SPECIAL ARTICLES

SOME ASPECTS OF THE INFLUENCE OF TEMPERATURE ON COPEPODS

DIVERSITY in size and in minor details of structure within the species is notable with several species of free-living copepods, both freshwater and marine, and has been the occasion for an almost equal diversity of opinion as to scope of species, occurrence of races, polymorphism, postlarval growth and response to optima of temperature, food, etc. With regard to marine copepods, there has come to be an apparently general acceptance of the idea that copepods of cold waters are larger than corresponding copepods of warm waters, but experimental evidence of the relationship of size to conditions of the environment seems to be wanting, and the idea of an immediate influence of temperature has yielded place, in some minds at least, to concepts of races or of polymorphism, where slight differences in form were associated with differences in size. With reference to freshwater copepods, seasonal differences in sizes of wild copepods have rarely been noted and then without recognition of any clear correlation of size or form and temperature.[1] Obviously, when copepods collected in nature are studied, the temperature or other conditions under which the copepods have developed must be unknown, and, since the life of a copepod may extend over several seasons, a collection of any given date may be greatly mixed as to ages of the adults and, accordingly, as to the conditions under which development of the several copepods had occurred.

In a series of experiments conducted in the Laboratoire d'Evolution des Etres Organisés, of the University of Paris, by courtesy of Professor M. Caullery, the director, I attempted to ascertain something of the influence of temperature during development on size and form of certain species of freshwater copepods.

A very clear inverse correlation of size with the temperature at which the copepods were reared was found to prevail for a line of *Cyclops vernalis* Fischer, and apparently for *C. serrulatus* Fischer and *C. viridis* Jurine as well, although the observations with the last two species were more limited. With *C. vernalis* the influence of temperature is such that in our experiments there was virtually no duplication of sizes for the same sex in temperature classes 10–12° C. apart. In spite of much diversity of size within the class, the largest copepods reared at 29° C. would rarely be as large as the smallest of the same sex reared at 19° C., while few, if any, reared at 19° were equal in size to the smallest reared at about 9°. Change in size with successive generations, independently of the temperature at which the particular copepods were reared, was not noted. At any given temperature level the males, always smaller than the females, were relatively more uniform in size than were the females. Differences in size between temperature classes were also notably less for males than for females.

Development is greatly retarded both by low temperature and by shortage of food; but semi-starvation, carried so far as to prolong the period of development to six times the normal period for the temperature, seemed to have no marked effect, as compared with temperature, on size attained when development could be completed.

There was no clear indication of an optimum temperature for size, above and below which the copepods were smaller. Suggestions of an optimum temperature reflected in size and abundance of copepods receive no support from our experiments, since the optima for size and rate of development, respectively, would be near opposite ends of the range of tolerable temperatures.

Rate of development is a function of temperature and of food supply, and doubtless of inheritance, while, if our experiments are properly indicative, size of copepods is a function of temperature and of inheritance, and, only very slightly, if at all, of food supply (as far as quantity of food is concerned). Perhaps development presents a somewhat different problem to animals like copepods that have a definite number of developmental stages attained by successive molts, as compared with the problem presented to animals like fish that grow continuously, or with that confronting those like Cladocera which attain maturity by a variable number of stages (Wagler)[2] and which continue to grow after attaining sexual maturity. We merely raise the question, which seems to merit more consideration than it has had.

Reference may be made to Wagler's hypothesis for Cladocera that high temperature, commonly associated with richer food supply, heightens the metabolic rate to promote early sexual maturity at the expense of body size. The larger low temperature *Daphnia cucullata* first breed in the 5th or 6th instar, while high temperature and presumably well-nourished *cucullatas* breed in the 4th instar. Such a hypothesis would not, on the basis of our results, be applicable to

[1] Literature references will be supplied in other papers embodying details of the experiments and their results.

[2] Erich Wagler, "Über die Systematik, die geographische Verbreitung und die Abhändigkeit des *Daphnia cucullata* Sars von physikalischen und chemischen Einflüssen des Milieus," *Int. Rev. Hydrobiol.*, 11: 41–88, 265–316, 1923.

copepods; but as we have just indicated, the conditions are quite different with copepods, because, so far as is now known, these crustacea can not push forward or backward the stage of maturity, which can come only at the 6th copepodid stage.

The form of *C. vernalis* is modified by temperature, at least as regards the relation of width to length of the furcal rami. Length of furca relative to length of body is probably somewhat less in copepods reared at high temperatures than in those reared at low temperatures (slight degree of inverse correlation) but the direct correlation (with temperature) of width of furca relative to length of body and to length of furca is most obvious: temperature influences different qualities (width and length of furca) differentially. There are significant indications of a tendency to increased spination and also to the development of a spine in lieu of a seta on the outer border of the terminal segment of the endopod of the fourth swimming foot when copepods are reared at low temperatures. "Spine formulas" and the substitution of a spine for a seta at the place mentioned on the 4th foot have been used as bases for specific distinctions for *vernalis* Fischer, *robustus* Sars, *parcus* Herrick, *americanus* Marsh and *brevispinosus* Herrick. The results of these experiments support Lowndes' view that the spine formulas are invalid for specific distinctions in this group of copepods, and they go further in suggesting very strongly the immediate (whether direct or indirect) influence of the environment in the development of the characters upon which the four last-mentioned species were based. Although the three species last mentioned are recognized in the most recent American literature, we do not regard them, or Sars' *robustus* either, as entitled even to sub-specific rank.

It was learned that the copepods of each of the three species employed in the experiments (*vernalis, serrulatus* and *viridis*) have the faculty of becoming dormant at excessively high temperatures (31°–36° C., according to conditions) and of remaining so for hours after exposure to normal temperatures. This condition of dormancy seemed to be different from anything of the kind previously reported for copepods. It was not the "sleep" of Zenker, the kind of dormancy from which the animal can be awakened to immediate liveliness; it was not apparently like the resting condition of encystment in which many copepods survive periods of desiccation. It was a condition induced automatically at certain temperature levels, one from which the animal revived very slowly, one which could be repeatedly induced with an individual animal without obvious injury. During dormancy the animal was to all intents and appearances dead: it would respond to no mechanical stimulus, even though kept at room temperature for some time—hours in some cases. Upon revival in the course of from 4 to 24 hours or more, the condition of the animal was seemingly quite normal; it might continue to form sacs with fertile eggs.

The temperature at which dormancy ensued varied with the temperature at which the copepod had been reared; copepods reared at low temperatures became dormant at temperature levels several degrees below that at which high-temperature copepods succumbed. Retaining low and high temperature copepods under the same conditions of temperature for a week seemed to have no marked effect on subsequent relative tolerances to high temperature: "acclimation" in the usual sense could hardly be invoked. It appears that the temperatures prevailing during development leave some internal effects which are not essentially modifiable by fairly prolonged "acclimation" at room temperatures. (A week is a rather long period in the life of a copepod, such as *vernalis,* covering the period of a possible cycle from egg to egg at room temperature.)

The copepods reared at low temperatures were different from those reared at high temperatures in size and, to some extent, in form and in physiology. How general are the expressions of the influence of temperature on form and physiology is not yet ascertained. The experiments give no suggestion of heritability of the differences induced by temperature. Detailed reports of the experiments are to appear in the *Internationale Revus der gesamte Hydrobiologie,* the *Journal of the Elisha Mitchell Scientific Society* and possibly elsewhere.

Reference may be made also to our recently published report[3] of apparently indefinite inhibition of development without impairment of vitality at ordinary summer temperatures in a new species of copepod.

R. E. COKER

UNIVERSITY OF NORTH CAROLINA

AMEBIASIS IN REPTILES

PARASITIC ameba, similar to *Endamoeba histolytica,* occur in the digestive canal of various reptiles and amphibia.[1,2,3,4] So far as is known these organisms have not been implicated in disease processes affecting the intestines of their hosts, although amebic hepatitis has been described in *Rana temporaria.*[5]

[3] "Arrêt du Développement chez les Copépodes," *Bulletin de la Societe Biologique de la France et de la Belgique,* 67 (2): 276–287, 1933. Description of the species will appear in an early number of the *Journal of the Elisha Mitchell Scientific Society.*

[1] C. M. Wenyon, "Protozoology," 2 vols., 1926.

[2] G. Lavier, *Ann. de Paras.,* 6: 152, 1928.

[3] R. Knowles and B. M. D. Gupta, *Ind. Jour. Med. Res.,* 18: 97, 1930.

[4] E. P. Sanders and L. R. Cleveland, *Arch. f. Protist.,* 70: 267, 1930.

[5] G. V. Epstein, *Arch. Russes Protist.,* 5: 211, 1926.