stated size on a probability scale) has been the most widely used and generally accepted method of treating aerosol data since the 1930's (*10*). The major advantage of a log normal plot is that the size distribution can be directly correlated with lung desposition (*11*) based on the mass aerodynamic (Stokes) equivalent diameters. The log-normal size curves presented in my article can be used to assess the aerosol fraction which can penetrate and be retained in various portions of the respiratory system. However, there are many other ways to plot size data depending on what the investigator wants to determine.

As Whitby *et al.* point out I have used extrapolated data to obtain mass median diameter (MMD) values in some cases. (It is interesting that Whitby *et al.* have also yielded to the same temptation in their figure by extrapolating some of my replotted data beyond the upper size limit of about 4 μm in diameter.) I have reported (*12*) that some uncertainty may be associated with an MMD value derived by extrapolation and have pointed out that "values for the average percent of the particle mass ≤ 1 μm diameter . . . interpolated directly from the particle size distribution curves . . . provide a more accurate picture of the particle size than does the MMD, a value often obtained by extrapolating the distribution curve" (*13*).

The only other large body of mass size distribution data has been published by Lundgren (*8, 14*). His values published for both the MMD's and the geometric standard deviation are in good agreement with my findings (*1*). Patterson's work (*15*) referred to in the letter by Whitby *et al.* presents size data that are somewhat higher in MMD values than the findings presented by Lundgren and my group. The difference may be attributed to the presence of a nearby emission source, a higher particle capture velocity than the high volume sampler, or weighing problems. (A particulate concentration of 100 $\mu g/m^3$ sampled at 1 cubic foot per minute and fractionated over seven stages would amount to only 0.57 mg per stage, provided that there was equal loading, and represents an extremely small amount of material to weigh accurately.) Why there should be a relation between concentration and size of ambient particulate matter as indicated by Patterson is not clear.

Since my article was published, evidence has been accumulating that aerosols may be distributed in more than one mode. Expressing the distribution as single mode log-normal may be an oversimplification, although previous work by Lundgren (*8, 14*) and Lee (*2, 13*) indicated a log-normal plot well approximated the data obtained from available impactors. Treating four- and five-stage impactor data in any more depth than I have reported probably exceeds the limitations of these devices; that is, the size resolution is too poor to define subtle differences in the distribution. An eight-stage impactor system recently developed by Lundgren (*16*) apparently has sufficient resolution to characterize bimodality on a mass basis. This is encouraging since the article (*2*) cites the need for better instruments which would provide more effective size fractionation with better resolution of particle sizes than presently available devices.

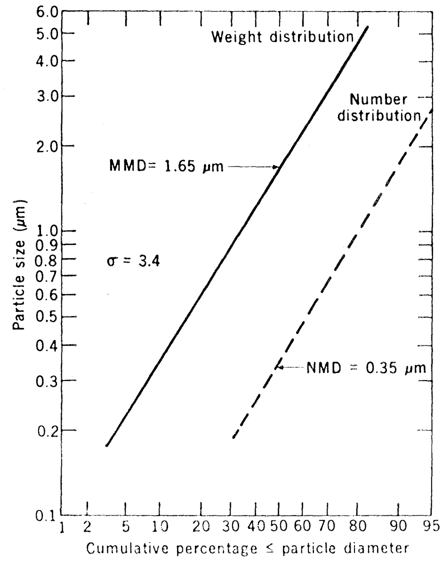

Fig. 1. Composite weight and transformed number distribution of cascade impactor samples collected in Cincinnati, Ohio, on 4 and 21 April 1971, during temperature inversions (*13*).

Visibility reduction is an optical effect of particles. In general, particles that have an optical size of about 0.2 to 1.6 μm diameter on a number distribution basis are most effective in scattering light. In Fig. 1, I have replotted a composite of the inversion data (*2*) both as a mass distribution and a calculated number distribution (*17*), recognizing that volatile particles are probably not accounted for in the transformation. On a mass basis, the MMD is 1.65 μm and constitutes the reference to "large" particles in my article, but on a number basis the MMD is 0.35 μm, which is precisely in the effective scattering range.

Aerosols are difficult to measure and represent the most complicated air pollutant to characterize. Increasing attention from researchers should result in a better understanding of aerosol sources, atmospheric interactions, and methods of control. Of particular importance, in my view, is the need to characterize the chemical composition of suspended particulate matter as a function of size for assessing the inhalation health hazard. Cascade impactors are especially suitable for collecting sufficient quantities of size fractionated materials for chemical analysis.

ROBERT E. LEE, JR.
Environmental Protection Agency,
Research Triangle Park,
North Carolina 27711

References and Notes

1. K. T. Whitby, R. E. Charlson, W. E. Wilson, R. K. Stevens, *Science* **183**, 1098 (1974).
2. R. E. Lee, Jr., *ibid.* **178**, 567 (1972).
3. Environmental Protection Agency, *Fed. Reg.* **36** (No. 84) 8186 (30 April 1971).
4. W. E. Ranz and J. B. Wong, *Ind. Hyg. Occup. Med.* **5**, 464 (1952).
5. T. T. Mercer, *Health Phys.* **10**, 873 (1964).
6. M. J. Heard, A. C. Wells, R. D. Wiffen, *Atmos. Environ.* **4**, 149 (1970).
7. R. K. Patterson, *Anal. Chem.* **45**, 605 (1973).
8. D. A. Lundgren, *J. Colloid Interface Sci.* **39**, 205 (1972).
9. J. N. Hu, *Environ. Sci. Technol.* **5**, 251 (1971).
10. P. Drinker and T. Hatch, *Industrial Dusts* (McGraw-Hill, New York, 1936).
11. Task Group on Lung Dynamics, *Health Phys.* **12**, 173 (1966).
12. R. E. Lee, Jr., R. K. Patterson, J. Wagman, *Environ. Sci. Technol.* **2**, 288 (1968).
13. R. E. Lee, Jr., and S. Goranson, *ibid.* **6**, 1019 (1972).
14. D. A. Lundgren, *J. Air Pollut. Control Assoc.* **20**, 603 (1970).
15. R. K. Patterson, personal communication.
16. D. A. Lundgren, unpublished data.
17. R. D. Cadle, *Particle Size Determination* (Interscience, New York, 1955).

9 January 1974

Radiocarbon Dates for Earliest Domesticated Animals from Europe and the Near East

In entitling our article "Earliest radiocarbon dates for domesticated animals," we followed the practice of keeping titles concise and brief (*1*) even though Bökönyi, Braidwood, and Read have taken exception to this (*2*). We then specified that "Europe is added to the Near East as another early center of domestication" (*1*, p. 235). Thus we indicated clearly at the outset which areas of the world we were dealing with.

The careful reader will undoubtedly notice the use of asterisks in the illustrations to indicate those areas in which a difference of opinion exists as to true domestication. Indeed, we are well aware of the fact that not all specialists will always agree upon how to recognize the bones of domesticated versus wild animals. Because of the complex approach to this research problem we kept Braidwood informed of our work, which he generously supported with bone samples and advice. Moreover, he reviewed our final draft, and we, in turn, made the necessary changes.

With respect to age determinations, we used the format that best provides correlation between radiocarbon and calendric dates—that is, tree-ring calibrated radiocarbon dates, as discussed extensively during the course of Nobel symposium 12 (*3*). In short, for maximum accuracy, radiocarbon dates need to be calibrated against a known chronology. The best to date, and the one with the greatest range, is the bristlecone pine chronology, which correlates dendrochronologically dated bristlecone pine tree-rings with their radiocarbon content. In turn, bristlecone tree-ring ages are taken as equivalent to calendric years since they are in agreement with the correlation between oak tree-rings and historical ages. So far nothing in history or prehistory has indicated that this approach is fundamentally wrong.

Collagen-based age determinations, when carried out correctly, provide excellent results, as we have shown in a study in which we compared collagen and charcoal radiocarbon ages for the same finds (*4*). In our *Science* article we cautioned against using charcoal in areas of the world where petroleum or asphalt occurs, simply because it is difficult to remove such contaminants from highly porous charcoal. In contrast, bones can be conveniently assayed by isolating amino acids that are native to collagen but that do not occur in significant quantity in petroleum. Thus collagen-based radiocarbon dates can often provide better results in petroleum-rich areas than charcoal, but this is not to say that we reject charcoal dates outright. To summarize, it does not hurt to be familiar with a little chemistry.

We do not understand Milojcic's concern. He himself refers to domesticated animals (*5*), citing the analyses of Boessneck for the Argissa-Magula. Of course, we hope that Milojcic is aware of the fact that radiocarbon dates of the same magnitude are essentially contemporaneous, irrespective of where in the world they originate.

Unfortunately, our critics left out some significant words when making claims as to our selection of bones for dating. Our article actually reads, "All bone selected was positively identified on morphological grounds as being from fully domesticated animals (with the exception of some sheep bones) . . . " (*1*, p. 237). Moreover, on the same page we clearly identified bones from animals presumed to be, but not certainly, domesticated. In fact, for Palegawra we state, "wild goats and sheep" (*1*, table 2, p. 237), using the dates to illustrate good correlation between chronology and stratigraphy. Thus we are not quite as naive as misquotes would have us.

Regarding Asiab, we did not cite domesticated sheep at all in table 1, and we placed a question mark in figure 1. This is in contrast to the unfounded allegation that we imply the presence of clearly domesticated sheep at Asiab.

Since our article dealt primarily with Europe and the Near East, we did not mention Lawrence's find of the world's earliest dog in Idaho. If we had written an article on worldwide domestication of animals, we would most certainly have included this important find (*6*).

A charcoal date of $10,800 \pm 300$ B.P. (W-681) has been taken as an indicator of the great antiquity of domesticated sheep in Zain Chemin Shanidar, Iraq (*7*). Indeed, this date may very well be correct. However, we have also observed the case of close association of sloth dung and an atlatl shaft inside Gypsum Cave in Nevada. There, contemporaneity had been assumed (*8*), yet later radiocarbon dates showed that the wood sample was thousands of years more recent than the dung. We would like a direct date on the sheep bones themselves at Shanidar because we agree with Read (*9*, p. 431): "We must be properly cautious in accepting as valid any lone C^{14} determination from an individual locality."

For Jarmo, we again indicate our doubt as to the presence of domesticated cattle by using an asterisk and footnote in both table 1 and figure 1, even though some specialists had suggested possible domestication. The same applies to the onager.

In general, we prefer to deal with facts based on sound measurements—not with fashionable nor emotional archeology. Therefore we have no strong feelings about diffusionistic or independent cultural development. If our article shed some new light on the archeology of Europe and the Near East, it served its purpose. But to say that new light is necessarily highly suspect does not follow, although it may disturb previously held views. More than ever it is necessary today to combine the classical methods in archeology with the changing array of scientific techniques applicable to the study of the past. If some of the techniques rooted in the physical sciences are sophisticated and complex, that does not mean they should be ignored.

RAINER BERGER
Departments of Anthropology and Geography and *Institute of Geophysics and Planetary Physics, University of California, Los Angeles 90024*

REINER PROTSCH
Fachbereich Biologie, Johann Wolfgang Goethe-Universität, Frankfurt am Main, Germany

References and Notes

1. R. Protsch and R. Berger, *Science* **179**, 235 (1973).
2. S. Bökönyi, R. J. Braidwood, C. A. Read, *Science* **182**, 1161 (1973).
3. I. U. Olsson, Ed., *Nobel Symposium 12: Radiocarbon Variations and Absolute Chronology* (Almqvist & Wiksell, Stockholm, 1970). Note especially the paper by H. E. Suess, pp. 303–311.
4. J. Bada *et al., Proc. Natl. Acad. Sci. U.S.A.*, in press.
5. V. Milojcic, J. Boessneck, M. Hopf, *Die deutschen Ausgrabungen auf der Argissa-Magula in Thessalien I* (Habelt Verlag, Bonn, 1962), p. 24.
6. B. Lawrence, *Z. Saeugetierkd.* **32**, 44 (1967); *Tebiwa* **11**, 177 (1969).
7. D. Perkins, Jr., *Science* **144**, 1565 (19[illegible] *ibid.* **164**, 177 (1969).
8. R. Berger and W. F. Libby, *Radiocarbon* **9**, 479 (1967).
9. C. A. Read, in *Prehistoric Agriculture*, S. Struever, Ed. (Natural History Press, Garden City, N.Y., 1971), pp. 423–450.

7 January 1974