qualitative, in the second case quantitative only, thus giving the immediate possibility of the production of two embryos from a single egg. It appears to me that we find here a principle of reconciliation between the hypothesis of mosaic development and pre-localization, and the apparently contradictory one of non-mosaic or correlative differentiation. The facts show that each of these apparently contradictory hypotheses contains an element of truth; that we must recognize in the development of every animal the fact of pre-localization and of mosaic development, but also the fact of correlative action. The relation between these two can not be predicted, but must be determined in each individual case; for the known facts are already sufficient to prove that the segregation of the formative stuffs is a process that occurs at different periods in different animals. At the time of fertilization, accordingly, the segregation differs both in degree and in form; and these differences have not yet been reduced to any general law.

In conclusion, I would express the opinion that, so far as the early stages of development are concerned, it is difficult to escape the hypothesis of formative stuffs or specific morphoplasmic substances, in some form. But while this hypothesis facilitates an understanding of the *modus operandi* or immediate causes of differentiation, it leaves us as much as ever in the dark as to the localizing or form-determining factors which are responsible for the determination of the segregation pattern. This problem, which is essentially one of correlative action, is not only unsolved, but suggests the existence of specific energies for which it is difficult at present to find an analogy outside the field of protoplasmic action.

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SCIENTIFIC BOOKS.

Contributions to the Study of the Behavior of Lower Organisms. By Herbert S. Jennings. Published by the Carnegie Institution of Washington. 1904. 256 pp., 81 text-figures.

In the series of papers which make up this volume Professor Jennings presents results which are of fundamental importance for our understanding of the behavior of lower organisms. The titles of the seven papers of the volume are as follows: (1) 'Reactions to Heat and Cold in the Ciliate Infusoria,' (2) 'Reactions to Light in Ciliates and Flagellates,' (3) 'Reactions to Stimuli in Certain Rotifera,' (4) 'The Theory of Tropisms,' (5) 'Physiological States as Determining Factors in the Behavior of Lower Organisms,' (6) 'The Movements and Reactions of Amœba,' (7) 'The Method of Trial and Error in the Behavior of Lower Organisms.'

For the purposes of this review the papers may be separated into three groups. Of these the first, which includes the first three papers, is devoted primarily to descriptions of the modes of reaction of several of the lower organisms, and to a discussion of the bearing of these reactions upon the 'orientation theories' of Loeb and Verworn. The second group is constituted by the paper on Amœba; in it the author deals in detail, as a result of his own observation, with the mechanics of locomotion, modes of reaction and psycho-physiology of the organism. Papers four, five and seven are included in the third group. In addition to presenting several points of interpretation, they contain discussions of the relations of the author's results to the general theory of tropisms.

I shall now attempt to state briefly the principal points made in each of these three subject divisions of the volume.

In explanation of the directive influence of stimuli on the movements of various organisms Loeb, Verworn and others have proposed the so-called orientation theories.

According to these theories a stimulus which acts unequally upon different portions of the body causes inequality of contraction in the musculature, and thus brings about a turning

of the body either toward or away from the source of stimulation. The animal is perfectly oriented with reference to the stimulus when symmetrical points on the body are equally stimulated.

By careful observation of the behavior of several types of lower organism Jennings has determined to his own satisfaction, and judging from the nature of his descriptions with certainty, that the reactions of the unicellular organisms, and also those of some of the metazoa, are not in harmony with the current theories of orientation. The reaction of ciliate infusoria to heat and cold is thus described, in summary, by the author, "the response, on coming into a region where the temperature is above or below the optimum, is by backing and turning toward a structurally defined side, followed by a movement forward. This reaction is repeated as long as an effective supraoptimal or suboptimal temperature continues. The result is to prevent the organisms from entering regions of marked supraoptimal or suboptimal temperature, and to cause them to form collections in regions of optimal temperature. The common orientation of a large number of individuals sometimes produced in this way is an indirect result of the method of reaction. Since movement in any other direction than a certain one is stopped, the organisms after many trials come into this direction. Orientation is, therefore, by 'exclusion,' or by the method of trial and error" (p. 28).

Similarly the author has shown that the reactions of ciliates and flagellates to light are not in accordance with the assumptions of the theories of orientation.

Among the multicellular organisms the Rotifera, according to the observation of Jennings, turn as a rule toward a structurally defined side—the dorsal—without relation to the side stimulated most strongly, and continue turning, or alternately turning and darting forward, until the anterior end of the body is directed away from the source of stimulation. "Thus the direction of turning is throughout dependent upon an internal factor, not primarily on the way in which the stimulus impinges on the organism. These reactions of the Rotifera are thus inconsistent with a theory of tropisms which regards orientation as a primary feature of the reactions, and which holds that the action of the stimulating agent is a direct one on the motor organs of that part of the body on which it impinges" (p. 88).

Of the correctness of Jennings's observations there can be little doubt, for all his work is characterized by admirable care in observation and accuracy in description, but in criticism of the manner in which he discusses the bearing of his own results upon the orientation theories it might be said that he does not make sufficient allowance for the asymmetry of the organisms with which he worked. The fact that the various unicellular organisms and rotifers whose behavior is described in these papers do not orient according to the theories of Verworn or Loeb by no means proves that their theories are in principle wrong. Jennings's work does, however, very emphatically call attention to certain weaknesses and false assumptions of the theories in question, for their advocates have too often adduced the presumably well-known reactions of these very organisms in support of one or another form of the theory of the tropisms.

It is only fair to the author to state that his arguments are directed more especially against the 'direct action' assumption of the tropism theory than against the theory of orientation. He believes that his observations prove beyond a doubt, for the animals studied, that stimuli bring about reactions by their general action upon the organism rather than by direct local action, and he, therefore, contends with good reason that the theory of the tropisms as stated by Verworn, Loeb and others is radically wrong.

It is worthy of note, in connection with the facts of Jennings's studies, that the turning toward a structurally defined side which is so common among the unicellular organisms serves usually, although not always, to direct the organism away from the source of stimulation. For example, *Paramecium* turns towards its aboral side, hence away from the currents of stimulating substance which are drawn

toward the oral region by the ciliary movements. The same conditions obtain in the Rotifera, for there the ciliary current passes to the mouth, on the ventral side, and the organism, in case the current carries a stimulating substance, turns toward the dorsal surface.

Turning our attention now to the second subject-group, we find that Jennings undertook the study of the behavior of Amœba with two definite purposes in mind: (1) To determine how far recent physical theories explain the activities of the organism, and (2) to add to, systematize and unify our knowledge of the subject.

Fortunately the author did not confine himself to the unexplored regions of his field of research, but instead repeated the experiments and attempted to verify or replace the so-called facts of other investigators, and test their theories.

The results of this thorough reinvestigation of the subject are in many respects startling. In the first place, Jennings finds that the descriptions of the protoplasmic currents within the moving Amœba given by Bütschli and Rhumbler are not true to the facts. These investigators have stated that there is a forward-moving axial current and a backward-moving surface current at the sides of the animal, the conditions in the organism being practically the same as that in a drop of inorganic substance whose surface tension is decreased at some point. Jennings has been able to demonstrate to his entire satisfaction by the use of several simple methods that there is only a forward current. As this is an important matter we may appeal to his excellent description of the observations. "In an advancing Amœba substance flows forward on the upper surface, rolls over at the anterior edge, coming in contact with the substratum, then remains quiet until the body of the Amœba has passed over it. It then moves upward at the posterior end, and forward again on the upper surface, continuing in rotation as long as the Amœba continues to progress. The motion of the upper surface is congruent with that of the endosarc, the two forming a single stream" (p. 148).

This is of special interest because it sweeps away one of the principal supports of the surface-tension explanation of the movements of Amœba. And it may well be added here that Jennings's methods are so much superior to those employed by many of the earlier investigators, and his observations so much more detailed, that his results will almost undoubtedly be verified by others shortly.

After a minute study of the formation of pseudopodia, the reactions to stimuli, food-taking, and several other interesting features of the behavior of the organism, the author formulates the following general conclusions with respect to the mechanism of movement: "Altogether, then, our results lead us to look upon Amœba as an elastic and contractile sac, containing fluid. In locomotion one side of this sac actively stretches out, becomes attached to the substratum, and draws the remainder of the sac after it in a rolling movement. The primary phenomena are the stretching of one side, the elasticity, and the contractility of the outer layer" (p. 172). The author does not attempt to account for the pushing out of the anterior edge, nor does he theorize concerning the nature of the contractility of the ectosarc.

Perhaps the most important general results of the study, so far as the views of the author are concerned, is that it shows pretty conclusively that we have not thus far succeeded in analyzing, as Bütschli, Rhumbler and others appear to think they have done, the behavior of any organism to the point of complete physical explanation. After all the external factors have been taken into account there appears still to be a necessary factor or complex of factors which have to be referred to the organism itself. External physical factors apparently suffice for the description of certain of the activities of the lower organisms as well as of the higher; but usually critical research shows that the descriptions are not complete. As Jennings remarks, 'Putting all our results together, we must conclude that the movements and reaction of Amœba have as yet by no means been resolved into their physical components' (p. 225).

In the third group of papers the author

brings out forcibly the fact that almost every reaction of an animal involves or is conditioned by the activity of the total organism. The tropism theory is misleading in so far as it seems to suggest that local action, largely independent of the conditions of the body as a whole, is the common rather than the exceptional determinant of reaction. In this portion of the volume it is evident that Jennings is emphasizing the unknown factors in animal behavior, while at the same time severely criticizing those observers and theorists who contend that they can reduce organic activity to physical factors.

Trial and error is the method of adaptive reaction which is most frequently observed in the lower organisms. In a discussion of this topic the author is drawn into a discussion of the meaning of 'error': "There is no common thread running through all the different agents which constitute 'error' in the reaction, save this one, that they *are* error from the standpoint of the general interests of the organism. * * * Why do we receive without opposition certain chemical stimuli and avoid others? The facts are quite parallel in man and in the lowest organisms in these respects. * * * In both cases the stimuli producing the negative reaction are in general injurious to the organism (p. 247).

"In ourselves the stimuli which induce the negative reaction bring about the subjective state known as *pain*, and popularly we consider that the drawing back is due to pain. Is there ground for this view? Or is the reaction entirely accounted for by the chemical and physical processes involved? * * * If we hold that in man we can not account for the reaction without taking into consideration the pain, then we must hold to the same view for the lower organisms. * * * Any one who holds that we can account fully for the reactions of *Euglena* or *Paramecium*, purely from the physico-chemical conditions, without taking into account any states of consciousness, must logically hold that we can do the same in man. The method of trial and error implies some way of distinguishing error; the problem is: How is this done? The problem is one, so far as objective evidence goes, throughout the animal series" (p. 248).

The criticism of this volume, as of many of Professor Jennings's other writings, that one is first inclined to make is that there is needless repetition, that the same simple facts are described and redescribed until one almost feels it an insult to intelligence. But this is a judgment which the author has passed upon himself, for he has elsewhere stated that he describes all his observations in almost painful detail in order that investigators who have cause to use his results may not have the disagreeable experience, that has been his often, of failing to find in the description of experiments some little point that is important for the problem in hand. Apart from its repetitions, the volume is well written; it is also well printed.

As to the content of the work, it may be repeated that the evidences of thoroughness, accuracy, fairness to other investigators, freedom from overhasty generalizing, are such as to inspire great confidence in the results, and to warrant one in believing that they will serve to advance our knowledge of the general subject of animal behavior in a very important manner. In fact, it is not at all improbable that they may necessitate important modifications in the tropism theory.

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RECENT BOOKS ON ECONOMIC AND SOCIAL SCIENCE.

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