

BIOLOGY

A GUIDE TO THE NATURAL WORLD



David Krogh

CUSTOM CORE EDITION

Second Edition

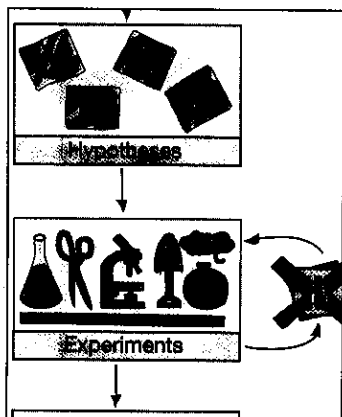
STUDENT CD-ROM INCLUDED

Contents

HIGHLIGHTS

Essay

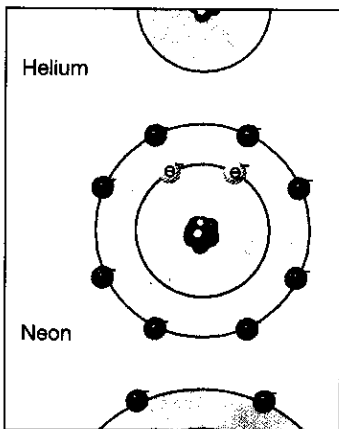
Lung Cancer, Smoking, and
Statistics in Science 10



Scientific Method. 8

Essays

Notating Chemistry 26
Free Radicals 29



Electron configuration. 24

Preface xxviii

Chapter 1 Science as a Way of Learning: A Guide to the Natural World 3

- 1.1 **How Does Science Impact the Everyday World?** 4
A Look at the News 4
- 1.2 **What Does the Public Think, and Know, about Science?** 6
Public Attitudes toward Science 6
Public Knowledge of Science 6
- 1.3 **What Is Science?** 7
Science as a Body of Knowledge 7
Science as a Process: Arriving at Scientific Insights 7
From Hypothesis to Theory 9
- 1.4 **Biology** 12
What Is Life? 12
Life Is Highly Organized, in a Hierarchical Manner 13
- 1.5 **Special Qualities of Biology** 13
Biology's Chief Unifying Principle 15
The Organization of This Book 15
Chapter Review 16

Unit 1 Essential Parts: Atoms, Molecules, and Cells

Chapter 2 The Fundamental Building Blocks: Chemistry and Life 18

- 2.1 **The Nature of Matter: The Atom** 20
Protons, Neutrons, and Electrons 20
Fundamental Forms of Matter: The Element 22
- 2.2 **Matter Is Transformed through Chemical Bonding** 23
Energy Always Seeks Its Lowest State 24
Seeking a Full Outer Shell: Covalent Bonding 24
Reactive and Unreactive Elements 26
Polar and Nonpolar Bonding 26
Ionic Bonding: When Electrons Are Lost or Gained 28
A Third Form of Bonding: Hydrogen Bonding 30
- 2.3 **Some Qualities of Chemical Compounds** 30
Molecules Have a Three-Dimensional Shape 30
Molecular Shape Is Very Important in Biology 31
Solutes, Solvents, and Solutions 31
On to Some Detail Regarding Water 32
Chapter Review 32

Chapter 3 Water, pH, and Biological Molecules 36

3.1 The Importance of Water to Life 37

- Water Is a Major Player in Many of Life's Processes 37
- Water's Structure Gives It Many Unusual Properties 38
- Two Important Terms: Hydrophobic and Hydrophilic 40

3.2 Acids and Bases Are Important to Life 40

- Acids Yield Hydrogen Ions in Solution; Bases Accept Them 41
- Many Common Substances Can Be Ranked According to How Acidic or Basic They Are 42
- The pH Scale Allows Us to Quantify How Acidic or Basic Compounds Are 42
- Some Terms Used When Dealing with pH 42
- Why Does pH Matter? 42

3.3 Carbon Is a Central Element in Life 44

- Carbon as a Starting Ingredient 44
- Carbon's Importance Stems from Its Bonding Capacity 45

3.4 The Molecules of Life: Carbohydrates, Lipids, Proteins, and Nucleic Acids 47

- The Building-Blocks Model of Organic Molecules 47
- Carbohydrates: From Simple Sugars to Cellulose 48
- Lipids: Oils, Fats, Hormones, and the Outer Lining of Cells 50
- Proteins 56
- Lipoproteins and Glycoproteins 60
- Nucleotides and Nucleic Acids 60
- On to Cells 62

Chapter Review 63

Chapter 4 Life's Home: The Cell 68

4.1 Cells Are the Working Units of Life 69

- Cells Bring Unity and Continuity to Life 69

4.2 All Cells Are Either Prokaryotic or Eukaryotic 70

- Prokaryotic and Eukaryotic Differences 70
- Compartmentalization in Eukaryotic Cells 71

4.3 The Eukaryotic Cell 75

- The Animal Cell 75

4.4 A Tour of the Animal Cell: Along the Protein Production Path 75

- Beginning in the Control Center: The Nucleus 76
- Ribosomes 77
- The Rough Endoplasmic Reticulum 78
- A Pause for the Nucleolus 78
- Elegant Transportation: Transport Vesicles 79
- Downstream from the Rough ER: The Golgi Complex 79
- From the Golgi to the Surface 80

4.5 Outside the Protein Production Path: Other Cell Structures 80

- The Smooth Endoplasmic Reticulum 80
- Tiny Acid Vats: Lysosomes and Cellular Recycling 81
- Extracting Energy from Food: Mitochondria 82

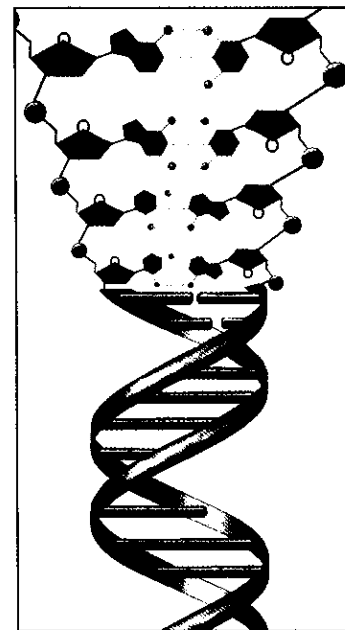
HIGHLIGHTS

Essays

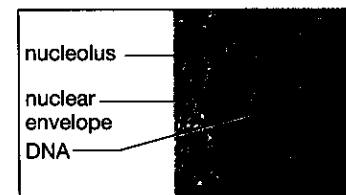
- Acid Rain: When Water Is Trouble 44
- Dietary Decisions: Should You Cut Carbohydrates? 54

MediaLab

- You Are What You Eat: Food and the Molecules of Life 66



DNA's structure. 61



The cell's nucleus. 76-

Contents

HIGHLIGHTS

Essays

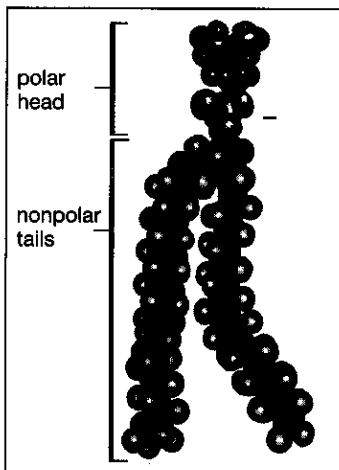
- The Size of Cells 72
The Stranger Within: Lynn Margulis and Endosymbiosis 83
How Did We Learn? First Sightings: Anton van Leeuwenhoek 92

Essay

- How Did We Learn? The Fluid-Mosaic Model of the Plasma Membrane 109

MediaLab

- Balancing Your Imports and Exports: Membrane Transport 114



Dual-natured molecule. 98

- 4.6 The Cytoskeleton: Internal Scaffolding 82**
Microfilaments 84
Intermediate Filaments 84
Microtubules 84
In Summary: Structures in the Animal Cell 86
- 4.7 The Plant Cell 86**
The Cell Wall 88
The Central Vacuole 89
Plastids 90
- 4.8 Cell Communication: Why Cells Need Not Be Islands 90**
Communication among Plant Cells 90
Communication among Animal Cells 91
On to the Periphery 91
Chapter Review 93

Chapter 5 Life's Border: The Plasma Membrane 96

- 5.1 The Importance of Activity at the Cell's Periphery 97**
- 5.2 Why Do We Need the Plasma Membrane? 98**
- 5.3 Four Components of the Plasma Membrane 99**
First Component: The Phospholipid Bilayer 99
Second Component: Cholesterol 100
Third Component: Proteins 100
Fourth Component: The Glycocalyx 100
The Fluid-Mosaic Membrane Model 101
- 5.4 Moving Materials In and Out: Diffusions and Gradients 101**
Random Movement and Even Distribution 102
Diffusion through Membranes 102
- 5.5 How Do Materials Get In and Out of the Cell? 104**
Passive Transport 104
Facilitated Diffusion: Help from Proteins 105
Active Transport 105
- 5.6 Getting the Big Stuff In and Out 106**
Movement Out: Exocytosis 107
Movement In: Endocytosis 107
On to Energy 108
Chapter Review 110

Unit 2 Energy and Its Transformations

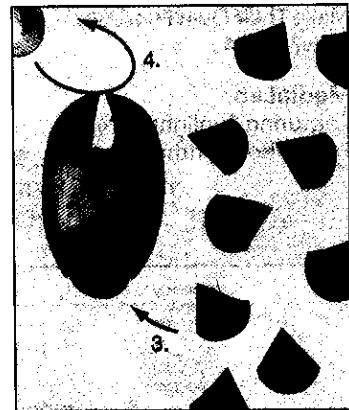
Chapter 6 Life's Mainspring: An Introduction to Energy 116

- 6.1 Energy Is Central to Life 117**
- 6.2 What Is Energy? 118**
The Forms of Energy 118
The Study of Energy: Thermodynamics 118
The Consequences of Thermodynamics 119

Contents

- 6.3 How Is Energy Used by Living Things? 120**
 Kinds of Work for Living Things 120
 Up and Down the Great Energy Hill 120
- 6.4 The Energy Currency Molecule: ATP 121**
 How Does ATP Function? 122
 The ATP/ADP Cycle 122
 ATP as Money 122
 Between Food and ATP 123
- 6.5 Efficient Energy Use in Living Things: Enzymes 123**
 Hastening Reactions 123
 Specific Tasks and Metabolic Pathways 123
- 6.6 Lowering the Activation Barrier through Enzymes 124**
 How Do Enzymes Work? 124
 A Case in Point: Chymotrypsin 125
- 6.7 Regulating Enzymatic Activity 126**
 Allosteric Regulation of Enzymes 126
 On to Harvesting Energy from Food 127
Chapter Review 127
- Chapter 7 Vital Harvest: Deriving Energy from Food 130**
- 7.1 Energizing ATP: Adding a Phosphate Group to ADP 132**
- 7.2 Electrons Fall Down the Energy Hill to Drive the Uphill Production of ATP 133**
 The Great Energy Conveyors: Redox Reactions 133
 Many Molecules Can Oxidize Other Molecules 133
- 7.3 The Three Stages of Cellular Respiration: Glycolysis, the Krebs Cycle, and the Electron Transport Chain 135**
 Glycolysis Is the First Stage in Energy Harvesting 135
 Krebs and the Electron Transport Chain Were Later in Evolving and Are More Efficient 135
 An Overview of the Three Stages 135
- 7.4 First Stage of Respiration: Glycolysis 136**
 The Steps of Glycolysis in Human Beings 138
- 7.5 Second Stage of Respiration: The Krebs Cycle 140**
 Site of Action Moves from the Cytoplasm to the Mitochondria 141
 Between Glycolysis and the Krebs Cycle, an Intermediate Step 142
 Into Krebs: Why Is It a Cycle? 142
- 7.6 Third Stage of Respiration: The Electron Transport Chain 144**
 Visualizing the ETC 145
 Where's the ATP? 145
 Bountiful Harvest: ATP Accounting 145
 Finally, Oxygen Is Reduced, Producing Water 146
- 7.7 Other Foods, Other Respiratory Pathways 146**
 Alternate Respiratory Pathways: Fats as an Example 146
 What Happens When Less Energy Is Needed? 146
 On to Photosynthesis 147
Chapter Review 147

HIGHLIGHTS



The enzyme changes shape. 127

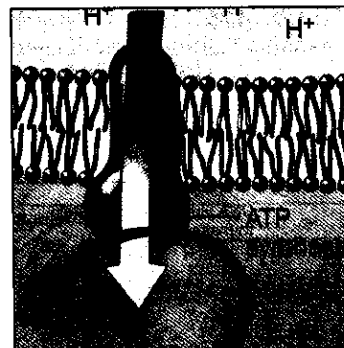
Essays

When Energy Harvesting Ends at Glycolysis, Beer Can Be the Result 138

Energy and Exercise 140

MediaLab

Dietary Fad or Miracle Drug? Using Science to Understand Metabolism 150



ATP synthesis. 144

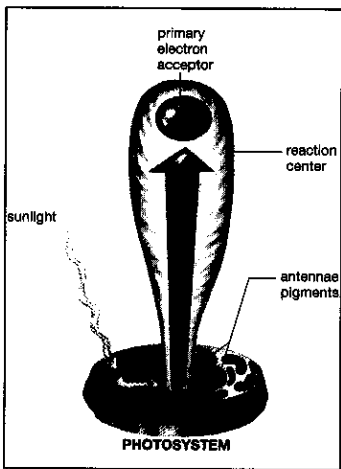
HIGHLIGHTS

Essay

How Did We Learn? Plants Make Their Own Food, But How? **164**

MediaLab

Capturing Sunlight to Make Food: Photosynthesis **168**



Photosystem. **156**

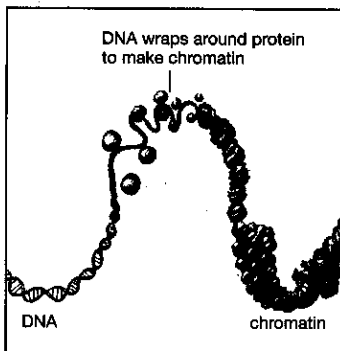
Chapter 8 The Green World's Gift: Photosynthesis 152

- 8.1 Photosynthesis and Energy 153**
From Plants, a Great Bounty for Animals 154
Up and Down the Energy Hill Again 154
- 8.2 The Components of Photosynthesis 154**
What Kind of Light Drives Photosynthesis? 154
Where in the Plant Does Photosynthesis Occur? 155
Photosynthesis Central: The Chloroplasts 155
There Are Two Essential Stages in Photosynthesis 156
The Working Unit of Photosynthesis Is Called a Photosystem 156
Energy Transfer in Photosynthesis Works through Redox Reactions 157
- 8.3 Stage 1: The Steps of the Light-Dependent Reactions 157**
A Chain of Redox Reactions and Another Boost from the Sun 158
The Physical Movement of Electrons in the Light-Dependent Reactions 158
- 8.4 What Makes the Light-Dependent Reactions So Important? 158**
The Liberation of Oxygen from Water 158
The Transformation of Solar Energy to Chemical Energy 158
- 8.5 Stage 2 of Photosynthesis: The Light-Independent Reactions 159**
Energized Sugar Comes from a Cycle of Reactions: The Calvin Cycle 160
- 8.6 Photorespiration: Undercutting Photosynthesis 161**
- 8.7 A Different Kind of Photosynthesis: The C₄ Pathway 161**
The C₄ Pathway Is Not Always Advantageous 162
- 8.8 Another Photosynthetic Variation: CAM Plants 162**
Closing Thoughts on Photosynthesis and Energy 163
Chapter Review 166

Unit 3 How Life Goes On: Genetics

Essay

When Cell Division Runs Amok: Cancer **175**



Chromatin. **177**

Chapter 9 Introduction to Genetics; Mitosis and Cytokinesis 170

- 9.1 An Introduction to Genetics 171**
The Key to Reproduction, Development, and Maintenance Is DNA 171
DNA Contains Instructions for Protein Production 172
How Do Genes Direct the Production of Proteins? 172
Genetics as Information Management 173
The Path of Study in Genetics 174
- 9.2 An Introduction to Cell Division 174**
The Replication of DNA 176
- 9.3 DNA Is Packaged in Chromosomes 177**
Matched Pairs of Chromosomes 178
Chromosome Duplication as a Part of Cell Division 179
- 9.4 Mitosis and Cytokinesis 180**
The Phases of Mitosis 180
Cytokinesis 182

9.5 Variations in Cell Division 182

- Plant Cells 182
- Prokaryotes 183
- Variations in the Frequency of Cell Division 184
- On to Meiosis 184
- Chapter Review 184**

Chapter 10 Preparing for Sexual Reproduction: Meiosis 190

- 10.1 An Overview of Meiosis 192**
 - A Chromosome Reduction before Union of Egg and Sperm 192
- 10.2 The Steps in Meiosis 192**
 - Meiosis I 194
 - Meiosis II 196
- 10.3 What Is the Significance of Meiosis? 196**
 - The Chromosome Duplication Problem Is Solved 196
 - Meiosis Ensures Genetic Diversity in Two Ways 196
 - Meiosis and Sex Outcome 198
- 10.4 Gamete Formation in Humans 200**
 - Sperm Formation 200
 - Egg Formation 201
- 10.5 Life Cycles: Humans and Other Organisms 202**
 - Not All Reproduction Is Sexual 202
 - Variations in Sexual Reproduction 203
 - On to Patterns of Inheritance 203
 - Chapter Review 203**

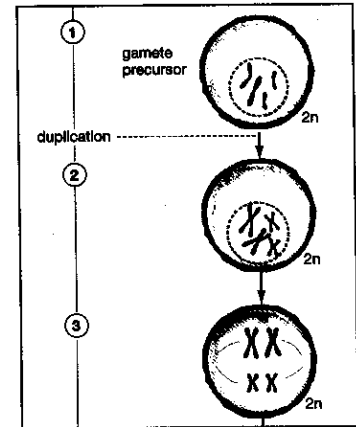
HIGHLIGHTS

MediaLab

Too Much Division: The Cell Cycle and Cancer 188

Essay

The Revealing Y Chromosome 198



Steps in meiosis. 193

Chapter 11 The First Geneticist: Mendel and His Discoveries 206

- 11.1 Mendel and the Black Box 208**
- 11.2 The Experimental Subjects: *Pisum sativum* 208**
 - Phenotype and Genotype 210
- 11.3 Starting the Experiments: Yellow and Green Peas 210**
 - Parental, F_1 , and F_2 Generations 210
 - Interpreting the F_1 and F_2 Results 211
- 11.4 Another Generation for Mendel 212**
 - Mendel's Generations in Pictures 212
 - The Law of Segregation 214
- 11.5 Crosses Involving Two Characters 216**
 - Crosses for Seed Color and Seed Shape 216
 - The Law of Independent Assortment 217
- 11.6 Reception of Mendel's Ideas 218**
- 11.7 Incomplete Dominance 218**
 - Genes Code for Proteins 218
- 11.8 Lessons from Blood Types: Codominance 220**
 - Getting Both Types of Surface Proteins 220
 - How to Think of Dominance 220

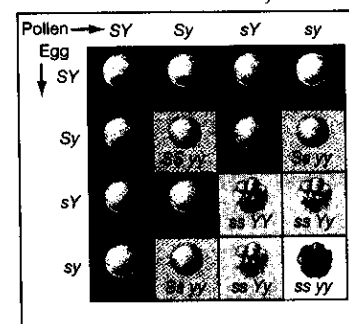
Essays

Proportions and Their Causes: The Rules of Multiplication and Addition 214

Why So Unrecognized? 219

MediaLab

Where Did I Get This Nose? Understanding Mendelian Genetics 228



Punnett square. 217

HIGHLIGHTS

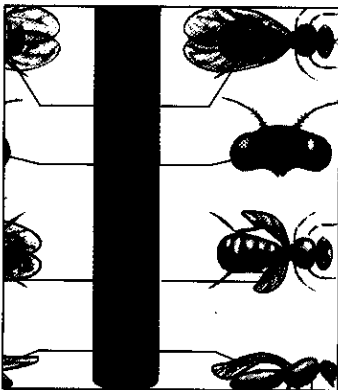
- 11.9 Multiple Alleles and Polygenic Inheritance 220**
- 11.10 Genes and Environment 223**
- 11.11 One Gene, Several Effects: Pleiotropy 223**
 On to the Chromosome 223
Chapter Review 224

Essays

- Testing for Genetic Trouble **238**
- How Did We Learn? Thomas Hunt Morgan: Using Fruit Flies to Look More Deeply Into Genetics **244**

MediaLab

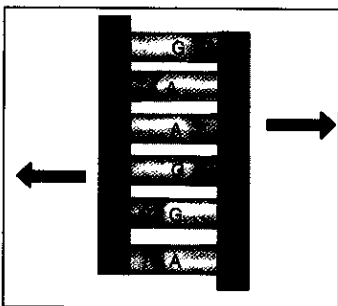
- Do We Know Too Much? Human Genetic Testing **252**



The wild and the mutant flies. 246

Essay

- How Did We Learn? Getting Clear about What Genes Do: Beadle and Tatum **264**



Normal DNA. 261

Chapter 12 Chromosomes and Inheritance 230

- 12.1 Sex-Linked Inheritance in Humans 232**
 X Chromosome: Male Vulnerability, Female Protection 232
- 12.2 Autosomal Genetic Disorders 233**
 Sickle-Cell Anemia 234
 Dominant Disorders 234
 Tracking Traits with Pedigrees 236
- 12.3 Aberrations in Chromosomal Sets: Polyploidy 236**
 Valuable in Plants, a Disaster in Humans 237
- 12.4 Incorrect Chromosome Number: Aneuploidy 237**
 A Common Cause of Aneuploidy: Nondisjunction 237
 Down Syndrome 238
 Abnormal Numbers of Sex Chromosomes 240
- 12.5 Structural Aberrations in Chromosomes 241**
 Deletions 241
 Inversions and Translocations 242
 Duplications 242
 How Did We Learn? 243
 On to DNA 243
Chapter Review 247

Chapter 13 DNA Structure and Replication 254

- 13.1 What Do Genes Do, and What Are They Made of? 255**
 DNA Structure and the Rise of Molecular Biology 256
- 13.2 Watson and Crick: The Double Helix 257**
- 13.3 The Components of DNA and Their Arrangement 259**
 The Structure of DNA Gives Away the Secret of Replication 259
 The Structure of DNA Gives Away the Secret of Protein Production 260
 The Building Blocks of DNA Replication 260
- 13.4 Mutations: Another Name for a Permanent Change in DNA Structure 261**
 An Example of Mutations Passed Along in a Line of Cells: Cancer 261
 The Value of Mistakes: Evolutionary Adaptation 263
 How Did We Learn? 263
 On to How Genetic Information Is Put to Use 263
Chapter Review 264

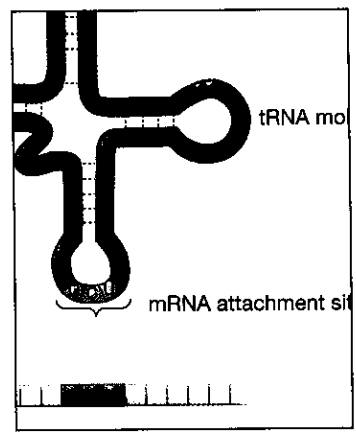
Contents

Chapter 14 How Proteins Are Made: Genetic Transcription, Translation, and Regulation 268

- 14.1 The Structure of Proteins 269**
Synthesizing Many Proteins from 20 Amino Acids 269
- 14.2 Protein Synthesis in Overview: Transcription and Translation 270**
The First Stage of Protein Synthesis: Transcription 272
The Second Stage in Protein Synthesis: Translation 273
- 14.3 The Importance of the Genetic Code 274**
Cracking the Code 275
A Redundant Code 275
The Genetic Code and Life's Unity 275
- 14.4 A Closer Look at Protein Synthesis 276**
Protein Synthesis Begins: Transcription 276
Translation in Detail 277
- 14.5 Genetic Regulation 281**
DNA Is the Cookbook, Not the Cook 281
A Model System in Gene Regulation: The Operon 281
- 14.6 The Magnitude of the Metabolic Operation 283**
The Number of Proteins Utilized 283
The Size of the Genome 284
- 14.7 What Is a Gene? 284**
How Did We Learn? 284
On to Biotechnology 284
Chapter Review 286

HIGHLIGHTS

- Essays**
Making Sense of "Junk" DNA 280
How Did We Learn? Cracking the Genetic Code 285
- MediaLab**
Can We Stop the Cycle? DNA to RNA to Protein 290



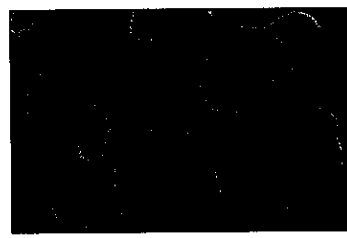
Transfer RNA structure. 277

Chapter 15 The Future Isn't What It Used to Be: Biotechnology 292

- 15.1 What Is Biotechnology? 294**
- 15.2 Some Tools of Biotechnology 294**
Restriction Enzymes 294
Another Tool of Biotech: Plasmids 295
Using Biotech's Tools: Getting Human Genes into Plasmids 296
Getting the Plasmids Back inside Cells, Turning out Protein 297
A Plasmid Is One Kind of Cloning Vector 297
- 15.3 Cloning and the Wider World of Biotechnology 297**
Reproductive Cloning: How Dolly Was Cloned 298
Reproductive Cloning and Recombinant DNA 299
Cloning and Xenotransplantation 299
Human Cloning: Just Around the Corner? 300
- 15.4 Other Biotechnology Processes: PCR 301**
- 15.5 Visualizing DNA Sequences 302**
Running DNA through a Gel 303
Sequencing Requires a Different Operation 304
- 15.6 Decoding the Human Genome 304**
The Significance of Decoding the Human Genome 307

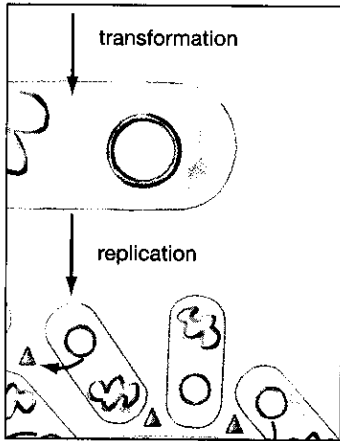
- Essay**
DNA in the Courtroom 305

- MediaLab**
Holding Out Promise or Peril? Biotechnology 318



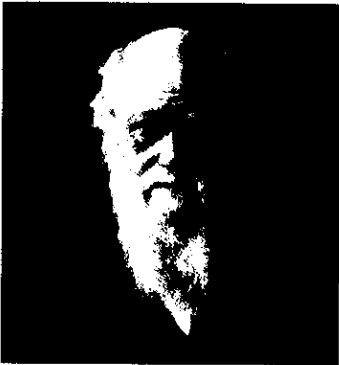
Plasmids. 295

HIGHLIGHTS



Genetic engineering. 296

Essay
Can Darwinian Theory Make Us Healthier? 331



Charles Darwin. 323

- Surprises from the First Drafts 307
- Limitations of Human Genome Sequencing 308
- 15.7 The Next Phase in Genetics: Genomics and Proteomics 309**
 - Biology and Computer Science 309
- 15.8 Genetically Modified Foods 310**
 - GM Foods Are with Us Now 311
 - Other Concerns about GM Foods 312
 - A Consensus Regarding Regulation? 312
 - The Future of GM Foods 312
- 15.9 Ethical Questions in Biotechnology 313**
 - Is It Inherently Unethical for Humans to Genetically Modify Themselves or Other Organisms? 313
 - Are Biotech Diagnoses Running Far Ahead of Biotech Treatments? 313
 - Will Biotechnology Lead to "Genetic Discrimination"? 314
 - On to Evolution 314
 - Chapter Review 314**

Unit 4 Life's Organizing Principle: Evolution and the Diversity of Life

Chapter 16 An Introduction to Evolution: Charles Darwin, Evolutionary Thought, and the Evidence for Evolution 320

- 16.1 Evolution and Its Core Principles 322**
 - Common Descent with Modification 322
 - Natural Selection 322
 - The Importance of Evolution as a Concept 322
 - Evolution Affects Human Perspectives Regarding Life 322
- 16.2 Charles Darwin and the Theory of Evolution 323**
 - Darwin's Contribution 323
 - Darwin's Journey of Discovery 324
- 16.3 Evolutionary Thinking before Darwin 325**
 - Charles Lyell and Geology 325
 - Jean-Baptiste de Lamarck and Evolution 326
 - Georges Cuvier and Extinction 326
- 16.4 Darwin's Insights Following the *Beagle's* Voyage 327**
 - Perceiving Common Descent with Modification 327
 - Perceiving Natural Selection 327
- 16.5 Alfred Russel Wallace 328**
- 16.6 Descent with Modification Is Accepted 328**
- 16.7 Darwin Doubted: The Controversy over Natural Selection 329**
 - Coming to an Understanding of Genetics 329
 - Vindicating Natural Selection's Role in Evolution 329
 - Darwin Triumphant: The Modern Synthesis 330
- 16.8 Opposition to the Theory of Evolution 330**
 - The False Notion of a Scientific Controversy 330

16.9 The Evidence for Evolution 332

- Radiometric Dating 332
- Fossils 332
- Comparative Morphology and Embryology 333
- Evidence from Gene Modification 333
- Experimental Evidence 334
- On to How Evolution Works 335
- Chapter Review 335**

Chapter 17 The Means of Evolution: Microevolution 338

17.1 What Is It That Evolves? 339

- Populations Are the Essential Units that Evolve 339
- Genes Are the Raw Material of Evolution 340

17.2 Evolution as a Change in the Frequency of Alleles 340

17.3 Five Agents of Microevolution 341

- Mutations: Alterations in the Makeup of DNA 342
- Gene Flow: When One Population Joins Another 342
- Genetic Drift: The Instability of Small Populations 342
- Nonrandom Mating: When Mating Is Uneven Across a Population 345
- Natural Selection: Evolution's Adaptive Mechanism 346

17.4 What Is Evolutionary Fitness? 348

- Galapagos Finches: The Studies of Peter and Rosemary Grant 348

17.5 Three Modes of Natural Selection 349

- Stabilizing Selection 350
- Directional Selection 350
- Disruptive Selection 350
- On to the Origin of Species 351
- Chapter Review 351**

Chapter 18 The Outcomes of Evolution: Macroevolution 356

18.1 What Is a Species? 357

18.2 How Do New Species Arise? 359

- Two Modes of Speciation: Cladogenesis and Anagenesis 359
- Speciation Occurs When Populations Cease to Interbreed 359
- The Role of Geographic Separation: Allopatric Speciation 359
- Reproductive Isolating Mechanisms Are Central to Speciation 360
- Six Intrinsic Reproductive Isolating Mechanisms 361
- Sympatric Speciation 363

18.3 When Is Speciation Likely to Occur? 365

- Specialists and Generalists 365
- New Environments: Adaptive Radiation 366
- Is Speciation Smooth or Jerky? 366

18.4 The Categorization of Earth's Living Things 367

- Taxonomic Classification and the Degree of Relatedness 368
- A Taxonomic Example: The Common House Cat 369

18.5 Constructing Evolutionary Histories: Classical Taxonomy and Cladistics 369

- Classical Taxonomy Looks for Similarities 369

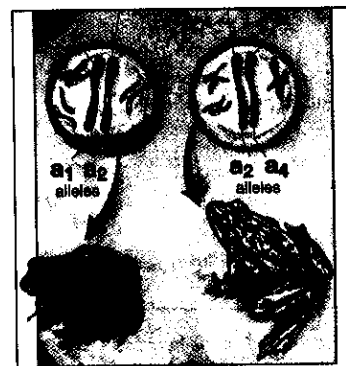
HIGHLIGHTS

Essay

Lessons from the Cocker Spaniel: The Price of Inbreeding 346

MediaLab

Are Bacteria Winning the War? Natural Selection in Action 354



The genetic basis of evolution. 341

Essay

New Species through Genetic Accidents: Polyploidy 362



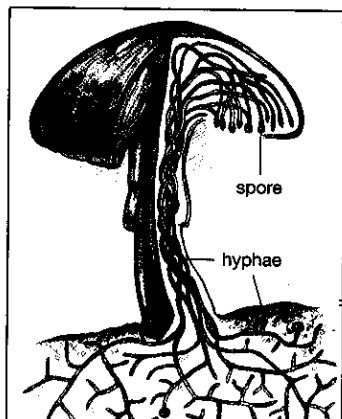
En route to speciation? 360

HIGHLIGHTS

Essay
Physical Forces that Have Shaped Evolution: Climate, Extraterrestrial Objects, and Continental Drift **380**



Africa: Cradle of the humans. **398**



Structure of a fungus. **421**

Another System for Interpreting the Evidence: Cladistics 370
Should Anything but Relatedness Matter in Classification? 372
On to the History of Life 372
Chapter Review 373

Chapter 19 A Slow Unfolding: The History of Life on Earth 376

- 19.1 The Geologic Timescale: Life Marks Earth's Ages 379**
Transition Does Not Always Mean Death: The Cambrian Explosion 382
What Is "Notable" in Evolution Hinges on Values 382
The Kingdoms of the Living World Fit into Three Domains 382
- 19.2 Tracing the History of Life on Earth: How Did Life Begin? 382**
In What Kind of Environment Did Life Begin? 383
What Was the Source of the Raw Materials for Life? 383
Life May Have Begun in Very Hot Water 383
The RNA World 384
Adding Life's Elaborations to Replication 385
- 19.3 The Tree of Life 386**
- 19.4 A Long First Period: The Precambrian 387**
The Slow Pace of Change in the Precambrian 387
Notable Precambrian Events 387
- 19.5 The Cambrian Explosion: A Real Milestone or the Appearance of One? 388**
- 19.6 The Movement onto the Land: Plants First 389**
Adaptations of Plants to the Land 389
Another Plant Innovation: A Vascular System 390
Plants with Seeds: The Gymnosperms and Angiosperms 390
- 19.7 Animals Follow Plants onto the Land 391**
Insects onto Land 391
Vertebrates Move onto Land 391
The Evolution of Mammals 393
The Primate Mammals 393
- 19.8 The Evolution of Human Beings 394**
Interpreting Fossil Evidence 396
The Descent from the Trees 396
Into the Genus *Homo*: *Habilis* and *Ergaster* 397
Human Beings Emerged in Africa but Eventually Traveled 397
One More Possibility: *Homo antecessor* 399
Modern *Homo Sapiens* 400
On to the Diversity of Life 400
Chapter Review 400

The Following Chapters are Available as Custom Chapters

**Chapter 20 Pond Dwellers, Log Eaters, and Self-Feeders:
The Diversity of Life 404**

- 20.1 Viruses: Making a Living by Hijacking Cells 408**
The Trouble Viruses Cause 409
For the Defense: The Immune System and Vaccines 409
How Did Viruses Originate? 410

Contents

20.2 Domain Bacteria: Masters of Every Environment 412
 Intimate Strangers: Humans and Bacteria 412
 Bacterial Roles in Nature 412
 Common Features of Bacteria 413
 Bacterial Organization and Biofilms 414
 Fighting Disease-Causing Bacteria with Antibiotics 414
 Modes of Nutrition: Bacteria Do It All 415

20.3 Domain Archaea: From Marginal Player to Center Stage 416
 Prospecting for "Extremophiles" 416

20.4 Domain Eukarya: Protists, Plants, Fungi, and Animals 417

20.5 Kingdom Protista: An Undefinable Collection 418
 Means of Mobility in Protists 419
 True Multicellularity: A Division of Labor 419
 Single-Celled Algae: The Importance of Phytoplankton 420

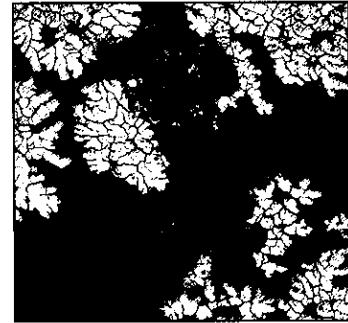
20.6 Kingdom Fungi: Life as a Web of Slender Threads 421
 The Important Roles of Fungi in Nature 421
 A Phase of Life Unique to Fungi: Dikaryotic Cells 423
 Fungal Associations: Lichens and Mycorrhizae 423

20.7 Kingdom Plantae: The Foundation for Much of Life 425
 What Are the Characteristics of Plants? 425
 There are Four Main Categories of Plants: Bryophytes, Seedless Vascular Plants, Gymnosperms, and Angiosperms 426
 Reproduction through Pollen and Seeds 429
 Pollination Can Be an Important Plant-Animal Interaction 430
 On to a Look at Animals 432
Chapter Review 432

HIGHLIGHTS

Essays

- The Unsolvable Taxonomy Problem **407**
 Not Alive, but Deadly: Prions and 'Mad Cow' Disease **410**
 Modes of Nutrition: How Organisms Get What They Need to Survive **415**



Lichens growing on a boulder. **423**

Chapter 21 Movers and Shakers: The Animal Kingdom 436

21.1 What Is An Animal? 438

21.2 Animal Types: The Family Tree 439
 Additions 1 and 2: Tissues and Symmetry 439
 Addition 3: Bilateral Symmetry 440
 Addition 4: A Body Cavity 440
 A Split in the Animal Kingdom: Protostomes and Deuterostomes 441

21.3 Phylum Porifera: The Sponges 442

21.4 Phylum Cnidaria: Jellyfish and Others 443

21.5 Phylum Platyhelminthes: Flatworms 446

21.6 Phylum Nematoda: Roundworms 447

21.7 Phylum Mollusca: Snails, Oysters, Squid, and More 448

21.8 Phylum Annelida: Segmented Worms 450

21.9 Phylum Arthropoda: So Many, but Why? 452
 Other Uniramians: Millipedes and Centipedes 454
 Subphylum Crustacea: Shrimp, Lobsters, Crabs, Barnacles, and More 455
 Subphylum Chelicerata: Spiders, Ticks, Mites, Horseshoe Crabs, and More 455



Cheetah. **458**

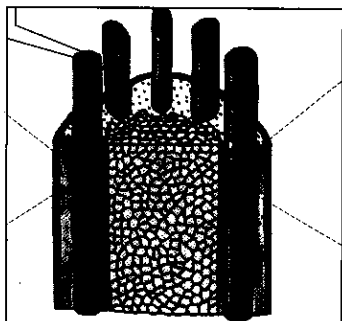
HIGHLIGHTS



Bay scallops. 448

Essays

- What Is Plant Food? 477
- Keeping Cut Flowers Fresh 483
- Ripening Fruit Is a Gas 485



Fluid-transport structure. 483

Essays

- A Tree's History Can Be Seen in Its Wood 507
- The Syrup for Your Pancakes Comes from Xylem 510

MediaLab

- Why Do We Need Plants Anyway? The Importance of Plant Diversity 524

21.10 Phylum Echinodermata: Sea Stars, Sea Urchins, and More 456

21.11 Phylum Chordata: Mostly Animals with Backbones 458

- What Is a Vertebrate? 458
- Diversity among the Vertebrates 459
- On to Plants 466
- Chapter Review 468

Unit 5 A Bounty That Feeds Us All: Plants

Chapter 22 An Introduction to Flowering Plants 472

22.1 The Importance of Plants 473

- Other Roles of Plants 475
- A Focus on Flowering Plants 475

22.2 The Structure of Flowering Plants 475

- The Basic Division: Roots and Shoots 475
- Roots: Absorbing the Vital Water 476
- Shoots: Leaves, Stems, and Flowers 478

22.3 How Flowering Plants Function 480

- Reproduction in Angiosperms 480
- Plant Plumbing: The Transport System 482
- Communication: Hormones Affect Many Aspects of Plant Functioning 484
- Plant Growth: Indeterminate and at the Tips 486
- Defense and Cooperation 486

22.4 Responding to External Signals 487

- Responding to Light: Phototropism 487
- Responding to Gravity: Gravitropism 488
- Responding to Contact: Thigmotropism 489
- Responding to the Passage of the Seasons 489
- On to a More Detailed Picture of Plants 490

Chapter Review 491

Chapter 23 Form and Function in Flowering Plants 494

23.1 Two Ways of Categorizing Flowering Plants 496

- The Life Spans of Angiosperms: Annuals, Biennials, and Perennials 496
- A Basic Difference among Flowering Plants: Monocotyledons and Dicotyledons 497

23.2 There Are Three Fundamental Types of Plant Cells 498

- Parenchyma Cells 498
- Sclerenchyma Cells 498
- Collenchyma Cells 498
- Parenchyma as Starting-State Cells 498

23.3 The Plant Body and Its Tissue Types 499

- First: A Distinction between Primary and Secondary Growth Tissue 499
- Dermal Tissue Is the Plant's Interface with the Outside World 499
- Ground Tissue Forms the Bulk of the Primary Plant 500
- Vascular Tissue Forms the Plant's Transport System 500
- Meristematic Tissue and Primary Plant Growth 502

Contents

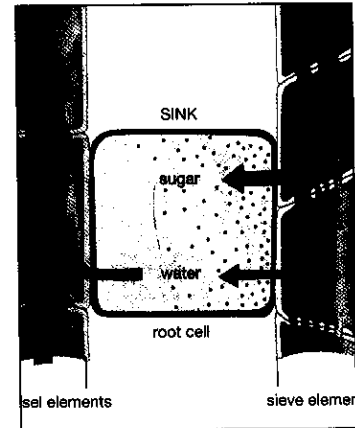
- 23.4 How a Plant Grows: Apical Meristems Give Rise to the Entire Plant 502**
 A Closer Look at Root and Shoot Apical Meristems 503
 How the Primary Tissue Types Develop 504
- 23.5 Secondary Growth Comes from a Thickening of Two Types of Tissues 505**
 Secondary Growth through the Vascular Cambium: Secondary Xylem and Phloem 505
 Secondary Growth through the Cork Cambium: The Plant's Periphery 508
- 23.6 How the Plant's Vascular System Functions 509**
 How the Xylem Conducts Water 509
 Food the Plant Makes Is Conducted through Phloem 511
 Water Flows from Xylem to Phloem and Back Again 513
- 23.7 Sexual Reproduction in Flowering Plants 513**
 Flowers Are the Reproductive Parts of Plants 513
 Flowering Plants Reproduce through an Alternation of Generations 513
 Development of the Male and Female Gametophyte Generation 516
 Fertilization of Two Sorts: A New Zygote and Food for It 516
- 23.8 Embryo, Seed, and Fruit: The Developing Plant 518**
 The Development of a Seed 518
 The Development of Fruit 518
 Development of the Embryo and Germination of the Seed 519
 On to Animals 520
Chapter Review 520

Unit 6 What Makes the Organism Tick? Animal Anatomy and Physiology

Chapter 24 Introduction to Animal Anatomy and Physiology: The Integumentary, Skeletal, and Muscular Systems 526

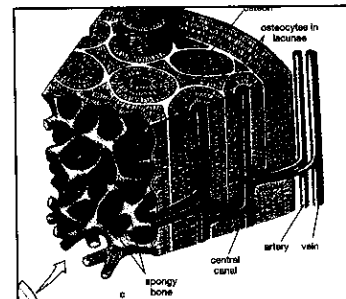
- 24.1 The Sciences of Anatomy and Physiology 527**
- 24.2 What Are the General Characteristics of Humans? 528**
 Internal Body Cavity 528
 Internal Skeleton 528
 Internal Temperature Regulation 528
- 24.3 Animal Architecture and Organization 529**
- 24.4 The Animal Body Has Four Basic Tissue Types 529**
 Epithelial Tissue 530
 Connective Tissue 530
 Muscle Tissue 532
 Nervous Tissue 532
- 24.5 A Summary of the Organ Systems of the Human Body 532**
 Organ Systems 1: Body Support and Movement—The Integumentary, Skeletal, and Muscular Systems 534
 Organ Systems 2: Coordination, Regulation, and Defense—The Nervous, Endocrine, and Lymphatic Systems 534
 Organ Systems 3: Transport and Exchange with the Environment—The Cardiovascular, Respiratory, Digestive, and Urinary Systems 535

HIGHLIGHTS



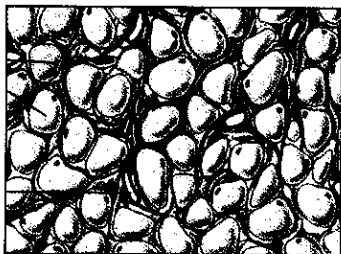
Food transport. 512

Essay
 Doing Something about
 Osteoporosis While You Are
 Young 540



Bone features. 531

HIGHLIGHTS

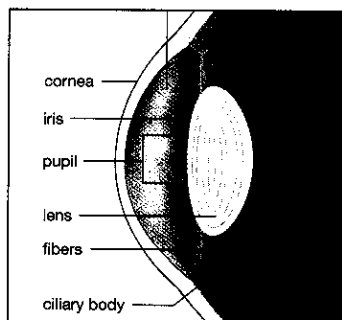


Adipose tissue. 539

- 24.6 The Integumentary System: Skin and More 536**
 - The Structure of Skin 536
 - Integumentary Structures Associated with Skin 537
- 24.7 Body Support and the Skeleton 538**
 - Structure of Bone 538
 - The Human Skeleton 541
 - Joints 541
- 24.8 Muscles and Movement 542**
 - Makeup of Muscle 543
 - How Does a Muscle Contract? 543
 - Major Muscles of the Body 545
 - On to the Nervous, Endocrine, and Immune Systems 545
 - Chapter Review 545**

Chapter 25 Control and Defense: The Nervous, Endocrine, and Immune Systems 550

- 25.1 Overview of the Nervous System 551**
 - Cells of the Nervous System 552
 - Nerves 553
- 25.2 How Does Nervous-System Communication Work? 553**
 - Nerve Signal Transmission within a Neuron 553
 - Transmission along the Whole Axon: The Action Potential 554
 - Communication between Cells: The Synapse 555
- 25.3 The Spinal Cord 556**
 - The Spinal Cord and the Processing of Information 556
 - Quick, Unconscious Action: Reflexes 557
- 25.4 The Autonomic Nervous System 558**
 - The Sympathetic and Parasympathetic Divisions of the Autonomic Nervous System 559
- 25.5 The Human Brain 559**
 - Six Major Regions of the Brain 559
- 25.6 The Nervous System in Action: Our Sense of Vision 560**
 - Three Tasks for Vision 561
- 25.7 The Endocrine System: Hormones and How They Work 565**
 - Types of Hormones 566
 - Actions of Hormones 566
- 25.8 How Is Hormone Secretion Controlled? 566**
 - Negative Feedback 567
 - Positive Feedback 567
 - A Hierarchy of Hormonal Control: The Hypothalamus 568
 - The Pituitary Gland Link 568
 - The Anterior Pituitary Gland 568
 - The Posterior Pituitary Gland 570
- 25.9 The Immune System: Defending the Body from Invaders 570**
 - Two Basic Types of Defense: Nonspecific and Specific 570



The human eye. 561

25.10 Nonspecific Defenses of the Immune System 572

- Physical Barriers 573
- Phagocytes 573
- Immunological Surveillance 573
- Interferons 573
- Complement 573
- Inflammation 573
- Fever 573

25.11 Specific Defenses of the Immune System 574

25.12 Antibody-Mediated and Cell-Mediated Immunity 576

- The Body's Lymphatic System 576

25.13 Antibody-Mediated Immunity in Detail 577

- The Fantastic Diversity of Antibodies 577
- The Cloning of Selected Cells in Antibody-Mediated Immunity 578
- Fighters and Sentries: The Differentiation of B Cells 578
- Action of the Antibodies 578

25.14 Cell-Mediated Immunity in Detail 579

- Macrophages Bearing Invaders: Antigen-Presenting Cells 579
- Activated Helper T Cells Are Central to the Immune Response 580

25.15 Allergies and Autoimmune Disorders 580

25.16 AIDS: Attacking the Defenders 581

- On to Transport and Exchange 582
- Chapter Review 582

Chapter 26 Transport, Nutrition, and Exchange: Blood, Breath, Digestion, and Elimination 590

26.1 The Cardiovascular System and Body Transport 591

- Blood Has Two Major Components: Formed Elements and Plasma 592
- Blood Vessels 594
- Systems of Circulation 595

26.2 The Heart and the Circulation of Blood 595

- Following the Path of Circulation 596

26.3 The Heart's Own Blood Supply: What Is a Heart Attack? 596

26.4 Getting the Goods to and from the Cells: The Capillary Beds 597

- Forces That Work on Exchange through Capillaries 598
- Muscles and Valves Work to Return Blood to the Heart 598

26.5 The Respiratory System and the Exchange of Gases 598

- The Functions of Respiration 599
- Structure of the Respiratory System 599
- Steps in Respiration: Breathing 600
- Steps in Respiration: Exchange of Gases 600
- Steps in Respiration: Oxygen and Carbon Dioxide Transport 601

26.6 The Digestive System 601

- The Digestive Process in Overview 601

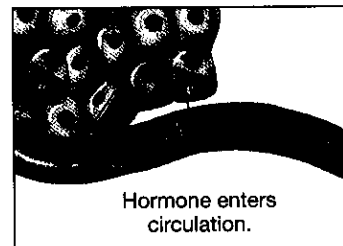
26.7 Components of the Digestive System 602

- The Digestive Tract in Cross Section 603

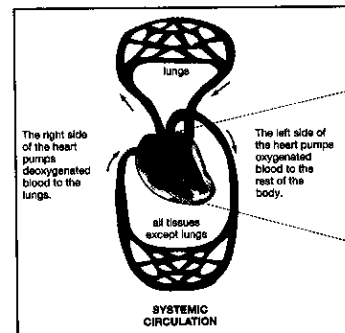
HIGHLIGHTS

MediaLab

How Does Your Body Fight the Flu? Understanding the Immune System 588

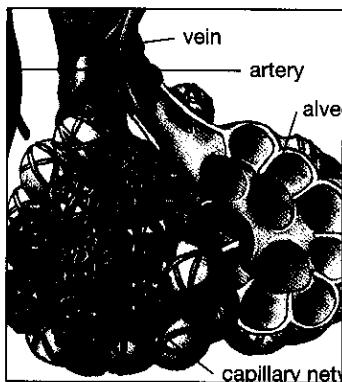


Endocrine cells releasing hormone. 566



Circulation's big picture. 595

HIGHLIGHTS



Where air and blood meet. 599

- The Oral Cavity 603
- The Pharynx and Esophagus 604
- The Stomach 604
- The Small Intestine 605
- The Pancreas 606
- The Liver and Gallbladder 606
- The Large Intestine 606

26.8 Different Digestive Processes for Different Foods and Nutrients 607

- Carbohydrates 608
- Lipids 608
- Proteins 608
- Water and Vitamins 608

26.9 The Urinary System in Overview 609

- Structure of the Urinary System 609

26.10 How the Kidneys Function 610

- First Kidney Function: Filtration in Bowman's Capsule 611
- Second Kidney Function: Reabsorption from the Nephron Tubule 612
- Third Kidney Function: Secretion into the Nephron Tubule 612
- Fourth Kidney Function: The Loop of Henle, the Collecting Duct, and the Conservation of Water 612
- Hormonal Control of Water Retention 612

26.11 Urine Transport, Storage, and Excretion 613

- The Urinary Bladder 613
- The Urethra 613
- Urine Excretion 614
- On to Development and Reproduction 614
- Chapter Review 614**

Chapter 27 An Amazingly Detailed Script: Animal Development 620

27.1 General Processes in Development 621

- Two Cells Become One: Fertilization 622
- Three Phases of Embryonic Development 622
- A Theme in Development: From the General to the Specific 625

27.2 What Factors Underlie Development? 625

- The Process of Induction 625
- The Interaction of Genes and Proteins 625
- Two Lessons in One Gene 626

27.3 Developmental Tools: Sculpting the Body 627

27.4 The Promise of Stem Cells 628

- Cell Fates: Determined and Committed 628
- The Breakthrough in Embryonic Stem Cells 629
- A Further Advance: Adult Stem Cells 629
- The Bigger Picture of Stem Cells 630
- The Ethical Debate over Embryonic Stem Cells 630
- The Potential of Stem Cells 631
- On to Human Reproduction 631

Chapter Review 631



Shaping by removing. 628

Contents

Chapter 28 How the Baby Came to Be: Human Reproduction 634

28.1 Overview of Human Reproduction and Development 635

Reproduction in Outline 636

28.2 The Female Reproductive System 638

The Female Reproductive Cycle 638

How Does an Egg Develop? 639

Changes through the Female Life Span 640

The Consequences of Follicle Loss 642

28.3 The Male Reproductive System 643

Structure of the Testes 644

Male and Female Gamete Production Compared 644

Further Development of Sperm 644

Supporting Glands 646

28.4 The Union of Sperm and Egg 646

How Sperm Get to the Egg 646

How Latecomers Are Kept Out 647

28.5 Human Development Prior to Birth 648

Early Development 649

Development through the Trimesters 650

28.6 The Birth of the Baby 653

On to Ecology 653

Chapter Review 654

HIGHLIGHTS

Essays

Hormones and the Female Reproductive Cycle 640

Methods of Contraception 645

Sexually Transmitted Disease 648

MediaLab

Are Test Tube Babies the Solution? Understanding Reproductive Problems 658



Near the moment of conception. 647

Unit 7 The Living World as a Whole: Ecology and Behavior

Chapter 29 An Interactive Living World: Populations and Communities in Ecology 660

29.1 The Study of Ecology 662

Ecology Is Not Environmentalism 662

Path of Study 662

29.2 Populations: Size and Dynamics 663

Estimating the Size of a Population 664

Growth and Decline of Populations over Time 664

Calculating Exponential Growth in a Population 666

Logistical Growth of Populations: Reality Makes an Appearance 667

29.3 *r*-Selected and *K*-Selected Species 668

K-Selected, or Equilibrium, Species 668

r-Selected, or Opportunist, Species 669

Survivorship Curves: At What Point Does Death Come in the Life Span? 670

29.4 Thinking about Human Populations 670

Survivorship Curves Are Constructed from Life Tables 670

Population Pyramids: What Proportion of a Population Is Young? 671

Immigration and Population Change: The United States 671



Keystone species: *Pisaster ochraceus*. 674

Contents

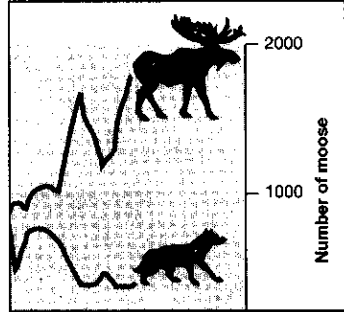
HIGHLIGHTS

Essay

Purring Predators: Housecats and Their Prey 679

MediaLab

Can Earth Support All of Us? Population Growth Patterns 690



Predator and prey populations. 679

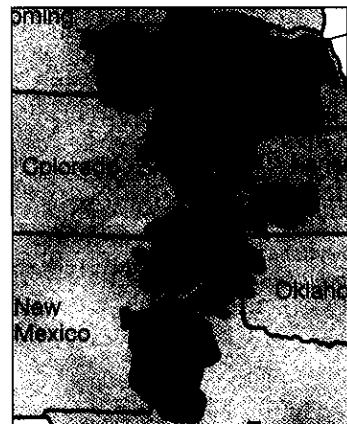
Essays

A Cut for the Middleman: Livestock and Food 706

Good News about the Environment 721

MediaLab

El Niño and the Greenhouse Effect: How Climate Affects Our Weather, Food, and Water Supplies 730



The High Plains Aquifer. 699

The Increase in World Population 672

Current Population Impacts on Quality of Life and the Environment 672

29.5 Communities: Looking at the Interactions of Many Populations 674

Large Numbers of a Few Species: Ecological Dominants 674

Importance beyond Numbers: Keystone Species 674

Variety in Communities: What Is Biodiversity? 675

29.6 Types of Interaction among Community Members 676

Two Important Community Concepts: Habitat and Niche 676

Competition among Species in a Community 676

Other Modes of Interaction: Predation and Parasitism 678

Parasites: Making a Living from the Living 679

The Effect of Predator-Prey Interactions on Evolution 680

Beneficial Interactions: Mutualism and Commensalism 681

Coevolution: Species Driving Each Other's Evolution 682

29.7 Succession in Communities 682

An Example of Primary Succession: Alaska's Glacier Bay 684

Common Elements in Primary Succession 685

Lessons in Succession from Mount St. Helens 685

On to Ecosystems and Biomes 686

Chapter Review 686

Chapter 30 An Interactive Living World: Ecosystems and the Biosphere 692

30.1 The Ecosystem Is the Fundamental Unit of Ecology 693

30.2 Abiotic Factors Are a Major Component of Any Ecosystem 694

The Cycling of Ecosystem Resources 694

Human Beings Are Not Separate from the Earth They Live on 700

30.3 How Energy Flows through Ecosystems 700

Producers, Consumers, and Trophic Levels 701

Accounting for Energy Flow through the Trophic Levels 703

Primary Productivity Varies across the Earth by Region 705

30.4 Earth's Physical Environment 706

Earth's Atmosphere 706

The Worrisome Issue of Ozone Depletion 707

The Worrisome Issue of Global Warming 708

Earth's Climate: Why Are Some Areas Wet and Some Dry, Some Hot and Some Cold? 711

The Circulation of the Atmosphere and Its Relation to Rain 711

Mountain Chains Affect Precipitation Patterns 713

The Importance of Climate to Life 713

30.5 Earth's Biomes 713

Cold and Lying Low: Tundra 714

Northern Forests: Taiga 715

Hot in Summer, Cold in Winter: Temperate Deciduous Forest 715

Dry but Sometimes Very Fertile: Grassland 716

- Chaparral: Rainy Winters, Dry Summers 717
- The Challenge of Water: Deserts 717
- Lush Life, Now Threatened: Tropical Rainforest 718

30.6 Life in the Water: Aquatic Ecosystems 719

- Marine Ecosystems 719
- Freshwater Systems 723
- Life's Largest Scale: The Biosphere 724
- On to Animal Behavior 725
- Chapter Review 725**

Chapter 31 Animal Behavior 732

31.1 The Field of Behavioral Biology 733

- Behavioral Biology Asks 'What,' 'Why' and 'How' 734
- Proximate and Ultimate Causes 735

31.2 The Web of Behavioral Influences 736

31.3 Internal Influences on Behavior 737

- Reflexes 737
- Action Patterns 737
- Orientation Behavior: Taxis 739
- Biological Rhythms: The Internal Clock 739
- The Effects of Hormones 741

31.4 Learning and Behavior 741

- Establishing Relationships: Imprinting 741
- Other Forms of Learning 742

31.5 Behavior in Action: How Birds Acquire Their Songs 747

31.6 Social Behavior 747

- Why Live Alone – or Together? 748
- Dominance Hierarchies 749
- Territoriality 749
- Eusociality: Life in Animal Societies 750

31.7 Altruism in the Animal Kingdom 751

- Inclusive Fitness at Work 753
- Reciprocal Altruism 754
- Learning about Animal Navigation 754
- On To ... The Rest of Life 754
- Chapter Review 757**

Appendix App-1

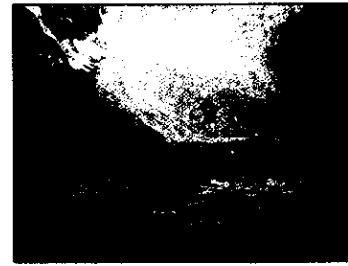
Answers to Multiple-Choice and Brief Review Questions A-1

Glossary G-1

Photo Credits PC-1

Index I-1

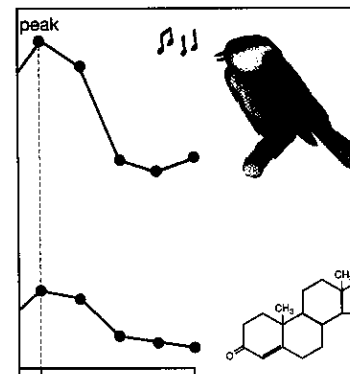
HIGHLIGHTS



Global warming, disappearing glaciers. 710

Essays

- Biological Rhythms and Sports 740
- Are Men 'Naturally' Promiscuous and Women Reserved? 744
- How Did We Learn? 755
- How Do Sea Turtles Find Their Way? 755



Testosterone levels and singing. 741