

CONTENTS

Preface xi

Chapter 1 Introduction: The Changing Planetary System 1

Space and Time Perspective of the World's People 2

Space and Time Scales of Earth Processes 3

The Concept of Cycling 4

The Technosphere 5

The Natural System and its Human Dimensions 7

Additional Sources of Information 11

Chapter 2 Earth's Lithosphere: Geologic Time and Building Blocks 12

Geologic Framework of Time 13

Some Historical Events 13

The Geologic Time Scale 15

Earth's Building Blocks: Minerals 18

Earth's Building Blocks: Rocks 22

Igneous Rocks 22

Sedimentary Rocks 23

Deep-Sea Sediments and Earth History 26

Metamorphic Rocks 31

Soils 31

Soil Classification 33

Climate and Soils 34

Concluding Remarks 38 • Study Questions 38 • Additional Sources of Information 39

Chapter 3 Earth's Lithosphere: Plate Tectonics 40

Earth's Interior 42

The Core of Earth 45

The Mantle of Earth 45

The Crust and Lithosphere of Earth 47

Oceanic Crust 47

Continental Crust 54

Concluding Remarks 63 • Study Questions 65 • Additional Sources of Information 65

Chapter 4 The Fluid Earth: Atmosphere 66

The Atmosphere 67

Stratosphere 75

Troposphere 75

Air Masses 80

Clouds 83

Prediction of Weather and Climate 85

Concluding Remarks 86 • *Study Questions* 88 • *Additional Sources of Information* 89

Chapter 5 The Fluid Earth: Hydrosphere and Air-Sea Interactions 90

The Water Cycle 91

Water Reservoirs 91

Oceans 93

Cryosphere 109

Minor Water Reservoirs 110

The Air–Sea Interactions 111

Intertropical Convergence Zone 111

El Niño–Southern Oscillation (ENSO) 113

The Atlantic and Pacific Decadal Oscillations 123

Concluding Remarks 125 • *Study Questions* 126 • *Additional Sources of Information* 127

Chapter 6 Our Living Planet: Earth’s Ecosphere 128

Chemistry of Biological Systems and Cells 129

Classifications of the Biota 132

Genealogy and Evolutionary Relationships 132

Classification within a Kingdom 136

Ecosystems and Their Dynamics 137

Components of Ecosystems 137

Ecological Pyramids 144

Terrestrial and Aquatic Ecosystems 146

Terrestrial Biomes 147

Aquatic Biomes 147

Biomass and Productivity 153

Fundamental Differences 157

Concluding Comment 157

Extinction 157

Concluding Remarks 160 • *Study Questions* 161 • *Additional Sources of Information* 162

Chapter 7 Biogeochemical Cycles of Carbon, Nutrients, and Oxygen 163

Construction of Global Biogeochemical Cycling Models 164

Reservoirs 164

Transport Paths and Fluxes 165

Modeling 166

Carbon 167

Short-Term Cycling: Photosynthesis / Respiration 167

Long-Term Cycling: The CaCO_3 – SiO_2 Connection 170

Medium-Term Cycling: The Organic Matter–Oxygen Connection 172

The Methane Cycle: The Wetland- CH_4 Connection 173

Summary 174

| | |
|--|-----|
| Oxygen | 174 |
| Nitrogen | 176 |
| Sulfur | 178 |
| Phosphorus | 180 |
| C-N-P-S-O Cycles and Human Interference | 182 |
| <i>Concluding Remarks</i> | 185 |
| <i>Study Questions</i> | 185 |
| <i>Additional Sources of Information</i> | 186 |

Chapter 8 Historical Framework of Global Environmental Change 187

| | |
|---|-----|
| “The Big Bang”—The Evolving Universe | 187 |
| Evolution of Planet Earth | 191 |
| Hadean Eon: Earth’s Violent Beginning | 193 |
| Precambrian Eon: Radical Atmospheric Changes and the Beginnings of Life | 198 |
| Phanerozoic Eon: Life Multiplies and Wanders | 204 |
| <i>Concluding Remarks</i> | 212 |
| <i>Study Questions</i> | 212 |
| <i>Additional Sources of Information</i> | 213 |

Chapter 9 Human Forcings on the Ecosphere: World Population, Development, and Resource Consumption 214

| | |
|--|-----|
| Brief Historical Review | 214 |
| Industrial and Human Population Trends | 217 |
| Industrialization | 217 |
| Population Growth | 218 |
| Gross National and Domestic Products (GNP and GDP) | 228 |
| Resources: Energy and Minerals | 235 |
| Energy Resources | 235 |
| Summary | 248 |
| Mineral Resources | 249 |
| Conservation | 253 |
| <i>Concluding Remarks and the 21st Century</i> | 254 |
| <i>Study Questions</i> | 257 |
| <i>Additional Sources of Information</i> | 258 |

Chapter 10 The Changing Earth Surface: Terrestrial Vegetation 259

| | |
|--|-----|
| Forests Worldwide | 260 |
| Global Forest Assessments | 260 |
| Historical Estimates of Wooded and Forested Land | 260 |
| Forests of the Past | 261 |
| Forests of Today | 263 |
| The Impact of Human Activities on Forests | 265 |
| Forest Ecosystems: The Effects of Change | 273 |
| Causes of Deforestation | 280 |
| Summary | 284 |
| Domesticated Ecosystems: Agrosystems as an Example | 285 |
| Fertilizers | 287 |
| Pesticides | 289 |

Irrigation Systems 291

Food Resources 291

Concluding Remarks and the 21st Century 293 • *End Note* 294 • *Study Questions* 294 •
Additional Sources of Information 295

Chapter 11 The Changing Earth Surface: Land and Water 296

The Soil Ecosystem 297

Soil Conditions 297

Summary 307

The Coupled Land–Water Ecosystem 308

Freshwater Resources 309

Water Pollution 311

Coastal Zones 321

Concluding Remarks and the 21st Century 334 • *Study Questions* 335 •
Additional Sources of Information 336

Chapter 12 The Changing Atmosphere: Acid Deposition and Photochemical Smog 337

Acid Deposition 339

Formation of Nitrogen and Sulfur Oxides 339

pH Factor 340

Sweden's Dying Lakes 341

Sources of Sulfur and Nitrogen Oxides 344

Sensitivity to Acid Deposition 346

Emission Abatement Measures 355

Photochemical Smog 364

Urban Pollution 365

Tropospheric Ozone 368

Sources of VOCs and Nitrogen Oxides 369

Effects of Air Pollution on Health 371

Controlling Tropospheric Ozone 371

Concluding Remarks and the 21st Century 373 • *Study Questions* 376 •
Additional Sources of Information 377

Chapter 13 The Changing Ecosphere: Pleistocene and Holocene Environmental Change 378

Records of Climate 379

Factors Influencing Climate 380

Fluctuations in Solar Energy 380

Orbital Parameters 382

Planetary Albedo 388

Climate and Environment of the More Recent Past 392

Pleistocene Epoch 392

Holocene Epoch 403

Concluding Remarks and the 21st Century 406 • *Study Questions* 409 •
Additional Sources of Information 409

Chapter 14 The Changing Atmosphere: Global Warming and Stratospheric Ozone Depletion 410

- The Greenhouse Effect and Climatic Change 412
 - Enhanced Greenhouse Effect 414
 - Atmospheric Greenhouse Gases 415
 - World Distribution of Human Sources of Greenhouse Gases 434
 - Climate and Ecologic Consequences of an Enhanced Greenhouse Effect 440
 - Concluding Comments 473
- Stratospheric Ozone and the Hole in the Sky 480
 - The Importance of Ozone 480
 - The Measurement of Ozone 481
 - The Ozone Balance 482
 - The Ozone-Depleting Chemicals 483
 - History of Ozone Depletion 483
 - Recent Findings Concerning Ozone Depletion 490
 - Concluding Remarks and the 21st Century* 496 • *Study Questions* 497 • *Additional Sources of Information* 497

Chapter 15 Human Dimensions of Global Environmental Change in the Twenty-First Century 499

- What We Know and Future Concerns 500
 - Human-Induced Global Environmental Change 500
 - Reactions to Global Environmental Change Issues 505
- An Example of Global Environmental Policy 515
 - The National Research Council Recommendations 515
 - Factors Involved in Policy Decisions 516
- Approaches to Global Environmental Cooperation 517
 - Business as Usual 517
 - Global Partnership 517
 - Global Governance 518
- The Question of Sustainability 518
 - Equity Condition 519
 - Legacy Condition 519
 - Continuity Condition 519
 - Concluding Comment 520
 - Concluding Remarks and the 21st Century* 520 • *End Note* 524 • *Study Questions* 525 • *Additional Sources of Information* 525

- Appendix* 526
- Glossary* 534
- References* 550
- Index* 562