Environmental Factors and Correlation Coefficients

In a report in *Science* [**132**, 34 (1960)], Levengood and Shinkle discuss environmental factors influencing the progeny yields in *Drosophila*. In their Fig. 1 they plot the change in progeny yield and barometric pressure for 17 generations of flies and claim that a correlation cofficient of 0.51 exists between progeny yield and barometric pressure and that this result is significant at the 95-percent confidence level. Looking at their curve, one observes that the peaks and valleys are about parallel in just as many instances as they are nonparallel. Nevertheless, the high correlation coefficient is not unexpected, because during the period of investigation the barometric pressure increased in general, as did the progeny yield.

The increase in progeny yield could have been the result of acclimation to the laboratory environment of the strain used, of improved methods of handling, or even of change in the ventilating and heating system of the laboratory during the months of October and November. The authors would have obtained a similarly good correlation between progeny yield and any other factor which accidentally increased or decreased during the same interval. For example, a good positive correlation would have been found with the fuel-oil consumption, and a good negative correlation with the outdoor activity of children.

The authors seem not to be aware that, when computing correlation between two series of quantities arranged in a time sequence, the correlation between the quantities and time has to be eliminated first. If a linear dependence between time and the other quantities is assumed, this can be done by computing the multiple correlation between time, progeny yield, and barometric pressure and determining the partial correlation coefficient between barometric pressure and progeny yield with the time variant eliminated. Another method would be to determine first the regression lines of each of the two variables relative to the time axis and then take the deviations from the regression lines instead of the deviations from the mean.

The partial correlation coefficient between progeny yield and barometric pressure data given in Fig. 1 of the report is not positive, but negative and negligible as compared to its error—

namely, $r = -0.015 \pm 0.250$. Since obviously the other series, for which no data were published, were treated in the same way, the authors' finding of a correlation between progeny yield of *Drosophila* and barometric pressure is not supported by their results.

Special attention has to be drawn to this type of mistake in computing correlation coefficients between two variables arranged in a time sequence, since, due to the fact that often there are comparatively few cases to which experimenters can look for guidance, other researchers, trusting the claimed high confidence levels, attach undue importance to such findings.

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The time ordinate used in Fig. 1 of our report was chosen simply as a convenient means of illustrating the data in graphical form. It was strictly fortuitous that during this period of test the barometric pressure showed a gradual increase, which Barnothy chooses to describe as a "linear dependence." Barometric pressure and time are independent events, and progeny yield and time are independent events; therefore, all that is necessary is to show the interdependence of the pressure and the progeny yield. Since publication of our report we have analyzed over 100 control cultures which represent, on a cumulative basis, a time span of well over 200 weeks, and we have not found a time-dependent relationship. For example, in one 16-generation series, the correlation of barometric pressure with time was essentially zero ($r = 0.06$), whereas the correlation between the barometric pressure and the progeny yield in this same series was high ($r = 0.73$, within the 95-percent confidence limits). Also, the maxima and minima in the progeny curve correspond with those in the barometric pressure curve at 14 out of a possible 14 data points.

In his letter Barnothy concentrates on our Fig. 1 and proceeds to ignore the data in Fig. 2, which extend over approximately a 7-month period and do not show a linear change with time. The progeny data in Fig. 2 disclose remarkably similar variations in curves for two spatially isolated culture bottles, and the peaks and valleys of the progeny curves coincide with those of the barometric-pressure curve at five out of six data points. Even though the partial coefficient is small for the Fig. 1

case and it appears that there is a cross correlation that is dependent on time, it has been shown that the factors of progeny and barometric pressure do not depend on time; therefore the statistics we used were appropriate.

After discussing Fig. 1 Barnothy states that it is obvious that other series mentioned in the report were treated in the "same way." Although the same method of applying the correlation coefficients was used, they were not treated in the same way experimentally. In our report we pointed out, after discussing Fig. 1, that a greater degree of correlation was obtained by using repeated filial generation crosses and the barometric pressure reading for the 72-hour period covering the day before the day of, and the day after the initial mating. Since publication of the report we have continued with this procedure and have repeatedly found the correlation between the progeny yield and the barometric pressure. It was also shown in our report that growth in an electric field reduced the correlation with barometric pressure and produced greater progeny yields than growth of control cultures out of the field. In a later discussion [*Science* **133**, 115 (1961)] it was pointed out that the electric-field effect (35-percent greater yield) may possibly be attributable to variations in air ion densities.

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Research Costs

The recent editorial "Wrong question" [*Science* **136**, 291 (27 Apr. 1962)] is of particular interest. It caused me to recall the period in the 1940's when I served on the "Advisory Committee on Research to the Quartermaster Corps" and found that the colleges and universities almost always underbid commercial organizations and either profit-making or nonprofit research groups who submitted proposals for Army research contracts. I have been concerned for a number of years with the costs of doing research, and I had the feeling then that the colleges and universities did not really know how to calculate their research costs, especially in regard to such factors as heat, light, power, rent, depreciation of equipment, library services, machine shop, administrative expense, and other indirect costs.