17 on structural features is also valuable. Mine waters also receive better treatment than they often do. But in his argument for the importance of ascending juvenile thermal waters one might have hoped to see a comparison of the analyses of waters with those which would be obtained from the connate or meteoric waters stimulated in circulation by hot intrusives. There is a lot of sodium carbonate and sulphate in the mine waters of many regions where "alkali" is also characteristic of the surface waters, while the mine waters of other districts are quite different. It may well be that we have a mixture of waters from more than one source, and while the author rightly attributes to precipitation by mixture of solutions an importance which is often overlooked, yet it may have even greater importance.

The range of reference is rather narrow, mainly, though by no means exclusively, to the western United States. In that respect both of the other books are superior. For instance in discussion of the class of zeolitic native copper deposits no reference is made to the work of Weed and Lewis on those of New Jersey, and one might think that Keweenaw Point was unique, except for a footnote reference to White River, Alaska. With regard to the Keweenawan deposits there are a number of minor slips (p. 397). Copper veins are still of considerable importance at the Ahmeek and adjacent mines, nor was the copper obtained from veins formerly, nor at present, wholly or mainly sulphide. It is usually native, sometimes the basic arsenide, and even in the Nonesuch lode one would hardly say that the ore was "chiefly" chalcocite. The Nonesuch mine saved only the native copper. It is noteworthy that there is no such systematic attempt to present diverging points of view fairly as is made by Ries. Compare for instance the treatment of oolitic iron ores in each. This is probably due to the origin of the book as a course of lectures. So, too, while Lawson is referred to, as to his western work, no reference is made to his Lake Superior work. Neither is Allen's declaration that the Animakie is middle Huronian considered. The Keweenawan is classed without a question as pre-Cambrian.

After the extensive treatment of ore deposits, iron, copper, gold, silver, zinc and lead receive treatment in separate chapters, while all the rest of the substances are dismissed in the last hundred pages.

Two relatively new terms are protore: "low-grade metalliferous material not itself valuable from which valuable ore may be formed by superficial alteration and enrichment," and the horsetail structure applied by Sales to divergent minor fractures. Both these seem to be useful.

There is no list of illustrations.

Alfred C. Lane

Aquatic Microscopy. By Alfred C. Stokes. Fourth Edition. New York, John Wiley and Sons. 1918. Pp. 324.

The new edition of this well-known guide for beginners retains the general features of the earlier editions. Chapter XII. of the third edition, "Some Common Objects worth Examining," has been replaced by a "Synopsis of the Preceding Chapters," which is a convenient, brief key to the forms described in the book. Minor changes have been made in the text, various scientific names have been modernized, and some of the keys have been extended. The book should continue to be a favorite, not only with the young microscopist for whom it is intended, but with many zoological students and teachers as well who desire to identify quickly and easily some of the commoner aquatic organisms.

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SPECIAL ARTICLES

ADAPTATION IN THE PHOTOSENSITIVITY OF CIONA INTESTINALIS

I

Ciona intestinalis of the Pacific Coast[1] re-

1 These experiments, the details of which will appear later, were performed at the Scripps Institution for Biological Research at La Jolla, California. My thanks are due to Dr. Ritter and his staff for the many courtesies shown me.

acts vigorously when exposed to light. The pigmented ocelli on the oral and atrial siphons are not the sense organs concerned. Stimulation of the ocelli does not result in a reaction, and their removal in no way interferes with the sensitivity of *Ciona*. The receptors responsible for the light sensitivity are localized in the inter-siphonal region in an area corresponding to the neural complex of ascidians. When this spot alone is exposed to light, the resulting effect is identical with the one following total body exposure.

II

The reaction time of *Ciona* to light is composed of two portions. The first is a sensitization period, during which *Ciona* must remain exposed to the light. The second is a latent period during which *Ciona* need not be exposed to the light. At the end of this period it gives its characteristic reaction, though at the moment it is no longer subjected to the source of stimulation. This latent period as found by averaging many determinations on a number of animals at different intensities, is 1.76 seconds.

III

The sensitization period (or roughly speaking, the reaction time) varies inversely as the intensity of the stimulating light. Moreover, the duration of the sensitization period multiplied by the intensity of the light is constant. This means that the amount of energy (time $\times$ intensity) required by *Ciona* for a reaction to light is the same for all intensities. This is a familiar phenomenon in the chemical effect of light (Roscoe-Bunsen rule) and signifies that the light decomposes a constant quantity of photosensitive substance before *Ciona* reacts to light.

IV

When kept in diffuse daylight, this species does not respond to a lower intensity of light. It does react to sunlight. However, if *Ciona* is placed in the dark, it will become "dark adapted" after a time and will respond to an artificial light of as low as 500 candle meters intensity. The investigation of the *rate* at which it becomes "dark adapted" is of considerable interest. This is found by determining the reaction time of an animal to a light of constant intensity at 15-minute intervals in the dark-room. The following is found to be true. At first the reaction time is long, then it shortens rapidly, then slowly, and finally it becomes constant.

The duration of the exposure time multiplied by the intensity of the light gives the amount of energy received. The amount of energy determines the quantity of photosensitive substance decomposed. Therefore, the extent to which the photosensitive material requires to be is changed in order to produce the same reaction during "dark adaptation," is at first large, then it decreases rapidly, then slowly, and finally it becomes constant.

The significance of this rate of change will become apparent when we shall have considered the nature of the photosensitive substance and its mode of formation.

V

Decomposition of the photosensitive material by light, presupposes the formation of this substance within the sense organ. It will simplify matters to assume that the action of the light results in the conversion of the photosensitive material into its precursor. Thus normally, and of course in the dark, the precursor (P) forms the substance (S) sensitive to light. In the light, however, S is converted back into P.

The rate of formation of the precursor from the photosensitive substance in the presence of light, has been shown to be a direct function of the amount of energy supplied by the stimulating light. The occurrence of the reaction in the opposite direction, however, must be considered in terms of the velocities of ordinary chemical reactions. The formation of the photosensitive material from its precursor is probably a reaction of the first order. For our purposes, however, it may be a reaction of even a higher order. Practically all chemical reactions have this in common: the velocity of the reaction is at first rapid, then it slows down gradually, and finally it reaches a point of equilibrium which represents a definite ratio between the concentrations of the reacting substances.

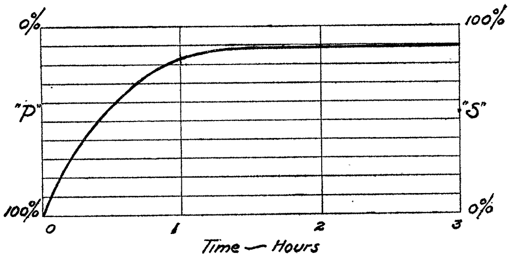

FIG. 1. Hypothetical course of the reaction $P \longrightarrow S$ (formation of photosensitive substance) which takes place during dark adaptation of *Ciona*. The regular change in the reaction time during dark adaptation depends on this chemical reaction. The curves expressing this change may be duplicated by plotting a constant fraction (1/10) of the unused P against time as abscissa.

In the case under consideration, the relation between the two substances may be represented in Fig. 1. The ordinates at the right indicate the per cent. of photosensitive substance (S) formed from the precursor (P). The ordinates at the left give the amount of the precursor (P) remaining during the progress of the reaction.

The production of the photosensitive substance in the sense organ of *Ciona* undoubtedly takes place in this manner when the animal is placed in the dark room. It will be seen from Fig. 1 that the amount of the precursor (P) is at first large, then it decreases rapidly, then slowly, and finally it reaches a constant minimum. This is also what happens to the reaction time, and therefore to the amount of photosensitive substance broken down before a reaction can occur during the process of "dark adaptation."

Since it was assumed that the photosensitive material decomposes into its precursor, the amount of the precursor formed at each reaction during dark adaptation, runs, in general, parallel to the amount of the precursor still unused in the reaction. Therefore, in order to serve as an "inner stimulus," the quantity of precursor formed by the stimulating light must bear a definite quantitative relation to the amount already present. This is merely the basis of the familiar Weber-Fechner concept, that the amount of stimulus necessary to produce a perceptible increase in sensory effect represents a constant fraction of the quantity of stimulus that has gone before.

VI

The crucial test of any explanation lies in its ability to predict the course of events. Such a test was applied to the hypothesis suggested above.

We do not know with any accuracy the course of the reaction taken to form the photosensitive substance from its precursor. But the reverse reaction—the formation of precursor from sensitive material—has already been shown to follow the Roscoe-Bunsen rule. Consequently, the quantity of precursor present depends upon the amount of light energy which the animal has recently received.

If a dark adapted *Ciona* is repeatedly exposed to light at sufficiently close intervals of time, only a negligible quantity of new photosensitive material should be formed. The amount of precursor produced by the light, however, will depend entirely upon the total exposure time. Moreover, if it is true that, in order to act as a stimulus, the amount of precursor formed must bear a constant ratio to the amount already present, the reaction time should always bear the same relation to the reaction times that have preceded it.

This is indeed found to be the case. *Cionas* that have been kept in the dark for several hours, and are then exposed to light at intervals of a minute, and their reaction times taken, follow exactly the prediction outlined above. A curve drawn with time as ordinates, and sensitization periods (reaction time minus 1.76 seconds) as abscissas, has a simple logarithmic form corresponding to the usual Weber-Fechner expectation. If instead, the logarithms of the sensitization periods are used as abscissas, the resulting curve is a straight line. This indicates that the amount of energy required to produce a reaction at any stage in the repeated stimulation is a constant fraction of the amount of energy which the sense organ has received previously.

VIII

Repeated stimulation of the kind just described, has frequently been called a process of adaptation to a stimulus. As such it has been used as a criterion for the presence of a "higher behavior" in many animals. Similarly, the fact that the reaction time continues to increase steadily has been taken to indicate a process of learning.

The experiments forming the basis of this communication, have, however, shown that these phenomena are dependent on changes which take place within the sense organs themselves. In addition, they have demonstrated that the process of "adaptation" to a photic stimulus in *Ciona* is subject to the course of a chemical reaction. The reverse of this reaction determines the ability of the organism to become "dark adapted." Furthermore, the changes which occur in the reaction time during both of these adaptional processes are consistent with the principle underlying the Weber-Fechner rule. This requires that in order to act as a stimulus, the light must form a quantity of a substance such that it will bear a definite ratio to the amount of that substance already present in the sense organ. The matter of "higher behavior" is nowhere evident in these experiments.

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A METHOD FOR PREPARING PECTIN

PECTIN bodies is a term applied to a group of substances occurring in practically all plants and fruits. They are complex carbohydrates, probably derived from one mother substance known as pectose, and are closely allied to the plant gums and mucilages. Pectin occurs most abundantly in the apple, quince, currant and gooseberry and appears in small quantities in strawberries, raspberries, etc. In suitable amounts of sugar and acid the pectins have the property of gelatinizing fruit juices or hot-water extracts of fruit pulp in which they are present or to which they may be added. The reason why some kinds of fruit juices do not jelly is due to an insufficient amount of pectin being present in them. For example the practise of mixing apple juice with raspberry or strawberry juice is for the purpose of increasing the pectin content and thereby make jelly from juices where it would be impossible to do so otherwise. The juices from the various kinds of fruits are known for their distinctive flavors. These qualities are impaired when a combination of juices are blended together. For this reason it has been the aim of manufacturers to make high-grade jellies from the low-containing pectin fruit juices by adding to them the purified pectin. The pectin, as now prepared, is very expensive and therefore its use in jelly-making is very limited.

Pectin is slightly soluble in water and therefore the pulp or pomace resulting from the pressing of ripe fruit contains practically all of the pectin. Hot water will slowly extract the pectin and for this reason fruits are cooked to a pulp with water before extracting the juice for jelly-making.

In the fruit-producing sections of the state of Washington, there is a considerable amount of cheap material such as cull apples, pomace from cider presses and cores and peelings from canning establishments which go to waste. This waste material might be utilized for the preparation of pectin which, in turn, could be used in making jelly from those fruit juices which lack pectin. The object of the experiment carried on in this laboratory was the finding of some simple and inexpensive process for the preparation of pectin from these waste products, without the use of alcohol, as is the case in Goldthwaite's[1] method.

The principle of the method is based upon the fact that pectin as extracted from the pulp or pomace is in a colloidal state and can be readily changed by electrolytes. Since pectin, after precipitation, must be dispersed again in order to be of any value as a gelatinizing agent, an electrolyte that will produce a reversible precipitation must be chosen. Also

[1] *J. Ind. and Eng. Chem.*, 2 (1910), 457.