LETTERS

The Rem

Eliot Marshall (News and Comment, 26 June, p. 1484) states that "On average, the stack [of the UCLA Argonaut reactor] emits 100 millirems of radiation annually." This is nonsensical. The rem (roentgen equivalent man), or its subunit, the millirem, is a unit of delivered dose adjusted for the relative biological damage to tissue from various types of ionizing radiation, not a quantity of emitted radiation. The emission must be described in curies, specifying the nuclides emitted and amounts of each. A summation of the exposure caused by the emitted radioactive source materials could be indicated by stating that at some specified location an average exposure rate of a certain number of rems (or millirems) *per unit time* exists or that at that location the total exposure annually or for some other time period amounts to x rems.

Either statement, however, has meaning only for a specific location, and is a measure of the radiation that would be received by a person (or measured by a suitable detector) at that site; it is not a measure of the amount of emitted radioactive material.

ERNEST G. SILVER
Oak Ridge National Laboratory Nuclear Standards Management Center, Oak Ridge, Tennessee 37830

Organic Farming

Lockeretz *et al.* (6 Feb., p. 540) make a comparison of "organic" and conventional farming, based in part on mail surveys and personal interviews. Such anecdotal methods are inadequate by comparison with those used by agronomists, in which an investigator typically makes side-by-side comparisons of two or more experimental units, such as plots, with measurements of yield, and chemical analyses of soils and of crops produced. The distinction between organic and conventional farming drawn by Lockeretz *et al.* is unclear; for example, they mention occasional use of herbicides by organic farmers. No analyses for pesticide content of organic crops are given, although in another report (*1*) organic foods were found to contain pesticide residues more frequently than did the average of all foods analyzed.

Organic farming is defined as including no use of urea, but organic farmers "frequently added an 'organic fertilizer,' " that is, manure, which inevitably contains urea. Organic farmers hence imply a nonexistent difference between synthetic and natural urea, shown by Wöhler 152 years ago to be identical (*2*). His experiment is commonly cited as erasing the "vital force" concept of biochemical synthesis. No single example is a clearer illustration than this of the unreality of "organic farming" ideas about fertilizers.

The adjective "organic" properly refers to compounds of carbon, as in "organic chemistry." Its neologic application to food and farming, introduced in 1942 (*3*), was, and is, accompanied by the allegation that food produced without chemical fertilizers is "more healthful" than food conventionally produced (*1*). This claim cannot be substantiated (*4*).

Lockeretz *et al.* state that the protein from organically grown corn was higher in lysine, methionine, histidine, threonine, and glycine, but lower in leucine and phenylalanine than that from "conventional" corn and that this difference could have been caused by "inadequate nitrogen availability." The customary belief is that the amino acid distribution in proteins is controlled genetically by nucleotide sequences in DNA molecules.

THOMAS H. JUKES
Department of Physics and Medical Physics, University of California, Berkeley 94720

References

1. *New York State Public Hearing in the Matter of Organic Foods* (State of New York, 1 December 1972).
2. F. Wöhler, *Ann. Phys.* **12**, 243 (1828).
3. C. Jackson and J. I. Rodale, *Apostle of Nonconformity* (Pyramid, New York, 1974), p. 63.
4. R. M. Leverton, *J. Am. Diet. Assoc.* **62**, 501 (1973).

Although the article by Lockeretz *et al.* makes a contribution to the comparison of organic and conventional farming, the study on which it is based is seriously flawed in several respects. This article should, therefore, be examined in conjunction with earlier reports from the study.

In a previous publication (*1*), the study team acknowledged that the organic farms were selected after "a preliminary judgment of each organic farmer's competency as a farm manager." The conventional farmers were reported to be "top management" farmers, but their yields were only slightly above county average, and fertilizer applications were no more than the state average. Some bias in favor of the organic group seems likely.

The data for 14 paired farms from 1974 to 1976 are all farmers' estimates rather than carefully measured yields. The first-year data are thus farmers' recollections of fertilizer, manure, and pesticide applications; days and number of livestock grazed; and crop yields in the preceding year. Such data are highly unreliable.

In an earlier publication (*2*), the organic farms are reported to have a 2 percent advantage in soil productivity potential.

On the eight farms for which soil maps were available, the conventional farms had 9 percent more of their land in harvested crops (of land that was deemed suitable). Because the Washington University team presents "economic performance" data on a per hectare of cropland basis, this considerable advantage for conventional farms is lost. The authors state, however, that if land in permanent pasture on organic farms is credited with production value equivalent to hay and rotation pasture the advantage for conventional farming as a result of more harvested cropland falls to only 3 percent. It would be more accurate to credit permanent pasture with no more than one half as much productive value because of the lower productivity of native pasture species and typically fewer fertility treatments. The disadvantage of the organic farms for this factor would then stand at 6 percent.

The economic performance of organic farms in 1974 and 1975 would have been considerably less favorable if the prices in those years had not been atypically high and the estimated hay yields unrealistically high (47 percent above conventional in 1974 and 15 percent in 1975). The likely explanation for the high hay yields is that farmers have less precise bases for estimating hay yields than grain yields and simply overestimated them. Although the hay yields averaged 31 percent higher on organic farms from 1974 to 1975, Lockeretz *et al.* state that "The two groups were about the same for oats and hay."

When appropriate adjustments based upon the preceding paragraphs are made with data from earlier publications, the real "economic performance" for organic farms is at least 20 percent less than for conventional farms.

To replace 20 percent lost production on present cropland would require at least 30 percent additional land because the available land is much less productive (*3*). Furthermore, much of this land, which is now idle, in permanent pasture, or forested, is relatively steep, hence highly erosive. Consequently, although erosion on individual farms is calculated by Lockeretz *et al.* to be less in cropping systems characteristic of organic farming

(fewer row crops, more close-growing, small grains and hay), the aggregate erosion on a regional or national basis would be greater if organic farming were widely adopted. . . .

Lockeretz *et al.* suggest that there may be "intermediate systems" which are more attractive than the two extremes studied. That would appear to consist of applying fertilizers at the optimum economic rate and applying pesticides only as needed. That is, in fact, the program suggested by the extension services of state colleges of agriculture as typified by the current widespread attention to integrated pest management. There is, however, no intermediate between growing a leguminous crop to supply homegrown nitrogen and a nonleguminous crop on a field in a given year.

SAMUEL R. ALDRICH
Agricultural Experiment Station and Department of Agronomy, College of Agriculture, University of Illinois, Urbana 61801

References

1. R. Klepper, W. Lockeretz, B. Commoner, M. Gertler, S. Fast, D. O'Leary, R. Blobaum, *Am. J. Agric. Econ.* **5**, 1 (1977).
2. W. Lockeretz, G. Shearer, R. Klepper, S. Sweeney, *J. Soil Water Conserv.* **33**, 130 (1978).
3. S. R. Aldrich, W. R. Oschwald, J. B. Fehrenbacher, *Ill. State Geol. Surv. Environ. Geol. Notes 46* (1971), p. 7

Lockeretz *et al.* state that, if the yield of corn under conventional management is low, a comparable field under organic management will give an equal or higher yield. If the conventional yield is high, a comparable organic yield will be equal or lower. They speculate that a crop may be unable to take advantage of conventional practices when some factors, such as moisture, are limiting. Two statistics are used to justify this belief and speculation. First, the slope of a line, fitted by the method of least squares, through 26 points representing yields of pairs of fields managed by organic and conventional methods, was less than 1. Second, the correlation between the proportional difference in yield on the two kinds of fields and the growing conditions at that location in that year was negative, −.58 (the negative sign is omitted in the article).

There are other reasons why the slope of the fitted line may be less than 1, and these cannot be disentangled here from the one the authors propose. The conventional yield, the independent variable in the statistical model used, is measured with error. The error includes, but is not restricted to, the sampling errors involved in measuring the yield of a field by harvesting several small plots. All errors in measuring the independent variable tend to make the slope lower than what it would be if the errors were not present. Any interpretation of the slope must recognize this bias.

The correlation cited is correct but has an unusual dependence on two extreme values of the proportional difference that arise in pairs of fields with the lowest conventional yields. Without these two points, less than 10 percent of the data, the correlation drops to a nonsignificant −.27. The authors have drawn important conclusions and used undeniably plausible explanations. The supporting evidence, however, is not so strong as is implied.

D. F. COX
Statistical Laboratory and Department of Statistics, Iowa State University, Ames 50011

Cox raises a valid caution regarding the interpretation of the organic-conventional yield differences in relation to growing conditions. We agree that we presented nothing more than "undeniably plausible explanations." If our inference was not correct—that is, if organic farmers do not fare relatively better under poorer conditions—then the relatively good performance they showed in our study was not helped by the adverse conditions during much of the study period and is more generally valid. [One minor technical point to clarify a possible misunderstanding for any readers who may wish to pursue Cox's point themselves: because this article defined the organic-conventional yield difference in the opposite sense from that in an earlier article (*1*) there no longer should be a negative sign in the correlation coefficient.]

Before we respond to Aldrich's letter, two general points must be made. First, although over the 5 years of our study we used many different techniques and studied several different samples of farms from a range of viewpoints, all of Aldrich's criticisms refer only to the first of two economic studies. Our subsequent work, including not only a new economic study but also soil analyses, yield measurements, and a sociological study, was designed largely to overcome the shortcomings and remove some of the limitations we discussed when we reported our initial efforts (*2*). Apparently we were successful, because 6 years after his first published criticism of our work (*3*), Aldrich still confines himself to this initial phase. (Moreover, whenever subsequent studies permitted explicit comparison, it turned out that our preliminary conclusions held up fairly well.)

The second problem in responding to Aldrich is that on several previous occasions he has criticized the very same work using the opposite reasoning. When he was trying to explain away the high energy inputs we found on conventional farms, he concluded that the fertilization rate was "unnecessarily high . . . thus raising the energy input above that needed on these farms" (*4*). Now this same rate apparently is too low, being "no more than the state average," thus showing that the conventional farmers weren't top managers. Likewise, Aldrich initially criticized us for presenting the data on a per hectare basis, since "the only valid comparison is on a whole-farm basis" (*3*); the same study was later criticized on the grounds that "a whole-farm system is simply not a suitable research entity" (*5*), while the current letter seems to rediscover the value of the whole-farm approach.

Aldrich expresses doubt that our sample was made up of "top management" conventional farmers. The evaluation "top management" was not made by us. All conventional farmers who served as part of the matched pairs were " 'top management' operators as judged by local ASCS [Agricultural Stabilization and Conservation Service] personnel" (*6*). No such recommendation was requested for the organic farmers. Thus, if there is a "bias" at all, it could very well be in favor of the conventional farmers. And of course this whole issue—as Aldrich does not point out—applies only to the first economic study, since the second study used all the organic farmers we could find who met certain objective criteria, while the control group consisted of all the farmers in the same counties (*7*).

Aldrich also expresses concern regarding the validity of farmers' estimates of yields. He neglects to mention that measured yield comparisons were entirely consistent with those based on yields reported by farmers, as we noted previously (*1*). Furthermore, the yield comparisons in the first year of the study (which depended on recollection) were quite consistent with those of the last 4 years of the study, during which time concurrent records were kept. Aldrich's concern for the large differences in hay yield is again the result of his apparent preference for the smaller of our two studies. In the initial study (*6*) we explicitly warned that differences in hay yield (in contrast to corn and soybean yields) "may be less meaningful because there were so few [pairs of] farms" growing this crop. Data from all 5 years included in both economic studies (*6–8*) show that hay yields on organic and conventional farms were about the same.

Aldrich points critically to the bias introduced by differences in land use and land quality between the two groups in our first study. We fully discussed this bias in favor of the organic farmers in our report of this study (*8*). We estimated the bias to be between 3 and 9 percent. (It is curious that Aldrich calls the reader's attention only to the 3 percent polar case and then proceeds to "correct" our stated 3 to 9 percent estimated range to his own estimate of 6 percent!) Nor does Aldrich note that in the second, larger study (*7*) no such bias existed; yet the results of the comparisons were similar.

Aldrich notes that the organic farmers wouldn't have done so well if crop prices hadn't been so high in 1974 and 1975. True. But he does not note that, because conventional farmers have a higher output, they benefited even more from the high prices.

But when all is said and done, arguing over whether or not Aldrich is right each time he tries to find a few percentage points here or there for the conventional farmer misses the main point of our conclusions: the amount by which the organic farmers fell below the conventional farmers in yield and productivity was *much less* than had been commonly supposed and certainly gives no support at all to the frequently expressed view that adoption of organic farming—or even of certain features of organic farming—would consign an enormous number of people to starvation and famine. Organic farmers have achieved the results we reported largely without benefit of assistance from agronomic researchers. (Surely agronomic researchers must believe that such assistance is worth at least a few bushels an acre.) Further, from the point of view of the organic farmer, the relatively small deficit in crop production is almost entirely offset by the lower cost of producing crops and the additional advantage of being insulated from shortages and future price increases of energy-intensive inputs. Thus there is good reason to give serious consideration to intermediate systems between the two that we studied, since such systems might offer many of the resource advantages of organic farming with little or no loss of the high productivity of conventional farming. To Aldrich, "intermediate" means no more than eliminating wasteful use of fertilizers or pesticides, which would correspond to an economically optimal version of conventional practice, as currently recommended by extension advisers. But organic and conventional practices differ in many more ways than simply in the quantity of fertilizers and pesticides used. Thus there is quite a difference between Aldrich's suggestion of reducing somewhat the use of these materials in the context of conventional practice and starting with organic farmers' rotations, tillage practices, and so forth, and then adding a modest amount of certain agricultural chemicals to the extent that it is advantageous to do so. (We conjectured, for example, that the small yield difference in corn between the two groups might be largely eliminated if organic farmers applied a small fraction of the amount of nitrogen fertilizer typically used with conventional practices. This rate would be much lower than the "economically optimal" rate under conventional practice.)

Jukes' characterization of mail surveys and interviews disposes of a lot of agricultural research. Actually, besides using these methods, we also did the things he regards as better: side-by-side yield comparisons; chemical analyses of soils; and chemical analyses of crops. (Jukes is right that we didn't analyze pesticide residues in crops, a topic about which our article says absolutely nothing.) Moreover, where the field measurements and the interviews covered the same topic (that is, crop yields), we checked the two for consistency and found good agreement, as noted above. Neither Jukes nor Aldrich, who, respectively, criticized our use of farmers' reported yields as "anecdotal" and "highly unreliable," mention this corroboration. (For that matter, they do not mention the field measurements at all.)

Jukes' implication that protein composition depends only on the nucleotide sequence of DNA does not entitle him to label this the "customary belief." The literature on protein synthesis is full of examples of environmental control of gene expression. In particular, it is well established that the amino acid composition of grain grown from seeds with homogeneous genomes varies with nitrogen fertilization (*9*).

Jukes' criticism of the term "organic farming" is a quibble. The point of words is to communicate ideas. We are confident that every reader knows what "organic" means when it modifies "farming" as opposed to its meaning when it modifies "chemistry" (especially since we set down explicitly the criteria for being included in the sample of organic farms). In addition, a quick check of any dictionary will show that before the word "organic" was applied to chemistry, it had—and still has—other senses that make the term "organic farming" a reasonable one that hardly illustrates the "unreality" of "organic farming" ideas.

Jukes' obvious (but irrelevant) point that urea in manure is identical to synthetic urea says nothing about organic farmers' knowledge of fertilizers. They value manure because it contains many things (which give it a characteristic non-urea-like color, texture, and smell) besides urea, including several that are beneficial to crops and soils. Organic farmers are not alone in recognizing the agricultural value of manure. The conventional farmers in our study applied not only conventional fertilizers (including urea) but also manure to their fields at approximately the same rates as did organic farmers (*6*). Whatever Jukes' view of this issue, the reader may be assured that organic farmers, at least, do know the difference between manure and urea. For instance, were an organic farmer sufficiently incensed by the tone of Jukes' instruction and decided to respond heatedly, he would certainly not make the mistake of asserting that Jukes' ideas on organic farming were full of urea.

WILLIAM LOCKERETZ
School of Nutrition,
Tufts University,
Medford, Massachusetts 02155
DANIEL H. KOHL
GEORGIA SHEARER
Department of Biology,
Washington University,
St. Louis, Missouri 63130

References and Notes

1. W. Lockeretz, G. Shearer, S. Sweeney, G. Kuepper, D. Wanner, D. H. Kohl, *Agron. J.* **72**, 65 (1980).
2. W. Lockeretz, R. Klepper, B. Commoner, M. Gertler, S. Fast, D. O'Leary, R. Blobaum, *A Comparison of the Production, Economic Returns, and Energy Intensiveness of Corn Belt Fertilizers and Pesticides* (Publication CBNS-AE 4, Washington University, St. Louis, Mo., 1975).
3. S. R. Aldrich, *Science* **190**, 96 (1975).
4. *Organic and Conventional Farming Compared* (Report No. 84, Council for Agricultural Science and Technology, Ames, Iowa, 1980), p. 23. This report was prepared under the chairmanship of S. R. Aldrich.
5. S. R. Aldrich, *Ill. Issues* (Sept. 1977), p. 19.
6. R. Klepper, W. Lockeretz, B. Commoner, M. Gertler, S. Fast, D. O'Leary, R. Blobaum, *Am. J. Agric. Econ.* **59**, 1 (1977).
7. G. Shearer, D. H. Kohl, D. Wanner, G. Kuepper, S. Sweeney, W. Lockeretz, *ibid.* **63**, 264 (1981).
8. W. Lockeretz G. Shearer, R. Klepper, S. Sweeney, *J. Soil Water Conserv.* **33**, 130 (1978).
9. S. Dubetz, E. E. Gardiner, D. Flynn, A. I. DeLaRoche, *Can. J. Plant Sci.* **59**, 299 (1979); M. Byers and J. Bolton, *J. Sci. Food Agric.* **30**, 251 (1979); V. V. Rendig and F. E. Broadbent, *Agron. J.* **71**, 509 (1979).

Erratum: In the report "Size of the chloroplast genome in *Codium fragile*" by M. F. Hedberg *et al.* (24 July, p. 445), measurements in the legend to Fig. 1a are mistakenly reported. The correct value of the contour length of the chloroplast DNA is 26.1 micrometers (54×10^6 daltons) and that of the scale is 5 μm.