Evidence from the Ocean

Productivity of the Ocean. Present and Past. W. H. BERGER, V. S. SMETACEK, and G. WEFER, Eds. Wiley-Interscience, New York, 1989. xviii, 470 pp., illus. $146. Life Sciences Research Reports, vol. 44. From a workshop, Berlin, F.R.G., April 1988.

With the discovery by French and Swiss researchers, from the analysis of polar ice cores, that the carbon dioxide content of the ice-age atmosphere was some 30% lower than modern preindustrial values, intense scientific interest has focused on the sensitivity of global biogeochemical cycles to climatic change. The signal is astonishing. In spite of the fact that the atmosphere exchanges some 30% of its carbon dioxide each year with other reservoirs the level is fairly insensitive to small climatic changes and has been quite constant for millennia before the recent intrusion of humans. Yet the change triggered by an ice age is large—by some estimates, temperatures in the last glaciation were some 30% to 40% lower than those that would result from orbital forcing alone, owing to the loss of this greenhouse gas from the atmosphere. Can equivalent surprises of opposite sign be in our greenhouse–gas-rich future?

Most researchers agree that this ice-age signal arose principally from perturbation of the biogeochemical cycles of the ocean, that the record of it is written there, and that a sharp increase in knowledge of the contemporary operation of these cycles is essential for assessing the possibility of a future unpleasant trigger.

Brought together in Dahlem Conference format, some 43 experts here report and debate in engaging manner the relationships between the productivity of the modern ocean, the geochemical record preserved in marine sediments, and the validity of possible climate signals. Effects of an anticipated warming are of implicit concern but are not directly addressed.

A masterly summary by the editors leads the way, linking modern maps of phytoplankton productivity with the transfer function to the sediments provided, not always simply, by sediment-trap observations. Such collecting devices, moored or drifting in the ocean, catch the fluctuating, dissolving, decomposing downward rain of debris and return samples for study.

Paleoceanographers have long been used to coupling difficult measurements with soaring imagination, and that is revealed in the imagery here. Is the downward flux simply "diminished by road tolls . . . and by import duties at the sea floor"? Or is it "trash left over from (seasonal) Oktoberfest events and from (sporadic) rock festivals"? The validity of reconstructions can critically depend on the answers to these questions, and modern observationalists frequently find large events dominating their signal.

Legendre and Le Fèvre argue for a dominant role of hydrodynamical singularities in the control of the size fractionation, and thus sinking rate, but the physics here is not obvious. Toggweiler points out the newly determined critical role of dissolved organic carbon fields in controlling ocean chemistry, a factor that reduces the emphasis that must be placed on the purely vertical transports. The measurement of dissolved organic carbon and nitrogen in sea water with the required accuracy and precision is a major problem. The reservoir for carbon is large, about twice that of the atmosphere, and the response of this system to climate change is unknown. Wefer confronts the episodic-production problem head on with Antarctic data showing annual flux variations of a factor of 300, strongly correlated with surface events often due to the bloom of a single species.

The Group Report here refers to the challenge that has been posed by Martin and Fitzwater, who have observed stimulated plankton growth following the introduction of nanomolar (so depleted is the remote ocean) amounts of iron and have postulated that atmospheric dust input, strongly enhanced in glacial times, can be a critical control through release of trace amounts of iron to sea water. Should this be so then "rock festival" becomes a double entendre; and the "sporadic" events can be extra-oceanic, associated with continental debris carried for great distances before deposition.

Over most of the ocean more than 90% of the material leaving the surface is consumed before reaching the sediments. Continental shelves provide one exception, for shallow depth means the "road tolls" are diminished. Walsh tackles this issue, with its horrendous sampling problem, and boldly extrapolates. What reaches the sediments is the object of intense study. Stirred by animals, dissolved by carbonic acid, and rotted by bacteria, a vestigial fraction remains to tell its tale. New tools from organic geochemistry (Prahl and Muehlhausen) and new views of the transfer function (Mix) can be brought to bear to help with the geologic reconstruction of marine productivity.

What did I find lacking? Consideration of technique, particularly the power of radiochemistry in key areas. Regrettably only one woman scientist is included among the contributions, Claire Reimers, who does an outstanding job on the control of benthic fluxes by the particulate supply. Direct reporting of Japanese contributions, rather than the frequent reference made, would also have helped; a debate between Yoshimi Suzuki and Shizuo Tsunogai, both with legitimate views, would have been something! A hard-nosed prediction of the effects of a long-term warming has yet to come.

What did I get? An excellent synthesis of an important field. The photographs of participants in Group Report clusters are a nice touch. New maps of productivity appear, and the satellite ocean color images now driving so much new thinking are beautifully reproduced. The next generation of satellite linked-ocean observing programs, particularly JGOFS (the Joint Global Ocean Flux Study) will, it is clearly stated here, be necessary for progress.

Berger, Smetacek, and Wefer have produced a near-perfect example of the conference-volume format.

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Clostridial Renascence

Clostridia. NIGEL P. MINTON and DAVID J. CLARKE, Eds. Plenum, New York, 1989. xiv, 304 pp., illus. $49.50. Biotechnology Handbooks, vol. 3.

The ups and downs of clostridia in the industrial arena are illustrated by the acetone-butanol-ethanol (ABE) fermentation of *Clostridium acetobutylicum*. Discovered in the 19th century, this saccharolytic species was developed for the production of acetone and butanol early in this century. However, in the 1950s the fermentation process succumbed to competition from cheaper synthetic processes using petrochemical feedstocks. Recently, interest has resurged in ABE fermentation as a future source of chemical feedstocks from renewable resources, such as agricultural wastes.

This handbook describes and summarizes our current understanding of the physiology and genetics of the clostridia and their potential for industrial-scale production of organic acids, alcohols, neutral solvents, and enzymes, as well as the use of these orga-

nisms for other potentially valuable biocatalytic processes. The editors have brought together prominent workers in clostridial biology and molded an informative and timely account (with references up to 1988) of the present status of the field. There is an agreeable crispness to the writing and a consistency in style and organization in the chapters.

The genus *Clostridium* consists of a large number of species of very diverse organisms with a high degree of phylogenetic heterogeneity (Cato and Stackebrandt). Clostridia can convert a large variety of complex organic materials to simple organic acids, alcohols, neutral solvents, CO_2, and H_2. The metabolic capabilities of these organisms are introduced by Andreesen, Bahl, and Gottschalk. Ljungdahl, Hugenholtz, and Wiegel discuss authoritatively the metabolic pathways that generate the wide range of organic acids produced by a large variety of clostridial species, with emphasis on the acetogens.

Many saccharolytic species produce neutral solvents as an alternate mechanism for disposing of excess reducing equivalents generated during fermentation. The species range from thermophilic saccharolytic species, such as *C. thermohydrosulfuricum*, that produce ethanol to mesophilic ABE fermenters in which acetic and butyric acids are converted to alcohols and acetone at the end of the acidogenic, exponential growth phase. This transition in metabolism is associated with the initiation of sporulation; the mechanisms responsible for triggering the change are not understood. The fermentation strategies for solvent production by these and related species are comprehensively reviewed by Jones and Woods, as are physiological aspects of inhibition by fermentation end products.

Clostridia also secrete a variety of enzymes that are potentially valuable, particularly the stable enzymes elaborated by the thermophiles. Saha, Lamed, and Zeikus describe the characteristics of a number of extracellular enzymes that are potentially exploitable, including hydrolases, such as amylases, pullulanase, pectinases, collagenase, proteases, selected oxidoreductases, and the complex of proteins making up the cellulosome of *C. thermocellum*.

Because of their anaerobic life style, clostridia possess a wide range of unusual enzymatic activities. The commercial exploitation of such enzymes for the synthesis of specific chiral compounds, for use in assays or diagnostic kits, and for other bioconversions is proposed by Morris. There is even a use (for therapeutic purposes) for the potent toxins produced by toxigenic clostridia (Shone and Hambleton).

This is an excellent time to review the birth of genetic analysis in this genus (Young, Staudenbauer, and Minton). Recombinant DNA technology has been used to clone clostridial genes into *Escherichia coli* and to analyze their structure and expression. Development of a reliable method of transformation of intact cells by electroporation and conjugal transfer of plasmids and transposons are important recent advances, as is the construction of *E. coli/Clostridium* shuttle vectors. Heterologous genes from other clostridia have been introduced into *C. acetobutylicum*. Eventually recombinant DNA technology should be useful for cloning new genetic capabilities into clostridia.

The handbook will be of great value to its intended readers and is recommended reading for graduate students in microbiology. It certainly belongs in microbiology department libraries.

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A Model in Waiting

The Biology of *Euglena*. Vol. 4, Subcellular Biochemistry and Molecular Biology. DENNIS E. BUETOW, Ed. Academic Press, San Diego, CA, 1989. xvi, 528 pp., illus. $150.

Euglena gracilis is not the only alga that normally produces colorless (or non-green) plastids in the dark and turns them into chloroplasts in the light, but it *is* the only alga in which the process of chloroplast development can be readily studied. The initial popularity of *Euglena* as an experimental organism, however, had less to do with chloroplasts than with Seymour Hutner, who determined in 1949 that axenic *Euglena* had an absolute requirement for vitamin B_{12}. Hutner exploited this requirement in a simple and sensitive bioassay for the vitamin and along the way devised several defined media that afforded relatively rapid growth rates (up to three divisions per day) and extremely luxuriant yields (around 15 grams per liter). In the ensuing 40 years *Euglena* became a rewarding subject, mostly for the study of chloroplast development, but also for the study of cell structure, diurnal rhythm, vitamin B_{12}, trace-metal nutrients, and locomotion.

Dennis E. Buetow has been editing *The Biology of Euglena* since 1968 and has himself contributed handsomely to euglenology. This latest volume continues an important tradition that is appreciated by *Euglena* aficionados and should be of profit to all students of phycology, plant biochemistry, and molecular biology.

As is usually true of multi-authored books, volume 4 is uneven. It must be said that the editing is imperfect: citations are in some cases incorrect, and the valuable chapter by S. Kitaoka *et al.* on virtually every enzyme studied in *Euglena* in the last 20 years could have been made more readable. (It was in Kitaoka's laboratory, incidentally, that *Euglena* were first made to yield coupled mitochondria and chloroplasts that could fix CO_2.)

Four chapters on organelles and subcellular particles illuminate the virtual uniqueness of *Euglena*: I know of no other microorganism from which nuclei, mitochondria, microbodies, lysosomes, autophagic vacuoles, and chloroplasts have all been isolated, albeit with varying success. Buetow's chapter on mitochondria is an excellent survey and includes some beautiful three-dimensional reconstructions of the changes that occur in the reticulate mitochondria with changes in nutrition and development. Unfortunately little research at the molecular level has been reported on *Euglena* mitochondria. The situation with microbodies, lysosomes, and autophagic vacuoles is worse, since the latest relevant reference in M. J. Merrett's chapter on those topics is 1981. The chapter by O. Bertaux *et al.* on the *Euglena* nucleus, however, is doubly disappointing. The treatment of the organization and structure of nuclei is drawn almost entirely from literature that is 10 years out of date, and the composition and transcriptional activities of isolated nuclei are presented without reference to what has been learned in contemporary studies on other organisms.

The last third of the volume bears most strongly on the problem of light-induced chloroplast development. The thoughtful analysis by Edelman and Kahana on protein synthesis in plastids marshalls evidence on plastid development at three different levels: in vivo, in organello, and in vitro. Again, the versatility of *Euglena* is demonstrated. The paper by Hallick and Buetow on chloroplast DNA is a summary of gene maps, gene sequences, genome organization, and DNA replication. With some 60% of the genome sequenced, the *Euglena* plastid genome is easily the most thoroughly understood outside of higher plants. The final chapters by N. G. Avadhani and G. Freyssinet on ribosomes and M. Nigon *et al.* on messenger RNAs are strongly weighted, as is the literature, toward clues to plastid development gleaned from the analysis of these elements.

As much as I enjoyed reading the book, I was also troubled: in chapter after chapter the bulk of the discussion centered on the literature of the '70s. It is not that the authors were negligent in including current references, although some were at fault in