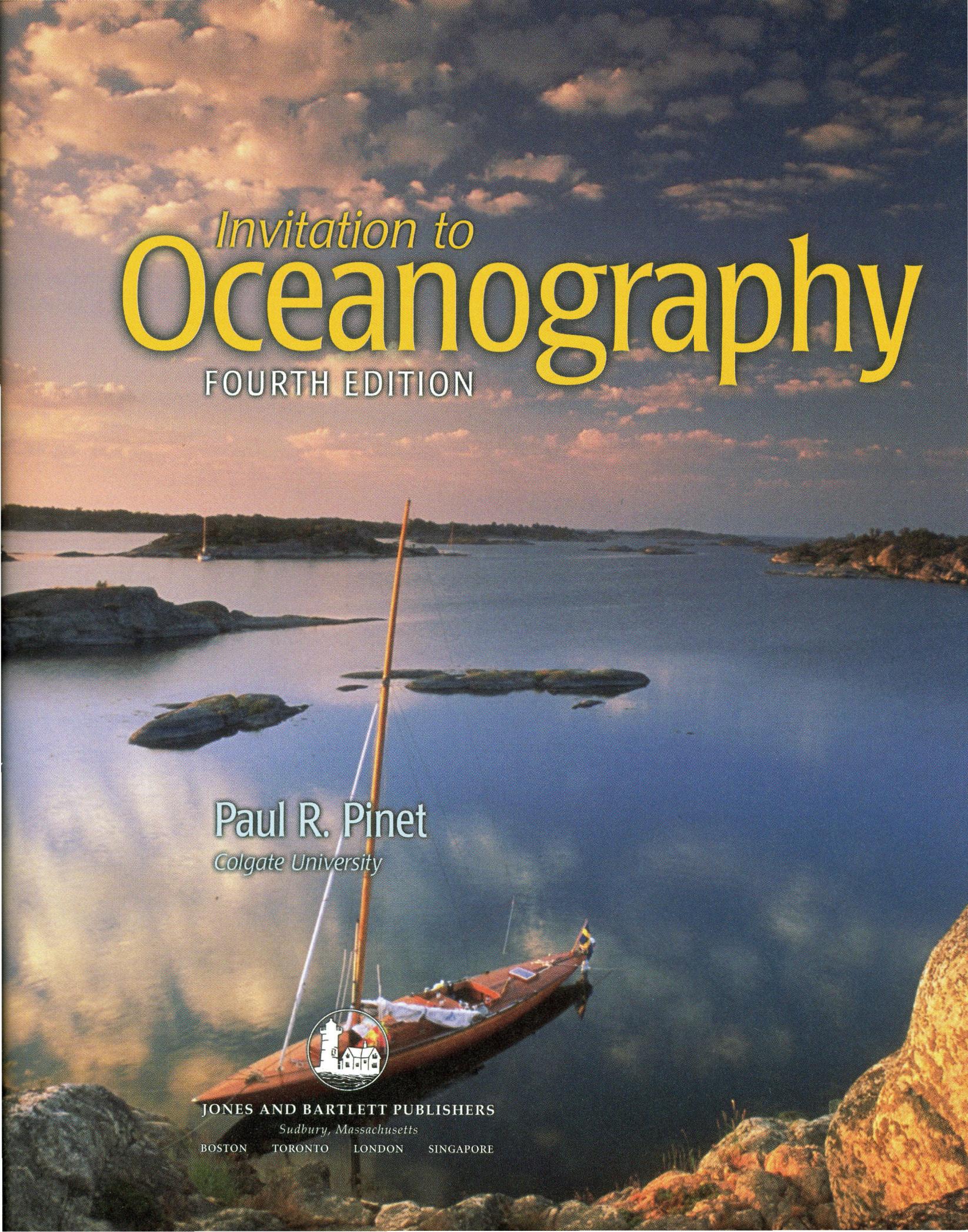
The background of the book cover features a scenic view of a bay at sunset. A sailboat with a tall mast is anchored in the foreground, its reflection visible in the calm water. In the distance, several small, rocky islands are scattered across the horizon under a sky filled with soft, orange and pink clouds.

Paul R. Pinet

Invitation to

Oceanography

FOURTH EDITION



Invitation to **Oceanography**

FOURTH EDITION

Paul R. Pinet
Colgate University



JONES AND BARTLETT PUBLISHERS

Sudbury, Massachusetts

BOSTON TORONTO LONDON SINGAPORE

Contents in Brief

CHAPTER 1	The Growth of Oceanography.....	2
CHAPTER 2	The Planet Oceanus	32
CHAPTER 3	The Origin of Ocean Basins.....	62
CHAPTER 4	Marine Sedimentation.....	94
CHAPTER 5	The Properties of Seawater.....	136
CHAPTER 6	Wind and Ocean Circulation	190
CHAPTER 7	Waves in the Ocean.....	234
CHAPTER 8	Tides.....	267
CHAPTER 9	Marine Ecology	296
CHAPTER 10	Biological Productivity in the Ocean	338
CHAPTER 11	The Dynamic Shoreline	384
CHAPTER 12	Coastal Habitats.....	422
CHAPTER 13	Ocean Habitats and Their Biota	462
CHAPTER 14	The Ocean's Resources	488
CHAPTER 15	The Human Presence in the Ocean	510
	Appendices.....	554

Contents

Preface	xiv
---------------	-----

CHAPTER 1 The Growth of Oceanography ..	2
--	---

1.1 Oceanography: What Is It?	4
1.2 Historical Review of Oceanography	4
Ocean Exploration	5
Early Scientific Investigations	17
Modern Oceanography	20
1.3 Current and Future Oceanographic Research	24
Study Guide.....	28
FEATURES	
The Process of Science. The Scientific	
Process	14
Science by Numbers. Graphs	17
The Ocean Sciences: Physics. Marine	
Archeology	23
Science by Numbers. Conversions	26



CHAPTER 2 The Planet Oceanus	32
---	----

2.1 The Earth's Structure	34
--	----



The Earth's Interior Spheres	34
The Earth's Exterior Envelopes	36

2.2 The Physiography of the Ocean Floor	36
Bathymetric Provinces	37
Deep-Ocean Basins	40
Midocean Ridges	40

2.3 Geologic Differences between Continents and	
Ocean Basins	41
The Earth's Topography and	
Bathymetry	41
Mass Balance and Isostasy	43

2.4 The Physiography of the Western North Atlantic	
Ocean	45

Study Guide	59
-------------------	----

FEATURES	
Science by Numbers. Powers of 10.....	43
The Ocean Sciences: Geology. Probing	
the Sea Floor.....	46
A Trek to the Crest of the Mid-Atlantic	
Ridge.....	49

CHAPTER 3 The Origin of Ocean Basins	62
--	----

3.1 Continental Drift	64
------------------------------------	----



3.2	Sea-Floor Spreading	66
	The Geomagnetic Field	68
	Spreading Ocean Ridges	70
3.3	Global Plate Tectonics	72
	Subduction Zones	72
	Plate-Tectonic Model	74
	The Opening and Closing of Ocean Basins	78
	A Summary of Global Plate Tectonics	82
3.4	Future Discoveries	83

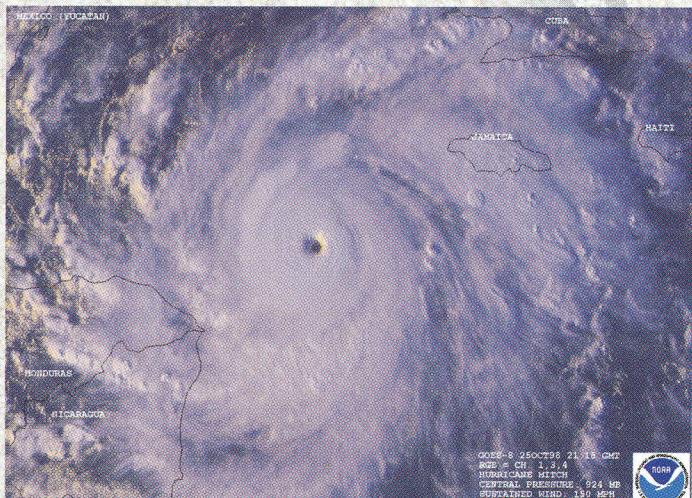
Study Guide	88
FEATURES	
The Ocean Sciences: Geology. The San Andreas Fault	79
The Process of Science. The Scientific Process: Sea-Floor Spreading	82
The Ocean Sciences: Geology. The Red Sea	84
Science by Numbers. Sea-Floor Spreading Rates	87

CHAPTER **4** Marine Sedimentation **94**

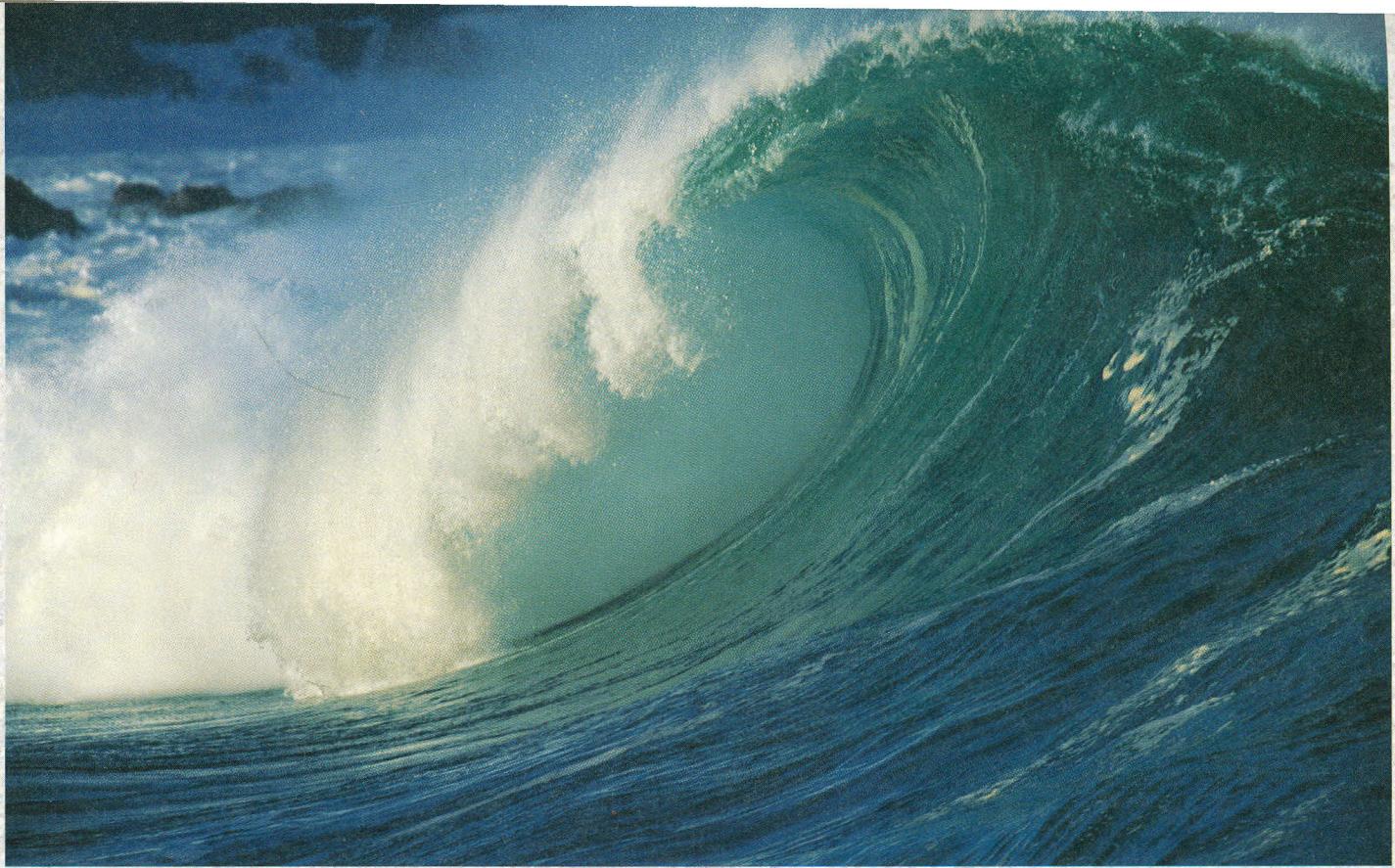
Preview	95	
4.1	Sediment in the Sea	96
	Classification of Marine Sediment	96
	Factors that Control Sedimentation	97
4.2	Sedimentation in the Ocean	101
	Shelf Sedimentation	101
	Deep-Sea Sedimentation	114
	Deep-Sea Stratigraphy	124
4.3	Future Discoveries	126
Study Guide	132	
FEATURES		
The Ocean Sciences: Geology. Probing the Sea Floor	96	
The Ocean Sciences: Geology. Dust Storms	106	
The Process of Science. Climate Variability and Change	110	
The Ocean Sciences: Geology. The Drying Up of The Mediterranean Sea	128	
Science by Numbers. Sedimentation Rates	131	



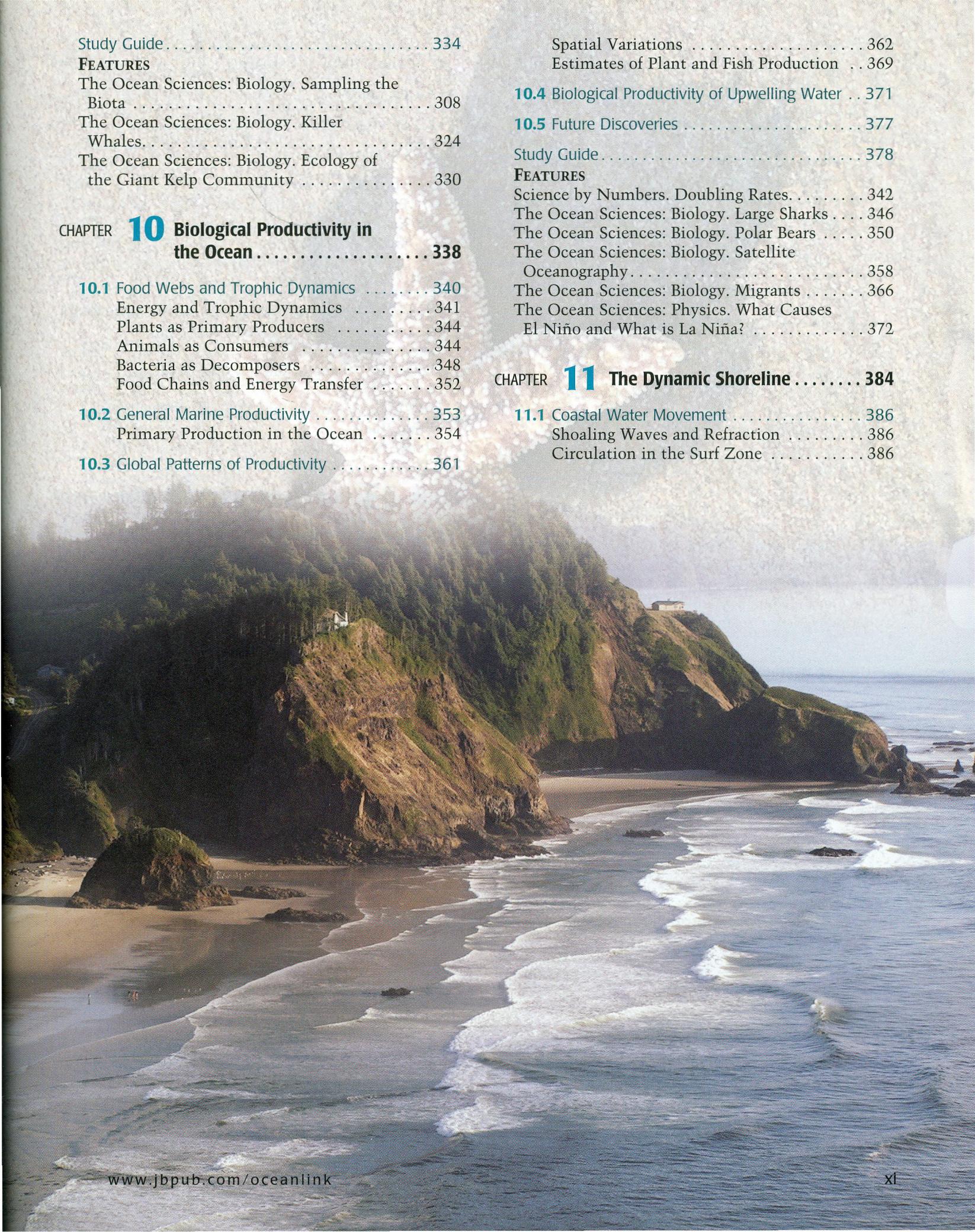
CHAPTER	5	The Properties of Seawater	136
5.1	Basic Chemical Notions	138	
5.2	Basic Physical Notions	139	
5.3	The Water Molecule	140	
	The Solutes of Seawater	144	
5.4	Salinity	147	
	Principle of Constant Proportion	147	
	Factors that Regulate the Salinity of Seawater	150	
	Effects of Salinity on the Properties of Water	154	
5.5	Chemical and Physical Structure of the Oceans	155	
	Temperature	155	
	Salinity	157	
	Density	161	
5.6	Gases in Seawater	162	
	Oxygen	165	
	Carbon Dioxide	166	
5.7	The Ocean as a Physical Chemical System	171	
	Reservoirs of Water	176	
	The Global Water Cycle	176	
	The Ocean as a Biogeochemical System	178	
Study Guide	183		
FEATURES			
Science by Numbers. Parts per Thousand	145		
The Ocean Sciences: Chemistry. Chemical Techniques	148		
The Ocean Sciences: Chemistry. Desalination	168		
The Ocean Sciences: Physics. Other Physical Properties of Water	172		



The Ocean Sciences: Chemistry.			
The Sea-Surface Microlayer	180		
Science by Numbers. Order of Magnitude	182		
CHAPTER	6	Wind and Ocean Circulation	190
6.1	Atmospheric Processes	192	
	Air Pressure	192	
	Coriolis Deflection	192	
	General Wind Circulation	195	
6.2	Surface Ocean Currents	198	
	The Wind-Driven Currents of the Sea Surface	198	
	Types of Surface Flows	205	
	A Model of Geostrophic Flow	207	
	Refinement of the Geostrophic-Flow Model	209	
6.3	Deep-Ocean Circulation	214	
	Water Masses and Density-Driven Water Flow	214	
	A General Model of Thermohaline Circulation	216	
6.4	Water Flow in Semienclosed Seaways	222	
6.5	Future Discoveries	229	
Study Guide	230		
FEATURES			
The Ocean Sciences: Physics.			
Current-Measuring Techniques	200		
The Ocean Sciences: Physics. Hurricanes and Typhoons	212		
Science by Numbers. Volume Transport	216		
The Ocean Sciences: Physics. Underwater Weather and Waterfalls	225		
CHAPTER	7	Waves in the Ocean	234
7.1	Properties of Ocean Waves	236	
	Wind Generation of Waves	236	
7.2	Wave Motions	240	
	The Motion of Water Particles beneath Waves	240	
	Motion of the Wave Form	243	
7.3	The Life History of Ocean Waves	244	
	Growth of Waves in the Fetch Area	244	
	Storm Waves Outside the Generating Area	245	
	Waves in Shallow Water	245	
	Shoreline under Storm Conditions	251	
7.4	Standing Waves	256	
7.5	Other Types of Progressive Waves	257	

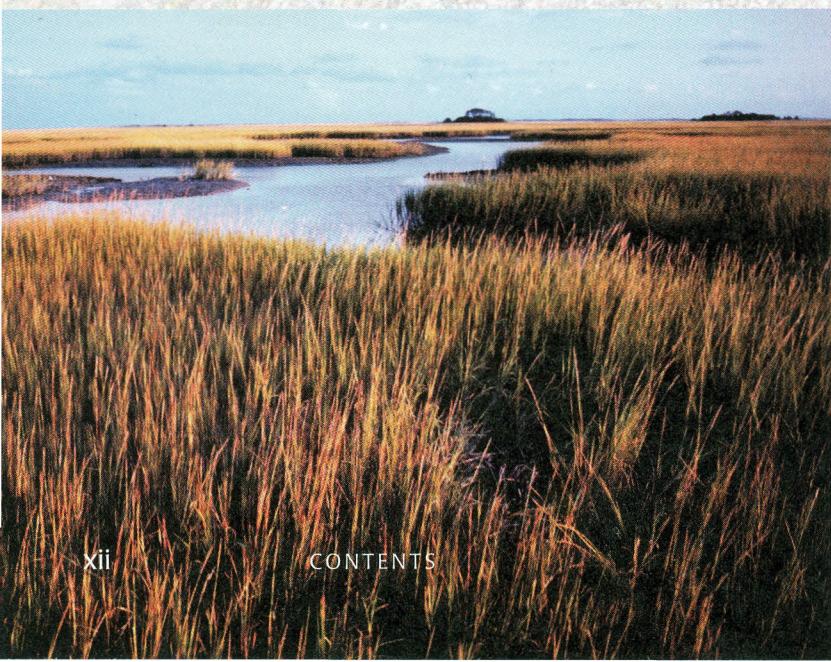


Internal Waves	257
Tsunamis	259
Study Guide.....	261
FEATURES	
The Ocean Sciences: Physics. Wave-Measuring Techniques	238
Science by Numbers. Wave Celerity (Speed).....	242
The Ocean Sciences: Physics. Tiny Waves and Giant Waves	252
The Ocean Sciences: Physics. The Megatsunami of December 26, 2004	260
CHAPTER 8 Tides	267
8.1 Tidal Characteristics	268
8.2 Origin of the Tides	270
Equilibrium Model of Tides	273
Dynamic Model of the Tides	275
8.3 Tides in Small and Elongated Basins	282
8.4 Tidal Currents	285
8.5 Power from the Tides	289
Study Guide.....	293
FEATURES	
The Ocean Sciences: Physics. Currents through Tidal Inlets.....	278
Science by Numbers. Speed of the Tide	283
CHAPTER 9 Marine Ecology	296
9.1 Ocean Habitats	298
9.2 Classification of Organisms	300
Kingdom Monera	301
Kingdom Protista	301
Kingdom Chromista	301
Kingdom Fungi	304
Kingdom Metazoa	304
9.3 Classification by Lifestyle	304
9.4 Basic Ecology	307
Temperature	307
Salinity	312
Hydrostatic Pressure	314
9.5 Selected Adaptive Strategies	315
Life Cycles of Plankton	316
Functional Morphology of Fishes (Nekton)	320
Benthic Communities	326
9.6 Future Discoveries	333



Study Guide	334
FEATURES	
The Ocean Sciences: Biology. Sampling the Biota	308
The Ocean Sciences: Biology. Killer Whales.....	324
The Ocean Sciences: Biology. Ecology of the Giant Kelp Community	330
CHAPTER 10 Biological Productivity in the Ocean 338	
10.1 Food Webs and Trophic Dynamics	340
Energy and Trophic Dynamics	341
Plants as Primary Producers	344
Animals as Consumers	344
Bacteria as Decomposers	348
Food Chains and Energy Transfer	352
10.2 General Marine Productivity	353
Primary Production in the Ocean	354
10.3 Global Patterns of Productivity	361
Spatial Variations	362
Estimates of Plant and Fish Production ..	369
10.4 Biological Productivity of Upwelling Water ..	371
10.5 Future Discoveries	377
Study Guide	378
FEATURES	
Science by Numbers. Doubling Rates.....	342
The Ocean Sciences: Biology. Large Sharks	346
The Ocean Sciences: Biology. Polar Bears	350
The Ocean Sciences: Biology. Satellite Oceanography.....	358
The Ocean Sciences: Biology. Migrants	366
The Ocean Sciences: Physics. What Causes El Niño and What is La Niña?	372
CHAPTER 11 The Dynamic Shoreline 384	
11.1 Coastal Water Movement	386
Shoaling Waves and Refraction	386
Circulation in the Surf Zone	386

CHAPTER 11 Coastal Environments	389
11.1 Shallow Coastal Waters	389
Shallow-Water Ecosystems	389
Algal Mats	389
Kelp Forests	390
Mangrove Swamps	390
Salt Marshes	391
Well-Mixed Estuaries	392
The Biology of Estuaries	392
Stratified Estuaries	393
Tides	393
Well-Mixed Estuaries	393
The Biology of Estuaries	393
Lagoons	394
Coastal Dunes	395
Beach Profiles	395
Sand Budgets	395
Barrier Islands	396
Barrier-Island Landscape	396
Origin of Barrier Islands	396
Storm Effects	396
Cliffed Coasts	397
Deltas	398
Impact of People on the Coastline	399
Future Discoveries	400
Study Guide	401
FEATURES	
The Ocean Sciences: Biology. Chesapeake Bay	401
The Ocean Sciences: Geology. Salt-Marsh Evolution	402
The Ocean Sciences: Biology. San Francisco Bay	403
The Ocean Sciences: Biology. Global Decline in Coral Reefs	404
Science by Numbers. Residence Time	405
CHAPTER 12 Coastal Habitats	422
12.1 Estuaries	424
Origin of Estuaries	424
Circulation and Sedimentation in Estuaries	424
Salt-Wedge Estuaries	425
Partially Mixed Estuaries	425
Well-Mixed Estuaries	426
The Biology of Estuaries	426
12.2 Lagoons	434
12.3 Salt Marshes	436
12.4 Mangrove Swamps	445
12.5 Coral Reefs	447
Biology of Corals	447
Ecology of Coral Reefs	448
Geology of Coral Reefs	448
Study Guide	457
FEATURES	
The Ocean Sciences: Biology. Chesapeake Bay	401
The Ocean Sciences: Geology. Salt-Marsh Evolution	402
The Ocean Sciences: Biology. San Francisco Bay	403
The Ocean Sciences: Biology. Global Decline in Coral Reefs	404
Science by Numbers. Residence Time	405
CHAPTER 13 Ocean Habitats and Their Biota	462
13.1 Biology of the Continental Shelf	464
Neritic Zone	464
Sublittoral Zone	469
13.2 Biology of the Open Ocean and the Deep Sea	470
The Oceanic Realm	471
The Deep-Sea Bottom	477
13.3 Future Discoveries	483
Study Guide	484
FEATURES	
The Ocean Sciences: Biology. Penguins	466
The Ocean Sciences: Biology. Bottom Feeding by Whales	472
The Ocean Sciences: Biology. Sargassum Gulfweed	476
The Ocean Sciences: Biology. Squids	478
CHAPTER 14 The Ocean's Resources	488
14.1 Law of the Sea	490
Law of the Sea Treaty	490
Exclusive Economic Zones	491
14.2 Mineral Resources	491
Oil and Natural Gas	491
Gas Hydrates	493
Sand and Gravel	494
Manganese Nodules	496
Cobalt-Rich Oceanic Crusts	498



Phosphate Deposits	499
14.3 Living Resources	500
Fisheries	500
Mariculture	504
Study Guide	506
FEATURES	
The Ocean Sciences: Geology. Offshore Oil and Gas in the Gulf of Mexico	494
The Process of Science. Fish Farming and "Super" Fish	498
The Ocean Sciences: Biology. Antarctic Krill ..	502

Chapter 15. The Human Presence in the Ocean 510

15.1 Pollution: What Is It?	512
15.2 Hydrocarbons in the Sea	513
15.3 Municipal and Industrial Effluent	520
Sewage	522
Metals	525
Artificial Biocides	527
15.4 Ocean Dredging and Mining	529
Dredging	529
Ocean Mining	531
15.5 Overfishing	532
15.6 Climate Change	537
15.7 The Ocean's Future	542
15.8 Future Discoveries	546

Study Guide	548
FEATURES	
The Ocean Sciences: Biology. The Torrey Canyon Disaster	514
The Ocean Sciences: Biology. Bioremediation ..	520
The Ocean Sciences: Biology. The Exxon Valdez Oil Spill	522
The Ocean Sciences: Biology. Collapse of the New England Fisheries	534
The Process of Science. The Global Rise of Sea Level and Its Effects	540
The Ocean Sciences: Biology. Red Tides	546
Science by Numbers. Steady State	548

Appendices

I Properties of the Earth	554
II Conversion Factors	555
III The Geologic Time Scale	556
IV Maps and Topographic Profiles	557
V Principal Marine Organisms	561
VI The Coriolis Deflection	562
Glossary	564
Index	581
Photo Credits	595