itself has come to an end, but that the work of the author is finished too. There are many who can carry forward investigations and complete new discoveries, but there are very few who are made competent by their thorough scholarship to understand, and through their delightful style to explain, the evolution of scientific thought from one age to another.

Percy M. Dawson

SPECIAL ARTICLES

THE PROCESS OF FEEDING IN THE OYSTER

A valuable contribution to knowledge of the ciliary mechanisms of Lamellibranch mollusks has been made by James L. Kellogg in Vol. 26, No. 4, of the *Journal of Morphology*.

In this paper Dr. Kellogg brings together, with numerous illustrations, his observations on the ciliary tracts of structures found within the mantle chamber of thirty-one species of lamellibranchs.

In each case the observations were made on the animal after one of the valves of its shell had been removed, and the presence and direction of ciliary currents were determined by means of powdered carmine, fine black sand or masses of diatoms, deposited upon the parts under observation.

Among the several conclusions at which Dr. Kellogg arrives as a result of his study concerning the activities and functions of these tracts of cilia, the following, published on pages 699 and 700, are those to which the "oral exceptions," referred to by Dr. Kellogg on page 640, have been taken and they are the ones also which will be called in question in this paper:

1. Volume alone determines whether the collected foreign matter that reaches the palps shall proceed to the mouth or shall be sent from the body on outgoing tracts [of cilia].

2. A Lamellibranch is able to feed only when waters are comparatively clear—when diatoms are brought to the gill surfaces a few at a time. In muddy waters, all suspended particles, of whatever nature, are led to outgoing tracts.

3. There is no selection or separation of food organisms from other water-borne particles.

4. The direction of the beat of cilia is never changed.

The exceptions taken to these statements were not based, as Dr. Kellogg states, on the fact that the waters over Chesapeake oyster beds are normally muddy for long periods of time or upon the fact that the stomach contents of oysters always contain a larger volume of sand than of food organisms, although both of these facts are difficult to explain on the Kellogg theory, but they are based primarily upon the results of experiments, to be described later, which show that oysters can and do feed rapidly and continuously in waters that are turbid with sediment.

Before passing to a consideration of the results of these experiments, however, which bear directly upon the *first* and *second* only of Dr. Kellogg's conclusions (as numbered in this paper), reference may be made to the findings of other observers not in agreement with those of Dr. Kellogg, which indicate that the conclusions numbered (3) and (4) were possibly drawn from an insufficient basis of observation or that the methods of study employed by Dr. Kellogg were not designed to reveal *all* of the activities of the ciliary mechanisms of lamellibranchs.

REVERSAL OF CILIA AND FOOD SELECTION

In Stentor, Schaeffer[1] has shown that there is a selection of food particles brought about by changes in the beat of the cilia of the pouch and funnel, certain particles being rejected by a localized reversal of the cilia. He also found that the behavior of the animal toward food is not the same when it is in a condition of hunger as when in a condition of satiety.

Stentor is not an isolated example of protozoan possessing the power of food selection and rejection exercised through the control of the ciliary mechanism of the mouth region. Numerous other cases might be cited.

Cases of reversal of cilia are also reported among metazoan animals, Parker[2] having found that in *Metridium* the cilia on the lips, which normally beat outward, can be made to

[1] Asa Arthur Schaeffer, "Selection of Food in *Stentor cœruleus*," *Jour. Exp. Zool.*, 1910.

[2] G. H. Parker, "The Reversal of Ciliary Movements in Metazoans," *Am. Jour. of Physiology*, Vol. XIII., 1905.

reverse by stimulation with pieces or the juices of crab meat, these ciliary tracts thus constituting a mechanism through which the feeding process can be controlled.

In this paper Parker refers also to a number of papers, not easily available to the writer and not referred to by Dr. Kellogg, in which the reversal of ciliary movement in metazoans has been observed. Of special interest in this connection are those by Engelmann and others in which the *reversal* of cilia of the *palps of lamellibranchs* is described.

The only positive evidence I can offer for the conclusion that the oyster is able to select food is that afforded by a microscopic examination of its stomach contents. The various species of diatoms there found are not present in the same relative proportions as they exist in specimens of water collected in the vicinity of the bed from which the oyster fed. Furthermore, certain species of diatom (for example, *Rhizosolenia*), abundant in salt water, are seldom found in the alimentary tract of the oyster. The absence of these diatoms from the alimentary canal can hardly be due to their spiny structure because their size is not sufficiently great to prevent their being carried by ciliary currents or entering the mouth.

The observations that have been made of the reversal of the beat of cilia in both protozoa and metazoa, and of the ability of various animals to so control the movement of the cilia as to accept or reject food particles presented to them, at least suggest the possibility that the oyster may also have some power of food selection and that reversal of the cilia of certain tracts on the palps, resulting perhaps from their stimulation directly or indirectly by food particles, may be the mechanism by which the selection is effected.

Why, then, if a reversal of cilia and selection of food takes place in lamellibranchs, did so good an observer as Dr. Kellogg fail to see the reversal process? To me it seems clear that it was due to the fact that the animals on which he made his observations were, in every case, in a mutilated condition. In the case of his experiments on the oysters the shell was first removed and in its removal the adductor muscle was cut and the visceral ganglion, which is embedded in this muscle, was necessarily severely injured. Under such a condition of shock normal behavior is not to be expected, especially in the case of activities that may be subject to nervous control. The history of the animals experimented upon by Dr. Kellogg, whether they were in a state of hunger or satiety, was also unknown.

EXPERIMENTS

During the years 1909 and 1910 oysters planted on beds located in Buzzards Bay remained poor and the death rate among them was unusually large. Coincident with and following the same period, dredging operations were carried on in the vicinity of certain of these oyster beds which caused an unusual amount of sediment to be carried from the dredges across the oyster beds with the rising tides.

The oyster planters readily imagined that the poor condition and death of their oysters were in some way causally connected with this sediment in the water and they brought suit to recover their losses, with generous interest, from those responsible for the dredging operations.

During this litigation it has been the oral contention of Dr. Kellogg that, since the oysters planted on the beds located near the operating dredges were exposed on rising tides to unusually turbid water and since food-bearing sediment was therefore entering the mantle cavity of the oysters during these intervals in unusual abundance, the oysters were underfed and starved because the ciliated food-collecting mechanism of the palps must, under such conditions, transport the food-bearing material away from instead of to the mouth.

The ciliated food-collecting mechanism of the oyster is so constructed, according to the theory held by Dr. Kellogg, that it can transport food material to the mouth only when the food particles reach the ciliated tracts few at a time, for when they reach the palps more rapidly they are seized automatically by the cilia of outgoing tracts. It is an important part of his theory that the direction of the beat of the cilia composing the food-transporting mechanism is non-reversible, hence his conclusion in this case that the oysters starved in the presence of an abundant supply of food. Although starving, the oysters were powerless to prevent the rejection of food material for the remarkable reason that the food material was reaching their feeding mechanism in embarrassing abundance.

It was not contended that the sediment was distasteful, for, in the organization of an animal with such a purely automatic feeding mechanism, what possible place could be found for so useless a thing as a sense of taste?

To test the validity of this contention the following experiments were carried out on the oyster beds where the oysters were said to have died from starvation, at a time when the waters were roiled and turbid from the operations of nearby dredges.

A considerable number of oysters of uniform size were first gathered from a bed far removed from the scene of the dredging operations. Five of them were immediately opened, their stomach contents removed and preserved in a vial for future study and analysis. The remaining oysters were thoroughly cleansed of all foreign material and stored for three days in a cool damp place. Twice each day they were placed for an hour in filtered sea water in order that they might expel from their shells the accumuated excreta. They were allowed to take no food. At the end of the third day of fasting, the primary object of which was to remove from the alimentary canal all previously ingested food material, the oysters were taken to a selected point on one of the oyster beds over which the sediment from the dredges was being carried by the rising tide and there, after five of them had been opened and their stomach contents removed, placed upon the bottom.

To facilitate depositing the oysters upon and removing them from the bottom, they were placed in a coarse-meshed wire tray to which cords were attached.

At the end of an hour from the time the oysters were deposited upon the bottom in the turbid water the tray was lifted for a moment, the stomach contents of five of the oysters were removed, and the tray with the remaining oysters returned to the bottom. At the end of the second hour this process was repeated and also at the end of the third hour. When the experiment was over the unused oysters were left upon the bottom in the tray for fourteen days to note the effect of the sediment upon them with the result that all thrived and made perceptible growth of shell.

The microscopic examination and estimate of the number of food organisms in the stomach contents taken from this series of oysters, which was made according to the "Rafter cell" method, resulted as follows:

Each oyster estimated to contain, when collected August 19, 10.30 A.M., 18,500 food particles.

Each oyster estimated to contain, after fasting till August 22, 1.30 P.M., 8,250 food particles.

Each oyster estimated to contain, after feeding 1 hour, August 22, 2.30 P.M., 11,500 food particles.

Each oyster estimated to contain, after feeding 2 hours, August 22, 3.30 P.M., 17,750 food particles.

Each oyster estimated to contain, after feeding 3 hours, August 22, 4.30 P.M.,[3] ?

A second experiment in every way similar to the first, except that the oysters were subjected to a preliminary fast of four instead of three days' duration, was carried out between August 31 and September 4, 1911. The estimates of the stomach contents of the oysters used in this experiment are as follows:

Each oyster estimated to contain, when collected, August 31, 10 A.M., 12,125 food organisms.

Each oyster estimated to contain, after fasting till Sept. 4, 1 P.M., 2,850 food organisms.

Each oyster estimated to contain, after feeding 1 hour, Sept. 4, 2 P.M., 10,250 food organisms.

Each oyster estimated to contain, after feeding 2 hours, Sept. 4, 3 P.M., 16,500 food organisms.

RESULTS AND CONCLUSIONS

The results of these experiments show conclusively that oysters can and did feed actively in waters that were turbid with sediment, a fact that is in direct opposition to Dr. Kel-

[3] The food material removed from the stomachs of the oysters which had been feeding for three hours in the roiled water was so densely crowded with sediment that it was impossible to make the diatom counts necessary for an estimate of the total number of food organisms.

logg's conclusion, numbered (2) in this paper, and one that casts doubt upon the correctness of the three other conclusions herein discussed.

It is my belief that the results of the experiments and observations herein described when considered in connection with the observations of other investigators on various species of lamellibranchs and on various protozoa and metazoa, afford a satisfactory basis for concluding that the oyster is not the helpless automaton Dr. Kellogg makes it out to be, but that it possesses sufficient control over its ciliary feeding mechanism to prevent its starving in the presence of water-borne food material, even though the food particles and associated sand grains may be carried to its gills and palps in bewildering abundance.

This control of the feeding mechanism and the ability to select food may conceivably be exercised through control of the direction of the effective beat of the cilia of certain tracts on the palp surfaces and, since reversal in the stroke of cilia on the palps (nebenkiemen) of lamellibranchs has actually been observed by Engelmann and others, and since selection and rejection of foreign particles through control of ciliary movement have been observed in various animals (*Stentor, Metridium, etc.*), we may well expect to find that the oyster exercises control over its feeding processes through ability to change the direction of the effective stroke of the cilia of certain tracts on its palps.

CASWELL GRAVE
JOHNS HOPKINS UNIVERSITY,
BALTIMORE, MD.

THE AMERICAN ASSOCIATION OF MUSEUMS

THE American Association of Museums held its eleventh annual meeting in Washington, D. C., May 15–18. The opening session was devoted to the transaction of business, and to a special report by Secretary Paul M. Rea on the "Condition and Needs of American Museums." This report summarized the work of the association during the past ten years, reviewed the studies of American museums which have been made on behalf of the association, and outlined the work which might be undertaken for the furtherance of museum development.

The evening of May 15 was devoted to a supper in celebration of the decennial of the American Association of Museums. Following this supper the presidential address was given by Dr. Oliver C. Farrington on "Some Relations of Art and Science in Museums." The remainder of the evening was occupied with informal remarks by members of the association. This session was presided over by Dr. W. J. Holland, of the Carnegie Museum, who was one of the founders of the association and its third president.

At the morning session on May 16 a group of papers was presented reporting progress in a concerted experiment by several museums in the use of museums for instruction in the history of civilization. This symposium was arranged by Miss Anna D. Slocum, acting on behalf of the association in cooperation with the Woman's Education Association of Boston. The titles of the papers were as follows:

"A Study of Nations through the Museum," by Miss Anna D. Slocum.

"History Study and Museum Exhibits," by Miss Delia I. Griffin.

"Museum Stories of Art and Civilization," by Miss Margaret E. Sawtelle.

"The Museum Story as an Introduction to History," by Mrs. Laura W. L. Scales.

"Teaching History in the Museum," by Mrs. Agnes L. Vaughan.

"The Museum and the School," by Miss Lotta A. Clark.

Other papers presented at this session were "A Museum Game," by Miss Eva W. Magoon, and a paper on the "Development of the N. W. Harris Public School Extension of the Field Museum of Natural History," by Mr. S. C. Simms. Miss Viola M. Bell, of Teachers College, Columbia University, presented by invitation a paper on "Relations of Domestic Science Teaching to Museums." Following these papers the association proceeded to the election of officers with the following result:

President, Henry R. Howland, Buffalo Society of Natural Sciences.

Vice-president, Newton H. Carpenter, Art Institute of Chicago.

Secretary, Paul M. Rea, The Charleston Museum (S. C.).

Treasurer, W. P. Wilson, The Philadelphia Museums.

Assistant Secretary, Laura L. Weeks, The Charleston Museum (S. C.)

The retiring president, Dr. Oliver C. Farrington,