinterpretation of disturbed sensations, no abeyance of the sensitive faculty while thought awakes, no activity of the will while the power still sleeps by which a movement most urgently willed could be accomplished, and none of those reflex actions which are performed with more than usual vigour during the absence of cerebral control. Any of these may occur upon awakening, limited to a corresponding segment of the brain or cord, but when sleep is sound they cease.

The reign of healthy sleep is accordingly limited to the cerebro-spinal nervous centres, and to the mental attributes and bodily organs connected with them. But there are organs which appear to be unaffected by it, and some which seem to be in an intermediate state, sharing in part only the quiescence of the central nervous system. Sleep in the brain and senses is manifestly compatible with continued activity in any organ not dependent on them. Hence respiration and the action of the heart, digestion, with the functions of its subordinate organs, and nutrition, go on during sleep. Life itself, without the first two, would end at once; and, if digestion were stopped by sleep, no man could awake hungry who had supped before sleeping. Digestion and nutrition depend on nervous

centres which are out of the area of sleep, whilst the medulla oblongata, which is within it, regulates the breathing and the action of the heart at a reduced rate, and yet, by reason of its release from cerebral control, is with less vigour relatively more effective. The brain sleeps wholly, the medulla oblongata lightly, the visceral nervous system not at all. Moreover considerable changes occur during sleep in the organs of special sense.*

Cause of Going to Sleep.

Sleep being thus defined within the limits of the cerebro-spinal nervous system, and the associated organs of voluntary motion and sense, we may return to the question of its cause.

In the absence of certain knowledge respecting it, the suddenness of the occurrence is apt to be overlooked, and the accession of sleep to be attributed to a general cause, as weariness of the body or mind. Weariness, it is true, facilitates our repose, but certainly does not produce it. For sleep is not a mere continuation, a gradual deepening, of weariness. Some persons, when by no means weary, can sleep almost at will, and when unquestionably weary can resist the disposition to sleep. Moreover, a determined thinker may so

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* It is notorious that the range of sleep is not the same in all animals; the horse, for instance, usually standing during that condition. But this essay is not intended to include the comparative physiology of sleep.

exert himself as to banish not only the desire, but also the capacity to sleep. The mechanism of sleep must be something more specific than a sense of weariness.

In his ingenious and philosophical exposition of the differences in the vigorous and the tired brain, Mr. Durham * allots to the waking state a waste of cerebral substance, and to the period of sleep the replenishing of it. And he explains how full vessels and a rapid circulation favour expenditure of the tissue, and a feebler and smaller vascular current conduces to repair. He adds that the very functional activity of the brain generates in it chemical compounds which, by interference with the mutual reaction of oxygen and tissue going on throughout the waking state, lower that activity, and indirectly tend to induce repose. Thus the necessity for sleep is doubtless rightly attributed to a wearing out of a part of the cerebral textures, and to clogging of the remainder with unremoved products of previous activity. But while explaining the reason for sleep, and the effect of it, this does not define its cause. Let the facts be accepted; let repair be possible only during a reduction of the blood current, and the brain, as a candle needing to be snuffed, be thus oppressed with chemical refuse; still, such a condition of the brain would be but the physical correlative of the feeling of weariness, and the adequacy of it to explain the pecu-

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

liarities of our going to sleep can be contested on the same grounds as that of the feeling to which it corresponds. Sleep is not a relapse from activity, and does not gradually supervene with the toxical oppression of our brain, or in the proportion of our previous occupation of mind; it is an abrupt change of state. There are persons who, with a brain fully cleared by recent night-long sleep, could slumber in the forenoon. All persons of active habits can resist the disposition to sleep, and some in doing so lose it altogether. They force the brain to action, notwithstanding its oppression by the products of previous thought, and having clogged it still more they cannot sleep at all. There must be a mechanism capable of producing sleep independently of the condition of the brain.

Dr. Carpenter, in his interesting and latest essay on sleep,* refers more closely to the manner of its production, and writes thus of the occurrence:—"The will abandons, as it were, all control over the operations of the mind, and allows it to yield itself up to the soporific influence." But, whilst weariness is adduced by him also as making sleep necessary, he fails to indicate the soporific influence to which the mind yields. And, notwithstanding the distinction which he conceives in the relation of will and of mind to sleep, his thought suggests the inquiry, Can will in any sense abandon mind, so as to abolish itself? Can it cease by not willing, or by

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* 'Principles of Human Physiology,' 6th Edition, 1864, p. 593.

thinking of not willing? Will may be superseded, but cannot reduce itself to a negation. The access of sleep is therefore not voluntary. It overwhelms the effort of a child to keep awake, of an exhausted pedestrian to think; and the readiest sleeper, however prompt his will in dismissing both physical and mental occasions of wakefulness, finds the actual production of sleep beyond his power. Sleep is neither an act nor a mere retirement of will; it is due to some more definite mechanism.

It must enhance our appreciation of this mechanism, if we consider the extraordinary effectiveness of it. Deep sleepers are at times held by a power which seems insuperable. No sensation appears capable of awaking them. Men sleep beside the roar of guns, through flashes of lightning, in the midst of odours, with sapid substances on their tongues, or in uneasiest postures. I have seen a woman asleep on a chain cable. Unconsciousness in circumstances so calculated to arouse the brain, and to excite the nerves and organs of special sense, must be due to a force which is either superior to those violent impressions, or (as is far rather conceivable) is out of the way of them. The mechanism of sleep is no mere weariness of the brain itself, no chemical process for clearing its texture, no voluntary suspension or gradual causeless subsidence of its activity: it acts with power, putting the functions of the brain into compulsory abeyance, and depriving the subsidiary organs of their sense.

Cause of Sleep Not in the Sleeping Organs.

Compulsion like this is clearly not exercised by the parts which sleep and wake, but by a separate mechanism. That would be no refreshing sleep in which each sense brought its accustomed impression unabated to the brain, and the will as often awoke to resist awaking. As, in the eye, there would be obvious inconvenience in making the closure of the pupil during sleep dependent upon the impression of light on the retina, and the duty is transferred to a mechanism which performs it in the absence of light, so is the case with the brain. That organ does not abstain from thinking, but is powerless as to thought, and it is brought into a state in which it is not able to perceive or respond to ordinary impressions on the external sensory organs. Even more than this, those organs are themselves deprived of their usual acute sensibility, and, the avenues of thought and feeling being thus the more surely blocked, the brain may sleep without interruption.

Cause of Sleep of the Brain in lessened supply of Blood.

Now the functional repose of the brain would be secured by a sufficient, but not an excessive, reduction of its arterial circulation. So certain is this that many cases of sleeplessness are successfully treated by simply abating the cerebral current of blood, and the demonstration of it as a fact has been made by many observers. Through an accidental injury of the head, Sir Astley

Cooper saw the brain grow pale as sleep came on, and red again as it passed off. The same observation was made in Montpellier a century ago in the case of a woman who had met with a similar accident, and it was noted that the brain rose and fell in proportion to the lightness or profoundness of the slumber. Donders,* Kussmaul and Tenner,† Durham,‡ and Hammond,§ have brought out the same facts by experiments on the lower animals. As a general rule, with more oxygen in the brain, occurs the brighter wakefulness; with less oxygen, the readier sleep. A "nightcap" of hydrocarbon, partially deoxydizing the arterial blood, unfits it to keep the brain awake. In the absence of such chemical alteration of the blood—that is, in natural sleeping—the same effect is producible by lessening the cerebral circulation in amount.

The essential connection of the mental phenomena with those that are physical, is shown by the rapidity of the vascular changes in the brain at the instants of transition, and by the permanence of the full-blooded state during wakefulness and of pallor of the brain throughout sleep; whilst, in the intermediate conditions of slumber and dreaming, the vascularity falls off, and the brain recedes from the aperture in the skull with a proportion so exact as to show a precise relation between a diminished supply of arterial blood and cerebral sleep.

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* Schmidt's 'Jahrbücher,' vol. lxix., 1851.

† New Sydenham Society's Selected Monographs, 1859.

‡ Guy's Hospital Reports, 1860.

§ On 'Wakefulness.' Philadelphia, 1866.

Notwithstanding, however, this accurate correspondence in time and degree between a visible emptying of the cerebral vessels and sleep, and their refilling with the return of wakefulness, the causal relation between the events has still to be distinguished. Does the pallor result from the sleep, and the reddening of the brain from the wakefulness? or conversely, are the sleeping and awaking due to the changes of the vascularity? Now the true relation of the physical and mental phenomena is capable of demonstration; for sleep can be induced, when no disposition to it exists, by arresting the current in the arteries leading to the brain. The carotids may be obstructed with the effect of producing a condition indistinguishable from true sleep. Rabbits first breathe slowly, and then sleep, when their vertebral arteries are compressed. A complete obstruction of both carotid arteries, the vertebrals being naturally rather small, has indeed proved fatal. The patient, a woman under the care of Mr. Key, died in four hours after the ligature of one carotid, the other being already obliterated by disease, with the one prominent symptom of sound sleep. Many examples of sleep arising upon the ligature, compression or obstruction of the carotid trunks, enable us to conclude decisively that the diminution of the arterial current in the brain which occurs at the instant of sleep is no mere concomitant occurrence, but its actual cause.

An objection to this conclusion may be taken from the fact, that feeble, exhausted, terrified, or even dying

persons, and some dying as on the battlefield from hæmorrhage, are occasionally wakeful, and capable of intense thought. But this objection does not invalidate the conclusion that calm and healthy sleep is a direct product of relative anæmia of the brain. There is evidently a reserve of power in that organ, whereby it may act in fulfilment of its duty to the mind with an energy out of all proportion to the quantity of blood that happens at the moment to mix with its texture, if there be not also a power of concentrating the current of blood towards any one active segment of the brain.

This reserve power of cerebral activity, irrespectively of the actual quantity of blood in the brain, is probably drawn upon in all rapid and intense thought; since without it the most brilliant operations of the mind must wait upon slow changes in the vascularity of the grey matter. Account must also be taken of the same reserve power in the difficult endeavour to reconcile certain dreams and active bodily exertions with a continuance of the state of sleep, or at least with a continuance of the cerebral anæmia, without which sleep itself would immediately cease. For not only may there be dreams which originate in a restoration of the circulation to particular segments of the brain or cord, but besides these there appear to be moments of intense, yet still limited, activity of the mind in somnambulism with but a partial reopening of the blood-stream in the brain.

Diminished Circulation in the Brain the Result of Contraction of the Arteries.

It may be taken without question, that the reduction of the quantity of arterial blood in the brain is effected by contraction of the arteries themselves. We are unacquainted with any means but this by which the proportion of the one stream issuing from the heart can be altered in its distribution to the various organs, and we do know the vessels in question to be provided with a muscular coat, and to be capable of dilatation as it relaxes, and of diminution when it contracts. Kirkes, in his 'Physiology,' 1863, p. 119, when writing of the contractility of arteries, selected the brain for his example of an organ which, "during sleeping and waking, within the same hour may be now very active and then inactive," and to which the supply of blood may be regulated by this power of arteries. But in what vessels of the brain the contraction takes place, is a question needing further consideration.

The arterial system of the brain, as elsewhere, is divided into trunk-vessels, branches, and capillaries. Only the smallest branches and the capillaries exist in the grey cerebral substance, and in it they are devoid of nerves. The vessels referred to as under observation during waking and sleeping through apertures in the skull were neither the trunks nor the capillaries, but the intermediate branches in the pia mater. These manifestly contained at different moments

less and more blood. Is it their contraction, or that of the capillaries, or of the trunks, which occasions sleep?

A contraction originating in, or confined to, the arteries within the brain must occasion fulness of those outside, which lead to them, whereas the vessels in the pia mater visibly contract. Moreover, the absence of nerves on the vessels within the brain, while those on its exterior possess them, shows that the terminal vessels, if they contract at all, do so under an impulse different from that which determines the conspicuous emptying of the vessels in the pia mater. If these contain less blood in sleep, there must also be less within.

That in the pia mater there is a comparative emptiness of the arterial branches is a fact of great importance, as giving a clue to the mechanism which causes sleep; for it shows that the change is produced outside the brain, and possibly without its influence. For questions which are to be raised in the sequel, it is necessary to decide whether or not these meningeal branches and twigs are the sole contracting vessels. The following reasons appear to justify the opinion that the arterial trunks at the base of the brain take part in the contraction on which sleep ensues.

In the first place it is known that, although large trunks do not vary materially in their calibre at different times, yet vessels of the size of the internal carotid and vertebral arteries are capable of much shrinking. The thinness of the arteries leading to the brain in the human subject would favour their contracting rapidly.

Again, there are no arteries in the body more abundantly supplied with vaso-motor nerves than those in the carotid canals; and although many of these are destined for the branches of the cerebral arteries (to the exclusion, however, of the intra-cerebral twigs), yet some end on the walls of the trunks.

Another reason is the uniform accession of healthy sleep at once over the whole brain. Were the contraction limited to the small arteries, it would be likely to go on unequally, and to leave a convolution, a lobe, or even a hemisphere wide awake after the rest of the brain had gone to sleep. It is not impossible that in unsound sleep this actually occurs, but there seems to be the most striking provision against such a contingency in the anastomotic unions of the larger arteries; and it is not likely to be subverted in health by separate and unequal action of their branches.

The identical effect of ligature or compression of the arteries with that of their own contraction corresponds with and confirms this argument. Wherever and however the stream through the brain is interrupted, the result is sleep.

Further, there are peculiar adaptations of all the large arteries at the base of the brain to such contraction. As the muscular iris lies in aqueous humour for facility of contracting at the instant when light excites the retina, so, alone of all the arteries in the body, the internal carotid and vertebro-basilar trunks are partly contained in fluid. The former pass through the cavernous sinus,

surrounded by its blood, and on emerging from it they enter the subarachnoid fluid at the base of the brain; the latter, from the passage of the vertebrals through the spinal dura mater and arachnoid to their confluence in the basilar artery, and throughout the course of that single trunk to the brain, are wholly contained in the same fluid. Contraction in this part of the arteries of the brain is thus not less provided for than in those which visibly contract in the cerebral pia mater, and which, with the vessels in the brain and spinal membranes, are surrounded by a hyaline sheath.

There is yet another reason for attributing sleep to a contraction of the trunks, as well as of the branches, of the arteries of the brain: it is what I may call the crucial test of somnambulism. But as this argument cannot be appreciated without a previous account of the manner in which the senses are abolished during sleep, and particularly without attention to the anatomical plan of the arteries, it will be convenient to defer the consideration of it. Enough, perhaps, has been already stated to justify the conclusion that the contraction of the arteries producing sleep extends as far as those vessels have muscular walls.

Contraction of the Arteries produced by Ganglionic Nerves.

If now it be considered reasonable to conclude that the contraction of the arteries conveying blood to the brain is the immediate cause of sleep, the question may next be entertained, under what control this contraction

takes place. Assuredly that power is not left with the brain itself, since, as has been already explained, the attention of that organ would then be required, not only to induce the abeyance of its own function, but also by that same lost function to supervise its cause. The absurdity of either supposition being manifest, it follows that the control of the cerebral arteries is not cerebral, but is outside the brain.

Notwithstanding the positive character of this statement, it is necessary to observe that something very nearly approaching the absurdity denounced does actually occur. The brain never produces, and does not ordinarily control its own sleep; yet it is within our power so to repose as to keep the duration of a slumber within our mental control. Such sleep, however, as it affords little refreshment to either mind or body, is never profound, and it is probably not the sleep of the whole brain. It is usually so broken as to be a night-long illustration of the delicate oscillation between sleep and waking, of which we have other frequent proofs, when sleep, though sought, is hard to get, and when it is nearly over. The condition in the two cases is the same, whether of its own wakeful purpose, or whether from some disturbing irritation, the brain arrests the mechanism of sound sleep. Either way the power is repressed by which the arteries are wont to contract.

The cause of the contraction of the arteries is not far to seek; since it cannot be cerebral, it must be gang-

lionic. The brain does not send nerves to its own arteries; they are supplied from the sympathetic system. Around the carotids is a large number of them, proceeding from the first great ganglion in the neck. The vertebrals receive their endowment in less abundance, and chiefly from the second and third cervical ganglia. The vertebral plexus communicates in each interval between the cervical vertebræ with a spinal nerve; the carotid plexus with but one such nerve, the abducens oculi. The results arising from these and other anatomical differences will come later into consideration. The fact must first be contemplated, that there exists a power outside the brain which is capable of arresting its functions.

There is but one difficulty in our assigning to the cervical sympathetic ganglia this power of controlling the activity of the brain, namely, the high opinion which we are accustomed, and rightly, to hold respecting the predominance of the brain in the nervous system. In the performance of some functions the ganglia appear to act under the control of this great and active organ, or after they have been, so to say, charged by it. It is probably thus that prolonged mental attention causes the action of some of the involuntary muscles. But the modern investigations of physiologists furnish evidence of the separate and independent action of the ganglia. None of these, perhaps, is more striking than the control which Bernard found them to exercise over the secretion of saliva through the

minute bloodvessels of the salivary glands, or that of the ophthalmic ganglion, independently of light, over the motions of the iris. If, then, ganglia can produce contraction of the bloodvessels of a gland with the effect of arresting its secretion, they may by the same means interrupt the activity of even so mighty an organ as the brain.

At first sight, this supposition may appear unreasonable, not only by assigning a monstrously disproportionate power to such small nervous centres, but inasmuch, also, as it seems to attribute to them a certain discretion, some faculty of thought, or at least a power of selecting the moment and the method of overpowering the brain.

Now, with regard to the first, it would be impossible to conceive that at its weakest tension the brain should yield its faculties to the bidding of a ganglion. But, in fact, there is no direct contest between them. The force of the ganglion is not exercised upon the brain, but upon its bloodvessels, and the power of the ganglion is to be gauged, not by the mass and energy of the brain, but by the amount of muscle in the arterial walls within the distribution of the ganglionic nerves. The brain sleeps when it receives too little blood for action: no mechanism is required for effecting this but such as reduces the quantity of blood; and it exists in muscular arteries, subject to a nervous control exterior to the brain which sleeps, and to the area of the arteries which are to contract. Accordingly sleep excludes the

perception of itself. It is out of our consciousness; for on the one hand it abrogates sensation, and on the other, it is induced through nerves and muscles which yield us no muscular sense: and it is out of our will, which is associated with cerebrum, and not with the sympathetic system.

With regard to the second objection, that some independent, not to say mental, capability must be ascribed to the ganglia, if we allow to them a power of superseding the functions of the brain, it must be confessed that this touches the innermost difficulty of accounting for the onset of sleep. Yet I do not conceive it to be insuperable. Ganglia have a primary power of their own, but their independence is not to be regarded too absolutely. They do not act against the power of a greater nervous mass, which indeed supersedes theirs, but are ready to put forth their power inevitably, blindly, as is sometimes said, instinctively, so soon as the nerve stream slackens from the dominant grey mass. With every variation in the activity of the brain, this mechanism appears to be in action, the automatic energy of the ganglia rising as thought subsides, and causing the arteries to contract, but yielding again, and therefore allowing the arteries to relax, as the brain resumes its sway. It is thus a mechanism precisely similar to that which regulates the secretion of organs, the influence of spinal nerves superseding that of the ganglia during the performance of the organic function, and that of the ganglia suppressing the secretion during the

intervals. Upon intense occupation of mind, with such a feeling as terror, ganglia not connected with cerebral arteries may rise to an extreme degree of power, and cause pallor of the skin, and even suppression of the milk. That, in the case of the cervical ganglia, nervous force should seem to return upon the very cerebral source whence it most emanates, is an object of surprise, from the arrest of thought which ensues, but is quite in accordance with what is known of ganglionic actions upon arteries elsewhere.

I have spoken of the power of ganglia as primary and independent; yet so intricate are the intercommunications and reciprocal dependence of one and another part of the nervous system, that something may need to be subtracted from the absolute character of that statement. For it cannot be asserted that the power of a ganglion is the same when normally connected with the rest of the nervous system, and when severed from it in an experiment. In suffering this violent injury the isolated organ does indeed, in the strictest sense, become independent, but its control over the arteries is weakened. Is it, then, necessary to trace back the mechanical cause of sleep yet further than the ganglia? Is ganglionic power not an ultimate fact? And is it after all cerebral force which gives to the ganglion its power over the cerebral arteries? The answer of the experimental physiologist to these questions may differ from that which is practically deducible from the phenomena, for sleep is a state too gentle, and its cause too delicate

to be measured by the rude proceedings of vivisection. If the arrest of the salivary secretion be referred to the ganglia, so may the corresponding effects, when they follow closure of the cerebral arteries. The division of the sympathetic in the neck leads not to contraction, but to some dilatation of the arteries of the head, but this effect is much more strongly marked when the cervical ganglia are destroyed. There is therefore a difference between the two experiments which may be credited to an independent power of the ganglia. Should it, however, be demanded that this residual power be referred back from the ganglia to the spinal nerves, which were uninjured in the experiment of dividing only the sympathetic cord, still the source and sustentation of the ganglionic power being in the medulla oblongata would be exterior to the thinking or the sleeping encephalon, and in its nature automatic. It would resemble and correspond to the nervous force which sustains the respiration; but still the ganglia would be needed to adapt and apply it to the arteries, if not also to augment it. This force, even if derived, would not be cerebral, and the application of it would be a primary function of the ganglia, with the discovery of which the search for a mechanical cause of sleep ends.

Summary of Mechanical Production of Cerebral Sleep.

Accordingly the mechanism of sleep appears to act thus upon the brain. Wakefulness opens the arteries, superseding the influence of the ganglia over them. If

intense and prolonged, wakefulness perhaps exhausts the ganglia, but certainly leads to a loss of tone in the cerebral arteries, which throb and are distended beyond the power of contraction, though the brain be weary. No exercise of the brain, therefore, can put it to sleep. But subsidence of its powers to a degree short of extinction gives occasion to the exercise of another power, which is withheld during the energy of the brain from producing sleep. The first power, that of the brain, overwhelms the less, which is that of the ganglion. Let the first moderate; the influence of the second rises. It is not necessary to conceive this latter as more than an automatic action, a resumption by the ganglion of its natural energy, which is forthwith expended upon the muscle with which it is connected. Be the brain therefore weary, or bewildered out of its attention, or soothed by a monotonous sound, or simply unoccupied, straightway the ganglia, set free for separate action, usurp supremacy, not over the brain, but over the arteries. The exact proportion of activity between the brain and the cervical ganglia, which is requisite for setting the latter free, is a matter of degree only, and is from the nature of the case undefinable, and possibly variable. But this indefiniteness, in fact, characterizes the subject. It is intelligible only as an exquisite balancing of uncertain forces, and too absolute a mind misses the fact of their relation in the shifting and vagueness of it. They sleep soonest who think the least. But, with those to whom thinking is a necessity or a delight, how delicately poised sometimes is the alternative of sleep-

ing and waking! The power seems to oscillate between mental willingness to withdraw from thought, and some unknown faculty which we can neither localize, nor feel, nor woo, and the accession of which to its desired supremacy waits only for the instant when we give up the attempt to command it, the effort to yield to it, the feeling even to long for it; for all such occupation of mind, as it keeps the brain active, withholds from the bloodvessels their ganglionic stimulus to contract. But at any moment when the attention of the brain is unconcentrated, instantly the ganglia become uncontrolled and primary nervous centres, and reduce the size of the arteries.

It may sometimes be that the arteries do not wholly contract at once, and that indeed usually the supervention of deepest sleep is not sudden. It is doubtless always so far gradual as to be due to the most thorough contraction of the arteries. Occasionally the brain, while moderating its own activity, but still alive to any sensory discomfort, may be again aroused, and again supersede the ganglia. Thus, while sleep is doubtfully coming and going, there may be variations in the size of the arteries, corresponding with the alternate departures and returns of consciousness. But all lessening of the bloodstream tends to reduce the capability of the brain for action, and gives an advantage to the ganglia, which increases until the arteries are duly shrunken, and the sleep is complete.

The mystery of Going to Sleep accordingly consists in the fact, that sleep obliterates the very faculties

by which alone we might discover its nature. In the present state of existence we know ourselves through the body, and so long as we are possessed of the sensations and consciousness due to the body we are not asleep. During any temporary extinction of those faculties, all knowledge is interrupted, including even the manner of the interruption, since the faculties are abolished by a mechanism through which we neither feel nor think. The structures fulfilling this function even dispossess the will, acting themselves involuntarily whilst depriving the brain of its function. And they act imperceptibly, both because they are themselves devoid of prompt feeling, and also because in their action they abolish that sense through which we could be made aware of the action. Such power, and still more that of annulling our consciousness in respect to thought, are surprising enough; but yet more so, perhaps, is the want of any direct relation between the mechanism which produces sleep and the influences which disturb it. The arteries being outside the brain, and the ganglia which rule them being in the neck, both are wholly indifferent to impressions which may be made on the organs of sense. Light and sound, for instance, reach only their appropriate organs, and do not affect cervical ganglia, or the arteries which keep the brain asleep. Hence it is that sleep, when profound, sometimes persists through great external disturbances, the mechanism of sleep being neither of a nature nor in a position to be in the least degree influenced by them.

Sleep of the Senses, or Subordinate Provisions for maintaining and deepening the Sleep of the Brain.

Although the sleep of the brain is produced and kept up by the reduction of its vascularity, yet it is liable to be lightened by impressions on the organs of sense, and it may be altogether interrupted if those impressions be so forcible or so prolonged as to arouse the brain to supersede the ganglia, and thus renew the dilatation of the cerebral arteries. Accordingly a double arrangement prevails, by which the sensitiveness of the peripheral extremities of certain nerves is abated at the same time as the function of their cerebral centres is reduced by sleep. This additional change takes place in perhaps all the chief organs of special sense, through which the faculties of the brain are accustomed to be aroused, and it is produced in each by separate and appropriate machinery. Different, however, as the provision is in the several organs, it appears in each of them traceable to the power of ganglia, set free for independent action on the withdrawal of the influence of the brain. By these arrangements occasions of premature awakening are doubly excluded.

For Exclusion of Light.

While, in common with the rest of the brain, the corpora quadrigemina lose their activity during sleep by the lessening of the cerebral circulation, there is a manifest arrangement for the repose of the eye by the

veiling of it behind the upper lid. This permanent closure of the eye is not produced by so vigorous a contraction of the ciliaris palpebrarum as a drowsy person might suppose from the heaviness of his upper eyelid. A slight involuntary action of that muscle may possibly close the eye, but the drooping of the lid is rather a result of defective innervation of the muscle which lifts it. For the lessening of the circulation affects not only the cerebral centre of the optic nerves, but also the roots of the third, fourth, and sixth nerves, whence all the muscles of the orbit lose the control of the brain during sleep.

Notwithstanding this practical incompetency of the muscles in the orbit, both to move the globe and to raise the lid, the eyeball is found so forcibly turned upward during sleep that some muscle is clearly in permanent action. This action is such as may be effected by the inferior oblique muscle, the nerve of which, alone among the branches of the third, is connected with the ophthalmic ganglion.

Besides the fall of the lid, and the rolling of the eyeball under the brow, there is a further provision for darkening the eye in contraction of the pupil. This state of the pupil in the absence of light can only be attributed to the independent influence of the ophthalmic ganglion. Were that ganglion subject to the third nerve, as it is in the waking state, the pupil would dilate in the absence of light. Contraction of it shows the separate power, and, so to speak, the wakefulness of

the ganglion during the sleep of the brain. Moreover, the pupil appears to be narrower in the profound sleep of children than in light sleep.

One other arrangement of the eye for sleep may be expected to exist, which would yet more remove the possibility of disturbance of the brain by sight; and it has been repeatedly observed with the ophthalmoscope by Dr. J. Hughlings Jackson. It is lessened vascularity of the retina. This should occur either upon contraction of the retinal arteries, under the influence of their ganglionic nerves, or upon contraction of the internal carotid, provided that trunk share the shrinking which is visible in its branches in the pia mater. If thus the carotid trunk do contract, the current of blood in the ophthalmic artery must be reduced, and its continuance may even become in some degree dependent on anastomosis with the stream of the facial artery. The increased size of the conjunctival vessels during sleep, while the brain and retina are known to be anæmic, renders such a reversal of the arterial current in the orbit not improbable.

For Arrest of Sound.

There is no external indication in the ear that it can obtain relief from the annoyance or the intensity of sounds, but anatomical arrangements suggest how the function of hearing is dulled during sleep. In the same manner as the central visual apparatus, so the root of the auditory nerve may become practically functionless;

and as the retina at the peripheral extremity of the optic nerve becomes visibly pale during sleep, so the terminal expansion of the auditory nerve in the vestibule, cochlea, and canals may be deprived of an adequate blood supply. Thus the auditory nerve, like the optic, would be partially insensible at both ends. That hearing may be blunted and restored in an anæmic person by so small a difference of the arterial current as arises from assuming the erect or the recumbent posture is known to us through the observation of Sir Thomas Watson, but from that cause, which affects the circulation equally in the ear and the brain, it is not possible to discriminate between the effects on the inner and outer extremities of the portio mollis. Anæmia in the labyrinth can only be surmised as likely to occur with that of the retina.

The middle is equally concealed from view with the inner ear. If therefore any physical adaptation to sleep be provided in it, corresponding with that which unquestionably occurs in the orbit, it cannot be demonstrated. As, however, the otic ganglion sends a branch to the tensor tympani, that muscle, like the inferior oblique, may be presumed to be in constant action during sleep. The apparatus of the middle ear, being thus rather fixed than nicely regulated to motion, and fixed by a power on which, inasmuch as it is ganglionic, sounds make no impression, may be incapable of the adaptations necessary for the exact transmission of them to the labyrinth.

For the Abeyance of Smell.

Of modifications of this delicate sense during sleep I have no knowledge. It is possible that the branches of Meckel's ganglion in the Schneiderian membrane lessen the vascularity, and thereby the secretions of the nostrils; and that thus the perception of odours is impaired. Whether the olfactory tract end in the base of the cerebrum or have its sensory centre in the pineal gland, it is equally within the area of the contracted cerebral arteries, and liable to lose the keenness of its function during sleep. This sense may nevertheless be so aroused as to be the cause of awaking. Smoke and gas may have this effect in the night, or such a nuisance as the following:—

"Some of the houses in Notte-street are very badly drained. There is a slaughter-house behind one of the houses, the drain from which is often choked. The inmates of the adjoining house complain that the smell arising from this source is so bad as sometimes *actually to awaken them out of their sleep.*"

For the Abolition of Taste.

This is partly secured by the habit of sleepers to keep the mouth shut and by the position of the tongue, but still more by arrest of the secretion of saliva, without which sapid substances, even when in contact with the tongue, produce little impression. The flow of saliva, which is constant in some degree throughout

the period of wakefulness, ceases on the approach of sleep, and continues thus interrupted until sleep is over. It is in consequence of this absence of fresh moisture for so long a time that many persons on awaking find the mouth dry or clammy, or perceive the taste of matters which have remained undiluted in the mouth all night. The arrest of the salivary secretion is a further proof that ganglia may resume power over arteries on the withdrawal of the action of the brain.

For Facilitating Breathing.

The mobile structures about the upper parts of the air passages are liable to much disturbance on the withdrawal of that intelligent control which keeps them in constant subjection during the waking state, and without which they would frequently interfere with the freedom of respiration. In sleep therefore, when they would otherwise be wholly unregulated, they appear to pass under the power of ganglia, and are automatically fixed. A slight influence suffices for closing the jaw, and it may be found in the distribution of a branch of the otic ganglion to the internal pterygoid muscle. This is the only sympathetic nerve allotted to the greater muscles of mastication. The lips, like the eyelids, are in sound sleepers lightly closed, as if the portio dura, under the regulation of Meckel's, the otic, and the submaxillary ganglia, with all three of which it is connected, maintained a gentle but active equilibrium of its subordinate muscles. By the in-

fluence of the otic ganglion over the tensor palati, and of Meckel's on the levator palati and azygos uvulæ, the soft palate may be shortened and stretched, and thus rendered motionless in the air which streams over it in respiration. There appears also to be provision for keeping the tongue quiet during sleep. It is found on awaking pretty firmly pressed forward and upward against the arch of the upper teeth and the hard palate. In weak persons it takes the form of the teeth during sleep, and sometimes in children seems marked on its tip in the shape of the space between the upper and lower incisors. The tongue therefore does not move during sleep, but is maintained in a position which ensures a free passage of air through the pharynx. The chief means of quieting the tongue is the negative method of arresting all secretions which might need to be swallowed. During our waking hours there is constantly flowing into the mouth and pharynx a lubricating liquid, which, as it collects in the pouches between the tongue and epiglottis, from time to time is swallowed. But for sound repose there needs an arrest of these secretions. Accordingly, the lachrymal gland acts but moderately, if at all, during sleep, in consequence of the lessening of its blood supply from the internal carotid, and the withdrawal of both direct and reflex stimulation through its nerve. We may sometimes verify this statement on awaking in the night, when we find the movement of the eyeball against the lids a little roughened. Meckel's ganglion diminishes or arrests

the flow of mucus from the Schneiderian and palatine membranes. Deprived of all excitement to secrete saliva, and having also its arteries contracted under the same ganglionic influence as those of the brain, the parotid gland wholly loses its function, and the sub-lingual and submaxillary glands from a similar cause. The passage of but a small quantity of saliva into the mouth keeps us from sleeping, for it loosens the tongue from its fixed position, and makes it necessary to swallow, and to replace the tongue. Very soon after awaking the usual fluids pour again into the mouth, relieve its dryness, and need to be swallowed; but throughout sleep nothing trickles over the fauces, the glosso-pharyngeal nerves are unexcited, and there is no deglutition.

For reducing ordinary tactile Sensibility throughout the Body.

Much of the quiet of this sense during sleep is secured by previous arrangements for our comfort, and so many occasions for exciting it are thus anticipated that it is not certain whether or not the feeling of touch is lost. In some sleepers it is easily aroused, whilst in others much discomfort and irritation pass unheeded. A flea, for instance, will sometimes not awaken us, though it will effectually prevent our going to sleep. It seems therefore clear that the faculties of the sensory centres are more or less blunted, as is the case with

the other special senses. Now it cannot be supposed that local mechanisms for reducing the sense of touch are scattered over the large surfaces of the body to which the nerves spread. But it is not improbable that moderate impressions yet fail to reach the spinal centres of the nerves of touch during sleep, being intercepted by the ganglia, which almost surmount the sensory portion of the fifth and of every spinal nerve. The spinal cord would be thus left in repose, and the opinion that it never sleeps may be only so far correct that in comparison with the brain its function is less reduced. There is, however, no reason to except the arteries of the cord from that power of contracting during sleep, which under ganglionic influence is possessed by those of the brain.

Area of Arterial Contraction in Sleep.

It is now convenient to reopen the question of the physical limitations of sleep, with a view to decide if unequal degrees of repose prevail in different parts of the nervous system. I put the inquiry whether sleep were a condition limited to the cerebrum, or whether it extended over the cerebellum also and the spinal cord, as well as the several organs connected with cerebro-spinal nerves. In view of the prominent importance of the arteries in the production of sleep, that question must now assume another form, and be in some degree altered in its terms. If all the four arterial trunks leading to the encephalon contract, then the whole organ sleeps; but, if the carotids contract alone, or if only the vertebro-basilar arterial system, then sleep is confined accordingly to the higher or lower part of the brain. Now it is demonstrated that the upper surface of the brain and the retina, which are supplied by the carotid, are pallid in sleep. The question therefore may now be whether sleep is limited to the area of the internal carotid circulation. This includes on the one hand more, and on the other less, than the proper cerebrum; for the carotid supplies the retina, but not the posterior cerebral lobe. Its range extends over the upper and lateral parts, and the anterior and middle lobes, of the cerebrum, the anterior and greater part of the corpus callosum, the corpora striata, the olfactory lobes, the front of the optic tract, and the

retina; but it does not include the posterior cerebral lobes, the back of the corpus callosum, the fornix, the optic thalami, the corpora quadrigemina, the pineal gland, or any part of the pons, medulla, or cerebellum, all which are supplied from the vertebro-basilar. It is necessary to fix particular attention upon this distinctness of the arterial areas in the brain.

Carotid and Basilar Currents in great part distinct.

Never perhaps was the physiology of an organ more obscured than by naming the union of the arteries before entering the brain as a Circle. It confuses all the vessels together, irrespectively of their destinations and relative sizes, and suggests nothing beyond the supposition that they all start forth from this anastomosing ring as from a new centre with a precisely balanced force. No reason is thus assigned or sought why the vertebrals unite; the use of the communicating arteries between the anterior cerebrals, and the want of any such combining of the middle cerebrals, are ignored; the slender posterior communicating arteries pass for equivalents of the adjoining trunks themselves, and all notion of the separate and differing dependence of the segments of the brain on their respective arteries is lost.

In the arrangement of the arteries of the brain there is a very distinct separation of the anterior from the posterior masses of the organ, and an equally clear lateral association of most of the symmetrical parts.

There is practically little communication between the carotid and the basilar arteries either beneath or within the brain. For the posterior communicating arteries are wholly inadequate, in the vascular activity of wakefulness, either to combine the action or to supply the current of trunks so large as those. They are but dwindled analogues of the great vessels which, in the ox and sheep, pass backward from the carotids and, without aid from the vertebrals, unite to form the basilar. Within the cerebrum also there is no freedom in the communication between the basilar and carotids. Not only has the middle cerebral artery of the carotid an insufficient anastomosis with the posterior cerebral of the basilar to be of service in the high vascularity of wakefulness, but its communication with both the arteries together which adjoin it is inadequate to secure maintenance for its own area of brain on the obstruction of its current by an impacted clot. The researches of the late Dr. Kirkes and others brought to light a limited but fatal anæmia as the result of such obstruction. Accordingly, the anterior and posterior parts of the brain are separately dependent on their own arteries.

But through collateral portions of the brain, on the contrary, to a large extent, there is a virtual unity of the arterial circulation, and a consent or equality in the action of those portions is thereby secured, as well as a relation of singleness to some laterally double structures beyond the brain, which have no mesial communication with one another. The largest of these arterial unions is

that of the two vertebrals, which combine in the single basilar the force of their currents (so liable to be disturbed in the neck), and send the blood with equal power to parts of the brain which, like the posterior cerebral lobes, are double and lie apart, and to some, as the corpora quadrigemina, which, though symmetrical, are single. The other is the combining, and then the parting again, of the two anterior cerebral arteries, which upon any disturbance instantly equalise the force of the currents entering the anterior and upper parts of the cerebrum. And yet even this free communication between the anterior cerebral arteries is sometimes unequal to the requirements of the brain either for functional activity or for due maintenance of texture. Symptoms occasionally arise upon the ligature of one carotid, which show the corresponding half of the cerebrum to be suffering from anæmia; and, some years after the ligature of one common carotid, Mr. Nunneley found * the anterior cerebral lobe on that side reduced to about one-half of the size of its fellow. The inadequacy of the far smaller posterior communicating artery for maintaining a defective circulation is thus the more obvious.

Besides these effects of the union of the vertebrals, and of the anterior cerebral arteries, into single central trunks, there may be noted a result of the subsequent re-dividing of those trunks. This provision admits of

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* Medico-Chirurgical Transactions, vol. xlviii, p. 28.

an alternate action of parallel segments of the brain, or of the exclusive employment of one of them, according as, upon any sudden ganglionic contraction of one lateral branch, the stream of the central artery is diverted into the other.

It may be conveniently observed in this place that the arrangement of the arteries has the further effect of conjoining in one blood stream some segments of the brain which are connected in function, and of separating others. Thus the anterior lobes, and the front of the corpus callosum, are supplied by the same artery, but the corpus striatum and the crura cerebri by different vessels. The posterior cerebral lobes, and the back of the corpus callosum have the same supply; and again, the hippocampi, fornix, and optic thalami. But the optic thalami and corpora striata receive blood from different sources, and again the corpora quadrigemina and the eyeball.

It may also be remarked that the union of the parallel arteries on their way to the brain has its effect not only on the equal lateral areas within the organ, to which they go, but also on the ganglia which the brain controls. For these, though symmetrically placed, are far apart, and mostly unconnected by any transverse communications; yet they are practically associated by the consentaneous action or abolition of action in the two halves of the brain. Hence, as it is impossible in a state of health for the brain of one side to sleep alone, it is also impossible for the ganglia

of one half of the head to act alone, and the notion, for instance, of "sleeping with one eye open" is a metaphor which is not just to the fact. If, for instance, either ophthalmic ganglion act in sleep, it does so upon an abeyance of function in the crus cerebri, which cannot but be common to both sides, since it is produced through the contraction of a single central artery. The admirable arrangement of the vessels of one organ thus establishes a consent between other and separate organs, and supplies the place of a commissure between them.

Now, beyond all doubt, the function of the cerebrum is abolished in sleep throughout that part which is supplied from the carotid; for the grey surface of the organ has been seen to be pale in the surgical accidents and the experiments which have been already referred to, and the ophthalmoscope has disclosed to Dr. J. Hughlings Jackson a similar condition of the retina. Of the state of the brain in the area of the vertebro-basilar circulation there has been no demonstration. Yet to limit the arterial contraction to the carotid system would be to suppose that the cerebrum sleeps everywhere but in its posterior lobe, unless indeed the vessels of that small portion of the cerebrum, though coming from the basilar, are to be regarded as virtually branches of the carotids, and are controlled by the carotid plexus. The confusion is no less in the interior and base of the cerebrum, where the open basilar artery would maintain wakefulness in the parts beneath the

velum interpositum, and especially in the optic thalami, while the corpora striata, which are continuous with them, would by contraction of the carotids be put to sleep. But in the retarded respiration of sleep we have proof that the pneumogastric nerves are less active than during wakefulness, and the probability of that mode of breathing arising in a diminished supply of arterial blood to their roots in the medulla oblongata is confirmed by the like occurrence in Sir Astley Cooper's experiment of compressing the vertebral arteries. The circulation in one part of the vertebro-basilar area being reduced, it is reasonable to think that area not less contracted throughout. Hence the posterior lobe sleeps with the rest of the cerebrum, and with all other parts which derive blood from the basilar and vertebral arteries.

Separate Contraction of Particular Arteries in the Brain—Somnambulism—States of Double Consciousness.

But, though this be the fact in natural sleep, circumstances may happen in which contraction is limited to but one arterial trunk, and the area of brain dependent on that one supply shall be asleep, while the rest, having its arteries still open, is awake. Various and intricate symptoms may then arise. Thus a patient for whom I recently tied the left carotid appeared to have the corresponding side of his brain put to sleep. The left side of his head was at ease, but the right orbit and temple throbbed painfully, and he complained of

having a strong desire to sleep, but to be kept awake by the feelings in the right side of his head. But perhaps the most striking illustrations of a partial interception of the blood current into the brain are those comprising the more usual forms of somnambulism and double consciousness.

The phenomena usually observed in somnambulism are some awakening of thought, consciousness, and will, recovered tactile sensibility, control over the muscles of the body and limbs, an open eye and dilated pupil; but obscure vision or blindness, dulness of hearing or deafness, and withal, after relapsing into sleep and complete awakening, no recollection of the purposes or occurrences of the somnambulistic state. In addition to these, Dr. Hughlings Jackson once found by the ophthalmoscope that, as in sleep, the retina of a somnambulist was pale.* All these phenomena appear intelligible on the supposition that the parts in the area of the carotid circulation continue asleep, while those supplied from the basilar artery awake; that, in fact, the somnambulism thus characterised is due to a renewed dilatation of the basilar artery alone.

In the first place, it appears to be clear from the entire absence of memory in the waking state as to what passed during the somnambulism, that some portion of the brain was wholly unoccupied with the thoughts and

* 'Observations on Defects of Sight in Brain Disease, and Ophthalmoscopic Examination during Sleep,' by J. Hughlings Jackson, M.D., 1863, p. 15.

unimpressed by the occurrences in the dream. It is not that they are forgotten, for on a recurrence of the somnambulism they may be remembered; it is that the brain was never engaged with them in that part, upon the activity of which the perfect memory of the intellect depends. There can be no consciousness, on the part of any sleeping segment of the brain, of activities in which it is taking no share, nor consequently on awaking can there be in it any trace of previous thought to recall. That cerebral segment must awake wholly devoid of impressions limited to another segment; so far as they are concerned, its memory is blank. Even if the sleeping segment were that which is dominant in the thinkings of the entire waking brain, it can assume on awaking no cognizance of the past occupations of a subordinate part. Only by awaking disproportionately refreshed might it perceive the weariness to which the other part awakes in consequence of its inadequate repose. Upon the theory of the interception of the carotid circulation alone, the intellectual seat, or the anterior and upper portion of the cerebrum, is in somnambulism unemployed. It is unconscious during the continuance of that state, and without the means of remembering it when it is over.

The abeyance of this faculty must modify the actions of the remainder, and impair the use of the various senses. As, however, somnambulists do display some thought, and are capable of designing and directing actions, a portion of the cerebrum must be awake. The

characters of thought in somnambulists have never been so strictly observed, nor the functions of the different parts of the brain so discriminated, that a correspondence should be traceable between the thought and the function. But the mental actions of the ordinary somnambulist may be very well performed by the posterior lobes. The mind seems occupied with one idea, and is not to be diverted from it; and it is commonly one expressive of the emotions and affections, which are usually the cause of the disquietude.

The awakening of the motor powers is shown in walking and the employment of the hands, and even sometimes in writing. This last is rare, and is the more remarkable since none of the movements which the brain plans and directs, are guided by vision. They are all controlled by the muscular sense, that is to say, by perception in a sensory part of the brain of the effect and adequacy of movements directed by a motor part of the brain. For this consent and balancing of sensation and motion, the thalami must be awake as the highest seat of sensation, and the anterior motor tract in the pons and crura cerebri, up to a level which brings it into relation with the thalami. Moreover, there must be complete wakeful activity of the cerebellum, as the co-ordinator of the many muscles which are combined, without specific thought about them, in the most intricate and graduated muscular actions. With these, for the same purposes of motion and sense, the cord also must be awake.

The raised upper eyelid and mobile globe imply wakefulness of the origin of the third nerve in the crus cerebri. Yet the power of that nerve is in some manner withheld from the iris. The pupil is not contracted, which is its normal condition during sleep, nor does it vary with degrees of light. Its state is neither that of wakefulness nor that of sleep, but it is permanently dilated. The explanation of this appears to be that the whole of the visual apparatus is in the vascular condition of wakefulness, with the single exception of the retina, which has been found with the ophthalmoscope to contain less blood than in the waking state. If such should be the cause of the derangement of the iris in somnambulism, the argument is strikingly confirmed, according to which sleep is due to contraction of all the arteries of the brain, and somnambulism to that of the carotids only.

For contraction of the pupil in wakefulness occurs under the power of the third nerve, on the excitation of the retina by light. The central communication which produces this consent of the optic and third nerves, lies at their roots in the corpora quadrigemina and crus cerebri. In sleep, these parts of the brain being emptied of blood, they are functionless; the iris is left to the influence of the ganglion, and, in the absence of light, is contracted. Neither the one nor the other of these is the case in the somnambulist. In abundant light, and with an open eye, the pupil is dilated. The third nerve is in action, for it raises the lid, and to the

power of the same nerve it is doubtless due that the ophthalmic ganglion is superseded, and no longer causes contraction of the pupil. Why, now, should the third nerve, though its root is manifestly awake, yet fail to affect the pupil? For want of the usual reflex incitement from the retina through the corpora quadrigemina. But these may be presumed to be awake, since they are supplied with blood from the same source as the crus cerebri, which is awake. The failure, therefore, must be in the retina, which is demonstrated to be comparatively bloodless, and the artery of which, the centralis retinæ, comes in the ophthalmic artery from the carotid. Thus all the nervous structures in the visual tract within the area of the basilar artery are awake; that vessel therefore is open: the retinal artery being comparatively empty, it follows that the carotid artery is contracted.

The cause of the deafness of the somnambulist is not capable of so much demonstration as the defect of sight. But a similar condition of the nervous apparatus in the labyrinth to that of the retina may be presumed to occur, and from the same cause. Dulness of hearing in somnambulism may thus to some extent depend on contraction of the trunk of the internal carotid artery, while the root of the auditory nerve, being supplied by the basilar, is awake. It must, however, be confessed that the nature of the inattention of a somnambulist to sounds cannot be decidedly asserted in the absence of a physical clue to the changes which may occur in the ear.

In some somnambulists there is added to the defects already mentioned a loss of the faculty of speech. To state the fact more correctly, such persons pursue their engrossing idea without speaking; for too little is known of their state to enable us to say that they cannot speak. It is possible that they are silent because, being deaf and sightless, they are not aware of the presence of a listener, and certainly under great excitement the faculty of speech, and even apparently of sight, may be temporarily recovered. In allowing, however, that speech is regained, it is not alleged or supposed that more than a few ordinary words are uttered. The usage of the multitude of recollected sounds which constitute a language involves such extraordinary combinations of memory within the brain, and such rapid and complex nerve impulses on the various organs employed in articulation, and moreover so much guidance of tones of voice, and expressions of feature through hearing and the muscular sense, that it is not conceivable that speech in the complete sense is within the capacity of a half-sleeping brain. Moreover, to distinguish any further defect would need acquaintance in each case with the vocabulary of the somnambulist, and the special deficiency in thought or language, which he might show in his dreaming state.

Should these views respecting the mechanical production of the more common features of somnambulism prove correct, they may become more than a proof of the separate influence of the cerebral arteries; they may

constitute a test of the functions of the particular segments of brain which those arteries supply. The present application of them is to the effect that the peculiarities of somnambulism are explicable by a theory which supposes all the parts supplied by the basilar artery to be awake, and all those within the area of the carotid to be asleep. If the theory be correct, it tends to confirm the previous arguments, according to which the contraction of the cerebral arteries, which produces sleep, extends as far as those arteries have muscular walls, and therefore to the trunks of the internal carotid and vertebral arteries, as well as to those which may be seen to shrink in the pia mater. And it shows further, by the contrast of somnambulism with sound sleep, that in the latter state the great posterior, as well as the anterior, arterial circulation is reduced.

Range of Action of the Ganglia in Sleep.

On reviewing, in accordance with the theory thus advanced as to an alternate action of the brain and the ganglia, the whole relation of the sympathetic to the cerebro-spinal nervous system in sleep, it may be perceived, that the ganglia ranged beside each vertebra in the sacrum, loins, and back, and the seven less regularly placed in the neck and beneath the cranium, encompass the whole spinal cord and the brain, together with its subordinate organs of sense, deprive them of all ordinary activity, and exclude them from influence over the remainder of the body. Saving the possible

origin and support of all sympathetic nerve power in the medulla oblongata, a man asleep thus lives only by his ganglia. He is not, indeed, absolutely without cerebral nervous force, since he would then be reduced to the deep prostration of coma, and would be unable to resume the waking state. But, if he is not precisely as one anencephalous, in whom the cord is also defective, he is one in whom the prime nervous power is ganglionic. That power everywhere surrounds the cerebro-spinal nervous centres, and shuts in their influence from the sensory and locomotive organs; but the great ganglionic masses in the trunk, which are outside the long chain of ganglia posted beside the vertebræ, are free to exercise their incident and reflex powers in sustaining and regulating the functions of the vital organs.

Awaking.

While sleep can occur in but one way, the causes of awaking appear to be numerous. They may all, however, be reduced to one ultimate action, namely, revoking the force of the ganglia upon the arteries, and re-opening the arterial current throughout the brain. Hence waking is different from acting in sleep; for this can happen upon the return of blood to a part only of the brain or spinal cord, but awaking is not complete until the arteries are all open, and the full stream of blood is restored.

The occasion of awaking may be in the brain itself, or in any of the special senses, or it may arise in the unsleeping organs of the trunk. In the last case the force of the ganglia which maintain the sleep of the brain is taken off by an excitation ascending along the sympathetic nerve or the spinal cord; and awaking is accompanied with a troublesome dream, the character of which often depends on the stage of digestion, or with surprise at being prematurely aroused, and by an unlooked-for or unknown disturbance. The first kind of awaking is more gradual, and proceeds with some sort of conscious consent on the part of the brain; for it does not commence till the brain is adequately refreshed, and as a consequence of the replenishing of its force. Automatically, then, and almost without will, the reinvigorated brain supersedes the ganglia, the arteries open, and the sleeper is wide awake. In such a person

the nervous constitution is the most perfect. His ganglia are as energetic when relieved from the control of the brain, as the reflex function in a paralyzed limb; but as, in a sound limb, reflex power is kept down without specific exertion of the will, by the mere influence of the dominant brain, so is the ganglionic force superseded in such a sleeper on the completion of his cerebral sleep. Many persons cannot thus awake. They must be assisted through one of the senses. One morning, accordingly, they are aroused through the sense of hearing, another through touch, or the intrusion of light. But such awaking involves the condition, that the brain shall be capable of resuming its activity without precise dependence on the quantity of blood it contains. In an aged person whose brain was feeble, if not actually diseased, this condition could not be fulfilled, and the process of awaking from sound sleep was sometimes prolonged over an hour, was attended with blindness, which passed away on complete awaking, and with faintness and slowness of breathing which threatened life.* To be aroused from sleep by a stimulus from without involves also the further condition, that the part of the

* Without drawing further upon the phenomena of disease for illustrations of the subject of awaking, it may be worthy of suggestion, that the surprising recoveries of consciousness towards the close of some mortal cerebral diseases are probably explicable by a temporary reduction of intra-cranial swelling. Arteries previously compressed against the base of the skull being thus released, the state of insensibility, due to the pressure on them, is removed by the return of arterial blood to still healthy portions of the brain.

brain excited to premature awaking shall be so situated as to exercise or induce control over the ganglia. There appears to be a definite nervous connection through which alone each ganglion is brought again under the dominion of the brain; for it is shown by the dreaming phenomenon already explained, of wakeful will and dormant motor power, that one grey mass is not competent to wake another. Awaking must take place through the ganglia; but the will in the dream referred to is forcing the impulses of the cerebral surface on the substance of the sleeping motor centre, not on the dominant ganglion beneath. Struggle as it may, no effort of the will reaches that body, the bloodvessels remain contracted, and the motor centre sleeps on.

It should be added, that the relative size of the ganglionic masses controlling the respective great arteries of the brain, suggests that the vertebrals contract less vigorously and less completely than the carotids, and that the sleep of the posterior parts of the brain is consequently less profound than that of the anterior. The sympathetic plexuses likewise are much smaller on the vertebrals than on the internal carotids; in the neck they are mingled with spinal twigs, and their branches within the cranium do not extend so far along the distribution of the arteries. Kölliker even asserts that the arteries of the cerebellum are without nerves. This, however, does not prove that the posterior parts do not sleep, but that they do so through the contraction of the trunk vessels chiefly

or alone. On the other hand, the proportion of branches from the spinal nerves entering the second and third cervical ganglia, which, taken together are much smaller than the first, is actually greater than that entering the superior ganglion. Hence it may be concluded, that, if awaking do occur upon the instance of the inferior cerebral and spinal centres, it may be more prompt and more frequent in the posterior than in the anterior parts of the brain, and that probably always the vertebro-basilar area of the brain awakes first.

THE END.

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