A second point requiring emphasis is that the $M$ statistic uses the ratio of each measurement divided by the sum of all measurements of the individual specimens. This procedure can significantly alter the correlation structure of the data (10). One can conclude that Cherry et al. may have induced a complex change in the existing correlation structure of their data and then selected a measure of morphological divergence that fails to account the correlations between characters.

An accepted distance statistic for continuous, intercorrelated variables is the generalized Mahalanobis distance ($D$). This statistic was introduced in 1936 as a response to Pearson’s coefficient of racial likeness which, like the $M$ statistic, does not correct for correlated characters. The Mahalanobis distance is widely used and is a by-product of many computer programs for discriminant analysis. Reference to the use of Mahalanobis distance is found in most modern textbooks on multivariate statistics (11).

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References and Notes
9. A. C. Wilson, personal communication.
12. I am indebted to N. A. Campbell, J. J. Rutledge, and W. Nordheim for their criticisms of a draft of this comment. This research was supported by the College of Agriculture and Life Sciences, University of Wisconsin, Madison.

The requirement for a large sample size stems from the fact that the Mahalanobis method is designed to correct for correlations between traits. To do that, one must obtain an accurate estimate, $r$, of the actual correlation, $p$, between traits. The difficulty of this task can be gauged by looking at the graph of the confidence limits of $r$ in an elementary statistical text (3). Sample sizes greater than 50 are needed before $r$ begins to behave consistently, especially when $p$ is zero. The problem of accurate estimation of $p$ is compounded when the covariance structures of the two populations being compared differ greatly (6).

As a consequence of these considerations about covariance, the Mahalanobis generalized distance $D$ would be expected to be unstable when small numbers of individuals per population are used. This same criticism does not apply to the $M$ statistic of Cherry et al. (3, 7), which takes variance but not covariance into account. Empirical examples demonstrating the instability of Mahalanobis $D$ are given in Table 1. For each pair of species compared, the values of $D$ span a wide range (about twofold) while those for $M$ span a narrow range (about 1.1-fold).

The simple metric, $M$, used by Cherry et al. (3) does not correct for covariance mathematically. If two traits are correlated and both contribute to differences between populations, the double dose of

![Fig. 1. The effect of intercharacter correlation ($r$) on the Mahalanobis distance ($D_r^2$) for values of $r$ ranging from 0.1 to 3.0. All curves are defined with $d_i^2 = d_i = 1.0$. The value of $D_r^2$ when $r = 0$ is also the Pythagorean distance with values to the left and right of zero for each curve demonstrate the effect of correlated characters.](image-url)
Anomalous Water in the Deep Ocean Suggests Lateral Advection-Stirring

Although the report of Amos and Ger- 
ard (1) is tantalizing, the temperature and density data are incorrectly interpreted. These investigators state that bottom water at 40°26.2°N, 56°55.8°W (station Lynch 47-186) in 5200 m of water has the properties of water found about 1000 m higher up in the same water column and suggests turbidity current activity. Their figure 2b (1) of near-bottom vertical profiles includes a break in the depth scale to show how the values of salinity S, temperature T, density ρ, and dissolved O2 content at the ocean bottom are also found from 4000 to 4300 m. The problem with this interpretation is that neither T nor ρ are conservative properties in the deep ocean (2, chap. 3, p. 1087).

The adiabatic gradient is indicated in their figure 2b for the deepest level; the value shown (0.096°C per kilometer) is, however, incorrect (2, p. 63; 2). In fact, the adiabatic temperature change associated with the downslope advection advocated for the 2.32°C water found at ~4200 m amounts to a warming of 0.13°C. A problem associated with using the nonconservative density function σ, in the deep ocean is that profiles of σ appear unstable. This is also illustrated in their figure 2b; apparently less dense water is found beneath denser water. This artifact of the equation of state of seawater can be circumvented if one uses a conservative density function referenced to a nearby pressure surface; usually the 4000-dbar surface is used as a reference for the density function, ρ(σ ′). If potential temperature θ and a properly refer-

References and Notes
4. The broad studies of anatomical evolution in which we are engaged require the comparison of extremely distantly related species as well as very similar ones. The Mahalanobis method was designed to compare very similar organisms, such as those from different populations within a species (2). We are not convinced that it is justifiable, in theory, to use the Mahalanobis method for estimating the morphological difference between species with similar species as humans and chimpanzees (where D2 = 552). Others have expressed similar caution (R. D. Reymont, Biometrika 18, 1 (1962); R. S. Corruccini, Am. J. Phys. Anthropol. 40, 425 (1974)).
6. In the case of humans and chimpanzees, for example, the covariance structures are very different. The differences in r value for pairs of traits range from −0.68 to +0.62. In contrast, the variances of each trait are similar in the two species (3).
7. In defining the M statistic Atchley substitutes "standard error of the difference between the means" for "pooled standard deviation of relative trait length." For the original definition of M, see (3).
8. We do not recommend the use of more than nine traits in computing M (3). More traits will magnify the problem of correlated traits to the point where M values become unreliable estimates of distance.
9. For a majority of species in museum collections, complete specimens of only a few representatives are available (2, footnote 6).
11. The high correlation of M with taxonomic rank (r = 0.38) was illustrated by Cherry et al. (7) for a series of frog species. A detailed presentation of the results of empirical tests involving Mahalanobis D (r = 0.74) and other metrics is in preparation.
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