order to secure harmonious relation and cooperation between the sections and the societies the sections of the association are expected to suspend their technical programs when the corresponding societies meet in conjunction. Joint programs are frequent and very desirable.

If a biologic simile is permissible, it may be said that the association attained reproductive maturity at the age of 50 (1888), and gave birth to numerous progeny. But this fertility has not produced exhaustion and dissolution, for the association is vastly larger, stronger and more active and influential in later years. Perhaps some of the lusty offshoots are not always as deferential to their aged and honored parent as filial duty would imply; but as a whole the great family is quite harmonious.

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(*To be continued*)

THE THEORY OF NERVOUS ACTIVITY[1]

IT is my intention to present to you the result of work carried out in my institute dealing with the ionic theory of stimulation.

Every mathematical theory is important for science in so far as it is capable of correlating in a quantitative way a series of natural phenomena and in so far as it permits the predicting of existence of phenomena not yet observed. The latter requirement constitutes the test of a theory, and if the predictions are realized through experiments, then the correctness of the theory is established. From this viewpoint, the theory appears as a guide to the investigator and opens up to him new avenues for quantitative experimentation.

The ionic theory developed by us stood the mentioned test, and I should like to present in a simple form the physico-chemical facts, omitting all mathematical development. For lack of time, it is not possible to present all our investigations into the mode of action of all sense organs and, therefore, I shall present as an example that part of the work which has attained its fullest development, namely, that dealing with peripheral colorless vision (when color is not differentiated). In this field the predictions of the theory were most interesting. The theory developed by us is based on two observations made about 20 years ago, one by Jacques Loeb and the other by Nernst. Starting from entirely different premises, they arrived at a conclusion that in the nerve and in the muscle the change from the state of rest to that of excitation is brought about by changes in the ionic concentration of the medium.

These observations were made the basis of our investigation into the general principles of the theory of excitation. We were then able to demonstrate that in all organs, under all conditions, excitation is possible only as a consequence of changes in ionic concentration of the medium. Whenever these changes are not present, excitation is not possible.

Bearing in mind these conclusions, and adding only one assumption, namely, that in the tissues the concentration of ions is small, we formulated a general law of excitation for the threshold of irritability—a law which served as a generalization of the laws presented by Loeb and by Nernst. Calculating in every case the possible changes in ionic concentration, we were able to explain the laws of Pflüger, to develop further a theory of nervous excitation, to formulate a theory of muscular excitation, a theory of vision, a theory of hearing and of taste, and very recently, it was possible to go further and to develop laws of the function of the central nervous system (of the brain).

Passing to the question with which we are principally concerned to-day, namely, the question of the ionic theory of vision, I should like to point out that we shall discuss principally the problem of peripheral vision when the function is limited only to the rods in which the decomposition of the pigment takes place.

We can imagine the process in the following way. Decomposition of the pigment takes place in the rods. This is a purely physico-chemical reaction, which results in ionization. The ionized substances are removed partly through diffusion and partly through chemical reactions which are followed by restitution of the pigment. This restitution should proceed with different velocity, depending upon the presence or absence of light. In order to coordinate all these conditions in mathematical terms, it was necessary, first of all, to explain the connection existing between the velocity of the chemical reactions, the coefficient of absorption of light, the concentration of substances and the intensity of light. This was done by us in a series of investigations and it was demonstrated in 1907 that the photochemical effect does not depend on the wave lengths but is proportional to the quantity of the absorbed energy. The experiments showed also that in photochemical reactions the ionization is in direct proportion to the quantity of decomposed material. This applies alike to solid and liquid substances. Thus, it was realized that the visual pigment, in the process of decomposition, causes stimulation of the nerve endings and consequently creates excitation. If all these considerations are expressed mathematically and if a few very simple mathematical operations are performed, then, at a given time, t,

[1] Read at the Cincinnati meeting of the Zoological Society in conjunction with Section F of the American Association for the Advancement of Science and in association with other biological societies on December 28, 1923.

the concentration of products of photochemical reaction in the pigment C_1, depending on the action of light, is shown by the following expression:

$$C_1 = \frac{\alpha kJC}{\alpha kJ + \beta}\left[1 - e^{-(\alpha kJ + \beta)t}\right]$$

C stands for the concentration of the pigment.
α and β are constants.
k = coefficient of absorption.
J = intensity of light.

The general law of excitation postulates for vision that the quantity of decomposition products C_1 (ions) must exceed a certain limit "A," in order that excitation may take place.

The simplest deduction, then, was that when the quantity of energy absorbed by the layer of pigment in the retina was the same for different colors, then the intensity of light at peripheral vision was constant. This deduction and all subsequent deductions were completely verified by the experiments.

In order to show the limit of possible deviations from the theory, I shall take the case of intermittent light with such a number of interruptions that the light just begins to appear continuous. According to the theory, the number of interruptions N must be connected with the values mentioned above in the following way:

$$\frac{(N - N_0) \cdot \sqrt{4\pi^2N^2 + \beta^2}}{\alpha kJ} = B = \text{Const.}$$

N_0 is a constant.

The results of the experiments vary between 0.42 and 0.43.

It is known by experience that the eye, exposed for a long time to light and transferred into darkness, does not at once distinguish objects and that the sensibility increases gradually and finally the eye is capable of seeing. It follows from the theory that these changes may depend upon the variations in the concentration of the visual pigment in the eye. Assuming that the reaction of restitution of pigment in darkness possesses the simplest character, namely, that a single molecule of the decomposition product is reconverted into a single molecule of the pigment, then the sensitiveness of the eye E at different intervals in darkness may be expressed by the following formula:

$$E = E_0 - E_0' e^{-\gamma t} \qquad (I)$$

E_0 and γ are constants.

E_0' depends upon the intensity of the acting light and at infinitely high intensity $E_0' = E_0$.

At the intensity equal to 0^0, $E_0' = 0$.

This conclusion was reached in 1914.

The experimental data existing in the literature showed discrepancies from the theory. Assuming that all variations in sensibility, according to our theory, depended on variations in the quantity of pigment in the membrane, it followed that the discrepancies between experiment and theory were due to the fact that variations in the sensitiveness of the brain centers were not taken into consideration and that the fatigability of the centers was not considered. This explanation was offered by Froelich. However, another explanation is possible, namely, that the older experiments were not carried out with sufficient care. This explanation was advanced by us in our first paper dealing with the problem of adaptation. The last three years were devoted by us to testing this assumption.

If you will take into consideration that every observation reported is the average of hundreds and that there were required a great number of single observations with varying time of adaptation and a great many individuals were studied for each experiment, then you will understand that there were made more than several thousand single observations in order to arrive at one formula. The formula (I) proved correct and hence it is possible to explain the discrepancies of the older observations.

From the present theory there follows what seems a paradoxical conclusion—that in fatigue, with the change of sensitiveness of the organ of vision, the brain centers are not fatigued. Because of the importance of this conclusion for physiology, it was tested directly. As soon as the eye adapted itself to darkness, it was subjected to electrical stimulation acting directly on the nerve. It was then found that when exposed to light the organ of sight showed a different sensitiveness to stimulation by light than it did when left in darkness and that the sensitiveness could undergo thousandfold variations. On the other hand, the sensitiveness to electric stimulation remained the same in both cases. From this observation the conclusion naturally follows of the indefatigability of the brain centers.

If all which was said is correct, and applicable to all nerve centers, we may conclude that in the absence of stimulation, the organism will not fatigue. Experiments carried out under special conditions demonstrated that the nervous system is preserved from fatigue for extended intervals if the periphery of the retina only is stimulated and if all other irritations are avoided. In our institute, when the experiments on adaptation lasted from 12 to 24 hours, individuals did not experience the least fatigue, as if unconscious of the flight of time. At first it might seem that if all external irritation were removed, the organism would not fatigue at all. However, under such conditions, the periphery would convey to the centers no impulses at all and the activity of the centers would be suppressed and the organism would lapse automatically into a condition approaching sleep. Experiments have confirmed this conclusion, also. It is interesting that this indefatigability of the nerve centers must be in close connection with the periodicity of the function of the centers. According to our observations and to those of other workers, periodic chemical reactions must take place in these centers. These reactions in their turn bring about periodic electromotive forces.

This parallelism between indefatigability and periodicity of function is best illustrated on the heart and on respiration.

The entire theory is based on the premise that the difference in the intensity of perception, in general, depends on the difference in the ionic concentration in the retina. Here arises a contradiction with the basic physiological conceptions.

If the intensity in stimulation and the magnitude of excitation depends upon the concentration of the ions in the retina, then the nerves ought to be in a different state of excitation depending on the ionic concentration. On the other hand, we know that the nerve may be either in a state of excitation or non-excitation. Consequently, the state of excitation of a nerve can not be of varying degrees. The explanation of the seeming contradiction is very simple. It is necessary to bear in mind that the retina consist of individual cells and that light, on the other hand, according to the present conception of the physicist, possesses a corpuscular structure and that there exists, as it were, a number of small balls, each carrying a definite quantum of energy on striking the retina. The number of these balls, quanta of energy, gives us the perception of the intensity of light. Consequently, the number of stimulated rods and the number of stimulated nerve fibers determine the sensation of intensity of light. From this it follows that when the number of the stimulated units is identical, the intensity of perception will always be constant. Also, if the same number of stimulated units will be situated, on either a small or a large surface of the retina, the effect will remain the same. All these conclusions were corroborated. You see that the present theory not only gave a quantitative coordination of the facts already known, but also was instrumental in the discovery of new facts. This is all that a physico-chemical theory is expected to accomplish.

P. LASAREFF

PLANS FOR THE ENLARGEMENT OF THE MARINE BIOLOGICAL LABORATORY

IN response to the request of the editor the following statement is made:

The enlargement of the facilities and endowment of the Marine Biological Laboratory is a matter of interest to the scientific public in a special sense, because its ownership and control are vested in the biologists of the country in precisely the same sense as their national biological societies. For this reason, also, the development of the laboratory is a matter of interest to all institutions engaged in biological research; the facilities of the laboratory are at their service and constitute an enlargement of their own laboratories and equipment. The Marine Biological Laboratory thus helps towards raising the research opportunities of the smaller institutions more nearly to the level of the larger and better equipped ones. Through its system of subscribing and cooperating institutions the laboratory provides for a nominal sum research opportunities that would cost each institution many times the amount to provide independently. This is important even for the largest institutions, and indispensable for all the smaller institutions that aim to maintain the research spirit of members of their staffs.

Up to the present year the Marine Biological Laboratory has been supported by fees for working places, by sales of biological supplies, certain minor sources of income, and by a contribution of $20,000 a year from the Friendship Fund endowed by Mr. C. R. Crane, president of the board of trustees of the laboratory. For about five years the demands for accommodations have far exceeded the capacity of the laboratory. Plans for enlargement have been in preparation all this time, and, indeed, for a longer period.

At the beginning of this year the laboratory received direct gifts amounting to $1,400,000 (from the Rockefeller Foundation $500,000, Mr. John D. Rockefeller, Jr., $400,000, The Friendship Fund $400,000, and the Carnegie Corporation $100,000), and an undertaking from another source to furnish additional sums needed to cover the increased cost of building arising since the original plans were prepared. Of the direct gifts, $900,000 has been placed in trust as endowment, the balance being available for building. The receipt of these gifts was due to the hearty cooperation of scientific men supported by the recommendations of the National Research Council.

The greatest needs foreseen by the management of the laboratory, apart from mere expansion, were the increase of facilities for all the more delicate and precise forms of biological experiment, comprised largely in the fields of biochemistry and biophysics, and for enlargement of the library. Advantage was also taken of the situation to provide an adequate auditorium for the evening lectures on research topics that have been a conspicuous feature of the summer session for many years.