

BOOK REVIEWS

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- TOMAS, CARMELO R. [ED.] 1993. **Marine phytoplankton: A guide to naked flagellates and coccolithophorids.** Academic Press. ISBN 0-12-693010-4. 263 p. Out of print.
- . 1996. **Identifying marine diatoms and dinoflagellates.** Academic Press. ISBN 0-12-693015-5. 598 p. Out of print.
- . 1997. **Identifying marine phytoplankton.** Academic Press. ISBN 012693018X. 858 p. \$79.95.

These books were written by the instructors of the “Advanced International Course for the Identification of Marine Phytoplankton.” The two earlier books were combined, with little change, to produce the most recent one (which is the only one still in print). They are intended to provide an in-depth introduction to the identification of marine phytoplankton, especially as viewed through a light microscope; they are not comprehensive tomes that include all species. With regard to most coastal phytoplankton, the books achieve their goal—but with two major limitations. Firstly, the framework of the classification scheme dates from the mid-century, and ignores the revolutionary new information regarding protistan classification that has been derived from electron microscopy and molecular biology. For example, the book places the Euglenophyceae in the Chlorophyta; it has been known for decades that euglenoids are distinctly different from the green algae, and I was shocked to see this appear in books published in the 1990s. Further, the Cryptophyceae, Dinophyceae and Prymnesiophyceae are combined with the heterokont chromophytes; these classes are not only distantly related to the heterokonts, they are distantly related to each other. The green algae have also undergone tremendous revision over the past quarter century, but this is not reflected in these books.

Secondly, in the earliest and latest of these three books the indexes at the back are devoid of any species names. The 1996 book has a mixed index of general terms and scientific names, but neither is comprehensive. The species indexes at the ends of chapters are particularly frustrating because they are hard to locate, and if a name appears in more than one chapter one must consult each index independently.

While the books are a welcome addition for those working in coastal waters, they are less useful for open-ocean scientists. The phytoplankton of open oceans is dominated by “little balls”—coccolith cells with little, if any, morphological character. It is not only difficult to identify species, but there is no consensus on what constitutes a species. It now seems likely that identification of these diverse, abundant, and ecologically important organisms will require new or improved technologies based upon molecular biology, so these books cannot really be faulted for ignoring them. The identity of picoplankton remains a serious challenge for oceanographers who are interested in species-level dynamics. By analogy, one can learn much about tropical rain forests by measuring the primary production of the vegetation, but there is also much to learn about the ecological interactions of the many species of trees, lianas, insects, mammals, birds, etc. Undoubtedly, similar exciting discoveries involving species interactions await oceanographers once the “little balls” can be identified quickly and accurately.

The 1993 book has three chapters. Chapter one, by Carmelo Tomas, is very short (four pages) and provides the outdated classification scheme mentioned above. Chapter two, by Jahn Thronsen, is a guide to the planktonic flagellates exclusive of

the dinoflagellates and coccolithophores; it discusses their motility, size, trophic modes, general cell ultrastructure, sexual reproduction, life cycles, occurrence, and important literature. There is a short introduction to phytoflagellate taxonomy and classification, but no dichotomous key is included. The various algal classes are treated by giving some introductory information, followed by a description of orders, families, and representative genera and species. Cell size, type of flagellation, chloroplast features, cell morphology, and geographic distribution are provided for representative species. The chapter includes two pages of definitions of important terms, and these same definitions appear in a more extensive glossary of terms at the end of the chapter. It contains numerous line drawings of good quality but unfortunately the scale structure of scaly flagellates is not illustrated; this is disappointing because scale morphology, as viewed by electron microscopy, is important (even mandatory) for accurate identification. Similarly, the periplast structure, which is key to the identification of cryptophytes, is also missing. Following the phytoflagellates, there is a short section on representative zooflagellates. Also included are some informative remarks on sample collection, preparation, preservation, and cultivation techniques. There is a dichotomous key based on various flagellate features, indicating the possible classes to which an organism in question could belong. A list of common nomenclatural synonyms is included, followed by an index of names, and an extensive list of literature citations.

The third chapter, by Berit R. Heimdal, is on modern coccolithophorids (i.e., fossil forms are not included). This chapter follows the same outline as the second chapter. Definitions of terms, many of which will be new to the nonspecialist, are not always clear. For example, a ‘crystallolith’ is defined as a ‘disciform holococcolith, consisting of regular rhombohedrons of calcite deposited on the distal surface of an organic scale.’ Fortunately, these are clearly illustrated, and in this case the picture is worth at least a 1000 words. All illustrations are line drawings, and they are generally of good quality, but there are no SEM micrographs of liths, which would have been a welcome addition. The coccolithophorids have an abundance of nomenclatural problems, due to their sometimes multiple-staged life history and to the integration of fossil and living names. Their classification remains in flux, but the chapter carefully explains the scheme used and considerable effort was expended to show nomenclatural synonyms, basionyms and types; this should aid the nonspecialist if they foray into the mess. The description of representative species varies in content, depending upon available knowledge, and generally there are excellent references to direct the user to the primary literature. The chapter concludes with a list of synonymous taxa, an index of names, and the literature cited.

Unlike the first book, the second does contain scanning and transmission electron micrographs and an index at the end of the book. The first chapter, by Grethe R. Hasle and Carmelo R. Tomas, is four pages long, and it describes the history of the Advanced Phytoplankton Taxonomy Course that spawned these three books. Chapter 2, by Grethe R. Hasle and Erik E. Syvertsen, covers diatoms. It begins with remarks on recent advances in diatom taxonomy, characteristics of diatoms, some older literature on life cycles (i.e., pre-David Mann), heteromorphy, resting spores, morphology, and ter-

minology; it is well supported with line drawings. The classification scheme does not follow the 1991 Round, Crawford and Mann tome exactly, but it is hard to fault this since there is no consensus among diatomists regarding classification. A key to the genera is presented for families, and a key to the included species is provided for genera. The chapter contains both figures and plates that are interspersed, and this sometimes proves confusing. Not all species are illustrated, but tables of pertinent information are provided in many cases. The biogeographical information is very general, consisting of three regions (northern cold water, southern cold water, warm water); certainly, much more information is available in the literature but the authors did not compile this for the readers. The book does include some benthic as well as planktonic forms, but this treatment is haphazard. It also has material on the collection and preparation of samples, new nomenclatural combinations, a list of synonyms and an index to the taxa. The literature cited is extensive (23 pp.), including the important older literature; however, recent papers are less well represented.

The third chapter, by Karen A. Steidinger and Karl Tangen, is devoted to the dinoflagellates. The chapter covers the same topics as before, and these are well prepared. Like chapter two, figures and plates are interspersed. The classification of dinoflagellates is currently in flux, with molecular phylogenies in conflict with traditional plate-based phylogenies. The authors have, perhaps wisely, avoided this discussion, and simply present a classification as a framework for the chapter. They mention the growing controversy over what constitutes a species, making it clear that further research is necessary to determine whether cryptic species or subspecific complexes are present in certain cases. Unlike earlier chapters, some genera are not illustrated; the treatment is dominated by the armored taxa. A number of species are designated as toxic but almost no further information is provided. It would have been very helpful if the type of toxin was specified, and if there were some brief discussion of the various toxins in the introductory material. Also, some taxa designated "toxic" are only presumed to be toxic, and this could be misleading. Finally, literature citations regarding toxins are never provided, and one is left wondering where to go to get more information. Data on geographic ranges are very good, perhaps the best of all chapters. Like the other chapters, it concludes with preservation and preparation techniques, nomenclatural synonyms, an index of names, and literature citations.

Book three (the only one still in print) was formed by combining books one and two. Most of the errors in books one and two are corrected in book three but no attempt was made to update the earlier books. Thus, even though book three was published in 1997, literature citations end with 1992 for the phytoflagellates and coccolithophorid chapters. Furthermore, molecular systematics have dominated phytoplankton systematics during the 1990s but this topic is not even mentioned. The book is published with a paper cover and it is unlikely that it will withstand heavy use. It seems incredible to me that the book does not have a comprehensive index of species names.

In summary, I am ambivalent about these books. On one hand, there was a serious need for books like these. They are already on the shelves of most phytoplankton taxonomists and are being used extensively. On the other hand, they could have been much better. The use of electron microscopy, especially for the flagellate and coccolithophorid chapters, is sorely lacking. Thronsen pioneered the use of electron microscopy for flagellates, and it is baffling to find them missing from his chapter. The division/class-level classification scheme is woefully out of date, and molecular systematics is completely neglected. And for the oceanographer, perhaps the most glaring omission is the lack of attention to the coccoid picoplankton. How can one write books on the marine phytoplankton and not include *Prochlorococcus*, putatively the most abundant or-

ganism on the planet? The authors have made a great step forward in producing these books, and we can hope (even beg!) that the revised editions will be more comprehensive.

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FENCHEL, T., G.M. KING, AND T.H. BLACKBURN. 1998. **Bacterial biogeochemistry: The ecophysiology of mineral cycling**. Academic Press, San Diego. ISBN 0-12-103455-0. 307 p. \$64.95.

Only three books on my science shelves were published 20 years ago or more: Paul de Kruif's "Microbe Hunters" which was originally published in 1926 (I don't know when I picked up my used paperback edition, dated 1954, but I paid \$1.65), a chemistry textbook from my first year in college (enough said), and "Bacteria and Mineral Cycling" (published in 1979) by Fenchel and Blackburn, the predecessor to the book reviewed here. In spite of becoming dated over the years, I have read and have made students read "Bacteria and Mineral Cycling" because it clearly describes bacterial physiology and biogeochemical cycles mediated by bacteria, all in a mere 225 pages (counting the index). "Bacterial Biogeochemistry" adds Gary King as an author and 75 more pages of text, and its cover says it is a second edition of "Bacteria and Mineral Cycling". I suppose the claim is not mere advertisement hype, as the two books do share some things in common. But as the preface mentions, "all chapters have been completely rewritten as a consequence of many advances and discoveries during the past 20 years." Indeed.

The 20 years since publication of "Bacteria and Mineral Cycling" have witnessed an explosion of research on bacteria and their roles in all ecosystems. The start of "bacterial biogeochemistry" (to use Fenchel et al.'s somewhat redundant title) can be assigned various dates (e.g., the late 19th century of Winogradski), but the exponential phase of the microbial revolution clearly began a few years after publication of "Bacteria and Mineral Cycling". During the early 1980's, many papers appeared about the "microbial loop", the pathway for carbon from phytoplankton to bacteria via dissolved organic carbon (DOC), which is described in Chapter 3 ("The water column") of "Bacterial Biogeochemistry". As Fenchel et al. point out, however, we knew much about the microbial loop before 1980; Krogh suggested back in 1934, for example, that DOC is the largest pool of carbon in the sea. Estimates of DOC concentrations have fluctuated a bit over the years (a story not mentioned by Fenchel et al.), but even at its current ebb, DOC looms large in carbon budgets. More importantly, several studies appearing since "Bacteria and Mineral Cycling" have shown that DOC fluxes are high and that a large fraction of primary production is somehow routed through the DOC pool, then processed by heterotrophic bacteria, and so on.

Soil microbiology has also probably progressed much over the last twenty years, although many of those advances are far from my interests and of most L&O readers. Perhaps because of that, I learned much from reading Chapter 4 "Biogeochemical cycling in soils", which is wedged between the water column chapter and a separate chapter on aquatic sediments. After an excellent summary of soil physics, Chapter 4 discusses how the biochemical composition of land plant detritus greatly impacts nutrient cycles and microbial assemblages in soils. Unique features of land plants such as

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 CO₂ 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-destrorying 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 non-protozoologist, 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 front-line 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

me that certification is the lesser of two evils. If we are going to be professionals, especially for increasingly important matters that involve regulation and litigation, we should be certified as such, at more than one level if necessary. *Freshwater Ecosystems* offers cogent arguments for both sides of this debate.

In summary, this is important reading for all freshwater scientists who are anxious about the future of limnological research and practice. Everyone reading this book will be stimulated to think, “That’s

the truth” or “I think this way would be better.” If it serves as the catalyst to improve our science and the results it generates, this book will have done its intended job.

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