Healy *et al.* (*3*), who attempted to show that the Denver earthquakes are the result of waste fluid pressures acting in conjunction with a preexisting system of tectonic stress in the basement rocks. In other words, waste fluid pressures appear to have been a *necessary* element in the initiation of the Denver earthquakes.

EDWIN KARP
Department of Geology, New York University, New York 10003

References

1. R. B. Simon, *Science* **165**, 897 (1969).
2. D. M. Evans, *Mountain Geol.* **3**, No. 1 (1965).
3. J. H. Healy, W. W. Rubey, D. T. Griggs, C. B. Raleigh, *Science* **161**, 1301 (1968).

6 October 1969; revised 1 December 1969

Three points to be emphasized in answer to the remarks of Karp are:

1) No seismograph stations with sensitive, matched, short-period instruments existed near Denver to record very small earthquakes there from the time of the largest felt shock in 1882 (*1*) until the Colorado School of Mines opened its observatory (GOL) in January 1962. The first Denver earthquake was recorded only 4 months after that.

2) The smallest earthquakes (magnitude $\gtrsim 1.0$) have always occurred quite near the wellhead on the Rocky Mountain Arsenal grounds. The larger earthquakes extend from slightly south of the well along a line 10 km to the northwest. The southern line of epicenters is sharply delineated whereas the northern boundary is diffuse (*2*).

3) There were three shocks of magnitude $\gtrsim 5.0$ in 1967, more than a year *after* termination of fluid injection. These larger shocks continue to date, 3 years after closing the well. In 1969 there have been two shocks of magnitude 3.5, with 14 more, greater than magnitude 2.5, felt by residents of the area.

The tectonic strains under northeast Denver are more apt to be the cause of the earthquakes now, as in the past, than fluid pressure which has not increased, but which has actually been decreasing, over the last 3 years (*3*).

RUTH B. SIMON
Department of Geophysics, Colorado School of Mines, Golden 80401

References

1. F. A. Hadsell, *Colo. Sch. Mines Quart.* **63** (1), 57 (1968).
2. M. W. Major and R. B. Simon, *ibid.*, p. 9.
3. D. B. Hoover and J. A. Dietrich, *U.S. Geol. Surv. Circ. 613* (1969).

19 December 1969

Allelic Form of Enzymes

Those of us who work on allelic form of enzymes in natural populations are often faced with the problem of distinguishing various hypotheses about the genetics of these enzymes. It is sometimes rather difficult to distinguish multiple protein forms produced by one locus from the results of two or more loci especially when these loci may be evolutionary duplications of each other and closely linked. An interesting case that has arisen concerns alcohol dehydrogenase in maize. Here on electrophoretic gels there are two separate systems of bands with a fast and slow form for each system. In addition, the second system shows in crosses between the fast and slow form an intermediate or hybrid band as well as the two parental bands. Two alternative explanations have been offered for these observations; one by Schwartz (*1*) proposes the two sets are the products of one genetic locus but that there is a second locus that codes for an enzymetically inactive polypeptide that interacts with the products of the first locus to produce the two different sets. An alternative explanation is given by Scandalios (*2*) who suggests that there are two loci, one responsible for the first set of bands and the second for the other. These two hypotheses both need to explain one overriding fact and that is that, in virtually every individual looked at, the fast band of the first set is accompanied by the fast band of the second set, and the slow band of the first set by the slow band of the second set with individuals heterozygous for the first set also being heterozygous for the second set. This virtually perfect association between the two systems leads Schwartz to his hypothesis and is met by Scandalios' extra assumption that the two loci that he postulates are very closely linked and out of random association with each other.

In order to test this hypothesis, Scandalios has looked for crossovers whose occurrence would tend to support his view, and in the paper just cited he presents three recombinant kernels out of a total of 20,124 kernels resulting from the selfing of F_1 plants between the fast and the slow varieties. The occurrence of these recombinants is then offered as proof of Scandalios' two closely linked genes hypothesis. Whereas I cannot distinguish the two hypotheses on the basis of the evidence so far presented, it is the purpose of this note to point out that the evidence presented by Scandalios does not in fact support the two closely linked genes hypothesis. Since there are only three so-called recombinants out of 20,000, the genes are indeed very closely linked. But two of the three exceptions are, under his hypothesis, homozygous for a recombinant chromosome. Since these are F_2 plants, it must mean that an identical rare recombinant occurred both in the sperm nucleus of the pollen and the egg nucleus that formed these kernels. Moreover, this rare double event must have occurred twice, once for each case. The chance of either one of these kernels appearing is quite small, and the chance that two of the three kernels would be of this form is vanishingly small. Alternative hypotheses might be a crossover in either pollen or ovule and a deletion or a mutation in the other nucleus involved in the union. But, again, there are impossibly rare occurrences. Whatever the source of the exceptional kernels that Scandalios reports, recombination between two closely linked genes is terribly unlikely.

R. C. LEWONTIN
Department of Biology, University of Chicago, Chicago, Illinois 60637

References

1. D. L. Schwartz, *Science* **164**, 585 (1969).
2. J. G. Scandalios, *ibid.* **166**, 623 (1969).

11 December 1969

Whereas I appreciate Lewontin's comments, he does not say more than that alternative explanations may be possible for the alcohol dehydrogenase (ADH) recombinants in maize, which I have recovered (*1*). The main point of my note was that the electrophoretically fast and slow variants of the two zones of ADH activities in maize are not associated without exception. The explanation Lewontin thinks I have proposed may be "terribly unlikely" and the association may be "virtually perfect" but it is not perfect. That is the fact. The occurrence of such recombinant types is compatible with my hypothesis.

In addition, I would like to point out that I did not speak of the "frequency of occurrence," but rather of the "frequency of recovery of the aberrant types." This distinction was made to allow for other, more physiological, explanations for the small number of aberrants we see and may not reflect the true frequency of the recombinational events. We are dealing with biologically active molecules that are close

Downloaded from http://science.sciencemag.org/ on April 20, 2021

to, but not the immediate products of the gene. Physiological controls can be exerted in the hierarchy of events from DNA to the functional enzyme species at several different levels. We are presently examining such possibilities, in the hope of arriving at an unequivocal answer.

J. G. Scandalios
MSU/AEC Plant Research Laboratory, Michigan State University, East Lansing 48823

Reference

1. J. G. Scandalios, *Science* **166**, 623 (1969).

5 January 1970

Structure of Water

Narten and Levy (*1*) argue that multi-"phase" models of water structure have not been adequately enough specified to allow a valid test against diffraction data, whereas they represent the one-"phase" model of Narten, Danford, and Levy (*2*) as an adequately specified model. I wish to point out that in fact the Narten-Danford-Levy model is just as inadequately specified as are existing multi-"phase" models. The Narten-Danford-Levy model describes the average structure around any water molecule on the basis of an arrangement of neighbors such as that in ice I, modified by the possible presence of molecular vacancies and interstitial molecules. The model also includes a Gaussian smearing (followed by a continuum) of interatomic distances, which corresponds to the possibility of distortions from the ice-I-like arrangement, in an instantaneous view of the local structure. Since the model is based on ice I, it is reasonable to assume that in an instantaneous picture ("snapshot") of the liquid structure, it will be possible to find numerous local regions having the ice-I-like molecular arrangement—that is, regions in which the distortions are not so large as to destroy the hydrogen-bonding topology of ice I. Narten and Levy have not given an actual probability for the occurrence of such ice-I-like regions in their model, but the only illustration of the model [figure 3 in (*1*)] is a picture of such a region. These regions must occur in all possible spatial orientations, to conform to the isotropy of the liquid. As we go from an ice-I-like region in one orientation to an adjacent one in another orientation, we must traverse a connecting zone containing some kind of structural discontinuity or distortion from the ice-I-like molecular arrangement. A complete specification of the liquid structure must include a description of these connecting zones. Narten and Levy have not shown that their particular model description of the average structure around each molecule contains an internally consistent instantaneous description of ice-I-like regions and of connecting regions between them. To demonstrate internal consistency, one would have to show that regions that are ice-like in structure can actually be connected to one another throughout the liquid by means of regions that are distorted from the ice-like structure in the ways allowed by the Narten-Danford-Levy description, and with the probabilities of distortion that are required by the assumed Gaussian smearings plus continuum.

The need for a demonstrably valid description of the connecting zones between differently oriented ice-I-like regions in the Narten-Danford-Levy model is quite the same as the need for a corresponding description of connecting zones between the various "phase" regions of a multi-"phase" model. In both cases, it corresponds to imposing conditions 8 and 9 (*1*, p. 449), which Narten and Levy put forward as applicable only to the multi-"phase" models. Insofar as Narten and Levy represent their model as a rigorous space average or time average of the water structure, or both, and yet do not demonstrate that the model is a self-consistent description that includes the connecting zones between different ice-like regions, their description is not really a structure *model* at all, but instead is simply the *assumed result* of an averaging procedure applied to a structure the necessary details of which have not been specified. It follows that the Narten-Danford-Levy model of water structure is in no essential way better specified than existing multi-"phase" models are. In several discussions (for example, *3*) of the radial distribution function for water, based on multi-"phase" concepts, Gaussian smearings have been applied to the atomic positions of the different "phases" in a way essentially the same as that of Narten, Danford, and Levy. It has not been demonstrated that such a treatment accounts better for the connecting zones in the one-"phase" Narten-Danford-Levy model than in the multi-"phase" models.

I wish to point out also that Narten and Levy (*1*, p. 453) did not correctly represent the ideas that I expressed in a discussion of water structure (*3*) based on ice polymorphism. I suggested that liquid water is a mixture of molecular arrangements not only of the three types represented by ices I, II, and III, but of many diverse kinds, of which the various ice structures are only illustrative examples. In calculating a radial distribution function containing contributions only from structures based on ices I through III, my purpose was only to show by actual example that combinations of ice-like phases could account for the main features of the observed radial distribution function, which other authors had tried to explain with structural models that either ignored ice polymorphism or overlooked the real features of the dense ice polymorphs (*4*). I pointed out (*3*) that the contributions from the connecting zones between ice-like regions would have to be included in any complete treatment of the radial distribution function.

To include these zones in a calculation of the radial distribution function would require a detailed knowledge of their structure, which we lack. This lack is a handicap not only for model testing by means of the radial distribution function, but also for a rational discussion of the structural basis of many important properties of water (such as fluidity and diffusion) that depend more on the non-ice-like than on the ice-like features of the structure (*3*). The importance of this aspect of water structure gives us added reason not to rely heavily on models that do not incorporate the non-ice-like features of water structure in a demonstrably valid way. The molecular vacancies and interstitial molecules of the Narten-Danford-Levy model are clearly valid possible features of liquid structure, and there is little doubt that such features do occur to some extent in the water structure. However, they would be just as stabilizing for a crystalline phase of the ice-I type as for a liquid (*5*), and it therefore seems unlikely that the presence of these features is the *essential* non-ice-like or noncrystalline aspect of the structure of liquid water. Until it is shown that, in liquid-structure models based on crystal structures, the Gaussian smearing feature (plus continuum) is capable of describing in a valid, internally consistent way the complete three-dimensional structure including the connecting regions between crystal-like regions, there is no

Downloaded from https://science.sciencemag.org/ on April 20, 2024

Science

Allelic Form of Enzymes

R. C. Lewontin and J. G. Scandalios

Science **167** (3924), 1519-1520.
DOI: 10.1126/science.167.3924.1519

ARTICLE TOOLS http://science.sciencemag.org/content/167/3924/1519.citation

PERMISSIONS http://www.sciencemag.org/help/reprints-and-permissions

Downloaded from http://science.sciencemag.org/ on April 20, 2021

Use of this article is subject to the Terms of Service

Science (print ISSN 0036-8075; online ISSN 1095-9203) is published by the American Association for the Advancement of Science, 1200 New York Avenue NW, Washington, DC 20005. The title *Science* is a registered trademark of AAAS.

Copyright © 1970 The Authors, some rights reserved; exclusive licensee American Association for the Advancement of Science. No claim to original U.S. Government Works.