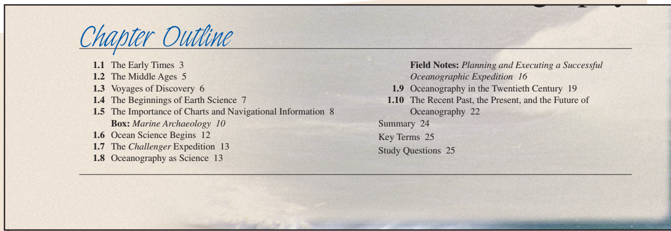
Guided Tour

A variety of tools within this textbook have been designed to assist with chapter review and critical analysis of chapter topics.

Chapter Outline

Each chapter begins with an outline of the subsections and boxed readings within each chapter.



Chapter Outline

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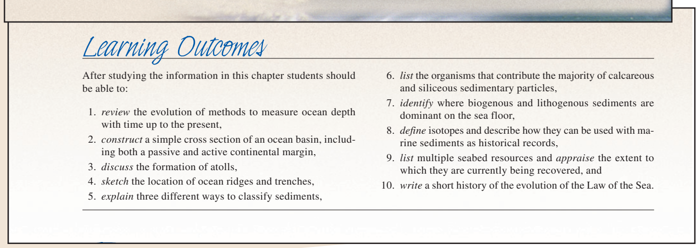
Learning Outcomes

Learning outcomes appear at the onset of each chapter to help instructors better facilitate course management and set goals for each chapter topic.



Learning Outcomes

After studying the information in this chapter students should be able to:

1. *review* the evolution of methods to measure ocean depth with time up to the present,
2. *construct* a simple cross section of an ocean basin, including both a passive and active continental margin,
3. *discuss* the formation of atolls,
4. *sketch* the location of ocean ridges and trenches,
5. *explain* three different ways to classify sediments,
6. *list* the organisms that contribute the majority of calcareous and siliceous sedimentary particles,
7. *identify* where biogenous and lithogenous sediments are dominant on the sea floor,
8. *define* isotopes and describe how they can be used with marine sediments as historical records,
9. *list* multiple seabed resources and *appraise* the extent to which they are currently being recovered, and
10. *write* a short history of the evolution of the Law of the Sea.

Field Notes Boxes

The essays represented within these boxes are written by oceanographers in the field. These readings highlight relevant oceanographic topics and provide insights into engaging oceanographic careers.

Field Notes

The Oceans and Climate Change

by LuAnne Thompson

LuAnne Thompson is an Associate Professor of Oceanography, Adjunct Associate Professor of Atmospheric Sciences, and Interim Director of the Program on Climate Change at the University of Washington. Her research interest is the role of the ocean in climate variability and change, which she explores using numerical models of ocean circulation, biogeochemical cycles, and atmospheric circulation.

The ocean serves as the memory of the climate system, storing heat, fresh water, and chemicals over time spans from decades to millennia. This memory results from the chemical and physical properties of seawater. First, water is heavier than air. A 10 meter column of water is heavier than a column of air that extends to the top of the Earth's atmosphere. Second, water has four-fold higher specific heat than air and five-fold higher specific heat than soil. Because it takes vastly more energy to heat up the ocean, ocean temperature is much more resistant to change than air or land temperature. Although the temperature of surface waters of the ocean varies according to latitude, the temperature of deep water in all oceans is almost always close to freezing. Finally, gases such as carbon dioxide dissolve in water making the ocean a major storage depot. In fact, fifty-fold more carbon dioxide is stored in the ocean than in the atmosphere. Without absorption of carbon dioxide by the ocean, atmospheric concentrations of this greenhouse gas would be even higher. Thus the oceans provide a damper that keeps the Earth's climate relatively constant and benign.

Over the past fifty years, large research programs have greatly informed how this ocean damper works. In 1957–58, under the auspices of the International Geophysical Year, detailed profiles of temperature and salinity were done in the Atlantic Ocean. These surveys allowed oceanographers to see clearly that the sources of the deep (below 1500 m depth) and intermediate water (between 500 and 1500 m depth) of the world's oceans come from geographically isolated regions, with deep water forming in the northern North Atlantic and near Antarctica, and intermediate water originating at high latitudes and in marginal seas.

In the 1970s, data collected during the Geosecs (Geochemical Ocean Sections Study) Program greatly added to our knowledge of the role of the ocean in global cycles of nutrients and gases such as carbon dioxide and oxygen. By this time, a fairly complete picture of the full three-dimensional structure of the ocean water properties was developed and there was general acceptance that the modern ocean system was relatively stable. In the 1980s a simple cartoon of the global ocean circulation called the great ocean conveyor belt (see Figure 9.14) was popularized. This cartoon suggests that cold water created in the high northern latitudes of the North Atlantic sinks to the abyss and moves slowly toward the North Pacific and Indian Oceans where it rises to the surface, warms, and then makes its way back to the Nordic Seas via surface currents and ultimately the Gulf Stream.

In the mid-1980s through the 1990s, extensive and detailed ocean surveys were conducted as part of the World Ocean Circulation Experiment (WOCE). These studies generated the most comprehensive observational analyses of the ocean general circulation and indicated that the conveyer belt circulation model is an oversimplification. Analyses of WOCE data clearly emphasize the significance of deep water formed near Antarctica, and suggest that much of the upwelling of deep water may occur in the Southern Ocean, and that there are multiple routes by which water is exchanged among the various ocean basins.

The role the ocean plays in climate variability and change is becoming clearer. Geochemical tracers show that deep-water cycles in the ocean take several centuries, while water cycles through waters above the thermocline much more quickly, on the order of decades. Analyses of satellite measurements suggest that the oceans carry the bulk of the excess heat away from the equator in the tropics. However, the amount of heat transferred by the oceans' amount falls off at higher latitudes, and poleward of 40° of the atmosphere carries the lion's share. These results have called into question how important the conveyor belt circulation is to maintaining the climate of Europe, and whether we would expect large and abrupt climate changes in the future if there were a large influx of fresh water into the high latitude North Atlantic Ocean from the rapid melting of Greenland ice, for example.

At the same time that more comprehensive observations of the oceans were being made, the first general circulation models of the ocean and the climate system were constructed. In the early 1970s numerical modeling of ocean circulation was born with the construction of the first general circulation model of the ocean that qualitatively reproduced the major ocean currents. Shortly thereafter, this model was coupled to a model atmosphere and exchange of heat and water across the air-sea interface was modeled. These models are the predecessors of the models used today. Written in Fortran, a scientific programming language, they divided the ocean up into boxes, with the sides of each box about 200–300 km, and the depth about 100–500 m. The original models were written on paper computer cards. Each model run took weeks or more of computer time even though necessarily restricted to poor resolution of features and physical processes in the ocean and the atmosphere.

The development of comprehensive climate models has allowed testing of hypotheses of how the climate system would respond to changes in both the greenhouse effect and to other climatic perturbations. For example, these models can be used to ask if Europe would rapidly cool if a significant fraction of

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Chapter Summary

Each chapter's summary provides a quick review of key concepts.

Key Terms

Key terms are boldfaced and defined within the text, and end-of-chapter key terms listings indicate the most important terms and their locations within each chapter.

Study Questions and Problems

Study Questions and Study Problems serve not only as a concept review, but challenge students to think further about the lessons within each chapter.

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The website offers a wealth of teaching and learning tools for instructors and students.

Instructors will appreciate:

- A password-protected Instructor's Manual with answers to the study questions and study problems in the text
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- A test bank utilizing McGraw-Hill's EZ Test Software

Students will find:

- A student center with multiple-choice quizzes
- A student study guide
- Key term flashcards
- Internet exercises
- Web links to chapter-related material

Summary

Phytoplankton are the dominant photosynthetic autotrophs in the sea. These microscopic organisms use sunlight and inorganic compounds to generate the organic matter that serves as food for life in the sea. The process of generating organic carbon from carbon dioxide is commonly referred to as carbon fixation. All photosynthetic organisms use the pigment chlorophyll *a* to absorb sunlight. Oxygen is formed as a by-product of photosynthesis. Organic matter is broken down through respiration to yield chemical energy, water, and carbon dioxide.

Gross primary productivity is the total amount of organic matter produced by photosynthesis per volume of seawater per unit of time. Net primary production is the gain in organic matter from photosynthesis by phytoplankton minus the reduction in organic matter due to respiration by phytoplankton. Primary productivity can be determined by measuring the rate of uptake of carbon dioxide or the rate of production of oxygen.

Phytoplankton remove required inorganic nutrients from seawater in a ratio that reflects their biological demands. When organisms die and decompose, the nutrients are released back into seawater in a similar ratio. Nutrients cycle between the land and the sea and through organic and inorganic compounds. Inorganic nutrient concentrations, sunlight, and temperature influence the rate of primary production. Phytoplankton blooms occur when phytoplankton reproduce more rapidly than they are consumed by zooplankton and other heterotrophs. Standing stock is the total phytoplankton biomass present at a given site at a given instant in time and is related to chlorophyll *a* concentrations.

Key Terms

All key terms from this chapter can be viewed by term or definition when studied as flashcards on this book's website at www.mhhe.com/sverdrup10e.

density, 51
seismic wave, 51
P-wave, 51
S-wave, 51
refract, 52
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hot spot, 74
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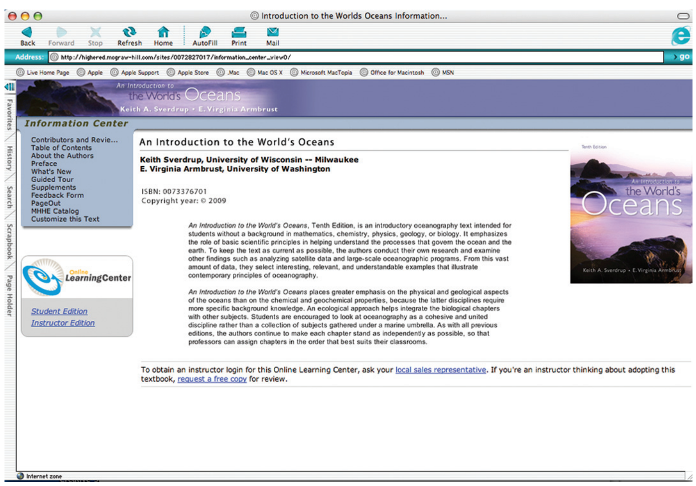
transverse/aseismic ridge, 79
craton, 82
terrane, 82
hydrothermal vent, 83

Study Questions

1. What is meant by the term *polar wandering?* Have the magnetic poles actually wandered?
2. Describe the three types of plate boundaries. What processes take place at each type of boundary? In what direction do the plates move at each boundary?
3. What mechanisms have been proposed to account for plate motion?
4. What is the difference between the leading edge and the trailing edge of a continent? Between a divergent plate boundary and a convergent plate boundary?
5. If the ability of the oceanic crust to transmit heat were uniform, the rate of heat flow through the ocean floor would depend only on the temperature change across the oceanic crust. Under such a condition, how would the heat flow measurements in figure 3.12 indicate the presence of ascending convection cells in the asthenosphere?
6. If the polar wandering curves for North America and Europe are made to coincide, how will these continents move relative to each other?
7. Using the techniques and reasoning employed to discover the properties of the interior of Earth, explain how you would determine what is inside a sealed box (for example, measuring the box, weighing it, spinning it, balancing it on different axes, sampling its exterior). What clue would each of these measurements give you to the contents of the box?
8. What had to be learned about Earth before Alfred Wegener's ideas could be accepted?
9. Why does a newly formed mid-ocean volcanic island gradually subside?
10. Explain the formation and symmetry of the magnetic stripes found on either side of the mid-ocean ridge system. What is their significance when the magnetic information is correlated with the age of the crust?
11. Under what conditions will a convergent boundary form a mountain range? An island arc system? Why do volcanoes associated with subduction zones usually erupt more explosively than mid-ocean volcanoes associated with hot spots and spreading centers?
12. On an outline map of the world draw in (a) earthquake belts, (b) mid-ocean ridges, and (c) trenches. Relate your map to figure 3.8. What do you conclude?
13. How have recent advances in seismic tomography modified our ideas of Earth's internal layers, as shown in figure 3.3?
14. Why do P-waves pass through Earth's outer core?
15. What is a terrane? What role do terranes play in our understanding of today's continents?

Study Problems

1. If a plate moves away from a spreading center at the rate of 5 cm/yr, what is the displacement of a landmass carried by that plate after 180×10^6 years?
2. Magnetic stripes with the same magnetic orientation are measured on either side of a ridge crest. The stripe on the west side of the ridge is displaced 11 km from the crest; the stripe on the east side is displaced 9 km from the crest. The age of the rock in both stripes is 4×10^5 years. Calculate the average spreading rate at this ridge.



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