citation. If the site of accumulation of ions responsible for the central excitatory state were the diffuse peripheral boundary of the nerve cell, which is inherent in their interpretation, I find it very difficult to understand how it is possible for an excitatory impulse reaching the cell at one point to summate with a similar impulse reaching the cell at a distant point; unless there is some special process of local conduction along the surface of the cell, this would be virtually impossible. If, on the other hand, one assumes a site of accumulation of ions common to impulses reaching the cell from every point and that all influence impinges ultimately at this point, the difficulties are minimized. I would urge further that the sharply circumscribed characteristics of refractory period, rate of discharge, etc., presupposes a discrete controlling center within the cell. However, the allocation of the central excitatory state to the region of the synapse has the logical advantage of placing it at the surface of the cell along which conduction is believed to occur. In offering an alternative interpretation, I do so, fully recognizing the inherent objections facing any theory of central excitation at the present time.

CONCLUSION

Single motor units, *i.e.*, anterior horn cells plus the muscle fibers they innervate, have recently been placed under direct observation while responding to a normal reflex stimulus. Details such as the normal rate of discharge, latent period, refractory period, influence of fatigue, etc., have been carefully studied. The work of Denny-Brown, Adrian and Bronk, Eccles and Sherrington have all indicated that the natural rate of discharge of the anterior horn cell is slow, *i.e.*, 5 to 25 per sec., and never more than 80 to 90 per sec. under intense stimulation. A motor unit discharging at 10 per sec. may continue in activity for indefinite periods of time without fatigue. Tonic responses are maintained by such rates of discharge and therefore no special tonic mechanisms need be postulated to explain the absence of fatigue.

An individual anterior horn cell may, through peripheral bifurcation of its axon, command 150 or more muscle fibers, and it may, in consequence, develop during natural tetanus, a tension of 20 to 30 gms (*e.g.*, units of gastrocnemius medialis). In soleus, a red "postural" muscle,[20] the ratio of nerve to muscle fibers is 1 to 120 and the average tension value of the unit 10 gms. Direct observations of the tension developed by single units confirm the values obtained through anatomical averages.

The neurone has a refractory period of 10 to 15σ, which accounts for its normal slow rate of discharge. When an axon is stimulated antidromically[14] the neurone becomes similarly refractory for a period of about 10.5σ and all evidence of a central excitatory state is removed by such a stimulus. The central excitatory state has many properties in common with the local excitatory process.

A RECENT DRIFT IN BIOLOGICAL THOUGHT[1]

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AT the close of the nineteenth century mechanism prevailed. The heavens no longer declared the glory of God but rather the marvelous phenomena that had accidentally transpired within the cosmic test-tube. Even the mind of man was but an epiphenomenon. It was the rattle of machinery. William Keith Brooks, in reaction to this mechanism, was frequently heard to remark, "Yes, my mind may be but the rattle of machinery, but what perplexes me is who hears the rattle?"

To modern physicists, the mechanism that prevailed three decades ago no longer appears to be satisfactory. Millikan closed his presidential address at Cleveland, last December, with the question "Has not modern physics thrown mechanism, root and branch, from its house?" and Jeans has placed a Creator back upon the throne. He says: "Everything points with overwhelming force to a definite event, or series of events of creation. . . . The universe can not have originated by chance out of its present ingredients."

Modern biologists are yet striving to reduce vital phenomena to mechanical terms. Surface phenomena, colloidal phases and molecular changes are invoked, and that properly so, to explain these phenomena. But we must keep in mind that vital phenomena carry us beyond the ponderable. So our scientific efforts will not suffice when we come to consider all that life displays. Even an ameba carries us beyond the realm of science. Men have sought to explain the movement of this unicellular animal as the result of surface tension disturbances, of changes in colloidal states or of molecular changes. An

[1] Address delivered at the Virginia Academy of Science, April 24, 1931.

[20] D. E. Denny-Brown, "The Histological Features of Striped Muscle in Relation to its Functional Activity," *Proc.* Roy. Soc., B/104: 371–411, 1929.

analogy is seen between an ameba's rejection or ingestion of food and the rejection or acceptance of a glass filament by a drop of chloroform. If the filament be naked the filament will be rejected, but if it be coated with shellac it will be taken into the drop of chloroform in a manner that suggests an ameba's ingesting an algal filament. The movement of an ameba and the factors determining whether food and non-food be accepted or rejected are all proper subjects for scientific investigation. Some day I expect these phenomena to be reduced to physical and chemical terms. Science has not yet explained the manner in which the muscles of man contract. I expect that the contraction of the muscles of man will be reduced to physical and chemical terms in time. Both the ameba and man, however, carry one beyond the limitations of science in their respective activities. When a man seeks to lay hold of a non-motile object he approaches it directly. A man seeking to lift a fountain pen, for example, does so directly. When, however, he attempts to lay hold of an animal that may escape, his approach is indirect and he endeavors to meet the contingency of escape. The ability of man to so move in order that he may meet the contingency of escape on the part of an animal is fraught with the idea of teleology or purpose. Science, as such, can not deal with teleology and purpose, but biology may have to do so.

With the aid of my students I have been able to observe that an ameba is very much like man in this respect. Ameba's food-reactions fall into two categories. When an ameba encounters a food-object—plant or animal—that is non-motile its reaction is direct. It intimately surrounds the object. When, however, a motile object of prey is encountered, the reaction may be quite varied and is always indirect. If, for example, the ameba encounters a quiet chilomonas or paramecium it will surround it with a wide embrace and cut off all lines of escape before the prey is disturbed. So varied and so frequent have been the reactions of this type that we have observed in our laboratory, that I am prepared to make the significant statement that the unicellular animal, *Amoeba proteus,* meets contingencies. This fact carries us beyond science, whether we like it or not.

These observations stand in contrast to the observations of a southern anatomist, who was in the habit of telling his auditors that he had dissected many human bodies and had never found a soul. Over against this I may remark that I have studied many amebas and have never failed to find more in them than that that occupied space, namely, the ability to meet contingencies.

All living things present this apparent teleology. It is because of this that biologists must so frequently use the phrase "in order that." Physicists and chemists can get along with the phrase "as a result of."

The physicists tell us that sand collects in an eddy as a result of the forces that are playing upon it; but a biologist sees that a shelled ameba (*Difflugia*) collects sand in order that its child may have microscopic stones with which to build its house.

Sticks and straws drift before the wind as a result of the energy exerted by the currents of air; but a robin collects sticks and straws in order that it may establish a home for its nestlings.

The moon shines as a result of the sun's light being reflected; but youths go out into the moonshine in order that ————!

All this implies a teleology or a purposiveness that even the mechanists can not get away from; for examine the biological writings of the most ardent mechanist and see how frequently one encounters the phrase "in order that" and how earnestly he writes in order that he may carry conviction.

But I shall not be content with citing the fact that a subtle teleology creeps into the writings and efforts of biologists who would avoid it. I have made some very significant observations, in this respect, upon a small turbellarian worm known as microstomum. It has been found that this animal eats hydrae primarily for the "stingers" (nematocysts) of the latter. A microstomum lacking "stingers" readily eats hydrae. Microstoma loaded with "stingers" will only with difficulty be made to eat hydrae. In this case, however, the "stingers" will be regurgitated. It has been demonstrated that the "stingers" of hydrae are actually used by the microstomum that had appropriated them. Perhaps the most significant feature of microstomum's ability to handle the "stingers" of hydrae is that it persists. Microstoma have been reared 22 asexual generations away from hydrae. Had all the individuals of these 22 generations been kept there would have been a population of 2,096,752 individuals. Only one of these potential animals was chosen for observation. This one had now been removed by 21 generations from experience with hydrae and its "stingers." And yet it ate a hydra and appropriated its nematocysts. Another line was maintained away from hydrae for 16 generations. Had all the individuals of these 16 generations been kept, there would have resulted a population of 32,768 individuals. One of this potential population was selected for experimentation. Its middle third was cut out and cared for. The anterior and posterior thirds were rejected. In time, the middle third had developed a new head and a complete body. The resulting animal thus had a new central nervous system and had been removed from experience with hydrae by 15 generations. And yet it accepted a hydra and appropriated the nematocysts or "stingers."

This research has convinced me that life persists and is purposive.

Were I to have made this claim fifteen years ago, I should have had difficulty finding support in biological literature.

But times have changed. There appears to be a drift away from mechanism in modern biological thought. Haldane gives "freedom of the will" as one of four factors of evolution. Jennings says, "Emergent evolution does away with that monstrous absurdity that has so long been a reproach to biological science; the doctrine that ideas, ideals, purposes have no effect on behavior." Wells, Huxley and Wells, in "The Science of Life," record that, "Human purpose is one of the achievements of evolution" and that "Modern biology is steadily moving towards the conception of a single world-stuff with both material and mental aspects."

In modern biological thought, therefore, purposiveness is coming to be recognized. Mind is no longer the clatter of machinery but an entity placed upon a par with matter. Less is heard these days of the cerebral cells secreting thoughts as the liver secretes bile than was the case twenty years ago. Biologists may come to realize that mind (life) is an entity with which they must deal as do physicists and chemists deal with matter. They may come to agree with Jeans when he says, "To-day there is a wide measure of agreement, approaching almost to unanimity, that the stream of knowledge is leading towards a non-mechanical reality; the universe begins to look more like a great thought than like a great machine."

The cosmic test-tube of the mechanists seems to have boiled over, and we find the purposiveness of Aristotle threatening to displace the mechanist's idea of chance survival.

SCIENTIFIC EVENTS

THE BRITISH NON-FERROUS METALS RESEARCH ASSOCIATION

LORD RUTHERFORD opened the new headquarters of the British Non-Ferrous Metals Research Association in London on June 8, near Euston Station. The building provides space for the collection of machinery to assist the staff in carrying out its work. The following summary of his address is given in the London *Times:*

The quantity and quality of the work of the association in the past ten years, Lord Rutherford said, were surprising when the early difficulties of the organization were considered. It seemed to him that in future they must divide the work of the association under three categories: (1) *ad hoc* researches or special investigations bearing on the difficulties of the industry at a particular moment, which might help to improve a product or get over some technical difficulty; (2) long-range fundamental research bearing on matters that lay at the foundation of the industry; and (3), finally, the steady accumulation of knowledge that would lead to the creation of new industries or the development of existing ones. An association of that kind could not take short views.

Referring to the need for close liaison between scientific men and industrialists, Lord Rutherford noted how much had been done by the association to simplify the results achieved by research to the industrial mind. He regarded this as an important matter, because it restricted the inevitable time lag that occurred between scientific discovery and its use in industry. In estimating the results of scientific research there was always a danger of taking too narrow a view of the work. They could not expect in research work a certain definite return every month. One of the marvels of the age was the development of the motor-car since 1900, on which tens of thousands of men were engaged to-day and for which special steels, special alloys and many other materials were required, each of them representing a great deal of research work. Of the 60 or 70 metals available for research only six or seven had been investigated by the association. What about the other 60? It was obvious that an enormous amount of work remained to be done.

There was probably not a single process that was going on in the industrial world that would not be capable of improvement if it were studied scientifically. He was quite sure that 90 per cent. of the processes used in industry could be improved by the application of science. In the new building there would be no lack of work in research for years to come, even if they multiplied the staff 10 to 20 times. The future of the metal industry, as of many others, was ultimately dependent on the application of science to industry. He thought that in the years to come only those industries would survive in the world which had shown their power of applying scientific knowledge to improve their methods of production.

RESEARCH RESERVES IN THE NATIONAL PARKS

A DEFINITE policy of preserving research reserves inside national park areas has been adopted by the National Park Service. The national parks themselves are areas preserved in as nearly as possible