MIND

A QUARTERLY REVIEW

OF

PSYCHOLOGY AND PHILOSOPHY

I.—THE PHYSIOLOGICAL FACTORS OF THE ATTENTION-PROCESS (II.).¹

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THE WAKING STATE AS A CONDITION OF ATTENTION.

THE mind is not always equally ready to react to impressions from without or to follow attentively its trains of ideas. From hour to hour and from moment to moment its degree of awakesness and alertness varies widely. At the zero-point of the scale of degrees of awakesness is the state of deep and dreamless sleep in which consciousness and attention are absent or at a minimum. At the other end of the scale stand those rare moments of exaltation when, through some happy conjunction of internal and external conditions, the whole being, senses, intellect and emotions alike, seems to be raised to a higher plane of activity than the normal. 'Tis then we perceive new features in long familiar scenes, and objects long well known to us become strangely beautiful or significant, while the mind seizes with a joyful sense of power and ease the ideas that rise in a free and rapid stream. Between these extremes a large but indefinite number of degrees of awakesness might be distinguished. Very low in the scale stands the state of ordinary dream-consciousness. In my own case a dream usually consists of a series of visual images loosely and somewhat inconsequently grouped and having a certain low degree of emotional colouring.

¹ For Part I. *cf.* MIND, N.S., No. 48.

Selection and concentration are not entirely absent, but are carried to a low degree only, one or other figure or part of a scene may predominate over the rest, but it remains ill-defined and its parts are not discriminated; it is as though the scene were viewed by an eye, which, though capable of movement, lacks a region of acutest vision. Attention must, I think, be admitted to be present, but in its lowest, most rudimentary form. Whether Attention is ever completely absent during the waking state is a disputed point, but certainly it may be of a very low grade only, as when one lies dozing in a warm bed after being roused from sleep. Occasionally one experiences a rapid transition from the state of profound sleep to a state of maximal attentional activity. I will first trace such a transition in terms of consciousness and bodily changes and then describe what I take to be the nature of the nervous changes underlying it.

During the small hours of the morning while I am lying in deep dreamless sleep, the stillness is broken by some unusual sound of moderate intensity arising within the house and repeated at short intervals. This commotion falls upon my auditory apparatus several times without provoking any response, whether in the form of movement or of affection of consciousness. On a further repetition of it my limbs make some aimless movements or I roll over in bed, and this, I think, is apt to occur before consciousness is at all affected. On looking back on the course of these events when fully awake, it appears that the auditory stimulus first affected consciousness as a pure undiscriminated sensation of sound having no objective reference; there was no attention to the sound and there was also, at this stage, complete absence of self-consciousness. On further recurrences of the sound consciousness is further aroused and its state may be represented by the phrase 'There is a noise,' and perhaps at the same time I become aware, through a dim retrospection, that this noise has been going on for some time. There is the minimal degree of Attention, a vague discrimination of the noise as such and a dim objective reference, together with a dawning self-consciousness that is the necessary correlate of this objective reference; and the whole state has a faintly disagreeable affective tone. If I were lying at an hotel it might well happen that further repetitions of the noise would fail to arouse any higher degree of consciousness or attention, and that I should presently fall asleep again in spite of recurrences of the noise, for under those conditions it would be for me a meaningless noise. But if I am lying in my own house further repetitions of the noise produce

further effects. With the dawning self-consciousness comes a sense of my surroundings and the 'There is a noise' passes into 'What is that noise?' with the stronger disagreeable affective tone, 'That ought not to be'. This implies a distinctly more attentive state than that of the preceding stage, and this is expressed by the greater tension of the muscles generally, perhaps also a raising of the head from the pillow and a setting of the muscles of ear, head and neck. Again the noise is repeated, and now comes like a flash, 'There's some one in the house'. The coming of this idea results in an immediate increase of Attention, clearly expressed in motor terms by my sitting up in bed with all the body set to an intense listening, while visual ideas of the spatial relations of the house become vivid as I try to refer the sound to this or that part, and at the same time my more rapid breathing and pulse indicate a considerable increase in the degree of emotional excitement. Once more I hear the noise and, listening intently, with all my muscles tense, with deep and hurried respirations and thumping heart, I rise to open the door as softly as possible and take measures for the defence of my property. Attention has reached the highest degree that this stimulus, in this particular set of circumstances, is capable of arousing.

In this experience, which with slight variations must be more or less familiar to almost all householders, we have a good illustration of the fact that the degree of Attention, that can be aroused by any object or stimulus, is to a large extent dependent upon the degree of awakeness at the moment of the incidence of the stimulus. For we have a series of states of successively higher degrees of Attention brought about by the repetition of one simple sensory stimulus, each incidence of the stimulus arousing a higher degree of Attention than its predecessor, because that predecessor has brought the mind to a more fully waking state.

We see further that the increase of attentive activity is brought about by the co-operation of the four factors that are the chief, if not the sole factors, in all such cases of rising Attention, namely :—

1. Sensory stimuli, which in the above case, although not violent, are nevertheless potent in arousing Attention in virtue of their relative novelty and of the contrast between them and the intervening periods of silence.

2. Muscular adjustment, beginning in this case with vague aimless movements and culminating in complex strenuous activity of pretty well the whole muscular system, directed and co-ordinated to a particular end.

3. The excitement of complex and well-developed mental systems connected with the necessity of expelling an intruder and defending my property.

4. An emotional excitement due to the affective tone of the ideas aroused and having its basis in the instinct of defence of self and belongings.

This series of states of increasing awakeness and of rising attention must now be described in terms of the physiological scheme that I have proposed in the first part of this essay. While I lie with closed eyes in a warm soft bed in a dark and quiet room, the sum of physical stimuli affecting the sensory endings of the afferent nerves is very small. The amount of 'neurin' generated in the afferent neurones per unit of time is therefore so small that it is insufficient to make good the loss by leakage into the muscular system that is continually going on in all parts of the nervous system. During the day fatigue-products have been accumulating in the blood, and these act upon all the synapses, the junctions of neurones, of the nervous system, to increase their resistance, to raise their thresholds, just as do ether and chloroform when present in the blood, and, like these drugs, they act with most effect upon the least organised synapses, those of the highest levels.¹ Hence there is low pressure of neurin in all the afferent neurones, and a high degree of resistance in all the paths by which it tends to escape into the efferent neurones and the muscles. The pressure of neurin is therefore insufficient to keep open any path or paths through the higher levels, or indeed any paths but those most thoroughly organised chains of neurones that constitute the reflex paths through which the activity of the fundamentally vital viscera, the heart and lungs, is regulated. All neurones, with the exception of these last mentioned, are therefore as nearly at rest as living cells can be, their metabolism, or rather their katabolism, is minimal, and therefore the amount of neurin set free in them is minimal, and, excepting these few fundamental reflex arcs, there are no paths discharging into efferent neurones; the skeletal musculature is therefore motionless and there is no consciousness. Further, the amount of neurin set free in unit of time is less than can escape by leakage, hence the charges of neurin in the individual neurones is

¹ Of these two conditions, which I take to be the two principal determinants of normal sleep, the latter is probably the more important during the early hours of the night and the former during the later hours as fatigue passes off.

drained to its lowest ebb, *i.e.*, their tonus is low, and therefore that of the muscles is also low, body and limbs lie limp and flaccid.

Such is the condition of the nervous system during deep sleep. When, as in the case described above, stimuli of moderate strength fall at short intervals upon the sensory ends of one or other set of afferent neurones of a nervous system in this condition, they may fail to evoke any response, whether as consciousness or as movement, until after a considerable number of repetitions. A familiar instance of this delayed response is the gradual waking of a sleeper by a gentle, oft-repeated knocking on his door. The earlier stimuli, which fail to produce any directly ascertainable effect, are yet not without effect, for it is by the summation of their effects that the nervous system is gradually brought into such a state that a further repetition of the stimulus may cause a reflex movement. A similar summation of effects has been shown to occur in the waking state in the case of sensory stimuli of minimal strength, as also in the isolated spinal cord. In the case in hand, it would seem that the neurin liberated in the auditory afferent neurones fails at first to discharge through any reflex lower-level path because it is absorbed and rendered latent or invisible, as we may say, in raising the tonus of those neurones, and also, no doubt, because at first part of it drains rapidly away into other systems of neurones with which they are connected on all sides, thus serving in some degree to raise the tonus of all or of a considerable mass of neurones of the lower-level systems. And this goes on until the tonus of the directly stimulated neurones is so far raised that a repetition of the stimulus determines a discharge through some purely reflex lower-level path into some group of muscles.

Then at once a great step towards the waking state is made, for the contraction of the group of muscles, thus reflexly excited, stimulates the afferent nerves of these muscles and their associated structures, tendons, joints, ligaments and so forth, and the movement, being the occasion of friction and new relations of pressure between parts of the skin and the bed and bedclothes, causes indirectly stimulation of the sensory nerves of those parts of the skin. The reflexly produced movement therefore determines a rapid setting free of neurin in a considerable number of afferent neurones, the quantity being in proportion to the extent of the movements and the mass and number of the muscles involved. This increment of neurin will to some extent diffuse itself through the neurones of the lower-level systems and

raise the general level of their tonus to a corresponding extent.¹

If the external sensory stimulus, in this case the noise, be a very powerful one, a single incidence of it may suffice to bring about the state just described, and the feebler it is the more frequently will it have to be repeated before it can effect this degree of change of state in the central nervous system ; just as, in the case of an animal deprived of the brain but with spinal cord intact, a sensory stimulus of only moderate strength must be repeated several times before it can excite a reflex movement, and can excite such movement through a single incidence only if it be of very violent character.² A similar cumulative effect of apparently ineffective or sub-minimal stimuli has been shown by Urbemtsch to occur in the fully waking state when auditory stimuli of very low intensity are used. These cases of summation of effects of successive and separately ineffective stimuli are instances, I take it, of that important effect specially studied by Exner,³ and by him named facilitation (*Bahnung*). I have already in another place attempted to show that this may be regarded as essentially a process of accumulation in neurones of successive charges of neurin individually insufficient to bring the potential of the neurones up to the discharging point.⁴

The description of this first step of the awakening process, which brings us to the reflexly produced movement, presents no difficulties. But we have now to face the first of those four problems formulated at the end of the first part of this essay,⁵ namely, ' Why is it that at any moment the excitation set up in the lower levels by some one of numerous simultaneous sensory impressions penetrates to and excites an organised system of paths in the higher levels of the brain ? Why is the excitation-process not confined to lower-level paths of which the normal or resting resistance is lowest ? ' In the instance in hand, Why does the excitation-process, set up in sensory neurones by the auditory stimulus, not

¹ Many persons and animals habitually stretch themselves on waking from sleep, powerfully innervating all their skeletal muscles, and this, as most of us know from our own experience, promotes very effectively the waking-process. It would seem that we share with the animals this instinctive tendency to secure in this way a rapid raising of the general tonus of the nervous system.

² Sherrington, Art., " Spinal Cord," Schaefer's *Text-book of Physiology*, p. 828.

³ *Entwurf s. physiolog. Erklärung psychischer Thatsachen*. Wien, 1894.

⁴ *Brain*, Dec., 1901.

⁵ *MIND*, No. 43, p. 349.

continue at each recurrence of the stimulus to discharge itself through purely reflex paths of level i., but instead penetrates to and excites a path of level ii., the sensory reflex level, so determining the undiscriminated sensation of noise?

Now we know from physiological experiments on animals deprived of the brain that the reflex paths of the cord, paths of level i., are of limited capacity, *i.e.*, they are incapable of transmitting an excitation of more than a very moderate intensity.¹ For on stimulating any given set of afferent nerves it is impossible to obtain reflex contractions of more than a moderate force and, when the sensory stimulus is increased in strength beyond the degree that suffices to bring about such contractions of moderate force, there is no further increase in the force of the contractions of the group of muscles first excited, but other muscles are set in motion. It would seem that the excitation-process overflows its most direct reflex path, the path of forward conduction of lowest resistance, and so spreads laterally to other paths of the same level with which it is connected by synapses of a normal resistance higher than that of the synapses connecting together the neurones of the direct path.

In the intact nervous system the spread or overflow of the excitation-process would seem to take place upwards into paths of higher level rather than laterally into other paths of the same level, and in the case in hand, the spreading of the excitation-process from paths of level i. to the paths of level ii., in which it determines the sensation of sound, may be regarded as due to overflow of the excess of neurin that cannot escape to the muscles by the lowest level path of limited conduction-capacity. Here, as we shall find in other instances, a hydro-dynamic analogy will serve to make clear the state of affairs that seems to obtain. Imagine a vessel having a single large inflow pipe and a series of smaller discharge pipes all opening about its base and leading from it to other vessels, and imagine these discharge pipes to be controlled by spring valves of different degrees of resistance. This vessel standing almost empty may represent the central nervous system during deep sleep; water dribbles into it so slowly that a small leakage about the valves prevents the accumulation of sufficient pressure to open the valve of lowest resistance. Then comes a series of gushes of water through the inflow pipe. At first the result is merely a rise of the level of the water in the vessel and a correspondingly

¹ Sherrington, *op. cit.*, p. 831.

increased leakage through all the valves. Then after a certain number of gushes the water in the vessel will reach such a level that its pressure overcomes the resistance of the weakest valve, which therefore opens and allows the passage of a stream of water. If now the amount of water coming in at each gush be so great that it cannot at once be carried away through the valve of lowest resistance, the level of the water will rise with each of the inward gushes in spite of the opening of that valve until the pressure suffices to open one or more of the valves of higher resistance, when overflow into the corresponding vessels will occur. The valve lowest in order of resistance represents the synapse or synapses of the reflex path of level i., the valve next in this order represents the synapses of the corresponding path of the sensory-reflex level, and the others various other junctions with paths of these two levels.

The outflow through paths of levels i. and ii. is not confined to the motor nerves of skeletal muscles only, but finds its way in part to the efferent nerves of the viscera, increasing the tonus and contractions of arterioles, heart, lungs and perhaps other organs. During sleep these organs have been kept in a state of gentle regular activity, through a circular process of self-control; their movements initiate an excitement of their sensory nerves which propagates itself through reflex paths of the cord and bulb and out along efferent nerves as a series of impulses which, returning to the same viscera, determine the initiation of a fresh afferent influx. On the incidence of the series of auditory stimuli this self-maintaining circular process is complicated and disturbed by a new series of efferent impulses, and the resulting changes in the visceral movements determine an increased afferent inflow which, as in the case described above, no longer finds a sufficient outlet through the reflex paths and therefore overflows to higher-level paths lying chiefly in the prefrontal cortex. The excitement of these paths is the physical basis of those obscure affections of consciousness from which the idea of the self is synthesised. So self-consciousness is aroused, and, owing to previous similar experiences, it takes the form of the idea of self-lying-in-bed, and this idea is intimately associated with that of the bedroom and the house in their spatial relations. Hence the excitement of those prefrontal paths, which determines the rise of self-consciousness, leads on to the excitement of that mental system or complex system of paths which is the physiological basis of the idea of the self-in-bed-in-my-own-house. These upper-level paths, being thus centrally excited, become paths of low resistance and therefore, when next

the sensory stimulus falls upon the auditory neurones and sets free a further quantity of neurin in paths of levels i. and ii., this overflows in part into these higher-level paths and the mental system of the idea of self-in-house apperceives the sound, converting the undiscriminated sensation of sound into the percept, a-noise-in-my-house-at-night. This is a percept that has a large affective value, for it leads directly to the excitement of the mental system that sub-serves the instinctive tendency to defence of self and belongings and which physiologically consists of numerous paths leading to widespread activity of both visceral and skeletal muscles. The contractions of these numerous groups of muscles determine a great influx of neurin to the afferent side of the nervous system, which influx brings about that general condition of raised tonus and widespread nervous activity which we feel as a state of emotional excitement. Then at last the whole nervous system is thoroughly awake; the neurones of all levels and all parts are fully charged so that any slight stimulus will cause their discharge; the excitation-process spreads freely from one system of upper-level paths to another, ideas as to what action must be taken flow rapidly and action follows; conation and attention are at a maximum.

The conjunction and interaction of the two systems of excitement, that of the mental system of the idea of self-in-house and that directly set up by the recurring sensory stimulus is the essential condition of the culmination of the process. On the one hand, if the stimulus does not recur at this stage the whole excitement will die down, the accumulated charges of neurin will drain slowly away, the high degree of tonus of neurones and of muscles subsides, the viscera resume their gentle regular activity and sleep is restored. On the other hand, in the absence of the conditions that bring up the idea of self-in-my-own-house, if for example I am lying at an hotel, this idea will not arise or, if it arises, is quickly suppressed and replaced by the idea self-in-hotel, and the sound is then perceived as noise-in-hotel. This perception has no such emotional value as the other, it does not lead to any instinctive excitement of visceral and skeletal muscular systems; hence there results no such free liberation of neurin in large groups of afferent neurones as occurs in the other case. And in the absence of this the nervous system adapts itself to the recurrent sound, i.e., the excitation-process initiated by it fails to propagate itself through any wide system of upper-level paths, but becomes confined to a comparatively narrow set of lower-level paths.

In the foregoing sketch of the series of changes constituting the transition from the state of sleep to one of fully waking activity there is implied the view that the maintenance of the waking state depends upon the maintenance of a certain high degree of tonus throughout the neurones of the lower levels of the nervous system; and further it is implied that this in turn depends upon a constant liberation of energy or, as I prefer to call it, neurin, in considerable groups of afferent neurones, under the influence of peripheral stimuli.¹ This view is based on the characteristic differences of the states of sleeping and waking in the normal human being, and on the observed influence of stimuli to the peripheral nerves, and of the lack of such stimuli, in favouring the transition from the one state to the other as traced above, and it receives confirmation from the consideration of such abnormal cases as that reported by Strümpell.² In the case of this patient one eye and one ear remained the only sensitive organs, all other parts were anæsthetic, and whenever all stimuli were cut off from these two organs the patient always fell asleep in less than two or three minutes and could then only be wakened by flashing a bright light into his sound eye, or by repeatedly calling his name into his sound ear.

It is further implied in the above account that we may regard all the neurones of the afferent side of the waking nervous system as constituting, in virtue of their interconnexions, a reservoir of energy, as containing a common stock of neurin upon which the various parts draw in turn as they become active, i.e. as they become in turn the principal paths of conduction from afferent to efferent side. And it would seem that, while the maintenance of a certain degree of pressure or potential is a necessary condition of the waking state, the degree of mental activity at any moment is more or less dependent upon and varies with the degree of this pressure, and therefore dependent upon a continual peripheral stimulation of afferent neurones of the organs of sense and of organic sensibility. It would seem in fact, that, so far from sensory stimuli being detrimental to activity of the higher levels of the brain, all peripheral stimuli promote mental activity so long as they are not powerful enough to attract attention to themselves. That mental activity is favoured by the incidence of a large volume of sensory stimuli of a kind that does not powerfully

¹ The over-excited brain which, in spite of fatigue and of the withdrawal of all but inconsiderable sensory stimuli, continues active and waking, is in an abnormal and semipathological condition, and is therefore an exception to the rule and does not call for consideration here.

² *Deutsches Archiv f. klin. Medizin*, Bd. xxii.

attract attention to itself is a fact that has not escaped the notice of psychologists. Thus Dr. Stout writes: "Dead silence and monotony of colour in the environment are in my own case very unfavourable conditions [for mental work]. The sound of running water, a well-lighted room, a variety of objects in it, an open window with a pleasing prospect are very favourable conditions, even though I take no notice of them."¹ And the favourable effect of gentle muscular exercise, such as walking, has been frequently remarked.

But the most valuable evidence in support of the view I am suggesting is afforded by certain experiments made by Dr. C. Féré. In an article in the *Revue Philosophique*² he reports experiments which prove that the energy of a movement of reaction to a sensory stimulus of given strength is considerably increased by the simultaneous stimulation of other sense organs, e.g., a reaction to a touch-stimulus may be made more energetic, and the time of the reaction may be shortened, by allowing light to fall on the retinae, and "conversely, the taking away of all light determines in perfectly normal subjects a prolongation of the time of reaction, which may exceed one-fourth or even one-third of the normal time." And he shows that similar effects can be produced by heat, sound and electrical stimuli. Féré shows also that a general state of tension of all the muscles of the body favours rapid and energetic movement of any one set of muscles, that, e.g., the time of a certain reaction is shorter when the subject stands than when he reclines during the experiment.

In his book *Sensation et Mouvement*³ Féré reports other observations which bear out this view. He shows (p. 7) that the converse of the above statements is true, that not only is a state of general muscular tension favourable to mental activity, but mental activity is favourable to muscular work, that the force of a maximal voluntary contraction measured by the dynamometer may be increased by as much as 25 per cent. through immediately preceding intellectual activity. On comparing the maximal muscular efforts that persons of different classes are capable of putting forth, he finds that persons accustomed to intellectual work can produce momentary contractions of greater force than can be produced by manual labourers, and he sums up the result of his observations of this kind in the statement that "the force of the maximal momentary contraction varies with the

¹ *Analytic Psychology*, vol. i., p. 172.

² Oct., 1890.

³ Paris, 1900.

degree of habitual exercise of the intellectual functions" (p. 5).

Féré shows also that active or passive movements of one limb, continued for some few seconds, result in an increase of the force of the maximal contraction of which the other limbs are capable by as much as 20 per cent. or more (p. 8); and that even the movements of speech may produce a similar effect. "When a limb is put into action, the movement, be it voluntary or passive, determines upon the cerebral motor centres of the limb an exciting action that extends itself to the neighbouring centres" (p. 12). M. Pitres is quoted as having shown that every destructive lesion of the motor region produces a muscular enfeeblement of all four limbs, and Dr. Féré asserts that in his experience "the destruction of any cerebral centre whatever produces in general a certain degree of intellectual enfeeblement" (p. 13). On page 25 we read: "All these observations taken together show us that a cerebral centre, each time that it becomes active, provokes, by a process not yet understood, an excitation of the whole organism". Féré then goes on to confirm these conclusions by a series of experiments on hysterical and hypnotised subjects in whom corresponding effects are still more markedly displayed; and he shows that stimuli applied to internal organs produce similar results, and he sums up thus (p. 53): "One may say then that every peripheral excitation determines an augmentation of potential energy," and again, "*les excitations périphériques déterminent une augmentation de l'énergie disponible, de la force utilisable*" (p. 60).

I have quoted thus extensively these observations and conclusions of Dr. Féré because they justify in the fullest manner, and indeed, not only justify, but imperatively demand that we entertain, some such conception as I am here suggesting, namely, the conception of the interconnected mass of the afferent neurones as forming a reservoir of energy to which all the afferent nerves contribute in proportion to the degree to which they are stimulated to activity, and on which all efferent channels draw when thrown into activity.¹ To put the whole matter concisely as I conceive it and in the terms I propose: The neurones of the afferent side of the nervous system constitute a common reservoir of neurin, and a variable head of pressure is kept up in it by the

¹ The cerebellum which seems to consist chiefly of a mass of neurones forming relays upon sensory paths leading to the cerebrum must be regarded as constituting a principal part of the reservoir, and it is in fact frequently spoken of by physiologists as a store-house of energy.

liberation of neurin in these neurones, a liberation which perhaps never altogether ceases in any part, but which is much accelerated in any groups of which the peripheral ends are in any way stimulated; and the pressure is high when large groups are subject to stimulation, low when peripheral stimuli are few and feeble. From this reservoir neurin escapes continually into efferent tracts by channels which vary from moment to moment of waking life, channels which form therefore an ever-changing tridimensional neuergic pattern.¹ And these channels are so organised and interconnected to form systems and subsystems that, when during the activity of any partial system, a rise of pressure of neurin in the reservoir is brought about in any way, this increase of pressure leads, not to an opening of other independent channels, but rather to a spreading of the excitement through other parts of the system already partially active.

This mode of spreading of the excitation-process is seen in its simplest form in the spinal cord after ablation of the brain. A gentle stimulus will cause a reflex contraction of a small group of muscles, and increase of the strength of the stimulus applied to the same nerve endings will then cause other groups of muscles to contract, the movements determined being, not irregular and haphazard, but co-ordinated and, in some degree at least, purposeful, i.e., adapted to the carrying out of some definite act such as walking or swimming, and this is true "even when the stimulus, instead of being restricted to a narrow sensory area or path, affects simultaneously large surfaces or wide channels".² The transition from sleep to waking brought about by the repetition of an auditory stimulus, as we have traced it above, is but a more complicated example of this spreading of the excitation-process through organised systems of neurones, the stimulus being in this case largely re-enforced and complicated by the internal stimuli arising in the viscera and skeletal muscles, and in this case the spreading involves conduction-paths, not only of level i. to which it is confined in the isolated spinal cord, but ultimately of all levels up to the highest.

This view of the mode of functioning of the brain is fully in harmony with that view of the functions of the spinal cord to which physiologists have been led by the rapid growth

¹ I adopt the phrase 'neuergic pattern' suggested by Mr. H. R. Marshall in his article in No. 44 of this journal.

² Schäfer's *Textbook of Physiology*, Prof. Sherrington's article 'The Spinal Cord,' pp. 848, 844.

of our knowledge of the facts in recent years. We can no longer regard the cord as consisting of 'centres,' i.e., of groups of nerve-cell-bodies that are the sole or principal storehouses of energy and the seats of its more or less spontaneous liberation and direction. We have rather to regard the cord as a complex interconnected system of nervous channels, every part of which is equally capable of setting free a certain amount of energy in response to stimulation and in proportion to the intensity of the stimuli, while the direction of the flow of the liberated energy is the function of the mode of interconnexion of the channels. The final step towards the adoption of this view has been rendered necessary by recent work of Prof. Verworn and his pupil, Dr. Baglioni.¹ It was formerly held that the spasms of the animal poisoned with strychnine afforded the most striking and unmistakable manifestation of the spontaneous liberation of energy in the 'motor centres' of the cord. These observers have shown however that even in the convulsions of the strychnine-poisoned animal the continued outflow of energy from the cord by the efferent nerves is dependent upon a continued influx by the afferent nerves, chiefly those of the 'muscular sense'.²

¹ *Engelmann's Archiv* for 1900 and supplementary volume of same year.

² Sir J. Burdon-Sanderson in a recent communication to the Physiological Society has questioned the validity of Verworn's and Baglioni's conclusion, showing that in the strychnine-poisoned animal a single stimulus may cause a series of about ten twitches of diminishing vigour, although all other afferent impulses be prevented from reaching the cord. It is not clear however that this constitutes an exception, it would seem rather to be an instance of multiple response to a single intense stimulus exactly parallel to the multiple response of the visual apparatus to a single intense stimulus which I have recently described (*Brain*, Winter, 1901, p. 603).