past summer, invitations have come to us from members of Oxford University and the British School in Jerusalem to cooperate with them jointly in prehistoric exploring expeditions both in Iraq and in Palestine. Such a program renders highly desirable not only permanent headquarters for the school but also adequate endowment and if need be special funds for special projects.

With a permanent base, preferably at home, serving as a laboratory and repository for apparatus, books and specimens, branch bases could be established, or existing ones made use of, on the other side as the occasion demanded. With adequate endowment, professorships and lectureships might be maintained, at least one of which should be for distinguished foreign specialists. We already have the promise from an able foreign prehistorian and ethnologist that he will come to America and offer gratis a course of lectures as soon as such a center shall have been established. Surely we can not afford to be so lacking in appreciation of such a generous offer as to fail to take advantage of it.

### Bulletins

During the year two bulletins have been published by the school: Bulletin 2 containing the minutes of the first meeting of incorporators and trustees, the certificate of incorporation, and the by-laws of the school; and Bulletin 3 containing the report of the director on the work of the sixth season (22 pp. and 26 figures).

George Grant MacCurdy

Yale University

## SPECIAL ARTICLES

### ON THE DISTRIBUTION OF CRITICAL TEMPERATURES FOR SPAWNING AND FOR CILIARY ACTIVITY IN BIVALVE MOLLUSCS*

I

Orton[1] classifies marine animals into three groups: (a) those which breed at a definite temperature, which is a constant for the species throughout its range; (b) those which breed at a particular temperature change, which may be at either the maximum or the minimum for the locality; (c) those which breed the year round.

Observations of the spawning temperatures of lamellibranch molluscs show that they fall within the first of these groups. Data gathered from the literature and collected by myself during some ten years of study of the marine lamellibranch larvae of our coastal waters show that of those bivalve molluscs which have been investigated each has its critical temperature for spawning. No species other than the American oyster has been studied extensively enough to determine the duration of the latent period after the critical temperature is reached before spawning begins. Since spawning occurs on a rising temperature in all forms thus far studied, it follows that the actual "trigger" temperature for these species is probably slightly below that of the water in which the first larvae are found.

The following species with their spawning temperatures represent those molluscs the larvae of which I have found, together with spawning temperatures gathered from the literature.

| | |
|---|---|
| 4– 5° C. | An as yet unidentified larva which appears in Barnegat Bay early in March. |
| 10–12° C. | *Mytilus edulis*, *Mya arenaria*, *Astarte*, *Venericardium*, *Nucula*. |
| 15–16° C. | *Ostrea edulis* (Orton[1]), *Ostrea lurida*, *Pecten irradians* (61.5° F. Belding[2a]), *Teredo navalis*. |
| 20° C. | *Ostrea virginica* (J. Nelson[3], Townsend[4], Moore[5], Stafford[6], T. Nelson[7b], Churchill[8], Prytherch[9]). |
| 24–25° C. | *Venus mercenaria* (76° F. Belding[2b]; 25° C., my finding). *Mytilus recurvus*. |

One is impressed by the fact that these spawning temperatures fall into groups which differ by approximately 5° C. Setchell[10] studying the temperature limits for growth and fructification of marine algae, marine spermatophytes, and land plants has been led to assign as critical temperatures for the initiation of these processes: 5°, 10°, 15°, 20°, and 25° C. Crozier[11] has brought together a large amount of data on the temperature characteristics of vital processes of the most diverse sorts, and from these and other

* Publication No. 11, N. J. Oyster Investigation Laboratory.

1 Mar. Biol. Assoc. XII, 339, 1920.

2 Report upon the Scallop Fishery of Mass., 1910; (b) Report upon the Quaghog and Oyster Fisheries of Mass., Boston, 1912.

3 Report N. J. Exp. Sta. for 1890, 314; Contr. to Canad. Biol. for 1915–16, 53.

4 Report U. S. F. C. for 1889–91, 343.

5 Doc. 610, U. S. F. C., 1907.

6 The Canadian Oyster, Ottawa, 1913.

7 (a) Report N. J. Expt. Sta. for 1920, 317; (b) Bulletin 351, N. J. Exp. Sta., New Brunswick, 1921; (c) *Proc. Soc. Exp. Biol. and Med.* XXI, 90, 1923; (d) Science, LXIV, 72, 1926.

8 App. VIII, Report U. S. F. C. for 1919.

9 App. XI, Report U. S. F. C. for 1923.

10 *Am. J. Bot.* XII, 178, 1925.

11 *J. Gen. Physiol.* IX, 525, 1926.

data he determines the critical points to occur most frequently in the neighborhood of 4.5°, 9°, 15°, 20°, 25°, 27° and 30° C. As he points out, the agreement of these figures with those of Setchell can hardly be accidental. It may be assumed, therefore, that the temperatures for spawning of the lamellibranchs here listed fall where they do by reason of similar fundamental processes which control vital phenomena in the plants and animals considered by Setchell and by Crozier.

II

Although spawning has been the most extensively studied in relation to temperature of all vital processes in bivalve molluscs, observations of ciliary activity made thus far on lamellibranchs reveal a similar distribution of critical temperatures. Gray[12] showed in *Mytilus edulis* a progressive increase in speed of the cilia, with normal amplitude of beat, from 0° to 32.5° C. One may take 0° C. therefore as the critical temperature for the initiation of ciliary activity in this form.

In *Ostrea virginica* I have shown (Nelson, T. C., a, c, d.) that the critical temperature for ciliary activity and for shell opening of animals taken during cold weather is close to 5.6° C. Below this temperature ciliary activity is practically in abeyance. Galtsoff[13] finds that the cilia of the oyster come to a standstill at 5° C. This critical temperature of 5° for ciliary activity is accompanied by a spawning temperature of 20° C. Roughley,[14] working with the Australian oyster, *O. cucullata,* has shown that this form fails to open in water of a temperature lower than 10° C., whereas above this point the molluscs are active. This observer also notes that pulsations of the heart become slow and weak at 10° C. while above this temperature the beats are vigorous and more rapid. The spawning temperature for this species is not known, but from the restricted distribution of *O. cucullata* and from the observation of Roughley that in some seasons it does not spawn at all in the northern part of its range, it is probable that its spawning temperature will be found to be either 20° or 25° C.

Of interest in this connection is the observation of Takatsuki[15] that the pulsation of the heart of *Ostraea circumpicta* is abolished at 0° C. but begins at 5°–7° C. It is hoped that future work at the Asamushi Station will establish the critical temperatures for spawning and for ciliary activity in this little known species of oyster.

12 *Proc. Roy. Soc.* 95, 6, 1923.

13 SCIENCE, LXIII, 233, 1926.

14 *Proc. Linn. Soc. N. S. W.,* LI, 446, 1926.

15 *Scientific Report,* Tokhoku University, 4th Ser., II, 3, 1927.

The bearing of critical temperatures upon the distribution of these lamellibranchs is of prime importance, but can not be discussed here further than to mention the following facts. *Ostrea virginica,* the most valuable mollusc in the world, is barred from most of the otherwise favorable coast lines of the earth since the waters there rarely attain a temperature of 20° C. for a sufficient period to permit spawning. The inferior species *O. lurida* and *O. edulis* may thrive there since much of the coastline of the northern hemisphere rises to 15° C., or slightly above, for the time necessary to permit these species to spawn. *Teredo navalis* with the same spawning temperature has been carried into most of the ports of the world. *Mytilus edulis* with its still lower spawning temperature is the most widely distributed marine lamellibranch in the northern hemisphere. *Venus mercenaria,* the hard clam, on the contrary, is found only in a relatively few sheltered areas where subtropical spawning temperatures of 25° C. are attained at some time during the summer.

Many more observations of other species of pelecypods in widely different environments are needed to determine whether the critical temperatures shown above are characteristic for this group of animals as a whole. This preliminary paper is presented with the suggestion that study of the spawning temperatures of groups of aquatic species in the light of our newer knowledge of critical temperatures will prove a valuable method of attack upon problems concerning the distribution and behavior of such organisms.

THURLOW C. NELSON
RUTGERS UNIVERSITY

## STARVATION KETOSIS OF THE PRIMATES

IN the course of experimental work on monkeys afflicted with "cage paralyses" the writer found that they excrete relatively large quantities of acetone bodies when starved, and, by analyzing the data in accordance with the ketogenic-antiketogenic conceptions of Shaffer,[1] the excretion (with the exception of the lemur) could be considered comparable in every way to that of man.

The following animals were used:

Black ape, *Cynopithecus niger* (Desmarest) (Celebes), male and female;

Bonnet Macaque, *Pithecus sinicus* (Linn.) (India), male and female;

Brown capuchin, *Cebus capucinus* (Linn.) (South America), male.

A mandrill, Papio sphinx (Linn.) (West Africa), male, on starving was found to excrete only traces of

1 Shaffer, P. A., The Harvey Lectures (Series XVIII), Lippincott, 1924.