of 29° (*5*), while according to Herrington (*2*), total heat production is approximately doubled at the lower temperature.

It seems probable that metabolic activity, rather than body temperature, is the predominant factor in increasing the mortality of mice exposed to severely damaging Roentgen radiation. Further experiments concerned with these relationships are in progress.

References

1. Dalario, A. J. *Radiology,* 1935, **25**, 617.
2. Herrington, L. P. *Amer. J. Physiol.,* 1940, **129**, 123.
3. Sugiura, K. *Radiology,* 1941, **37**, 85.
4. Tabor, H., and Rosenthal, S. M. *Amer. J. Physiol.,* 1947, **149**, 449.
5. Turner, M. L. *Amer. J. Physiol.,* 1948, **152**, 197.
6. Warren, S. L. *Amer. J. Roentgenol.,* 1936, **36**, 983.

A Method for Studying Growth in Different Groups of Arthropods

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Linear growth in arthropods is largely discontinuous and usually, but not always, most conspicuous during the molting interval (*1, 5*). Shafer (*9*) likens the linear-growth curve to a series of steps. Size increments during the successive molts are subject to pronounced variation depending, in many instances, on the food supply and on the temperature factor. Also, the final size attained following a particular molt is a function of the initial size, *i.e.* the dimensions prior to molting. Hence, the effect of variation in respect to a particular molt is likely to be cumulative to different degrees in succeeding molts. Wesenberg-Lund (*10*) refers to the rearing method and the method of population analysis for studying age and size of insects at particular instars. MacKay and Weymouth (*4*) in their classical study of *Cancer magister* Dana used population data, largely, for their estimates of per cent increase in size, number of instars, age at sexual maturity, and maximum age.

Animals that grow by molting comprise such a large group that no one method is likely to apply reasonably well to all of them. Rather it is expected that a combination of two or more methods may be needed in the study of even one restricted systematic group. From our studies of the blue crab, *Callinectes sapidus* Rathbun, a method has evolved for estimating the number of post-larval molts typical of a species, and also the size characteristics of the different instars (*2, 3, 6,* and *7*). Because of the application of this procedure to other arthropod groups and its potential value as a tool in attacking diverse practical, as well as theoretical, growth problems, the essentials of the method are related here. The technic was made possible by the large numbers of crab measurements made by Miss Ellen H. Gray and the ingenious rearing experiments carried out by Mrs. Mildred D. Sandoz while working with the writer at the Chesapeake Biological Laboratory and the Virginia Fisheries Laboratory.

The immediate antecedent of these observations was the work of Robertson (*8*) who, by great patience and effort, was able to rear postlarval crabs of this species to an advanced stage in development. Cognizance of the difficulties involved and the obvious variability in the results discouraged similar attempts by us to solve the problem of rearing blue crabs through to the last instar.

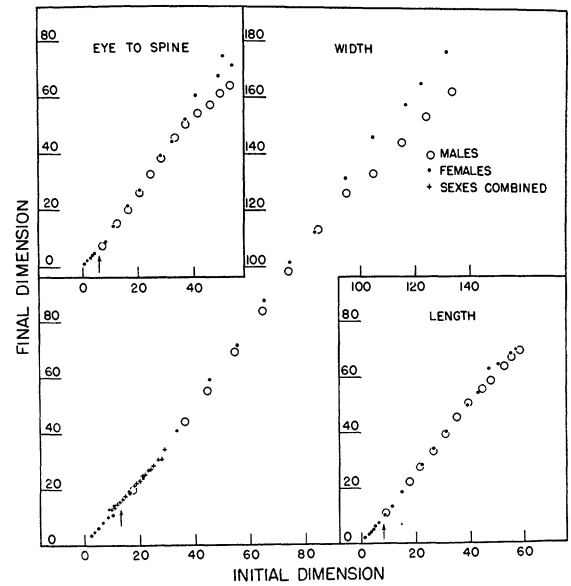

FIG. 1. Relation of initial to final size in *Callinectes sapidus* Rathbun. Sexes are combined in groups to the left of the arrows and in the plus groups.

Even if it were possible to do so, individual variation is so great that a prohibitive, and doubtless impossible, number of crabs would need to be reared in order to yield reliable size averages, representative of the species. The procedure outlined below proved to be reasonably satisfactory and is, seemingly, subject to wide application in the arthropod group.

Small crabs caught just prior to molting were kept in running salt water in the laboratory until they molted. Large crabs molted successfully in specially constructed floats kept near the shore. Hence, simulation of essentially normal conditions was accomplished. Reasonably large numbers of crabs of all sizes were measured before (initial dimension) and after (final dimension) molting. From these data a curve was constructed indicating, for example, the final width, corresponding to any initial width (Fig. 1). This growth curve proved to be a very valuable tool, because once the width of the first instar is known, we have a starting point for using the curve to estimate the theoretical number of instars characteristic of the species. Mrs. Sandoz established the mean width of the first postlarval instar to be 2.5 mm. Thus, from the chart we learn that a crab having an initial width of 2.5 mm has a final width of 3.7 after molting. But this final dimension now becomes the initial width

of the second instar which, according to the curve, reaches a final width, on molting, of 5.1 mm and it, in turn, again becomes a new initial width. Continuing in this manner, it has been possible to estimate the number of postlarval molts and the width of each instar, of which

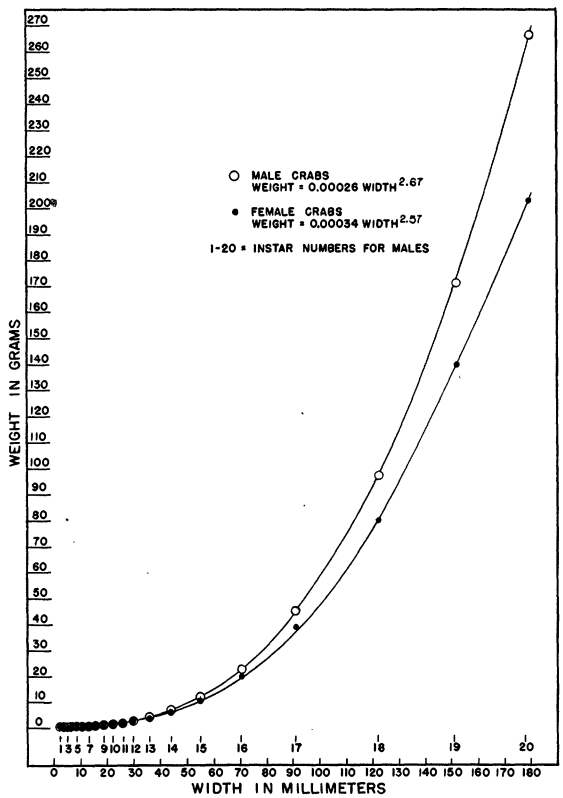

FIG. 2. Showing growth trends in *Callinectes sapidus* Rathbun, based upon growth curve of Fig. 1.

there are believed to be 19 or 20 in males and 18, or possibly 19, in female blue crabs (*7*). A mathematical equation was fitted to the molting curve for males and females so that from any initial width one can calculate directly the final width after molting. Hence, knowing the width of the first postlarval instar, it was possible to calculate the widths of the remaining instars.

To complete the story, it was necessary to establish the relationship between the width dimension, selected for a basic index of size, and other linear and also weight measurements. The allometry equation $Y = aX^b$, was found to constitute a satisfactory expression of the different linear and also weight relationships. Consequently, from a width measurement, any of the corresponding linear and weight dimensions can be readily ascertained. Since the width of each instar has been determined, it is now possible to calculate the remaining linear dimensions and the weights of each instar (Fig. 2).

The information provided by this procedure makes it possible to analyze certain characteristics of the growth of body parts in relation to one another and to the whole body. Also, a basis is provided for interpreting the effect of environmental conditions and mechanical injury on the normal growth curve as established by the preceding technics. The method has potential use for comparing differential growth rates in geographic varieties as well as closely related species.

References

1. CALVERT, PHILLIP P. *Proc. Amer. philos. Soc.*, 1929, **68** (3), 227–274.
2. GRAY, ELLEN H., and NEWCOMBE, CURTIS L. *Growth*, 1938, **2** (3), 235–46.
3. GRAY, ELLEN H., and NEWCOMBE, CURTIS L. *Growth*, 1938, **2** (4), 285–96.
4. MACKAY, DONALD C. G., and WEYMOUTH, FRANK W. *J. Biol. Bd. Canad.* 1935, **1** (3), 191–212.
5. MUSCONI, L. *Boll. Lab. Zool. gew. agrar. R. Scuola Sup. Agric.*, 1925, **18**, 95–118.
6. NEWCOMBE, CURTIS L., ECKSTINE, ALLEN M, and CAMPBELL, FRANK. *Southern Fisherman*, in press.
7. NEWCOMBE, CURTIS L., SANDOZ, MILDRED D., and ROGERS-TALBERT, ROSALIE. *J. exp. Med.*, in press.
8. ROBERTSON, ROY L. Masters Degree Thesis, University of Maryland, 1938, 1–30.
9. SHAFER, G. D. *Stan. Univ. Publ. biol. Sci.*, 1923, **3**, 307–338.
10. WESENBERG-LUND, C. *Inter. Rev. gesam. Hydrobiol. Hydrogr.*, 1913, **6**, 4–5, 373–422.

Cultivation of the Lansing Strain of Poliomyelitis Virus in Cultures of Various Human Embryonic Tissues[1]

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An extraneural site for the multiplication of the virus of poliomyelitis has been considered by a number of investigators (*2, 5*). The evidence that this may occur is almost entirely indirect, although recent data indicate that Theiler's mouse encephalomyelitis virus as well as various mouse pathogenic poliomyelitis-like viruses of uncertain origin may multiply in nonnervous tissue (*1, 3*). Direct attempts by Sabin and Olitsky (*4*) to demonstrate *in vitro* multiplication of a monkey-adapted strain of poliomyelitis virus (MV strain) in cultures composed of certain nonnervous tissues failed. They obtained, however, an increase in the agent in fragments of human embryonic brain.

The general recognition that the virus may be present in the intestinal tract of patients with poliomyelitis and of persons in contact with them emphasizes the desirability of further investigation of the possibility of extraneural multiplication. Accordingly, experiments with tissue cultures were undertaken to determine whether the Lansing strain of poliomyelitis virus could be propagated

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