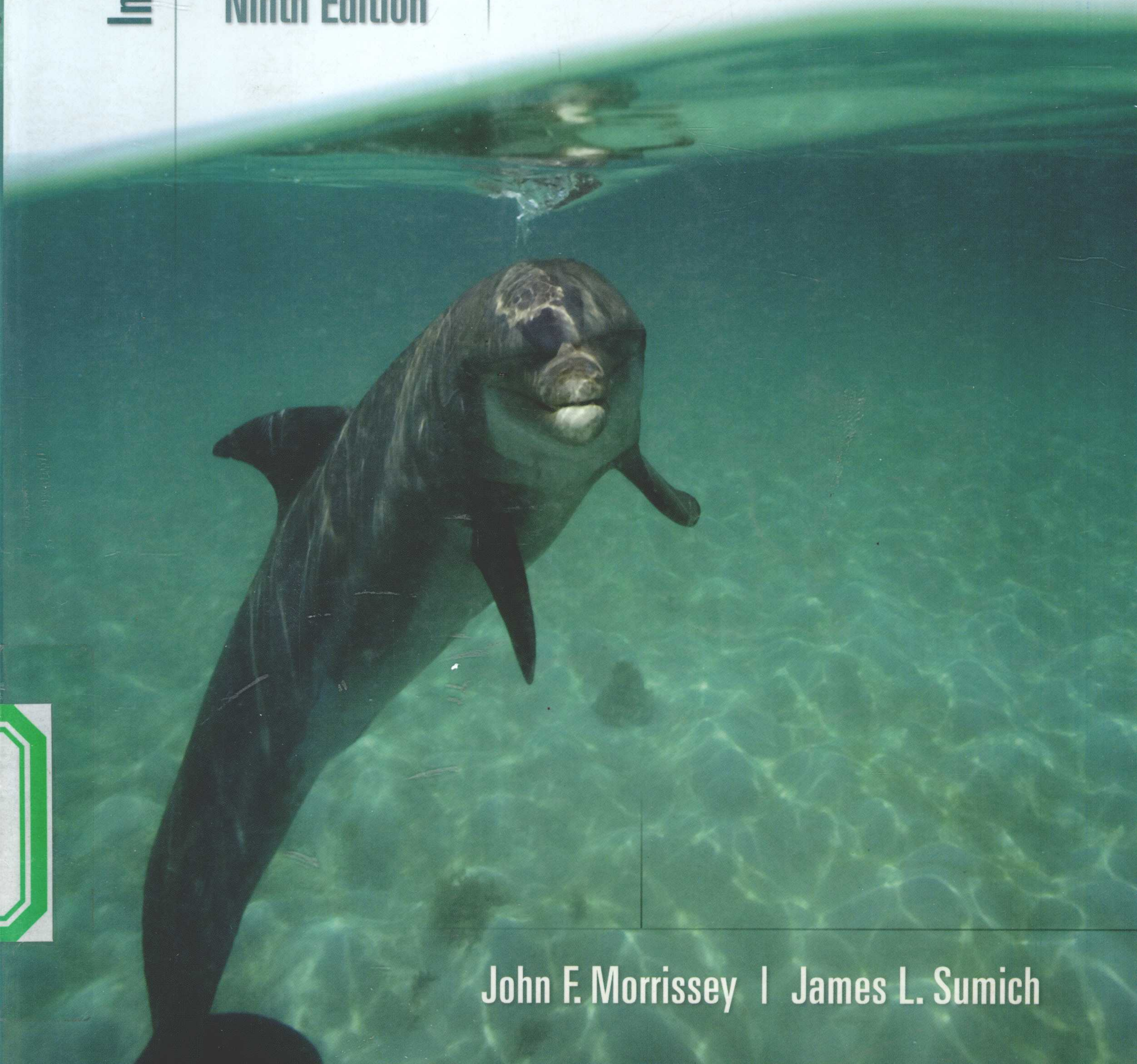
Introduction to the

Biology of Marine Life

Ninth Edition



John F. Morrissey | James L. Sumich

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Sweet Briar College

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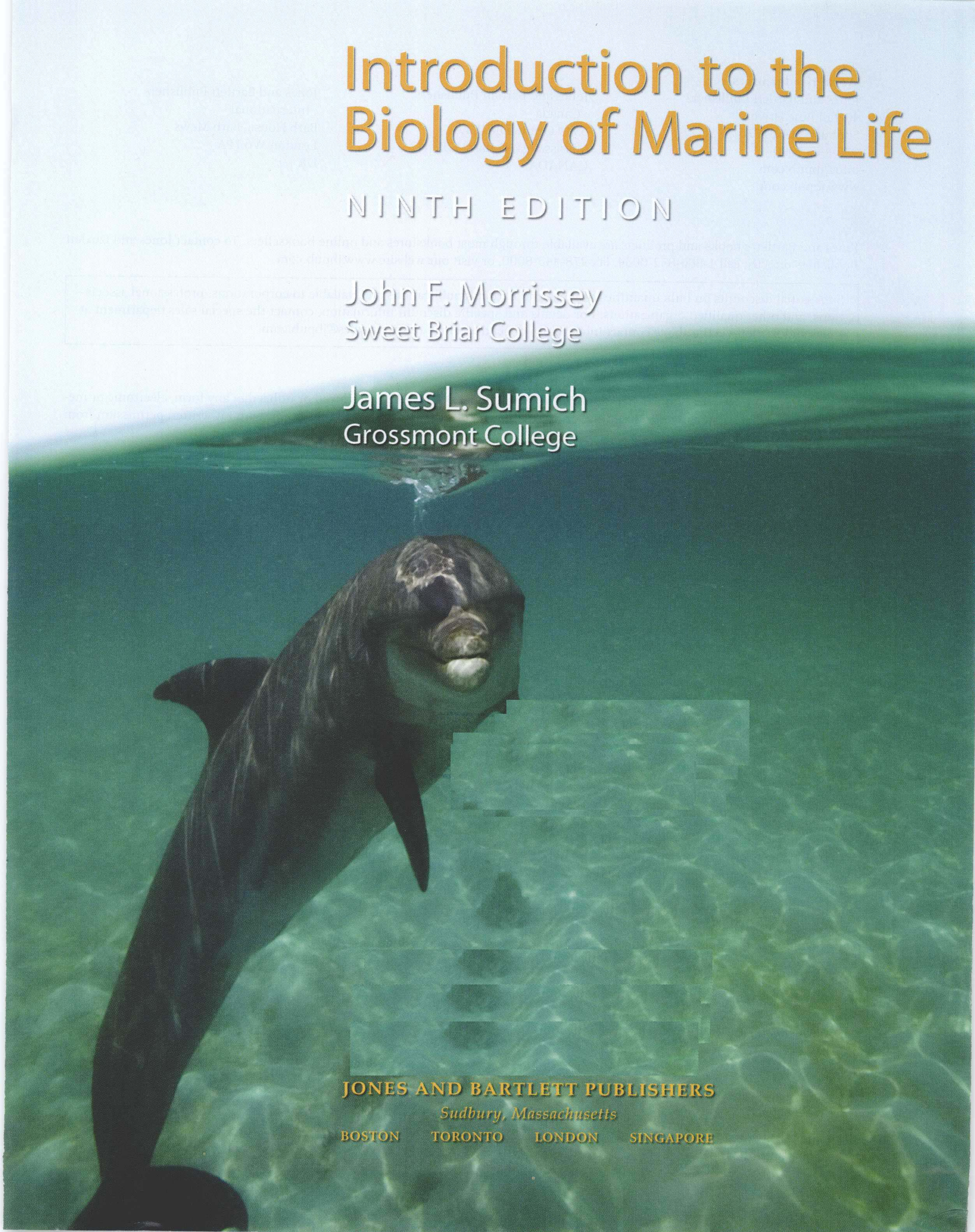

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Preface

We have written *Introduction to the Biology of Marine Life* to engage introductory, college-level students in the excitement and challenge of understanding marine organisms and the environments in which they live. We assume no previous knowledge of marine biology; however, some exposure to the basic concepts of biology is helpful. This book uses selected groups of marine organisms to develop an understanding of biological principles and processes that are basic to all forms of life in the sea. To build on these basics, we present information dealing with several aspects of taxonomy, evolution, ecology, behavior, and physiology of these selected groups. We have intentionally avoided adopting any one of these major subdivisions as the framework of this text. *Biology* is an inclusive term, and we hope that a student's initial venture into this exciting field provides some flavor of the mix of disciplines that constitutes modern biological science.

As in most textbooks, we intend the sequence of topics to be flexible. We begin with an introduction to the sea as a habitat (Chapter 1), highlighting the many ways that the ocean realm differs tremendously from more familiar terrestrial environs, and then provide a brief summary of basic chemical and biological principles for the beginning student (Chapter 2). Chapters 3 through 6 summarize all life in the sea, with two chapters dedicated to autotrophic producers, followed by two chapters of heterotrophic consumers. We have organized Chapters 7 through 12 of this new edition around the major marine habitats: estuaries, temperate coasts, coral reefs, the open ocean, the deep sea, and polar seas. Finally, we conclude by describing the history of and prognosis for marine fisheries and aquaculture in Chapter 13.

Although this text includes more material than might be covered in one semester, instructors can select and mold the material to match their teaching styles and time limitations. With judicious use of outside supplementary readings, this text can easily provide the structure for a two-semester or upper-level course.

Changes in the Ninth Edition

The widespread and positive reception of the eighth edition of this text has been very encouraging and is due in no small way to our move to Jones and Bartlett Publishers. This ninth edition represents our continuing effort to better meet the needs of those who use the text. The many welcome and helpful suggestions and comments from readers and reviewers have been instrumental in the considerable changes that have been made for this new edition.

Most noticeable is the completely revamped art package that accompanies this text. Each chapter now contains many new color photographs to assist students in visualizing the concepts presented. Moreover, all line-art drawings, graphs, and charts have been carefully scrutinized for relevance, accuracy, and ease of interpretation; many were altered to make them superior pedagogical tools that instantly convey up-to-date information.

We trust that our users will be pleased to see the many ways that the text itself has been augmented. Major new sections have been added that (a) detail our new appreciation of the **important role of cyanobacteria** in primary production in tropical seas, (b) carefully explain and distinguish the important concepts of **compensation depth and critical depth**, (c) summarize the importance of **marine viruses**, (d) introduce the complex **production models and consensus algorithms** that are used with satellite-based estimates of global production, (e) present the distribution and ecology of **marine fungi**, (f) consider the causes of surprisingly high **deep-sea biodiversity**, (g) greatly expand our coverage of the unique chemoautotrophs and highly dependent heterotrophs associated with **hydrothermal vents and cold-seep communities**, and (h) demonstrate that the time to act is now if we are to mitigate **global warming and climate change**. In fact, Chapter 11 (The Deep-Sea Floor) alone has been expanded by 20 percent to incorporate recent breakthroughs in our understanding of this largely unknown frontier.

In addition, end-of-chapter summaries, questions for discussion, and supplementary reading lists, which encourage further in-depth exploration of covered topics, have been revised and updated. Additional updated references, listed at the end of the text, will be useful to students who have the enthusiasm and communication skills necessary to cope with the challenges of reading original literature.

Research in Progress Boxes

Marine biology, like all sciences, is a dynamic and active field. Each year, recent discoveries about the sea are published in thousands of new scientific papers. In this edition, we strive to present our current understanding of marine biology as a work in progress. In each chapter, contemporary research issues, recent technological advances, and current topics of interest are presented as *Research in Progress* boxes, with selected references to lead interested students to additional background information. Through these boxes we hope to show the process of science, as well as to suggest to our readers that marine biology is a vibrant field of study, ready for their future contributions. The *Research in Progress* boxes, in chapter order, are:

Powers of 10 and the Metric System
Metabolic Rates of Large Mammals
Oceanography from Space
Can an Army of Snails Destroy a Salt Marsh?
Marine Sanctuaries
Serendipity in Science: The Discovery of Living Coelacanths
A Surprising Result of Wetland Loss
War: The Forgotten Source of Oil Spills
Threats to the Diversity of Living Sea Turtles
Dolphin Swimming
Deep Submersibles for Seafloor Studies
Global Warming and Climate Change: It Is Time to Act
Using Science to Detect Misleading Science

Ancillaries

The **Instructor's ToolKit—CD-ROM** Compatible with Windows and Macintosh platforms, provides instructors with the following traditional ancillaries:

The **Instructor's Manual**, provided as a text file, includes chapter outlines, summaries, and objectives; key concepts and terms; teaching tips, insights and anecdotes relevant to each chapter; lists of the key genera discussed within each chapter; essay questions; and additional critical thinking questions to test the students' level of comprehension of more difficult topics. To answer, the student must understand and integrate the facts as well as the concepts.

The **Test Bank**, prepared by John Morrissey, is available as text files and contains many multiple choice and true/false questions.

The **PowerPoint® Lecture Outline Slides** presentation package, prepared by John Morrissey, provides lecture notes and images for each chapter of *An Introduction to the Biology of Marine Life*. A PowerPoint viewer is provided on the CD. Instructors with the Microsoft PowerPoint software can customize the outlines, art, and order of presentation.

The **PowerPoint® Image Bank** provides a library of all the art, tables, and photographs in the text to which Jones and Bartlett Publishers holds the copyright or has permission to reproduce digitally. With the PowerPoint program you can project images from the text in the classroom, insert images into your existing PowerPoint lecture presentations, or print your own acetates.

Animations of selected illustrations in the text expand the reach of the figures beyond the static page. Because certain concepts in marine biology involve motion, these animated illustrations are an invaluable tool for helping students to understand the concepts.

Additional public-domain movies and animations from the National Oceanographic and Atmospheric Administration (NOAA) are provided as a courtesy.

Marine Biology On-Line, this text's web site, **http://biology.jbpub.com/marine**, provides additional resources to expand the scope of the textbook and make sure students have access to the most up-to-date information in marine biology. Students can find a variety of study aids in the eLearning area, such as chapter outlines, flash cards, and review questions. Carefully chosen links to relevant Web sites enable students to explore specific topics in more detail. A brief description with each link places the site in context before the student connects to it.

Acknowledgments

Much credit for the ongoing development of this text goes to students and instructors who have used previous editions and have offered valuable comments and criticisms. We thank our instructors of the past and colleagues of the present for their contributions to this book. Special thanks also go to the many colleagues and institutions that graciously permitted use of their exceptional photographs. Finally and especially, we thank our present and former students for their interest and enthusiasm in discovering rewarding methods of communicating this information.

Brief Contents

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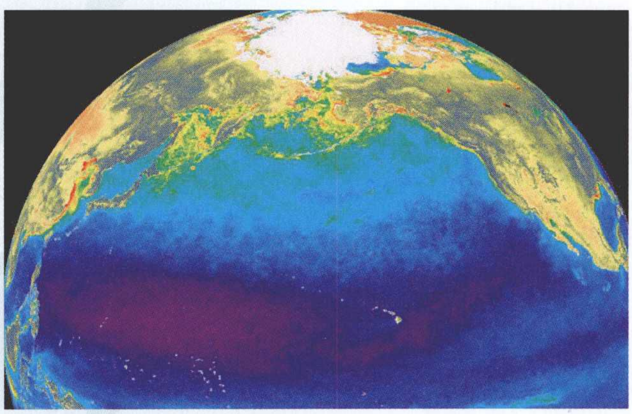

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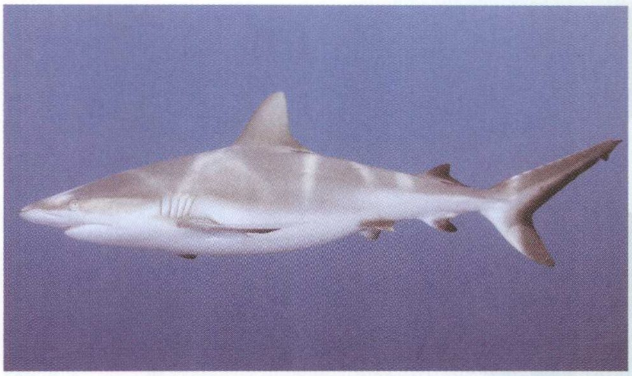

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To Students Using This Text

We encourage you to immerse yourself in this material as much as possible and in as many ways as you can invent. Spend time at the seashore just messing about. Walk along a beach after high tide and examine the bits of plant and animal debris the sea left behind. Wade into a rocky tide pool, stand still, and watch the action around you. If you can swim, snorkel or dive for a closer look. If you don't swim, learn. Pick up the less fragile organisms for a closer look. If you dislike touching cold and wet creatures, work around your reluctance to change what you dislike. Watch how young children observe things, and mimic their enthusiasm. Take a day trip on a fishing boat. Volunteer at a local aquarium even if you think you don't yet know enough to contribute; you'll learn. Mostly, it a matter of investing time—time in the field and seat time in classroom. You will get to experience the fun stuff only if you are there.

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CHAPTER 1

A synthetic view of our ocean planet.

CHAPTER OUTLINE

The Ocean as a Habitat

Earth's oceans are home to an extraordinary variety of living organisms adapted to the special conditions of the sea. The characteristics of these organisms and the variety of marine life itself are consequences of the many properties of the ocean habitat. This chapter provides a survey of the developmental history and present structure of the ocean basins and a general discussion of some properties of seawater and of ocean circulation processes. Adaptations to these properties and processes have molded the character of the ocean's inhabitants through their very long history of evolutionary development.

As students of the Earth's oceans, an appropriate perspective is needed. We naturally tend to see the world from a human point of view, with human scales of time and distance and with land under our feet and air surrounding us. To begin to understand the marine environment of our home planet and how it and its inhabitants evolved to their present forms, we must broaden our perspective to include very different time and distance scales. Terms such as "young" and "old" or "large" and "small" have limited meaning unless placed in some useful context. Figure. 1.1 compares size and time scales for a few common oceanic features and inhabitants. Throughout this book, these scales are revisited, and others are introduced to help you develop a practical sense of the time and space scales experienced by marine organisms.

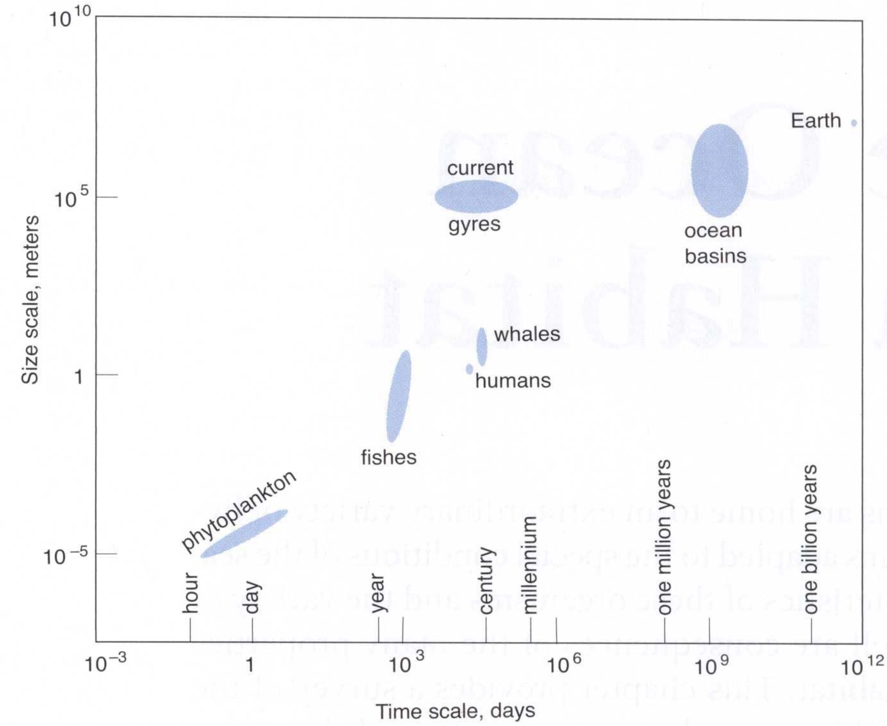

Figure 1.1

Time and size scales for a range of major marine features and inhabitants.

1.1 The Changing Marine Environment

Our solar system, including Earth, is thought to have been formed about 5 billion years ago. Modern concepts of the origin of our solar system indicate that the planets aggregated from a vast cloud of cold gas and dust particles into clusters of solid matter. These clumps continued to grow as gravity attracted them together. As Earth grew in this manner, pressure from the outer layers compressed and heated the Earth's center. Aided by heat from decay of radioactive elements, the planet's interior melted. Iron, nickel, and other heavy metals settled to the core, whereas the lighter materials floated to the surface and cooled to form a density-layered planet with a relatively thin and rigid crust (Fig. 1.2).

Early in Earth's history, volcanic vents poked through the crust and tapped the upper mantle for liquid material and gases that were then spewed out over the surface of the young Earth, and a primitive atmosphere developed. Water vapor was certainly present. As it condensed, it fell as rain, accumulated in low places on the Earth's surface, and formed primitive oceans. Additional water may have arrived as "snowballs" from space in the form of comets colliding with the young Earth. Atmospheric gases dissolved into accumulating seawater, and other chemicals, dissolved from rocks and carried to the seas by rivers, added to the mixture, eventually creating that complex brew of water, ions, and molecules that we call seawater.

Since their initial formation, ocean basins have experienced considerable change. New material derived from the Earth's mantle has extended the continents so that they are now larger and stand higher than at any time in the past. The oceans have kept pace, getting deeper with accumulations of new water from volcanic gases and from the chemical breakdown of rock. Earth's early life forms (represented by bacterial fossils older than about 3.5 billion years) also had a significant impact on the character of their physical environment. Whether the earliest life forms originated at hot seeps on the deep-sea floor or in warm pools at the sea's edges is a matter of continuing speculation and research. What is clear, however, is that life on this planet requires water; in fact, living organisms are mostly water.

Early in life's history on Earth, molecular oxygen (O_2) began to be produced in increasing amounts by microscopic photosynthetic **prokaryotes**. The O_2

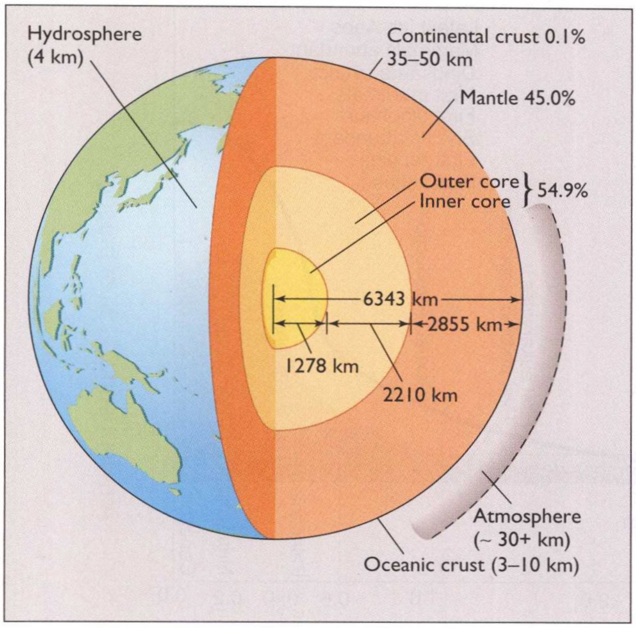

Figure 1.2

A section through the Earth, showing its density-layered interior structure and the thickness of each layer.

content of the atmosphere 600 million years ago was probably about 1% of its present concentration. It was not much, but it was an important turning point, the time when organisms that could take advantage of O_2 in aerobic respiration became dominant and organisms not using O_2 (anaerobes) became less prevalent (more on this in Chapter 2).

The evolution of more complex life forms using increasingly efficient methods of energy utilization set the stage for an explosion of marine species. By 500 million years ago, most major groups of marine organisms had made their appearance. Worms, sponges, corals, and the distant ancestors of terrestrial animals and plants were abundant, but life at that time could exist only in the sea, where a protective blanket of seawater shielded it from intense solar radiation.

As O_2 became more abundant in the upper atmosphere, some of it was converted to **ozone** (O_3). The process of forming ozone absorbed much of the lethal ultraviolet radiation coming from the sun and prevented the radiation from reaching Earth's surface. The O_2 concentration of the atmosphere 400 million years ago is estimated to have reached 10% of its present level and achieved its current concentration in the Mesozoic Era, about 200 million years ago. The additional ozone screened out enough ultraviolet radiation to permit a few life forms to abandon their sheltered marine home and colonize the land. Only recently have we become aware that industrialized society's increasing use of aerosols, refrigerants, and other atmospheric pollutants is gradually depleting this protective layer of ozone. Figure 1.3 provides a general timeline for a few of the major events in the early development of life on Earth.

Charting the Deep

People must have explored their local coastal environments very early in their history, but few of their discoveries were recorded. By 325 B.C., Pytheas, a Greek explorer, had sailed to northwestern Europe and developed a method for determining **latitude** (Fig. 1.4). About a century later, Eratosthenes of Alexandria, Egypt provided the earliest recorded estimate of Earth's size, its first dimension. His calculated circumference of 39,690 km was only about 1% less than today's accepted value of 40,008 km. During the Middle Ages, Vikings, Arabians, Chinese, and Polynesians sailed over major portions of Earth's oceans. By the 15th century, all the major inhabitable land areas were occupied; only Antarctica remained unknown to and untouched by humans. Even so, precise charting of the ocean basins had to await several more voyages of discovery.

Between 1768 and 1779, James Cook, an English navigator, conducted three exploratory voyages, mostly in the Southern Hemisphere. He was the first to cross the Antarctic Circle and to understand and conquer scurvy (a disease caused by a deficiency of vitamin C). He is best remembered as the first global explorer to make extensive use of the marine chronometer developed by John Harrison, a British inventor. The chronometer, a very accurate shipboard clock, was necessary to establish the **longitude** of any fixed point on the Earth's surface. Together with Pytheas's 2000-year-old technique for fixing latitude, reasonably accurate positions of geographic features anywhere on the globe could be established for the first time, and our two-dimensional view of Earth's surface was essentially complete. Today, coastal Long Range Navigation (LORAN) stations and satellite-based global positioning systems (GPSs) enable individuals to determine their position to within a few meters anywhere on the Earth.

In 1872, one century after Cook's voyages, the first truly interdisciplinary global voyage for scientific exploration of the seas departed from England. The H.M.S. *Challenger* was converted expressly for this voyage. The voyage lasted over 3 years, sailed almost 69,000 **nautical miles** in a circumnavigation of the globe (Fig. 1.4), and returned with such a wealth

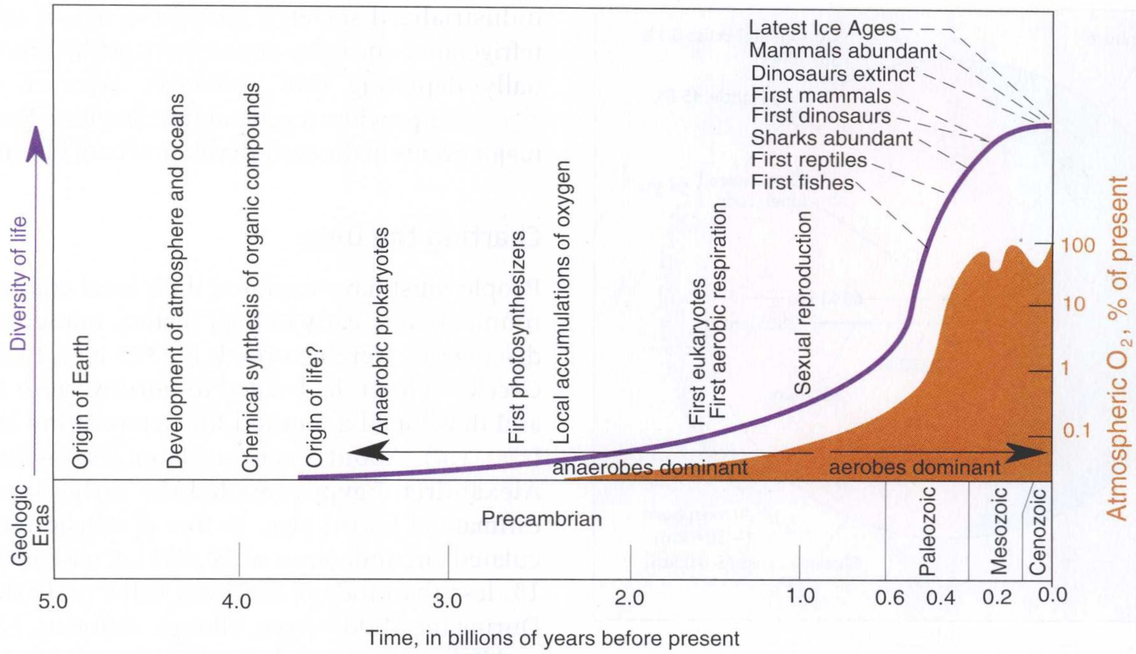

Figure 1.3

A summary of some biological and physical milestones in the early development of life on Earth. The blue curve represents the relative diversity of life; the orange curve represents the O_2 concentration of the atmosphere. Several of the terms used here are defined in Chapter 2.

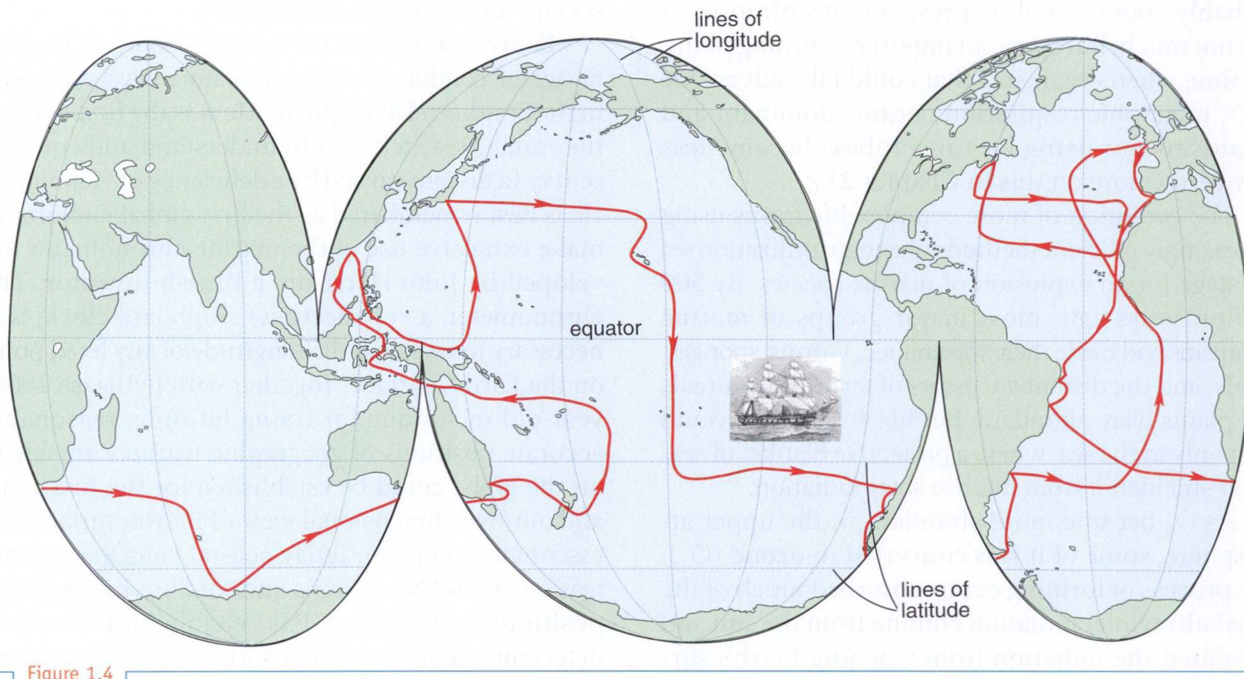

Figure 1.4

An "orange peel" projection of the Earth's surface, with latitude and longitude lines at 30-degree intervals. The red track traces the voyage of H.M.S. *Challenger* (inset).

of information that 10 years and 50 large volumes were required to publish the findings. During the voyage, 492 depth soundings were made. These soundings traced the outlines of the Mid-Atlantic Ridge under 2 km of ocean water, plumbed the Mariana Trench to a depth of 8185 m, and filled in rough outlines of the third dimension of the world ocean, its depth.