THE PHYSIOLOGICAL ZERO: AN EXPLANATION OF THE DEPARTURE FROM THE LINEAR GRAPH OF REACTION RATE VALUES AT THE LOWER TEMPERATURES.*

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Considerable controversy has arisen between investigators dealing with the influence of temperature upon physiological reaction rates. Some reactions are decidedly exponential, others clearly linear functions of the temperature. To the first class belong the results of Snyder (1913), on the rate of beat of the mammalian heart and those of Loeb and Northrop (1917) on the length of life of *Drosophila*. The work of Sanderson (1910), Peairs (1914) and others on insect development and that of Krogh (1914) on general metabolism establish the latter relationships.

Marked deviations from the linear curves have been noted at the upper and lower temperatures, making necessary the qualifying clause that the linear relations only held between the normal limits of growth. The departures at the upper temperatures have received an explanation. It is generally conceded that the linear is a modified exponential whose secondary factor increases more rapidly than the primary one at the higher temperatures.

The departures at the lower temperatures have only been noted in connection with methods for the calculation of the physiological zero. Thus if we were to apply Peairs' method for the determination of the physiological zero to the development of *Drosophila melanogaster* it would come at about 8°C. in the work of Loeb and Northrop (1917), and at 10°C. in my own experiments (Krafka (1919–20)).

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Yet Plough reared larvae and pupae at 5°C. Similar deviations are apparent in all of Krogh's curves.

These deviations at the lower temperatures further support the hypothesis that the linear curve

$$y \backsim x$$

is in reality a modified exponential curve

$$y \backsim 2^x$$

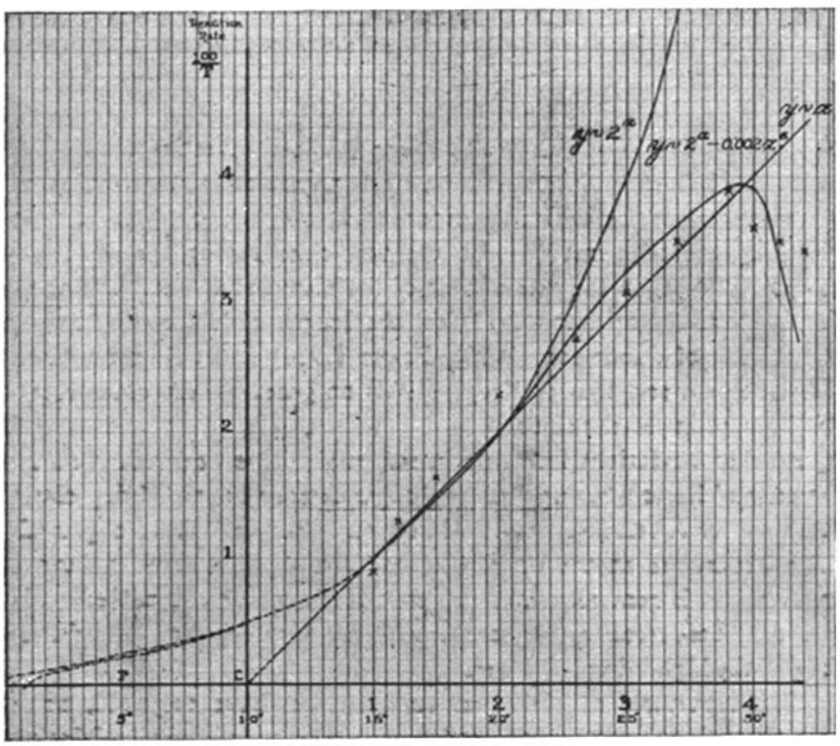

FIG. 1. Curves representing the relations between the temperature and the rate of development of the fruit fly, *Drosophila melanogaster*. The experimental points x fall along the linear curve $y \backsim x$ between certain limits. Projecting this curve to the base line the physiological zero of Peairs is obtained at 10°C. The point P represents an observation establishing development below this by Plough. The curve $y \backsim 2^x$ is a theoretical van't Hoff curve involving two experimental values, while the modified exponential is shown as the middle one at each end.

for under these conditions they are normal and expected, since they represent only the continuation of the primary exponential.

Dr. R. P. Stephens and Dr. David F. Barrow have supplied me with an empirical formula from data on the rate of development of the fruit fly, *Drosophila melanogaster*, which fulfills the conditions for the flattening of a primary exponential into a linear with a sharp bend at the upper end.

$$y \propto 2^x - 0.002x^6$$

This corrective factor at the same time breaks the primary exponential at the lower temperatures so that a theoretical zero becomes possible.

While any number of mathematical functions could be devised whose graphs would fit the experimental points fairly well, the latter formula stated in general terms should have some practical value.

$$y \propto A^x - Bx^n$$

where A represents van't Hoff's constant, B and n calculated values to represent the divergence between the linear and exponential at the uppermost points.

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