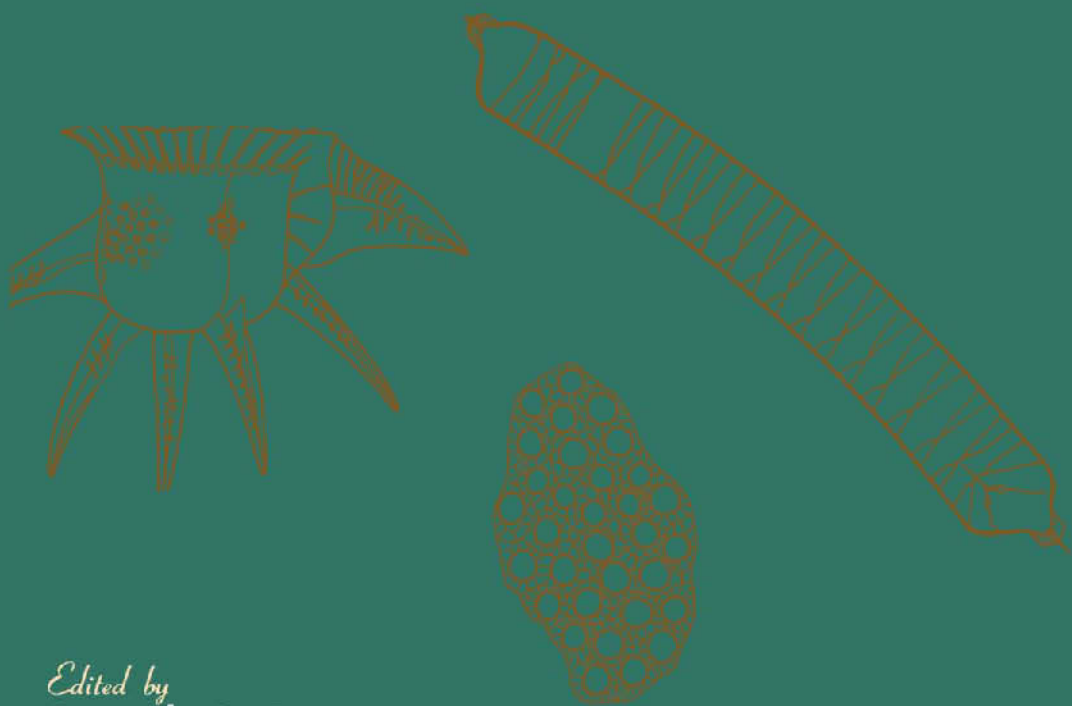
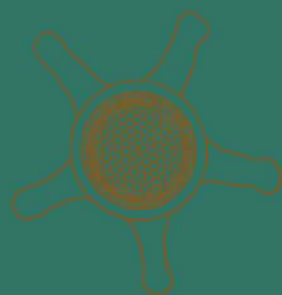


# *Identifying Marine Diatoms and Dinoflagellates*



*Edited by*  
**Carmelo R. Tomas**

*Contributors*  
Grethe R. Hasle • Erik E. Syvertsen • Karen A. Steidinger • Karl Tangen

*Identifying  
Marine Diatoms  
and Dinoflagellates*

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# *Editor's Foreword*

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The present volume is the second identification manual created from the literature developed for the Advanced International Phytoplankton Course. This version, enlarged and modified from the earlier literature, deals with the identification of marine diatoms and dinoflagellates. The definitive text for the identification of all marine phytoplankton species will probably never be written and this work clearly claims not to be so; however, species from all oceans and climatic zones are presented here. The absence of any species from this volume does not imply doubt as to its validity but the data and references presented here should allow the researcher to pursue the question of valid species and how they can be verified. While this volume is amply illustrated, by necessity, not all species could be shown. For these as well as for the ones illustrated, when necessary, we encourage the user to return to the original literature to confirm further details.

For the diatoms presented, the major emphasis is on pelagic marine species while there is a presentation of tychopelagic and some benthic species, which in turbulent environments are found within the water column. The dinoflagellates, however, include pelagic and benthic marine species, some of which may be found in brackish environments as well as in the open ocean. Due to their ecological and human health importance, representative toxic and parasitic species are presented here.

As in the companion volume “Marine Phytoplankton: A Guide to Naked Flagellates and Coccolithophorids” (1993), this manual is oriented toward the researcher who uses light microscopy as the major research tool with perhaps limited access to electron microscopy (either scanning or transmission electron microscopy). However, both the diatom and dinoflagellate chapters refer to TEM and SEM views of structures and morphology to emphasize characters which differentiate species. Most of the species illustrated can be identified with light microscopy with occasional use of electron microscopy to confirm identification.

For the user's convenience, there is a list of common synonyms. These synonyms are presented without judgment as to the validity or preference of the names listed. It is left to the user to seek further information in this regard.



The extensive literature citations are not only meant to document the species discussed but to stimulate the user to locate original descriptions in making confirmations of species that are difficult to identify. Finally, it is hoped that this literature will serve as a constant reference to those doing phytoplankton work, novice as well as experienced researcher alike, and make available materials for identifying phytoplankton species which previously were difficult to collect and use routinely.

As Editor of this and the previous manual mentioned, I wish to express my deep gratitude to all the authors. My role as Editor was to act as project facilitator, assisting when I could with text organization, construction, and clarity. Each author had the freedom to design each chapter in their own way respecting the broadest of structures in order to provide the book with an overall format. Clearly the content of each chapter is the creation of the authors and should not be construed in any other way. I feel privileged to have been a part of the team which created this literature and hope that its value will remain for the years to come.

*Carmelo R. Tomas*

# *Contributor's Foreword*

---

The diatoms have been studied for almost 300 years. A multitude of monographs and floras covering smaller and larger areas has been published, and the exact number of thousands of species distributed can hardly be given. Although the marine planktonic diatoms probably constitute a smaller fraction of the total number of species described, we are still dealing with some thousands of species. The elaborately and intricately ornamented siliceous diatom frustule was a challenge to the first transmission electron microscopist in the 1940s, and in the 1960s scanning electron microscopy was introduced in diatom studies providing even better insight into the structure of the diatom cell. This information led to new combinations of species, rejection of species, and description of taxa of all taxonomic categories. The thousands of species, the hundreds of years of studies, the clarification of intricate structures and relationships between taxa obtained by electron microscopy, and the confusion caused by introduction of new names may explain the length of the present chapter.

The history and development of the diatom chapter coincide with the rest of the project, starting with a simple text in 1976, mainly based on the authors' own research. The basis for a manuscript was therefore at hand when the possibility to publish the course notes as a book started to materialize in 1989. The first draft for a complete text was ready for the editor's corrections at the end of 1991 and was returned to the authors at the end of 1992. This version went back to the editor in April–May 1993, to be returned to the authors 1 year later. In April 1994, the editor and the senior author sat together for a short week to finally prepare a manuscript ready to submit to Academic Press.

Diatom research fortunately did not stand still between the start and the final step of the preparation of the diatom chapter. Efforts were made to incorporate, although to a limited extent, literature published in 1992–1994, but with the qualification that time and space did not permit a detailed treatment. During the last years of preparation nomenclatural problems related to the diatoms under study came to our notice. Thanks to Dr. Paul C. Silva as the nomenclature specialist on algae, most of the problems have been solved.

New taxa and nomenclatural combinations having their first appearance in this chapter will hopefully be dealt with in detail in future publications.

The authors are grateful to Tyge Christensen for correction of the latin, to Paul Silva for his patience with the senior author's numerous questions, to Greta Fryxell for comments on *Pseudo-nitzschia* and *Thalassiosira*, to Frithjof Sterrenburg for comments on *Pleurosigma*, and to Bo Sundstrom for letting us copy his *Rhizosolenia* drawings. Carmelo Tomas is especially thanked for his editorial assistance; his initiative and sustained effort fulfilled the senior author's long-dreamt dream to get literature prepared for the International Phytoplankton Courses formally available to a greater audience. E. Paasche and Carina Lange carefully read and commented on parts of the manuscript; Berit Rytter Hasle assisted with the preparation of the line drawings, and the electron micrographs were made at the Electron Microscopical Unit for Biological Sciences at the University of Oslo.

The project was supported by grants from the Norwegian Fisheries Research Council (1202-203.075 to E.E.S.), and from the Norwegian Research Council for Science and the Humanities (457.90/027 to E.E.S., 457.91/001 and 456.92/006 to G.R.H.). The senior author expresses gratitude to the Department of Biology, University of Oslo, for financial support and also for continued working facilities after retirement.

Grethe R. Hasle

# *Contributor's Foreword*

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Advances in microscopy have furthered our ability to differentiate genera and species based on morphology and cytology. Concurrent with these advances in equipment and technique were individual studies that clarified useful characters; for example, E. Balech's recognition and characterization of sulcal and cingular plates; D. Wall's, B. Dale's, and L. Pfister's characterization of life-cycle stages; H. Takayama's characterization of apical grooves or what B. Biecheler described as acrobases; J. Dodge's characterization of apical pore complexes; and F. J. R. Taylor's synthesis and interpretations on dinoflagellate taxonomy, biology, and evolution. These scientists are counted among my heroes. In the future, there will be more heroes who will have worked on optical pattern recognition, biochemical systematics and molecular probes, and other new avenues to identify species and relatedness among species.

My deepest respect and appreciation go to my Norwegian colleagues to whom I am indebted for inviting me to be an instructor and for sharing their knowledge, wisdom, kindness, and sense of humor with me. To Dr. Karl Tangen of OCEANOR, my collaborator, I offer special thanks. To my friend and mentor, Dr. Enrique Balech of Argentina, I offer my sincerest appreciation for teaching me to see beyond what is obvious and to interpret plate patterns and species differences. To Dr. Jan Landsberg (Florida Department of Environmental Protection, Florida Marine Research Institute) and Julie Garrett (Louisiana State University) I offer my gratitude for encouraging and helping me to complete this project. To the editor of this series, Dr. Carmelo Tomas, I express my gratitude for his patience, resolve, and continued friendship. I also thank and acknowledge Dr. Earnest Truby (Florida Department of Environmental Protection, Florida Marine Research Institute) and Dr. Elenor Cox and Clarence Reed (Texas A&M University) for the loan of their exceptional, unpublished scanning electron micrographs of armored species that were used to draw some of the composite illustrations in the plates. Julie Garrett provided most of the scanning electron micrographs of apical pore complexes. Consuelo Carbonell-Moore (Oregon State University) shared her knowledge of the Podolampaceae with me and is credited for photographs in Plate 7. Llyn French (Florida Department of Environmental Protection, Florida Marine Research Institute)

assisted in preparation of the plates and provided artistic advice. Diane Pebbles, a biological illustrator and artist, provided 80% of the species illustrations, many of them original drawings based on scanning electron micrograph images. Her work increases the value of this chapter. Dr. Haruyoshi Takayama (Hiroshima Fisheries Experimental Station) provided all the photographs of apical grooves in Plates 1 and 2.

*Karen A. Steidinger*

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# *Introduction and Historical Background*

*Grethe R. Hasle and Carmelo R. Tomas*

The content of this book as well as the earlier companion volume “Marine Phytoplankton: A Guide to Naked Flagellates and Coccolithophorids” had its origins as teaching and “handout” literature developed for the Advanced International Phytoplankton Course. Since the original course in 1976, the literature has been updated, improved, and tested on the talented selected participants for each course. With each course offering, requests were made to have the literature presented in a more permanent format as a published book(s). The urgency for the need of such literature was seen as photocopies of the handouts began to appear in various laboratories around the world. Prior to the last course in 1990, an attempt to finalize this goal was realized with the agreement to write one book containing this literature. Here we will briefly present the steps of the procedure leading to the publication of this volume.

The idea of an International Course in Phytoplankton had its origins with Professor Trygve Braarud at the University of Oslo, Norway. Within his archived files are notes where Professor Braarud considered a course to teach young students of phytoplankton. The faculty would consist of Professor F.



Hustedt (Diatoms), Professor J. Schiller (Dinoflagellates), and Professor E. Kamptner (Coccolithophorids). These names, gurus of the phytoplankton studies of the first half of this century, would have truly made an all-star teaching team. This dream was realized but not with the cast originally designed, as by the time the course was ready to be taught, most of these mentors were deceased.

In January 1969, a working Group of Phytoplankton Methods (WG 33) was established during the executive meeting of the Scientific Committee in Oceanic Research (SCOR). During this meeting, Professor Braarud pointed out the urgent need for considering phytoplankton methods other than those involving pigment and other chemical analyses. The IOC Working Group on Training and Education also commented on the need for modern textbooks and manuals (Unesco technical papers in marine science no. 18, Paris, 1974).

In Item 4 of the Terms of Reference to WG 33, the Working Group was asked to prepare a report including reference to literature in taxonomy of the main groups and on methods for using quantitative phytoplankton data in ecological studies. To fulfill this request, the Working Group suggested a list of the contents of such a manual and a tentative plan for a "Phytoplankton Course for Experienced Participants." The University of Oslo was chosen as the place for the course and the Marine Botany Section as responsible for the teaching program.

The preparation of a Phytoplankton Manual of Methodology started with a meeting at the University of Oslo under the auspices of SCOR in 1974. The "phytoplankton manual" was published in 1978 by Unesco as "Monographs on Oceanographic Methodology 6" with A. Sournia as the editor. No further steps were taken to prepare a corresponding manual on phytoplankton taxonomy although a need had been expressed by some members of WG 33.

The first "Phytoplankton Course for Experienced Participants" was held at the University of Oslo during 4 weeks in August–September 1976 with 17 participants from 13 different countries. After the first offering, the length of the course was cut to 3 weeks, and the next two courses, in the autumns of 1980 and 1983, were held at the Biological station in Drøbak, belonging to the University of Oslo. Stazione Zoologica "Anton Dohrn," Naples, Italy, hosted and organized the courses now called "Advanced Phytoplankton Courses, Taxonomy and Systematics" in 1985 and 1990. Another session of this course is presently being planned for Fall 1995 to be held again at the Naples facility.

From the very beginning interest in the courses was considerable and increased with each offering. In 1990, more than 100 applications were received for the 15–17 places available. The apparent need for a course dealing with identification of phytoplankton species became more evident with the increased activity in mariculture, the recurrence of harmful phytoplankton blooms, the

documented toxicity of certain species, the apparent increased pollution of the sea, and global atmospheric changes.

A total number of 77 participants, representing 35 countries, participated in the five courses to date. The instructors in 1976 were the late Karen Ringdal Gaarder (coccolithophorids, dinoflagellates), Grethe Rytter Hasle (diatoms, dinoflagellates), E. Paasche (algal physiology, cultures), Karl Tangen (dinoflagellates), Jahn Thronsen (naked flagellates), and Berit Riddervold. All the instructors with the exception of Berit Riddervold Heimdal (coccolithophorids), from the University of Bergen, were from the University of Oslo. In 1983, Karen A. Steidinger, Florida Marine Research Institute, and Karl Tangen, now Oceanor, Trondheim, Norway, taught dinoflagellates and Barrie Dale, University of Oslo, lectured on dinoflagellates cysts. Erik E. Syvertsen, University of Oslo, assisted G. R. Hasle with the diatoms. From 1985 the staff of Stazione Zoologica also participated in the teaching.

The courses were sponsored by SCOR and IABO, and financially by UNESCO, NORAD (Norwegian Agency for International Development), the Norwegian Ministry of Foreign Affairs, the Italian Ministry of Foreign Affairs, the Italian National Research Council, the U.S. Office of Naval Research, Stazione Zoologica "A. Dohrn" di Napoli, and the University of Oslo.

Despite the unique collection of reprints and identification literature available during the course at the University of Oslo, and later at the Stazione Zoologica, class notes and handouts had to be prepared. They started out with a few pages on each group and increased gradually with additional information from the literature and the respective instructor's own research. In 1983, mainly by Karen Steidinger's initiative, contacts were made with publishing companies to formalize an officially published text. These attempts failed, but in 1989 Carmelo R. Tomas (participant of the 1983 course) started successful negotiations with publishing companies for a text to be used in the 1990 course. Again this deadline was not accomplished but a firm commitment from the authors, editor, and publishing company was definitely made. Consequently, the course notes changed in format and increased in content to form the basis of a manuscript for publication. It became evident that the flagellate and coccolithophorid texts would be completed ahead of those on the diatoms and dinoflagellates. This plus the fact that the newly expanded version of the diatom and dinoflagellate sections exceeded the original project would make a book containing all parts too large for a handy volume. After renegotiation between Academic Press and Carmelo Tomas as the editor, it was decided that a volume on flagellates and coccolithophorids would be published first to be followed by the present one on diatoms and dinoflagellates.

Running expenses inside Norway, related to the manual project, were covered by grants from the Department of Biology, University of Oslo; the Norwegian Research Council for Science and the Humanities (NAVF 457.90/041); and from the Norwegian Fisheries Research Council (project 66170).

Planning funds for the literature were also awarded to the editor from UNESCO while funds for illustrations, technical assistance, postage, and communications were given by Stazione Zoologica of Naples. Since no member of this team was funded to work full-time on this project, each person gave of their personal time and effort to accomplish the goal of completing these manuals. The respective institutions gave support, as was possible, affording each author and editor the opportunity to work on this project. The support notwithstanding, each member of this team worked on this literature while assuming full duties of their permanent work assignments.