from observations on Jupiter's satellites, and the radius of the earth 6378·233 kilometres.

Again, the sun's parallax deduced from M. Cornu's values of the velocity of light in conjunction with the value of aberration is, with Bradley's estimate of 20″·25, 8″·882, and with Struve's, of 20″·445, 8″·798. These values of parallax compare favourably with determination by other methods, of which we give a few examples. The value given by the transits of Venus in 1761 and 1769 was 8″·5776 computed by Encke, but increased to 8″·891 by Mr. Stone on a redetermination. By the record of an observation of the occultation of $\psi_2$ Aquarii on October 1, 1672, M. Leverrier obtained 8″·866 ; by meridian observations of Mars at Greenwich in 1862, 8″·932 ; by the latitude of Venus obtained from transits of 1761 and 1769, combined with present latitudes, M. Leverrier finds 8″·853 ; from the discussion of meridional observations of Venus in an interval of 106 years 8″·859 ; by the opposition of Mars in 1860 by M. Liais 8″760 ; by opposition of Flora in 1873 by Prof. Galle 8″·873. Judging from these results the velocity of 186,638 miles per second is not very far from the mark, and the care in selection of methods and in computing results can scarcely be surpassed.

G. M. S.

## *EVOLUTION OF NERVES AND NERVO-SYSTEMS*[1]

NERVE-TISSUE universally consists of two elementary structures, viz., very minute nerve-cells and very minute nerve-fibres. The nerve-fibres proceed to and from the nerve-cells, thus serving to unite the cells with one another, and also with distant parts of the animal body. Moreover, nerve-cells and fibres, wherever we meet with them, present very much the same appearances. Here, for instance, is a sketch of highly magnified nerve-tissue as we find it in the human brain, and here is one of my own drawings of nerve-tissue as I have found it in the jelly-fish ; and you see how similar the drawings are—notwithstanding they are taken from the extreme limits of the animal kingdom within which nerve-tissue is known to occur.

Nerve-cells are usually found collected together in aggregates which are called nerve-centres or ganglia, to and from which large bundles of nerve-fibres come and go. These large bundles of nerve-fibres are what we see with the naked eye as nerves, permeating the body in all directions. When such a bundle of nerve-fibres reaches a ganglion, or collection of nerve-cells, it splits up like the end of a rope which has been teased out, and the constituent fibres pass into and out of the nerve-cells, so interlacing with one another in all directions, as here diagrammatically represented. More true to nature is this diagram, which represents a magnified section of human brain—the human brain being itself nothing more than a collection of very large ganglia.

To explain the *function* of nerve-cells and nerve-fibres, I must begin by explaining what physiologists mean by the word "excitability." Suppose this to represent a muscle cut from the body of a freshly-killed animal. So long as you do not interfere with it in any way, so long will it remain quite passive. But every time you stimulate it either with a pinch, a burn, or, as represented in the diagram, with an electrical shock, the muscle will give a single contraction in response to every stimulation. Now it is this readiness of organic tissues to respond to a stimulus that physiologists designate by the term excitability.

Nerves, no less than muscles, present the property of being excitable. Suppose, for instance, that this is another muscle prepared in the same way as the last one, except that together with the muscle there is cut out the attached nerve. Every time you pinch, burn, or electrify any part of the nerve, the muscle will contract. But you will carefully observe there is this great difference between these two cases of response on the part of the muscle ; viz., that while in the former case the muscle responded to a stimulus *applied directly to its own substance*, in the latter case the muscle responded to a stimulus *applied at a distance from its own substance*, which stimulus was then *conducted* to the muscle by the nerve. And here we perceive the characteristic function of nerve-fibres, viz., that of conducting stimuli to a distance. This is the function of nerve-*fibres ;* but the function of nerve-*cells* is different, viz., that of accumulating nervous energy, and at fitting times of discharging this energy into the attached nerve-fibres. The nervous energy when thus discharged from the nerve-cells acts as a stimulus to the nerve-fibre ; so that if a muscle is attached to the end of the fibre it contracts on receiving this stimulus. I may add that when nerve-cells are collected into ganglia they often appear to discharge their energy spontaneously, without any observable stimulus to cause the discharge ; so that in all but the lowest animals, whenever we meet with apparently spontaneous action, we infer that ganglia are probably present. But the point which most of all I desire you to keep well in mind this evening is the distinction which I here draw between muscle and nerve. A stimulus applied to a nerveless muscle can only course through the muscle by giving rise to a visible wave of contraction, which spreads in all directions from the seat of stimulation as from a centre. A nerve, on the other hand, conducts the stimulus without undergoing any change of shape. Now in order not to forget this all-important distinction, I shall always to-night speak of muscle as conducting a visible wave of *contraction*, and of nerve as conducting an invisible or molecular wave of *stimulation*. Nerve-fibres, then, are functionally distinguished from muscle-fibres—and also, I may add, from protoplasm—by displaying the property of conducting invisible or molecular waves of stimulation from one part of an organism to another—so establishing physiological continuity between such parts *without the necessary passage of contractile waves*.

I will now conclude all that it is necessary to say about the function of nervous tissue by describing the mechanism of reflex action. Suppose this to represent any peripheral structure, such as a part of the skin of some animal, this a collection of nerve-cells or ganglion, and this a muscle. The part of the skin represented is united to the nerve-cells composing the ganglion by means of this in-coming nerve-trunk, while the nerve-cells in the ganglion are united to the muscle by means of this out-going nerve-trunk. Therefore when any stimulus falls on the skin where this in-coming nerve-trunk takes its origin, the nerve-trunk conveys the stimulus to the nerve-cells in the ganglion. When the nerve-cells receive the stimulus they liberate one of their characteristic discharges of nervous energy, which discharge then passes down this out-going nerve and so causes the muscle to contract. Now this particular kind of response is called response by reflex action, because the stimulus wave does not pass in a straight line from the seat of stimulation to the muscle, but passes in the first instance to the ganglion, and is from it *reflected* to the muscle. This, at first sight, appears to be a roundabout sort of a process, but in reality it is the most economic process available ; for we must remember the enormous number and complexity of the stimuli to which every animal is more or less exposed, and the consequent necessity that arises in the case of highly organised animals of there being some organised system whereby these stimuli shall be suitably responded to. Or, to adopt a happy illustration of Prof. Bain, the stimuli are systematised on the same principle as the circulation of letters by post is systematised ; for just as in the case of the letters there is no

[1] Abstract of a Lecture delivered at the Royal Institution on Friday evening, May 25, 1877. By George J. Romanes, M.A., F.L.S., &c.

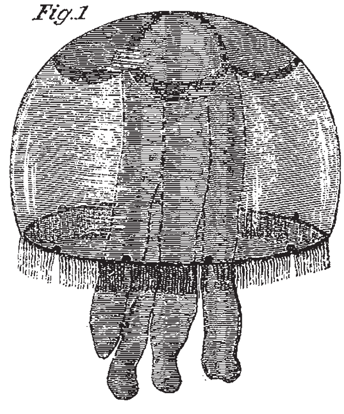
direct communication between one street and another, but every letter passes first to the central office; so the transmission of stimuli from one member of the body to another is effected exclusively through a centre or ganglion.

Those among you who are acquainted with Mr. Herbert Spencer's writings are doubtless well aware how strong a case he makes out in favour of his theory respecting the genesis of nerves. This theory, you will remember, is that which supposes incipient conductile tissues, or rudimentary nerve-fibres, to be differentiated from the surrounding contractile tissues, or homogeneous protoplasm, by a process of integration which is due simply to use. Thus, beginning with the case of undifferentiated protoplasm, Mr. Spencer starts from the fact that every portion of the colloidal mass is equally excitable and equally contractile. But soon after protoplasm begins to assume definite shapes, recognised by us as specific forms of life, some of its parts are habitually exposed to the action of forces different from those to which other of its parts are exposed. Consequently, as protoplasm continues to assume more and more varied forms, in some cases it must happen that parts thus peculiarly situated with reference to external forces will be more frequently stimulated to contract than are other parts of the mass. Now in such cases the relative frequency with which waves of stimulation radiate from the more exposed parts, will probably have the effect of creating a sort of polar arrangement of the protoplasmic molecules lying in the lines through which these waves pass, and for other reasons also will tend ever more and more to convert these lines into passages offering less and less resistance to the flow of such molecular waves—*i.e.*, waves of stimulation as distinguished from waves of contraction. And lastly, when lines offering a comparatively low resistance to the passage of molecular impulses have thus been organically established, they must then continue to grow more and more definite by constant use, until eventually they become the habitual channels of communication between the parts of the contractile mass through which they pass. Thus, for instance, if such a line has been established between the points A and B of a contractile mass of protoplasm, when a stimulus falls upon A a molecular wave of stimulation will course through that line to B, so causing the tissue at B to contract—and this even though no *contractile* wave has passed through the tissue from A to B. Such is a very meagre epitome of Mr. Spencer's theory, the most vivid conception of which may perhaps be conveyed in a few words by employing his own illustration—viz., that just as water continually widens and deepens the channels through which it flows, so molecular waves of the kind we are considering, by always flowing in the same tissue tracts, tend ever more and more to excavate for themselves functionally differentiated lines of passage. When such a line of passage becomes fully developed, it is a nerve-fibre, distinguishable as such by the histologist; but before it arrives at this its completed stage—*i.e.*, before it is observable as a distinct structure—Mr. Spencer calls it a "line of discharge."

Such being the theory, I will endeavour to show how it is substantiated by facts. And here it becomes necessary to refer to my own work. You are all, I suppose, acquainted with the general appearance of a Medusa, or jelly-fish. The animal presents the general form of a mushroom. The organ which occupies the same position as the stalk does in the mushroom is the mouth and stomach of the Medusa, and is called the polypite; while the organ which resembles in shape the dome of the mushroom constitutes the main bulk of the animal, and is called the swimming-bell. Both the polypite and the swimming-bell are almost entirely composed of a thick transparent and non-contractile jelly; but the whole surface of the polypite, and the whole *concave* surface of the bell, are overlaid by a thin layer or sheet of contractile tissue. This tissue is not exactly protoplasm and not exactly muscle, but something between the two. It constitutes the earliest appearance in the animal kingdom of anything resembling muscular tissue. The thickness of this continuous layer of incipient muscle is pretty uniform, and is nowhere greater than that of very thin paper. The margin of the bell supports a series of highly contractile tentacles, and also another series of bodies which are of great importance for us to-night. These are the so-called marginal bodies, which are here represented, but the structure of which I need not describe. Lastly, it may not be superfluous to add that all the Medusæ are locomotive. The mechanism of their locomotion is very simple, consisting merely of an alternate contraction and relaxation of the entire muscular sheet which lines the cavity of the bell. At each contraction of this muscular sheet, the gelatinous walls of the bell are drawn together; the capacity of the bell being thus diminished, water is ejected from the open mouth of the bell backwards, and the consequent reaction propels the animal forwards. In these swimming movements systole and diastole follow one another with as perfect a rhythm as they do in the beating of a heart.

The question as to whether the Medusæ possess a nervous system is a question which has long occupied the more or less arduous labours of many naturalists. Until

*Fig. 1*



lately, however, there has been so little certainty on the subject that Prof. Huxley—himself one of the greatest authorities on the group—thus defined the standing of the question in his "Classification of the Animal Kingdom:" "No nervous system has yet been discovered in any of these animals." The cause of this uncertainty is to be found in the fact that the transparent and deliquescent nature of the tissues of the Medusæ renders adequate microscopical observation in their case a matter of extreme difficulty; so much so that, looking to the quantity and quality of the labour which has been bestowed on the question, I doubt whether the latter would ever have been satisfactorily settled by the histological methods alone. But those of you who were present at my lecture last year will no doubt remember that by employing methods other than the histological, I was able to set this long-standing question finally at rest. For you will no doubt remember my having told you that on merely cutting off the extreme marginal rim of the bell I was surprised to find that the previously active motions of the animal suddenly and entirely ceased; the paralysis caused by this simple operation was instantaneous, enduring, and complete. On the other hand, you may remember, the severed margin which had just been taken from the swimming-bell invariably continued its rhythmical motions with a vigour and a pertinacity not in the least impaired by its severance from the main organism. For hours, and even for days after the operation, these motions persisted; so that the contrast between the death-like quiescence of the mutilated swimming-bell and the active contractions of the thread-like portion which had just been removed from its margin, was a contrast as striking as it is possible to conceive.

These experiments, then, conclusively proved that in the marginal rim of the Medusæ there is situated an intensely localised system of nervous centres, or ganglia, to the functional activity of which the rhythmical motions of the swimming-bell are exclusively due.

(*To be continued.*)

## *ON ELEMENTARY INSTRUCTION IN PHYSIOLOGY*[1]

THE chief ground upon which I venture to recommend that the teaching of elementary physiology should form an essential part of any organised course of instruction in matters pertaining to domestic economy, is that a knowledge of even the elements of this subject supplies those conceptions of the constitution and mode of action of the living body and of the nature of health and disease, which prepare the mind to receive instruction from sanitary science.

It is, I think, eminently desirable that the hygienist and the physician should find something in the public mind to which they can appeal; some little stock of universally acknowledged truths, which may serve as a foundation for their warnings, and predispose towards an intelligent obedience to their recommendations.

Listening to ordinary talk about health, disease, and death, one is often led to entertain a doubt whether the speakers believe that the course of natural causation runs as smoothly in the human body as elsewhere. Indications are too often obvious of a strong, though perhaps an unavowed and half unconscious, undercurrent of opinion that the phenomena of life are not only widely different in their superficial characters and in their practical importance, from other natural events; but that they do not follow in that definite order which characterises the succession of all other occurrences, and the statement of which we call a law of nature.

Hence, I think, arises the want of heartiness of belief in the value of knowledge respecting the laws of health and disease, and of the foresight and care to which knowledge is the essential preliminary, which is so often noticeable; and a corresponding laxity and carelessness in practice, the results of which are too frequently lamentable.

It is said that, among the many religious sects of Russia, there is one which holds that all disease is brought about by the direct and special interference of the Deity, and which, therefore, looks with repugnance upon both preventive and curative measures, as alike blasphemous interferences with the will of God. Among ourselves, the "Peculiar People" are, I believe, the only persons who hold the like doctrine in its integrity, and carry it out with logical rigour. But many of us are old enough to recollect that the administration of chloroform in assuagement of the pangs of childbirth was, at its introduction, strenuously resisted upon similar grounds.

I am not sure that the feeling, of which the doctrine to which I have referred is the full expression, does not lie at the bottom of the minds of a great many people who would yet vigorously object to give a verbal assent to the doctrine itself. However this may be, the main point is that sufficient knowledge has now been acquired of vital phenomena to justify the assertion that the notion that there is anything exceptional about these phenomena receives not a particle of support from any known fact. On the contrary, there is a vast and an increasing mass of evidence that birth and death, health and disease, are as much parts of the ordinary stream of events as the rising and setting of the sun, or the changes of the moon; and that the living body is a mechanism the proper working of which we term health; its disturbance, disease; its stoppage, death. The activity of this mechanism is dependent upon many and complicated conditions, some of which are hopelessly beyond our control, while others are readily accessible and are capable of being indefinitely modified by our own actions. The business of the hygienist and of the physician is to know the range of these modifiable conditions, and how to influence them towards the maintenance of health and the prolongation of life; the business of the general public is to give an intelligent assent and a ready obedience based upon that assent, to the rules laid down for their guidance by such experts. But an intelligent assent is an assent based upon knowledge, and the knowledge which is here in question means an acquaintance with the elements of physiology.

It is not difficult to acquire such knowledge. What is true, to a certain extent, of all the physical sciences, is eminently characteristic of physiology—the difficulty of the subject begins beyond the stage of elementary knowledge, and increases with every stage of progress. While the most highly trained and best furnished intellect may find all its resources insufficient when it strives to reach the heights and penetrate into the depths of the problems of physiology, the elementary and fundamental truths can be made clear to a child.

No one can have any difficulty in comprehending the mechanism of circulation or respiration, or the general mode of operation of the organ of vision; though the unravelling of all the minutiæ of these processes may, for the present, baffle the conjoined attacks of the most accomplished physicists, chemists, and mathematicians. To know the anatomy of the human body, with even an approximation to thoroughness, is the work of a life, but as much as is needed for a sound comprehension of elementary physiological truths may be learned in a week.

A knowledge of the elements of physiology is not only easy of acquirement, but it may be made a real and practical acquaintance with the facts, as far as it goes. The subject of study is always at hand in oneself. The principal constituents of the skeleton, and the changes of form of contracting muscles, may be felt through one's own skin. The beating of one's heart, and its connection with the pulse may be noted; the influence of the valves of one's own veins may be shown; the movements of respiration may be observed; while the wonderful phenomena of sensation afford an endless field for curious and interesting self-study. The prick of a needle will yield, in a drop of one's own blood, material for microscopic observation of phenomena which lie at the foundation of all biological conceptions; and a cold, with its concomitant coughing and sneezing, may prove the sweet uses of adversity by helping one to a clear conception of what is meant by "reflex action."

Of course, there is a limit to this physiological self-examination. But there is so close a solidarity between ourselves and our poor relations of the animal world, that our inaccessible inward parts may be supplemented by theirs. A comparative anatomist knows that a sheep's heart and lungs, or eye, must not be confounded with those of a man; but so far as the comprehension of the elementary facts of the physiology of circulation and of respiration and of vision goes, the one furnishes the needful anatomical data as well as the other.

Thus, it is quite possible to give instruction in elementary physiology in such a manner as not only to confer knowledge, which, for the reason I have mentioned, is useful in itself; but to serve the purposes of a training in accurate observation, and in the methods of reasoning of physical science. But that is an advantage which I

[1] A paper read at the Domestic Economy Congress, by Prof. Huxley, F.R.S.