high C:N ratios and lignin content are major factors that distinguish terrestrial element cycles from those in aquatic systems. Although the isolated biochemical facts come as no surprise, the chapter succeeds in drawing out the ecological (''ecophysiological'') implications and made me think differently about aquatic processes I thought I knew well.

One reason why many are interested in microbes is that several biogeochemical reactions mediated by bacteria affect atmospheric gases and thus perhaps climate. Microbial ecologists are not going to ''solve'' the greenhouse problem, but we need biology and especially microbial ecology if we are to understand what's going to happen as atmospheric CO_2 and other greenhouse gases continue to increase during the next fifty years. Chapter 9 ''Microbial biogeochemistry and the atmosphere'' should be required reading for all working on climate change. Perhaps some can skip the introduction to atmospheric science (microbial ecologists shouldn't), but everyone should read the sections discussing how microbes can affect atmospheric concentrations and fluxes of oxygen, methane, nitrogen gas and nitrous oxide. The chapter has a nice summary of the dimethyl sulfide story, although the Gaia hypothesis is mentioned in another chapter. Even many microbial ecologists will be surprised to learn about the degradation of anthropogenic gases such as hydrochlorofluorocarbons (HCFCs) introduced to replace ozone-destroying chlorofluorocarbons. HCFCs are greenhouse gases, albeit ozone-friendly, so any degradation by microbes is noteworthy.

Over the last twenty years—really the last five years or so—we have found that bacteria are the most numerous organisms in nature, occurring in just about every conceivable nook and cranny of our planet. Chapter 8 (''Biogeochemistry and extreme environments'') briefly discusses bacteria in marine sediments >500 m deep and in other subsurface environments such as Cretaceous period shales isolated from the surface for 10,000 years. Because it is difficult to cleanly sample bacteria in rocks and deep sediments and because of possible recent exchange with surface communities, reports of bacteria in deep and old subsurface environments have been questioned; nevertheless, evidence is growing that somehow some cells survive out of contact with surface sources of energy and carbon for thousands of years or longer. Much of the research in these and other extreme environments has been motivated by practical problems (e.g., what to do about radionuclide wastes leaching into groundwaters) and by promises of microbial gold (e.g., an enzyme from a Yellowstone hot spring bacterium, originally isolated by L&O author T. Brock, has spawned several million dollar industries and has revolutionized much of biology and some of ecology). But work in extreme environments also touches on questions asked long before the advent of biotechnology: How did life begin? Is life present on other planets? The book ends with a chapter ''Origins and evolution of biogeochemical cycles'' where you can read about prebiotic earth and how cells perhaps first started off on bits of clay or pyrite.

It is not hard to find fault with any book trying to cover all of biogeochemistry in 307 pages—that total includes an appendix, index, and many pages of quite up-to-date references. My main complaint is that sometimes the book reads like a textbook, other times not, although arguably it is the best we have to date. The textbookish appendix is an excellent introduction to microbial thermodynamics, and Chapter 1 ''General considerations'' has the basic facts about bacteria, such as a nice little table about how much energy is expended on various biosynthetic processes (protein synthesis is the most costly at 61% of the total). But the chapter is not light reading and much of the book is perhaps not for beginning students. The section on ''Dissimilatory metabolism'', for example, starts off with an introduction to ATP but then precedes to march through virtually every type of bacterial metabolism in about 30 (small) pages. The sheer density of facts will make it difficult for students to follow.

Fortunately the book is usually much more than a textbook. Rather than listing facts, what the book does is present the authors' view of how the biogeochemical world works. The authors could not cover all biogeochemistry in 307 pages and so choices had to be made. While no reader is likely to agree with all choices, many sections of the book will stimulate if not educate all readers. ''Bacterial Biogeochemistry'' is a worthy successor to ''Bacteria and Mineral Cycles'' and stands a good chance of being found on my shelves of scientific books twenty years from now.

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PATTERSON, D. J. Drawings by S. HEDLEY. 1996. **Free-living freshwater protozoa—a colour guide.** John Wiley & Sons, New York. 223 p. $49.95. ISBN 0-470-23567-5.

Protozoa, the animal-like protists, are found essentially anywhere there is water—from damp soil and mosses to lakes, estuaries, and the open ocean. Despite their near ubiquity and the fact that they are seen by every student learning to use a microscope, protozoa have been often overlooked in aquatic studies. However, this disregard is rapidly changing. For anyone interested in this group—including people brought to the study of protozoa for professional reasons as well as amateurs captivated by their first microscopic observations of protists—*Free-Living Freshwater Protozoa* will be a valuable reference. This informative, easy-to-use book fulfills its stated aim of making the study of protozoa accessible to the nonprotozoologist, and it deserves a broad audience. Although targeted at nonspecialists, professionals will want to have it in their libraries; it will be extremely useful as a teaching aid. Further, despite its title, it will also be useful to marine biologists because many of the genera it describes are represented in brackish waters.

Essentially, this book is a guide to the identification of protozoa at the level of genus based on the attributes of living cells observed with light microscopy (rather than on characters that require specialized techniques of staining or preservation that are often required for species identification). Excellent color photomicrographs are presented in combination with equally good annotated line drawings of each micrograph, and the figure legends often provide ecological information about habitat or feeding behavior. The dichotomous key is unlikely to overwhelm the novice with unfamiliar terminology, and a useful glossary of terms is provided for quick reference. Other details that add to the book's ease of use include having the figures for a genus on the same page as their endpoint in the key and having each step of the key indicated at the outside margin of the page on which it occurs.

Introducing the bulk of the book, which consists of the key and figures, there is a chapter that describes microscopical and collecting methods; it also includes a general classification scheme of protozoa. The author appropriately includes descriptions and illustrations of microorganisms that fall outside of a strict interpretation of the term "protozoa." Some unicellular algae are included with the heterotrophic flagellates, and there is a short section on microorganisms that overlap in size with the protozoa—rotifers, gastrotrichs, and flatworms—all of which bear cilia and are often confused with protists. Several short sections in the final chapter characterize general protistan communities (e.g., plankton, benthos, and sewage

treatment plants); this chapter could have been expanded, but community ecology is not the intended focus of the book. The references are current for the book's original 1992 publication and contain enough diversity and depth to introduce a serious student to the detailed protozoan literature.

It is unfortunate that many of the students or amateurs that will use this book will not have access to the high-quality phase contrast and differential interference optics that produced this book's fine micrographs. These are as close as still photography can come to capturing the beauty of protists at the microscopic level. This compact book is an excellent choice for anyone interested in these fascinating microorganisms.

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NATIONAL RESEARCH COUNCIL. 1996. **Freshwater ecosystems: Revitalizing educational programs in limnology.** National Academy Press, Washington, D.C. 364 p. + xiii. $49.95, ISBN 0-309-05443-5.

This is an important book for those who recognize the importance of freshwater aquatic ecosystems to global ecological welfare, deal professionally with aquatic systems, or are concerned that limnologists might not be prepared to meet future academic and applied challenges. Authored by the Committee on Inland Aquatic Ecosystems of the United States National Academy of Science, it addresses two basic concerns: (1) that ''limnological educational programs are inadequate for the training of future professional limnologists, resource managers and the informed public''; and (2) that ''there is poor linkage between academic programs and the practical application of limnology in the protection, management and restoration of aquatic ecosystems.'' (Limnology is defined as all aspects of freshwater aquatic and wetland physics, chemistry, biology, and ecology).

The book offers a succinct Executive Summary, 170 pages of main text, and 180 pages of background papers and appendices. The main text is organized around five themes: (1) ''Overview: Status of Inland Waters,'' documenting the increasing need for information and informed management on our degraded aquatic systems; (2) ''Limnology, the Science of Inland Waters: The Evolution and Current Status of Limnology,'' a surprisingly detailed chapter on the history of limnology; (3) ''Contemporary Water Management: The Role of Limnology,'' emphasizing the importance of qualified limnologists to applied aquatic problems; (4) ''Education in Limnology: Current Status and Recommendations for Improvement,'' a provocative chapter outlining the present diverse, and fragmented approach to limnological education, with specific alternatives for future education scenarios; and (5) ''Future of Limnology: Linking Education and Water Resource Management.''

The book is well written, reads easily (despite the potentially dry subject matter), and contains numerous inserted boxes with interesting examples that amplify and reinforce the text. The historical section is especially good, tracing the history of limnology from the days of Forel and Forbes through to the present. This sets the stage for the main theses of the book—that education in limnology is haphazard and uneven and that fundamental changes will be required if we are to provide the limnological expertise and leadership that will be needed to successfully deal with problems in applied limnology.

There is no question that the lack of systematic, visible limnological curricula is hindering the production of people whose decisions and actions affect aquatic ecosystems. Unlike other disciplines, such as oceanography and forestry, limnologists in North America are trained in a variety of academic departments. Consequently, good ones have usually been jacks-of-all-trades, whose training was more a matter of luck than good planning. I am reminded of when a zoology master's student of mine was to defend his thesis on winter circulation of arctic lakes. Beneath his thesis defense announcement on the examination room door, a faculty member had written ''What does this have to do with Zoology?'' Indeed, very little—which is exactly the point made in this book. The book then goes on to detail the need for core limnological programs at both the undergraduate and graduate levels, the options for identifiable departments and interdisciplinary programs, and ways to expose undergraduates to limnology.

Most graduate programs in limnology focus on the production of a thesis on a narrow subject. Such programs are the legacy of a time when the primary employer of graduating limnologists was academia. But nowadays, most limnological jobs are in applied fields like impact regulation, lake management, consulting, and conservation organizations. And frankly, our profession is not doing a good job of preparing people to meet this demand. The current situation in northern Canada (a region of burgeoning resource developments that affect aquatic ecosystems) is a case in point. The few regulatory and consulting biologists who were trained in institutes designed specifically to produce resource managers have broad, if sometimes superficial, exposure to the social and physical issues confronting modern limnologists. But most practitioners—even those with Ph.D. degrees—have had woefully incomplete exposure to the physics, chemistry, and biology of inland waters (not to mention the sociological and communication skills that so often make the difference between a good and not so good limnologist).

Freshwater Ecosystems proposes specific solutions to this problem. The one that especially appeals to me is continuing education. This can take various forms: coursework specifically designed to update practicing limnologists (timed to fit in with the busy schedule of such professionals), collaborative programs between industry, government, and universities (there is nothing like a harried frontline regulatory manager presenting the latest environmental horror story to grab the attention of an undergraduate limnology class), and adjunct professorial programs. The latter is an excellent way to expand the expertise available in universities, allowing students to learn from limnologists who are responsible for dealing with real problems, as well as providing opportunities for government and consulting limnologists to refresh themselves academically. My own experience with this arrangement has been very positive: I am a government scientist with an adjunct professor position at a nearby university, and I direct the thesis work of a person employed by a government agency that is responsible for regulating industrial activities that affect arctic lakes. Her thesis topic is a specific problem important to this agency (which grants her time off to pursue her academic work), and funding comes from a joint industry/native organization concerned with long-term aquatic resource management in the region. Being her supervisor keeps me abreast of the latest developments in limnology, which influences my own research.

Another topic discussed at length in the book is the question of certification. Engineers do it; hydrologists do it; why don't limnologists? I have come across people who called themselves limnologists, who were not qualified to row a boat, never mind testify as an expert in a hearing. Granted, it will be difficult to develop certification standards in a diverse field like limnology, but it seems to