are obliged to cope with nature in all its complexity through the additional dimension of time because history never exactly repeats itself, hence the subject must always have a large descriptive component. Geologists have more intellectual kinship with historians than with physicists, and there are severe limits to a reductionist approach. Furthermore (p. 47), "Geology is not a predictive historical science. It is not even an immature predictive historical science. It is the most highly developed retrodictive historical science."

To illustrate how Kitts applies his basic thesis to particular subjects it may prove useful to consider his attitude to the claim made by a number of people, myself included, that the widespread acceptance by geologists a few years ago of plate tectonics provides an admirable illustration of Kuhn's conception of a scientific revolution. Kitts argues that the comparison is somewhat misleading because Kuhn's examples of changing paradigms are concerned with fundamental scientific laws or principles, whereas continental drift is a specific historical hypothesis that does not challenge basic physical theory. Now this is true enough, but I for one persist in my belief that both in its more general and its more restricted Kuhnian usage the word revolution is a succinct and accurate description of what took place in the earth sciences. Perhaps this is because my fundamental criterion is social rather than theoretical, as I am more interested in what produces mass conversion of scientists from one set of beliefs to another. I would rather adapt Kuhn to geology than drop the term revolution. After all, Kuhn's influential work has been criticized in various quarters for being an oversimplified and to some extent distorted version of what actually goes on in the scientific community.

Although Kitts is basically right in maintaining that geologists cannot challenge fundamental physical laws, and instead depend on them absolutely to make some kind of sense of the past, he provoked me to wonder by what criterion a fundamental, inviolable law of nature is to be established. Presumably we are all happy to preserve the constancy of the velocity of light, but what about the universal gravitational constant? A small minority of geologists believe that the earth has expanded through time, and it has been seriously argued that this could have been achieved simply by a reduction in the value of G. Are we to reject such an interpretation outright because geologists have no license to tamper with such a basic physical principle?

Kitts's essay on paleontology and evolutionary theory provokes a different sort of general question. Is the relation of paleontology to biological theory exactly parallel to that of geology to physical theory? The answer must surely be no, if the most general biological theory is that of Darwinian evolution. This is because evolutionary theory has an essential historical component and fossils must provide critical evidence. The extent to which paleontologists must bow to the interpretations of geneticists, ecologists, and molecular biologists in formulating their own hypotheses of macroevolution is still far from decided, however.

Whether in discussing historical explanation or the establishment of degree of certitude in geology or in evaluating the methodological proposals of a leading 19th-century geologist such as G. K. Gilbert, Kitts rarely fails to be stimulating and thought-provoking. Only his essay on geological time left me absolutely none the wiser. I can warmly recommend Kitts's little book both to philosophically minded geologists and to those philosophers and historians of science who wish to extend their horizon from the very different world of physics and chemistry.

A. HALLAM
Department of Geological Sciences,
University of Birmingham,
Birmingham B15 2TT, England

Processing Solar Energy

Biological Solar Energy Conversion. Papers from a conference, Miami, Nov. 1976. AKIRA MITSUI, SHIGETOH MIYACHI, ANTHONY SAN PIETRO, and SABURO TAMURA, Eds. Academic Press, New York, 1977. xiv, 454 pp., illus. $18.50.

Interest in the potential of biological systems for solar energy conversion has generated numerous meetings, workshops, and symposia in the last few years. This volume of proceedings summarizes much of what has been happening since an earlier workshop in September 1973, and it is recommended reading for specialists as well as the general public. Because the report of the 1973 meeting was available only as a government publication, the release of the present volume with its expected more general distribution is welcome. Further, the book contains considerably expanded discussions and some presentations of new results bearing on topics only tentatively mentioned previously.

What emerges is an overall impression of much potentially promising work on the use of enzyme systems, particularly hydrogenases, as well as photosynthetic organisms for solar energy conversion, although in a concluding chapter an evaluation of the constraints inherent in the use of such systems underscores the need for cautious optimism concerning their eventual applicability in large-scale energy provision. A more realistic attitude is to regard bioconversion as an important component in a many-factorial solution to the energy problem.

The four sections of the book cover all aspects of bioconversion, ranging from algal metabolism, the enzymology of hydrogen activation, and photohydrogen production through the photosynthetic production of organic compounds and nitrogen fixation to large-scale engineering development. Much in the later sections is a rehash of old material, but there are enough new data, as well as descriptions of ongoing research, to justify publication of the book. A particularly attractive feature is the inclusion of papers on research in Japan and, to a lesser extent, in Germany, giving the reader a perspective that includes some appreciation of effort worldwide.

There are clear indications of lacunae. The material presented in the first section is an example. The origin of photohydrogen in algal systems remains uncertain despite considerable experimentation. The much-needed surveys of marine organisms for alternative sources of hydrogenase, as well as whole-cell photohydrogen production, are still in a preliminary stage. Encouraging results with a marine blue-green algal strain that shows comparatively large light-dependent hydrogen production underscore the need to promote such efforts. Applications of aquaculture using algal and bacterial mixed cultures as food sources are still potentially intriguing but are hardly developed beyond the pilot stage. Characterization of hydrogenases, which, along with extensive surveys of source materials, is a necessary step in attempts to achieve stabilization, has moved slowly. Little more is provided about the catalytic and structural properties of hydrogenases than was known some years ago.

However, an attitude of reasoned enthusism is indicated. One recalls the old saying that "everyone talks about the weather, but no one does anything about it." About bioconversion of solar energy there is likewise much talk, but also some do.

MARTIN D. KAMEN
Molecular Biology Section,
University of Southern California,
Los Angeles 90007