

Content Area Literacy Digital Supplement

Biology Chapter Excerpt

BSCS: Biology Ecological Approach, 9th Edition

- Introduction (pp. 2 – 15)
- Chapter 4 (pp. 16 – 47)
- Glossary (pp. 48 – 72)
- Index (pp. 73 – 93)

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2 3 4 5 6 7 8 9 10 10 09 08 07 06

CONTENTS



Foreword

xvi

UNIT 1

The World of Life

3

1 The Web of Life

5

Interactions among Living Things

6

1.1 Organisms Interact with Organisms They Eat

6

1.2 Plants, Animals, and Other Organisms Make Up a Food Chain

8

Matter and Energy—The Foundations of Life

11

1.3 All Biological Activity Requires Energy

11

1.4 The Sun and Photosynthesis Supply Food Energy

12

1.5 Matter Is Used to Build Living Things

13

Studying the Living World

15

1.6 The Biosphere Is Home to All Living Things

15

1.7 A Hypothesis Is a Statement That Attempts to Explain an Observation

16

INVESTIGATION 1.1 The Powers of Observation

20

INVESTIGATION 1.2 You and the Web of Life

21

INVESTIGATION 1.3 Field Observation

22

INVESTIGATION 1.4 How Do Flowers Attract Bees?

A Study of Experimental Methods

24

2 Populations

29

Individuals, Populations, and Environment

30

2.1 Populations Are Made Up of Individuals

30

2.2 Four Rates Determine Population Size

31

2.3 The Environment Limits Population Size

32

Carrying Capacity

34

2.4 Abiotic and Biotic Factors Work Together to Influence Population Size

34

2.5 Population Density May Fluctuate

35

2.6 Populations May Spread to Neighboring Areas

36

2.7 Barriers Can Prevent Dispersal

36

Human Populations

38

2.8 Few Barriers Prevent Human Dispersal

38

2.9 Earth's Carrying Capacity Is Limited

39

2.10 Uneven Distribution of Food May Limit Population Size

40

2.11 Human Activities Change the Environment

41

2.12 Managing Earth Requires Global Cooperation

42

INVESTIGATION 2.1 Studies of Population Growth

47

INVESTIGATION 2.2 Water—A Necessity of Life

54

INVESTIGATION 2.3 The Pasture: Introduction to the Tragedy
of the Commons

57

3 Communities and Ecosystems

61

Life in a Community

62

3.1 Many Interactions Are Indirect

62

3.2 An Ecosystem: Many Populations Interact in a Community

62

3.3 A Niche Is the Role of an Organism	64
3.4 Organisms May Benefit or Harm One Another	64
Ecosystem Structure	66
3.5 Boundaries of Ecosystems Overlap and Change	66
3.6 Most Communities Have More Producers than Consumers	67
Ecosystem Stability and Human Influences	69
3.7 Humans Lower the Stability of Ecosystems	69
3.8 Humans Threaten the Diversity of Organisms	71
3.9 The Value of Biodiversity	73
3.10 Humans Also Can Help Conserve Species	75
INVESTIGATION 3.1 Abiotic Environment: A Comparative Study	78
INVESTIGATION 3.2 Competition	80
INVESTIGATION 3.3 Acid Rain and Seed Germination	83
4 Matter and Energy in the Web of Life	87
Matter and Energy	88
4.1 Matter Is Made of Atoms	88
4.2 Chemical Bonds Hold Atoms Together	88
4.3 Chemical Reactions Are Essential to Life	89
4.4 Energy Makes Work and Order Possible	91
Energy for Life	92
4.5 The Sun and Photosynthesis: How We Get Energy	92
4.6 Energy Is Released as Food Is Broken Down	94
4.7 ATP, the Cell's Currency for Energy Transfer	95
Life Is Based on Carbon	96
4.8 Carbon Is Found in All Living Things	96
4.9 Carbohydrates Are Used for Energy Storage and Energy Production	97
4.10 Lipids Are Efficient Energy-Storage Compounds	98
4.11 Proteins Function as Enzymes and Structural Components of Cells	98
4.12 Enzymes Catalyze Chemical Reactions	100
4.13 Nucleic Acids Contain the Blueprint for Life	101
Carbon Cycling	103
4.14 Plants Make and Use Carbon-Containing Sugars	103
4.15 Carbon Cycles within an Ecosystem	104
INVESTIGATION 4.1 Organisms and pH	108
INVESTIGATION 4.2 Compounds in Living Organisms	110
INVESTIGATION 4.3 Enzyme Activity	113

UNIT 2

Continuity of Life 119

5 The Cell 121

Cells Are the Units of Life 122

5.1 Cell Theory: The Smallest Unit of Life Is the Cell 122

5.2 Biologists Use Microscopes to Study Cells 124

5.3 Cells Are of Two Basic Types 125

Cell Structure 128

5.4 Membranes Organize Eukaryotic Cells 128

5.5 Eukaryotic Cells Contain Various Organelles 129

Cell Functions 131

5.6 Cell Activities Require Energy 131

5.7 Substances Enter and Leave Cells by Diffusion 132

5.8 Cells Move Substances in a Variety of Ways	133
Cell Division	135
5.9 The Cell's Life Is a Cycle	135
5.10 Mitosis Is a Continuous Process	136
5.11 Cells Become Specialized during Development	138
INVESTIGATION 5.1 Observing Cells	141
INVESTIGATION 5.2 Diffusion through a Membrane	144
INVESTIGATION 5.3 Cell Size and Diffusion	146
INVESTIGATION 5.4 Mitosis and Cytokinesis	148
6 Continuity through Reproduction	151
Reproduction	152
6.1 Reproduction Is Essential for the Continuation of Life	152
6.2 Reproduction May Be Sexual or Asexual	153
Formation of Reproductive Cells	154
6.3 Gametes Are Reproductive Cells	154
6.4 Gametes Have Half the Chromosomes of Body Cells	156
6.5 Gametes Are Formed by Meiosis	156
The Human Reproductive System	160
6.6 Gamete Development Differs in Males and Females	160
6.7 Hormones Control Reproductive Cycles	162
6.8 Only One Sperm Fertilizes the Ovum	166
INVESTIGATION 6.1 A Model of Meiosis	168
7 Continuity through Development	171
Regulated Development	172
7.1 A Zygote Gives Rise to Many Cells	172
7.2 Cell Differentiation Is a Major Part of Development	173
7.3 Interactions between Cells Influence Differentiation	175
Animal Development	177
7.4 Some Animals Develop in an External Environment	177
7.5 Mammalian Embryos Develop within the Mother	177
7.6 Embryos Are Affected by Substances in the Mother's Blood	180
Cancer	182
7.7 Development Usually Is Well Controlled	182
7.8 Cancer Cells Divide without Limit	183
INVESTIGATION 7.1 The Yeast Life Cycle	186
8 Heredity and Genetic Variation	193
The Hereditary Role of Genetic Material	194
8.1 Genes Determine Biological Potential	194
8.2 Mendel's Work Led to the Concept of the Gene	194
8.3 Mendel Identified the Unit of Heredity	196
Patterns of Inheritance	199
8.4 Dihybrid Crosses Produce a Distinctive Pattern	199
8.5 Gene Expression Can Reveal or Hide the Phenotype of Genetic Inheritance	200
8.6 X-Linked Traits Show a Modified Pattern of Inheritance	202
8.7 Abnormal Chromosomes Can Affect Patterns of Inheritance	204
Genes and Chromosomes	207
8.8 DNA Is the Genetic Material	207
8.9 Genes Are Long Chains of DNA Nucleotides	208
8.10 Many Genes Are on Each Chromosome	209

Gene Expression	210
8.11 Genes Direct Biosynthesis	210
8.12 Through mRNA, DNA Directs the Synthesis of Proteins	212
Biotechnology	215
8.13 New Tools Aid Genetics Research	215
8.14 Proteins Can Be Manufactured by Genetic Engineering	216
INVESTIGATION 8.1 Probability	222
INVESTIGATION 8.2 DNA Replication and Transcription to RNA	224
INVESTIGATION 8.3 A Dihybrid Cross	227
9 Evolution: Patterns and Diversity	233
Diversity, Variation, and Evolution	234
9.1 Living Organisms Are Both Similar and Varied	234
9.2 All Organisms Are Grouped into Species	235
9.3 Darwin Observed Variation among Organisms	238
Evolution and Natural Selection	240
9.4 Darwin Identified Selection as a Force in Evolution	240
9.5 Darwin's Theory Changed Biology	241
Evolution and Genetics	243
9.6 Evidence from Genetics Supports Natural Selection	243
9.7 Several Evolutionary Mechanisms Can Affect Populations	245
9.8 Isolation Is Needed for Speciation	247
9.9 Various Evolutionary Patterns Occur	250
INVESTIGATION 9.1 Natural Selection: An Activity	254
INVESTIGATION 9.2 A Step in Speciation	256

UNIT 3

Diversity and Adaptation in the Biosphere 263

10 Ordering Life in the Biosphere 265

Biological Classification 266

- 10.1 Classification Is a Way of Seeing Relationships 266
- 10.2 Classification Is Based on Homologies 266
- 10.3 Species Are Grouped into Broader Categories 268
- 10.4 Biologists Use a Binomial System 270

The Kingdoms of Organisms 272

- 10.5 Cell Structure Is Evidence for Relatedness 272
- 10.6 Organisms Are Grouped into Five Kingdoms 275
- 10.7 Classifications Can Change 278

The Origin of Life 280

- 10.8 All Species May Have Come from One Ancestral Species 280
- 10.9 Stars Provide Evidence of Earth's Early History 281
- 10.10 The First Cells Probably Were Heterotrophs 282
- 10.11 Several Types of Photosynthesis Evolved 285
- 10.12 Matter Is Organized on Several Levels 286

INVESTIGATION 10.1 DNA Sequences and Classification 289

11 Prokaryotes and Viruses 295

Prokaryotes 296

- 11.1 Prokaryotes Are Structurally Simple but Biochemically Complex 296
- 11.2 Archaeobacteria Are Different from All Other Organisms 298

11.3 Several Types of Archaeobacteria Exist	299
11.4 Eubacteria Are a Diverse Group	301
11.5 Eubacteria Make the Nitrogen Cycle Possible	303
Disease	305
11.6 Diseases Result from Interrelationships	305
11.7 Some Eubacteria Are Pathogens	306
11.8 Viruses Are Unusual Pathogens	308
Sexually Transmitted Diseases	312
11.9 Eubacteria Cause Several Sexually Transmitted Diseases	312
11.10 AIDS Is a Deadly Disease	313
11.11 Prospects for Treatment of AIDS Are Improving	314
INVESTIGATION 11.1 Distribution of Microorganisms	317
INVESTIGATION 11.2 Control of Eubacteria	319
INVESTIGATION 11.3 Screening for AIDS	321
12 Eukaryotes: Protists and Fungi	325
Autotrophic Protists	326
12.1 Algae Are Photosynthetic Protists	326
12.2 Green Algae May Have Been the Ancestors of Plants	326
12.3 Diatoms Are Important Producers	327
12.4 Brown and Red Algae Are Multicellular	328
Protozoa: Animal-Like Protists	329
12.5 Flagellates May Be Consumers or Producers	329
12.6 Many Sarcodines Use Pseudopods	330
12.7 Sporozoans Are All Parasites of Animals	331
12.8 Ciliates Have Two Types of Nuclei	331
12.9 Slime Molds Resemble Both Fungi and Protozoa	332
Fungi	334
12.10 Fungi Are Important Decomposers	334
12.11 Conjugating Fungi Can Destroy Foods	335
12.12 Sac Fungi Have a Special Reproductive Structure	335
12.13 Reproductive Structures of Some Club Fungi Are Edible	337
12.14 Imperfect Fungi Have No Known Sexual Reproductive Structures	337
Fungi in a Community	339
12.15 Fungi Support Many Food Chains	339
12.16 Mycorrhizal Fungi Help Many Plants Grow	339
12.17 Lichens Are Symbiotic Pairs of Organisms	341
INVESTIGATION 12.1 Variety among Protists and Cyanobacteria	343
INVESTIGATION 12.2 Life in a Single Cell	344
INVESTIGATION 12.3 Growth of Fungi	349
13 Eukaryotes: Plants	353
The Evolution of Land Plants	354
13.1 Two Major Groups of Land Plants Evolved	354
13.2 Vascular Plants Have Adaptations That Conserve Water and Permit Gas Exchange	355
13.3 Bryophytes Require Water for Reproduction	356
13.4 Flowering Plants Have Special Reproductive Adaptations	358
Bryophytes and Seedless Vascular Plants	361
13.5 Bryophytes Have No Roots, Stems, or Leaves	361
13.6 Club Mosses and Horsetails Are Seedless Vascular Plants	362
13.7 Fern Leaves Grow from Underground Stems	364

Seed Plants	367
13.8 Many Conifers Are Evergreens	367
13.9 Many Flowering Plants Have Special Pollinators	370
13.10 Flowering Plants Produce Fruits with Seeds	371
13.11 Flowering Plants Are the Most Diverse Group of Land Plants	372
INVESTIGATION 13.1 Increasingly Complex Characteristics	377
INVESTIGATION 13.2 Reproductive Structures and Life Cycles	380
INVESTIGATION 13.3 Fruits and Seeds	383
14 Eukaryotes: Animals	387
The Animal Way of Life	388
14.1 Animals Are Adapted to the Demands of Their Environments	388
14.2 As Size Increases, Complexity Increases	389
Diversity and Adaptation in Animals	390
14.3 Sponges and Cnidarians Are the Least Complex Animals	390
14.4 Flatworms Have True Organs	392
14.5 Roundworms and Molluscs Have a Body Cavity	393
14.6 Annelids and Arthropods Are Segmented	394
14.7 Chordates Have Internal Skeletons	397
Life Functions in Animals	402
14.8 Digestion May Be Intracellular or Extracellular	402
14.9 Animals Have Several Ways of Obtaining and Transporting Materials	403
14.10 Excretory Systems Maintain Water and Chemical Balance	405
14.11 Nervous Systems Control Responses to Stimuli and Coordination of Functions	407
14.12 Muscles and Skeletons Provide Support and Locomotion	408
14.13 Animals Are Adapted for Reproductive Success	409
INVESTIGATION 14.1 Temperature and Circulation	412

Unit 4

Functioning Organisms	415
15 The Human Animal: Food and Energy	417
Ingestion and Digestion	418
15.1 Specific Actions and Reactions Take Place along the Digestive Tract	418
15.2 Chemical Digestion Breaks Down Large Food Molecules to Smaller, Absorbable Molecules	419
15.3 Absorption Takes Place in the Small Intestine	420
15.4 The Large Intestine Absorbs Water	421
Cellular Respiration	422
15.5 Cellular Respiration Releases Energy from Food Molecules	422
15.6 Glycolysis Begins the Production of Energy	423
15.7 Aerobic Respiration: The Krebs Cycle Completes the Breakdown of Glucose	425
15.8 The Electron Transport System Packages Energy from Glucose as ATP	426
15.9 The Krebs Cycle Plays a Central Role in Cellular Metabolism	427
15.10 Anaerobic Respiration: Energy-Releasing Processes Are Essential to Life	427
Nutrition	429
15.11 Dietary Habits Affect Health	429
15.12 Lipids Are Concentrated Sources of Food Energy	431

15.13 Carbohydrates Provide Energy, Nutrients, and Fiber	434
15.14 Protein Provides the Body's Framework	436
15.15 Eating Disorders Are Widespread	437
INVESTIGATION 15.1 Food Energy	439
INVESTIGATION 15.2 Assessing Risk for Cardiovascular Disease	443
16 The Human Animal: Maintenance of Internal Environment	451
Circulation	452
16.1 The Heart Pumps Blood through a Series of Tubes	452
16.2 Plasma Contains Blood Cells and Other Substances	454
16.3 Clotting Is an Interaction between Platelets and Plasma Proteins	455
16.4 Some Cells and Materials Move between Blood Vessels and Tissues	456
Immunity	457
16.5 The Body Has Several Defenses against Foreign Invaders	457
16.6 Protection by the Immune System Is Specific	458
16.7 Many Problems Can Arise with the Immune System	461
Respiration and Excretion	465
16.8 Respiration Involves Breathing and Gas Exchange	465
16.9 Respiratory Gases Are Transported in the Blood	467
16.10 The Kidneys Are Major Homeostatic Organs	467
16.11 Nephrons Filter the Blood	468
Temperature Regulation	471
16.12 The Rate of Chemical Reactions Is Influenced by Temperature	471
16.13 Major Heat Loss Occurs through Evaporation and Radiation	471
16.14 Internal Temperature Is Controlled by the Brain	472
INVESTIGATION 16.1 Exercise and Pulse Rate	474
INVESTIGATION 16.2 The Alpine Slide Mystery	475
INVESTIGATION 16.3 Exercise and Carbon Dioxide Production	478
INVESTIGATION 16.4 The Kidney and Homeostasis	479
17 The Human Animal: Coordination	483
The Muscular System	484
17.1 Muscle Contraction Depends on Energy from ATP	484
17.2 Interaction of Bones, Joints, and Muscles Produces Movement	486
17.3 Cardiovascular Fitness Depends on Regular Exercise	487
The Nervous System	488
17.4 Neurons Transmit Nerve Impulses	488
17.5 The Central Nervous System Coordinates Body Functions	490
17.6 The Peripheral Nervous System Transmits Information to and from the Central Nervous System	492
The Endocrine System	494
17.7 Hormones Are Chemical Messengers	494
17.8 Several Hormones Act Together to Control Blood Glucose Levels	495
17.9 The Hypothalamus and Pituitary Control Other Endocrine Glands	496
Stress, Drugs, and the Human Body	501
17.10 Stress Is the Body's Response to Change	501
17.11 Psychoactive Drugs Affect the Central Nervous System	501
INVESTIGATION 17.1 Muscles and Muscle Fatigue	507
INVESTIGATION 17.2 Sensory Receptors and Response to Stimuli	509

18 The Flowering Plant: Form and Function	513
Leaf Structure	514
18.1 Leaf Structure Allows for Movement of Carbon Dioxide	514
18.2 Guard Cells Regulate the Rate of Water Loss	515
18.3 Some Leaves Have Functions Other than Photosynthesis	516
Stems and Conduction	516
18.4 Stems Support Leaves and Conduct Materials	516
18.5 Pressure within Phloem Cells Helps Move Sugars Down a Plant	520
18.6 Transpiration Pulls Water Up through the Xylem of a Plant	520
Roots and Absorption	523
18.7 Roots Anchor a Plant and Absorb Materials	523
18.8 Many Nutrients Move into a Plant by Active Transport	524
Plant Growth	526
18.9 A Seed Protects and Nourishes the Embryo Inside	526
18.10 Primary Growth Increases the Length of a Plant	526
18.11 Secondary Growth Increases the Diameter of a Plant	528
INVESTIGATION 18.1 Water and Turgor Pressure	530
INVESTIGATION 18.2 Leaves, Stems, and Roots: Structural Adaptations	534
INVESTIGATION 18.3 Seeds and Seedlings	537
19 The Flowering Plant: Maintenance and Coordination	541
Photosynthesis	542
19.1 Photosynthesis Takes Place in Chloroplasts	542
19.2 Photosynthesis Requires Light	542
19.3 Photosynthesis Involves Many Interdependent Reactions	544
19.4 Oxygen Gas Is a By-product of the Light Reactions	545
19.5 Sugars Are Formed in the Calvin Cycle	546
Photosynthesis and the Environment	548
19.6 Environmental Factors Affect the Rate of Photosynthesis	548
19.7 Photorespiration Inhibits Photosynthesis	550
19.8 Special Adaptations Reduce Photorespiration	550
Hormonal and Environmental Control of Plant Growth	552
19.9 Plant Hormones Interact to Regulate Plant Processes	552
19.10 Plant Hormones Have Diverse Effects	553
19.11 Plants Respond to Environmental Stimuli	556
19.12 Many Plants Respond to the Length of Day and Night	558
INVESTIGATION 19.1 Gas Exchange and Photosynthesis	561
INVESTIGATION 19.2 Tropisms	565

Unit 5

Patterns in the Biosphere 569

20 Behavior, Selection, and Survival	571
Behavior and Selection	572
20.1 Behavior Usually Falls into Two Categories	572
20.2 Organisms Interact with One Another	576
20.3 Many Animal Societies Are Hierarchical	577
20.4 Many Animals Defend a Territory	578

20.5 Sexual Selection Plays an Important Role in Many Populations	579
20.6 Some Animals Display Cooperative Behavior	580
The Environment and Survival	580
20.7 Animals Adjust to Environmental Changes in Several Ways	580
20.8 Organisms Vary in Their Tolerance	582
20.9 Human Activity Affects the Behavior and Survival of Other Animals	584
INVESTIGATION 20.1 Conditioning	587
INVESTIGATION 20.2 Environmental Tolerance	589
21 Ecosystems of the Past	593
Reconstructing the Past	594
21.1 Scientists Can Determine the Ages of Fossils	594
21.2 Fossils Provide Information about Ancient Life	596
21.3 The Fossil Record Reveals Both Change and Stability	597
Evolution and Plate Tectonics	599
21.4 Evolution Has Occurred on Moving Plates	599
21.5 Plate Tectonics Explains the Distribution of Species	601
A Sampling of Paleoecosystems	603
21.6 Cambrian Communities Were Aquatic	603
21.7 Land Plants and Animals Appeared in the Devonian	604
21.8 Giant Forests Grew during the Carboniferous	606
21.9 Dinosaurs Dominated Jurassic and Cretaceous Ecosystems	607
21.10 Large Mammals Roamed North America in the Cenozoic	607
The Emergence of Humans	609
21.11 Humans Are Classified in the Order Primates	609
21.12 Hominids Are Primates That Walk Upright	610
21.13 The First Humans Appeared in Africa	610
INVESTIGATION 21.1 Evolution and Time	617
INVESTIGATION 21.2 Archaeological Interpretation	620
22 Biomes around the World	625
Climate, Ecosystems, and Biomes	626
22.1 Abiotic Factors Influence the Character of Ecosystems	626
22.2 Latitude, Air Circulation, Ocean Currents, and Landforms Affect Climate	627
Biomes Characterized by Seasonal or Constant High Levels of Solar Energy	629
22.3 Tundra Vegetation Is Low Growing	629
22.4 Taiga Is a Coniferous Forest	631
22.5 Midlatitude Forests Have Four Distinct Seasons	632
22.6 Tropical Rain Forests Have a Uniform Climate	634
Biomes with Low Amounts of Precipitation	635
22.7 There Are Three Distinct Types of Grassland	635
22.8 Midlatitude Deserts Border the Grasslands	637
Biomes with Variable Amounts of Precipitation	639
22.9 Savannas Are Tall Grasslands in Tropical Dry Areas	639
22.10 Chaparral Covers Dry Areas with Thin Soil	640
Ecosystems Are Not Permanent	641
22.11 Factors That Influence Change in an Ecosystem	641
22.12 Communities Change through Relatively Long Periods of Time	642
22.13 Succession May Not Always Be Orderly	643

Human Influence on Biomes	646
22.14 The Need for Land Has Changed Some Biomes	646
22.15 Tropical Forests Are Declining	647
22.16 Desertification Is Spreading Rapidly	647
22.17 Acid Deposition Has Many Harmful Effects	648
INVESTIGATION 22.1 Climatograms	651
INVESTIGATION 22.2 Long-Term Changes in an Ecosystem	654
INVESTIGATION 22.3 Effects of Fire on Biomes	656
23 Aquatic Ecosystems	661
Standing Freshwater Ecosystems	662
23.1 Ponds Are Shallow Enough for Rooted Plants	662
23.2 Lakes Are Larger and Deeper than Ponds	664
Flowing Freshwater Ecosystems	667
23.3 Stream Size and Flow Affect Aquatic Organisms	667
23.4 Flowing Waters May Serve as a Laboratory	668
Ocean Ecosystems	670
23.5 Many Abiotic Factors Influence the Ocean	670
23.6 Productivity Is Limited in the Open Ocean	672
23.7 Ocean Depths Support Some Forms of Life	672
23.8 Coastal Waters and Coral Reefs Support a Diversity of Life	674
23.9 The Intertidal Zone Is a Difficult Place to Live	676
Human Influences on Aquatic Ecosystems	677
23.10 Wetland Ecosystems Are Threatened	677
23.11 Sewage and Industrial Wastes Affect Aquatic Ecosystems	680
23.12 The Oceans Receive the Major Part of Human Waste	681
23.13 Some Practices Can Reduce Water Pollution	683
INVESTIGATION 23.1 A Field Study of a Stream	686
INVESTIGATION 23.2 Effects of Salinity on Aquatic Organisms	689
INVESTIGATION 23.3 Crisis in the Gulf of Maine	691
24 Managing Human-Affected Ecosystems	695
Human Culture and Technology	696
24.1 Human Culture Has Affected Our Role in the Ecosystem	696
24.2 The Establishment of Agriculture Had Wide-Reaching Effects	696
24.3 The Industrial Revolution Increased the Demand for Resources	698
24.4 Human Culture and Technology Have Created Many Problems	699
24.5 All Environmental Issues Are Connected to Population Growth	700
Change and the Future	701
24.6 International Cooperation Is Necessary to Solve Modern Problems	701
24.7 Technology Can Help Solve Some Problems	705
24.8 Sustainable Agriculture Is Important	706
24.9 Many Measures Require Ethical Decisions	707
24.10 Managing the Earth Effectively Requires Personal Commitment	708
INVESTIGATION 24.1 Views of the Earth from Afar	710
INVESTIGATION 24.2 The World as a Commons	713
INVESTIGATION 24.3 Having an Impact	716

Appendix One	General Procedures for the Laboratory	719
Appendix Two	Supplementary Investigations	727
Appendix Three	Tables	739
Appendix Four	A Catalog of Living Things	757
Glossary		785
Index		811

Biology Today Features

Chapter		Chapter	
2 Famine in Africa	43	14 Marsupials and Monotremes	401
3 Naturalist/Interpreter	74	15 Cardiovascular Diseases	435
4 The Carbon Cycle and Global Warming`	106	16 Monoclonal Antibodies	463
5 The Development of Cell Theory	123	17 The Human Eye and Vision	493
6 Birth Control	165	18 City Forester	521
7 Prenatal Diagnosis	178	19 Development of New Plants	555
8 Genetic Screening: A Dilemma for All of Us	218	20 Camouflage and Mimicry	575
9 The Cheetah on the Way to Extinction?	249	21 Biological Anthropologist	613
10 Preserving Biodiversity	273	22 Biodiversity in Danger	644
11 Slow Infections of the Brain	310	23 Plant Ecologist	679
12 Models of Eukaryotic Origins	333	24 Bioremediation	702
13 Biological Illustrator	375		

Pioneers Features

Chapter		Chapter	
1 Ecologist	18	13 Evolutionary Geologist	366
7 Breast Cancer Genes	185	15 The Changing Face of the Food Guide Pyramid	432
8 Informatics: Mapping and Sequencing the Human Genome	217	16 From the Depths to the Heights	470
		17 Physician and Physiologist	503

FOREWORD



Did you take a look at the frog on the cover of this book. A really close look? How is this frog like any other frog? How is *this* frog unique?

Frogs have much to tell us about the history of life on our planet. Frogs are classified as amphibians. About 400 million years ago, amphibians were the first vertebrate animals to leave the seas for life on land. Their fossil remains tell this fascinating story. Today, amphibians have another story to tell about the general condition of many environments.

The life cycle of a frog is dependent on many aspects of its environment: part of its life is spent in water, and part on land, breathing air. The frogs of today have become “sentinel animals,” because changes taking place in their lives alert us to changes in our environment.

How do frogs show us these things? Some very strange-looking frogs, frogs with bizarre physical abnormalities, have started showing up in agricultural areas of the United States. These are places where pesticide use is heavier than in other parts of the country. Many other types of frogs have become extinct; vanished forever from the tropical rain forests of Central and South America. These rain forests are disappearing at the hands of humans. People are chopping down the trees, clearing the land for food crops, and using the wood for building.

So why are the frogs disappearing? Is it because of loss of their habitat? Is it due to malformations caused by pesticide use? Is it because of diseases? Is all the news bad? We frequently hear reports of global warming and the extinction of plants and animals, often blamed totally on humans. Yet ancient rocks, glacial ice, and fossil records tell us that cycles of temperature change and extinctions of life are a part of earth’s history. How can we determine the role humans play in the changing environments of today’s earth?

Where will we find solutions to problems so that we can make responsible personal decisions as well as contribute our voice to public policy? There are many ways to explain the world around us. Historically, people have used art, philosophy, or religion to describe the world. Today we can also use science to investigate the natural world, to make conclusions about our investigations, and to question those conclusions.

Welcome to BSCS Green Version! BSCS Green is a biology program that encourages you to investigate how organisms and their behaviors are shaped by their environments. You will ask questions about what happens as organisms and their environments interact. You will be introduced to the big picture showing how different local environments fit together to form patterns of life on Earth.

With BSCS Green Version, you will practice science as a way to study and learn about your world. In other words, Green Version is your opportunity to learn about science by actually *doing* science. You will see the ways that science can help provide solutions to the problems you have identified and studied. Finally, you will see that people who use science to study an issue are also left with the very human challenge of acting on their conclusions.

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Chapter Topics

Matter and Energy

- 4.1** Matter Is Made of Atoms
- 4.2** Chemical Bonds Hold Atoms Together
- 4.3** Chemical Reactions Are Essential to Life
- 4.4** Energy Makes Work and Order Possible

Energy for Life

- 4.5** The Sun and Photosynthesis: How We Get Energy
- 4.6** Energy Is Released as Food Is Broken Down
- 4.7** ATP, the Cell's Currency for Energy Transfer

Life Is Based on Carbon

- 4.8** Carbon Is Found in All Living Things
- 4.9** Carbohydrates Are Used for Energy Storage and Energy Production

- 4.10** Lipids Are Efficient Energy-Storage Compounds

- 4.11** Proteins Function as Enzymes and Structural Components of Cells

- 4.12** Enzymes Catalyze Chemical Reactions

- 4.13** Nucleic Acids Contain the Blueprint for Life

Carbon Cycling

- 4.14** Plants Make and Use Carbon-Containing Sugars

- 4.15** Carbon Cycles within an Ecosystem

Investigation 4.1 Organisms and pH

Investigation 4.2 Compounds in Living Organisms

Investigation 4.3 Enzyme Activity



MATTER AND ENERGY IN THE WEB OF LIFE



All living things are tied together by their need for nutrients and energy. Using matter from the surrounding soil and air and incorporating energy from the sun, producers such as green plants make their own food to sustain themselves. Consumers, on the other hand, must obtain their nutrients and energy from other organisms. Humans, for instance, eat plants and animals to get their nutrients and energy. Our food is made up of biological molecules, which we consume and digest. We then use the products from the breakdown of foods to make our own unique group of biological molecules. This chapter examines these important molecules and investigates some characteristics of matter and energy.



How does this deer interact with his environment? What role does he play in the web of life? How does the deer's browsing on plant material relate to the flow of energy and the cycling of matter?

Matter and Energy

GUIDEPOST

How are matter and energy related in the biosphere?

4.1

Matter Is Made of Atoms

Biological molecules are **organic compounds**. Organic compounds are molecules built of carbon combined with other elements. Like all other compounds, organic compounds can be broken down to the elements from which they were formed. For example, molecules of sugar, an organic compound, can be broken down to the elements carbon, hydrogen, and oxygen. Carbon, iron, nitrogen, gold, silver, calcium, and chlorine are some elements with which you probably are familiar. Four elements—carbon, oxygen, hydrogen, and nitrogen—are common to all living systems.

Matter is made of atoms. An atom is the smallest particle of an element that retains the properties of that element. For example, the element carbon is made of only carbon atoms. Each atom has a core, or **nucleus**, that contains positively charged particles called **protons** and uncharged particles called **neutrons**. One or more **electrons**, which are negatively charged particles, rapidly orbit the nucleus. Because the number of electrons equals the number of protons, an atom is electrically neutral.

The total number of particles in an atom determines what element is formed. For example, a hydrogen atom is made of one proton and one electron (hydrogen is the only atom that does not have neutrons in its nucleus). An atom of carbon contains six protons, six neutrons, and six electrons. Oxygen atoms are composed of eight protons, eight neutrons, and eight electrons. Figure 4.1 shows models of these atoms.

4.2

Chemical Bonds Hold Atoms Together

Atoms combine to form molecules, resulting in different forms of matter. For example, hydrogen and oxygen can combine to form water. Reactions between atoms depend on the number of electrons each atom has. Sometimes a reaction involves an electron moving from one atom to another. For example, when atoms of sodium (Na) and atoms of chlorine

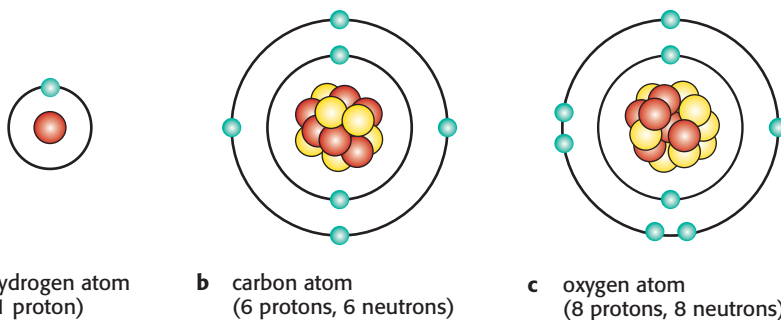


Figure 4.1 ▲

Simplified models of (a) hydrogen, (b) carbon, and (c) oxygen. Red circles represent protons; yellow circles represent neutrons. Electrons (in a turquoise color) are shown in shells, or levels, around the nucleus. The number of electrons in the outer level determines chemical activity.

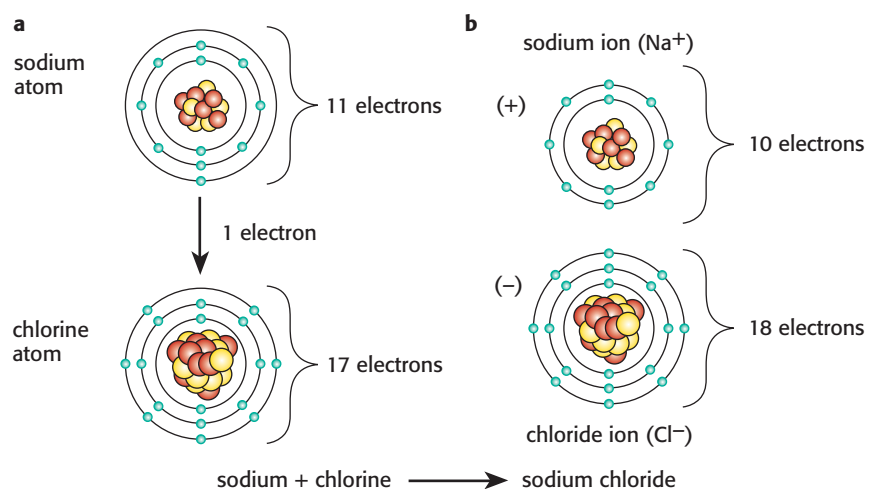


Figure 4.2 ▲

Sodium and chlorine can react to form sodium chloride (NaCl), table salt. By losing one electron, sodium becomes a positive ion, and by gaining one electron, chlorine becomes a negative ion, chloride.

(Cl) react to form sodium chloride (NaCl , common table salt), each sodium atom gives up an electron to a chlorine atom, as shown in Figure 4.2. As a result, the number of protons and the number of electrons in the sodium atom are no longer equal. Because the sodium atom has 11 protons (positive charge) and only 10 electrons (negative charge), it has an overall positive charge. The chlorine atom, which captured the electron from the sodium atom, now has one more electron than it had originally. Consequently, it has an overall negative charge. A charged particle that has either a negative or a positive charge is called an **ion**. In this example, the chlorine atom has become an ion with a negative charge, a chloride ion (Cl^-). The sodium atom has become an ion with a positive charge (Na^+). The positively charged sodium ions and the negatively charged chloride ions are attracted to each other and come together, forming sodium chloride (NaCl).

Often when atoms react, they do not gain or lose electrons. Instead they share electrons. For example, in a molecule of water (H_2O), one oxygen atom shares electrons with two hydrogen atoms (see Figure 4.3). Molecules of carbon dioxide (CO_2), hydrogen gas (H_2), and oxygen gas (O_2) also are formed by shared electrons. The attractions that hold atoms or ions together are called **chemical bonds**.

4.3

Chemical Reactions Are Essential to Life

There are two general categories of chemical reactions in living cells. When sodium and chlorine ions combine to form table salt or when oxygen and hydrogen atoms combine to form water, compounds are made (synthesized). Reactions that make compounds are called **synthesis** reactions. Compounds also may be broken down. When this happens, the reaction is known as a **decomposition** reaction. The digestion of foods involves decomposition reactions.

For chemical reactions to take place, the reacting substances must come in contact with each other. This happens most easily when the substances

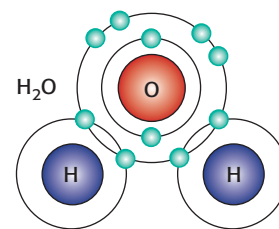


Figure 4.3 ▲

In a molecule of water, the oxygen atom forms an electron-sharing bond with each hydrogen atom.

Topic: atoms/molecules/compounds
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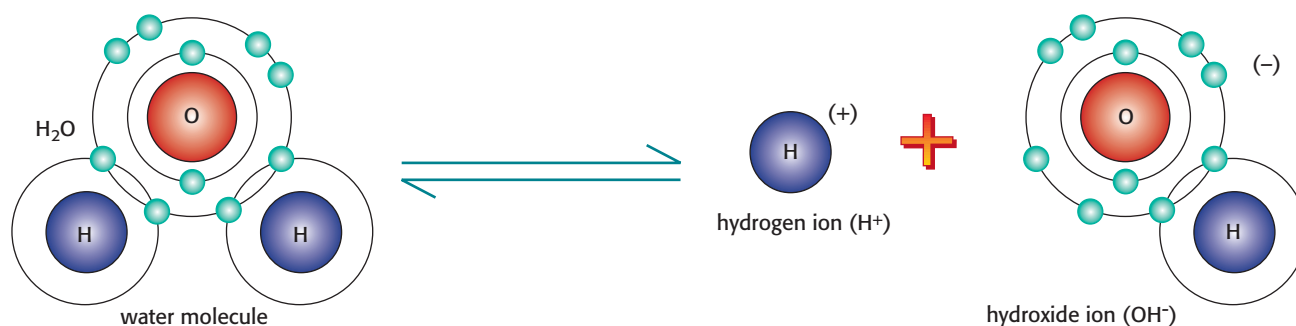


Figure 4.4 ▲

Water molecules ionize into hydrogen and hydroxide ions.

are in solution, that is, dissolved in water. When table salt dissolves in water, the sodium and chloride ions separate from each other, but they remain as ions in solution.

Compounds that are not made of ions can undergo a reaction called **ionization**. For example, water can be converted into ions through ionization (see Figure 4.4). In liquid water, there are always a very few water molecules (H_2O) that separate into hydrogen ions (H^+) and hydroxide ions (OH^-). A hydrogen ion is a single proton: a hydrogen atom that has lost its only electron. The missing electron is held by the hydroxide ion, which consists of an oxygen atom, a hydrogen atom, and the electron the hydrogen atom has lost.

Although water is a common compound, its ability to undergo ionization is one of the properties that makes it essential for life. Only about one in 10 million molecules of water forms ions, but all life processes depend on this small percentage. Hydrogen and hydroxide ions are involved in most of the reactions that occur in organisms. If more hydrogen ions than hydroxide ions exist in solution, the solution is said to be acidic. If more hydroxide ions than hydrogen ions are present, the solution is said to be basic, or alkaline. The relative levels of hydrogen and hydroxide ions are very important to organisms because of their effects on chemical reactions.

The hydrogen ion level of a solution is described by a range of numbers known as the **pH scale** (see Figure 4.5). The scale runs from 0 to 14. A solution that has equal numbers of hydrogen and hydroxide ions is neutral and has a pH of 7. Pure water has a pH of 7. As the hydrogen ion level rises, the solution becomes more acidic, and the pH drops. For example, a carbonated soft drink with a pH of 2 to 3 is highly acidic. Solutions with a

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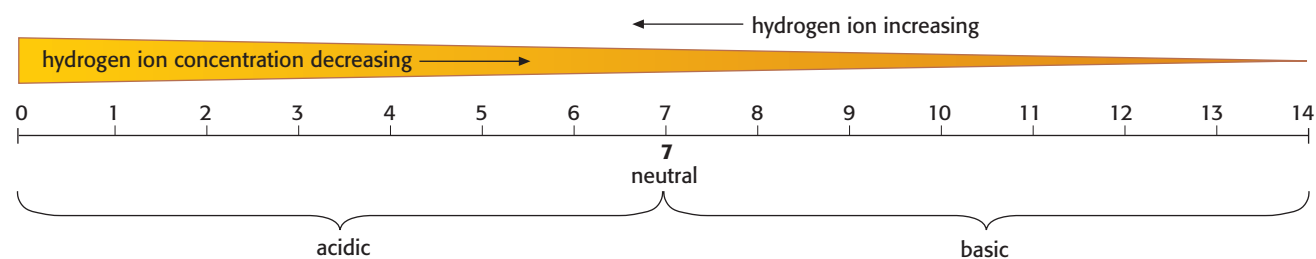
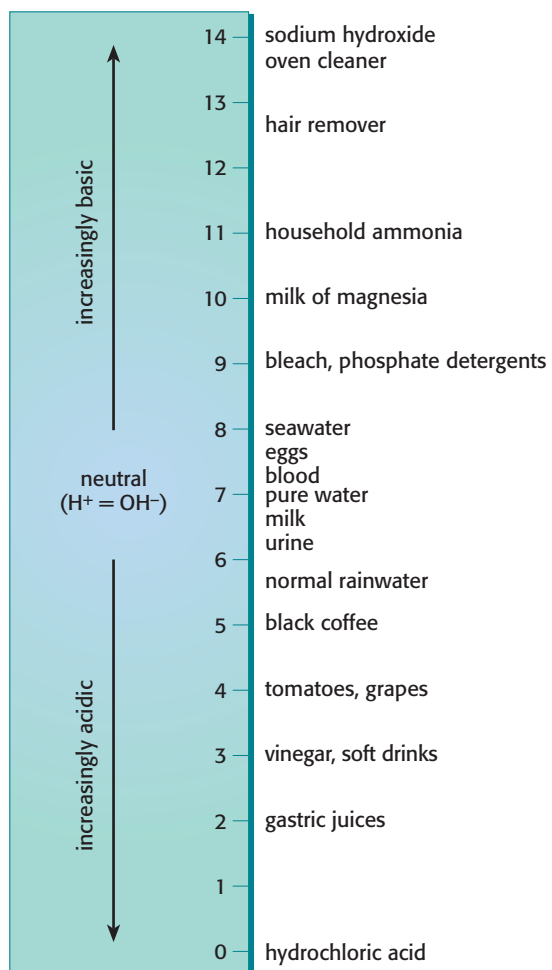


Figure 4.5 ▲

The pH scale ranges from 0 to 14. When is a substance acidic? When is it basic?



◀ **Figure 4.6**

Compare the pH values of some common substances.

pH above 7 are basic. They have relatively low levels of hydrogen ions and high levels of hydroxide ions. Figure 4.6 shows the pH of several common substances.

Organisms have an internal pH that must remain fairly stable for chemical reactions to occur optimally. Environmental factors may affect that stability in a variety of ways. In Investigation 4.1, you can discover how internal pH is regulated.

Even when they are dissolved in water, molecules involved in synthesis and decomposition reactions may react extremely slowly. Certain substances, however, promote chemical reactions. These substances are called **catalysts**. Catalysts are present only in small amounts, and although they participate in the reactions, they themselves are not changed or used up. Catalysts make it possible for reactions to occur at rates high enough to sustain life. The specialized and highly specific catalysts present in organisms are proteins called **enzymes**. These are discussed in Section 4.12.

4.4 Energy Makes Work and Order Possible

Chemical reactions involve **energy** transfer. In general, synthesis reactions require an input of energy, and decomposition reactions release energy. What is energy, and how is it used in living systems?

In a general way, energy can be defined as the ability to do work or to cause change. It is work to move an arm, play tennis, jump, heat a house, or build a skyscraper. Growing a leaf or a wing also can be considered work because energy is used in these processes. In a cell, energy is used to do many things, such as move substances and build new molecules. This, too, is work.

Energy also is required to establish and maintain order. Living things are very complex. Their atoms and molecules are arranged in highly organized systems. You can imagine a highly organized system in your own body: a unique type of cell forms cardiac (heart) muscle tissue, which in turn functions as the specialized organ, the heart. High levels of organization, however, can be unstable. If left to themselves, all systems tend to become simple and disorganized. Only by a continual input of energy can organization be maintained.

A living organism is an organized system. For instance, the internal organization of a frog is maintained because the frog eats flies and other insects that contain energy. This energy keeps the frog alive and allows it to grow and reproduce. If the frog does not get enough food, it dies. As soil decomposers break down the frog's body, it loses its organization. The decomposers survive by using the matter and energy derived from the frog's body cells.

Many life processes, such as reproduction or growth and development, tend to bring about an organized state with a minimum of randomness. That requires energy. Where does the energy come from?

CONCEPT REVIEW

1. What are the parts of a typical atom?
2. Describe two ways that chemical bonds form.
3. In terms of pH value, what is the difference between neutral, acidic, and basic solutions?
4. How is matter different from energy?
5. What is a catalyst?
6. Why do all organisms need energy?

Energy for Life

GUIDEPOST

What is the source of energy for living organisms, and how is the energy used?

4.5

The Sun and Photosynthesis: How We Get Energy

Living things grow, move, and reproduce. These and other types of biological activity require energy. Consumer organisms get their energy from the food they eat, but where do the producers get their energy? Usually, their energy comes from the sun. Because no organism can use light energy directly from the sun as a source of food energy, the energy must be converted to chemical energy.

In the process of photosynthesis, plants (and some other organisms) convert light energy from the sun into chemical energy that is stored in complex sugar molecules (food). That chemical energy then can be used either by the plants themselves or by organisms that eat the plants. Because animals cannot make their own food, most animals depend on plants as their source of energy either directly or indirectly. Therefore, using energy from the sun, photosynthesis is the pathway that provides the source of energy for biological activities in most organisms on earth.

The first step in photosynthesis is the absorption of light energy by a green plant. The energy is absorbed primarily by **chlorophyll**, a green pigment that gives plants their color. A plant also absorbs carbon dioxide (CO_2) from the air and water from the soil. Light energy, carbon dioxide, and water are the raw materials used to make the biological molecules called sugars. The light energy absorbed by the plant is used to break down water molecules into hydrogen and oxygen, and then to combine the hydrogen with carbon dioxide to form sugar molecules. The oxygen is released into the air as oxygen gas (O_2). In this way, some of the light energy absorbed by the plant is stored in the sugar molecules as chemical energy. Figure 4.7 highlights these events.

When sugars are formed, several small molecules are linked together by chemical bonds. The energy used to form the sugars is stored in those chemical bonds. When sugar molecules are broken down in a cell, the energy stored in the chemical bonds is released. That energy is used by the cell to carry out the cell's activities.

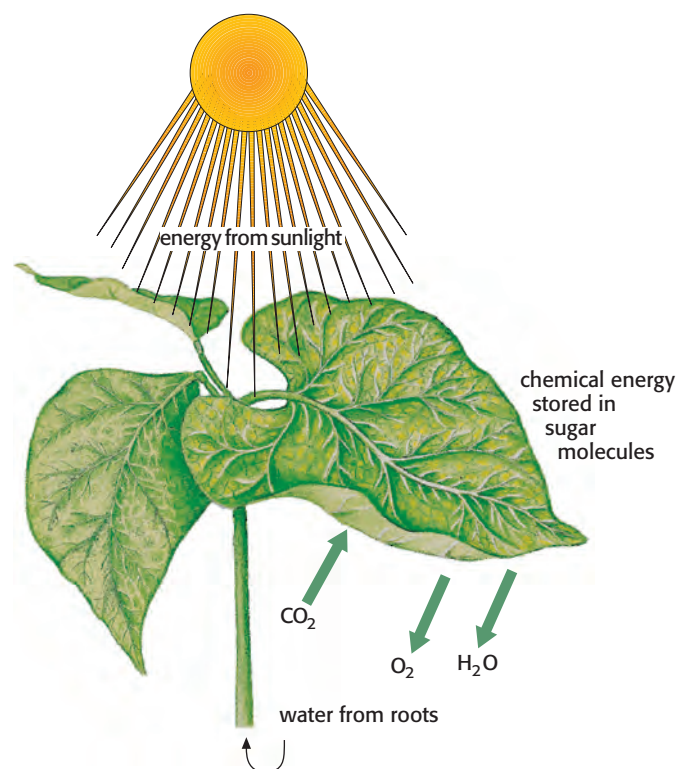
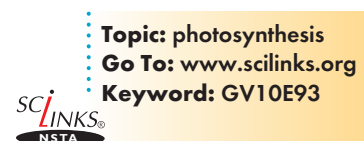


Figure 4.7 ▲

The energy in sunlight is converted to chemical energy during photosynthesis.

4.6

Energy Is Released as Food Is Broken Down

How is the energy stored in the chemical bonds of sugar molecules released so that the cell can use it? The major energy-releasing process is **cellular respiration**. Cellular respiration consists of a series of chemical reactions that occur in all living cells. During these reactions, sugars, like those made in photosynthesis, are broken down, and energy is released. The released energy is either stored in another molecule (to be used later) or is lost as heat.

The function of sugar in cells, then, is somewhat like the function of fossil fuels in machinery. Fossil fuels also contain chemical energy. During the chemical reactions that occur in burning, the fuels are reduced to simpler compounds like carbon dioxide (CO_2). The chemical energy from the fuel is released in the form of heat and light, as shown in Figure 4.8a.

The chemical energy in food is also released by chemical reactions. The chemical reactions in a cell, however, are quite different from those in a fire. When fuels burn, a large amount of energy is released in a short time. The sudden release of energy produces high temperatures—high enough to provide heat for cooking. In cells, however, energy is released gradually, in many small steps that are controlled by enzymes. Figure 4.8b suggests the step-by-step process by which foods are broken down.

The cell uses the energy in food that is released during respiration to carry out work in the cell (the stored energy in Figure 4.8b). Carbon dioxide and water molecules are the by-products that are formed as the food molecules are broken down. Notice that carbon dioxide and water are the same molecules the plant uses to make sugars in photosynthesis. Illustrating the interrelatedness of organisms, Figure 4.9 summarizes relationships between photosynthesis and cellular respiration at the level of the ecosystem.

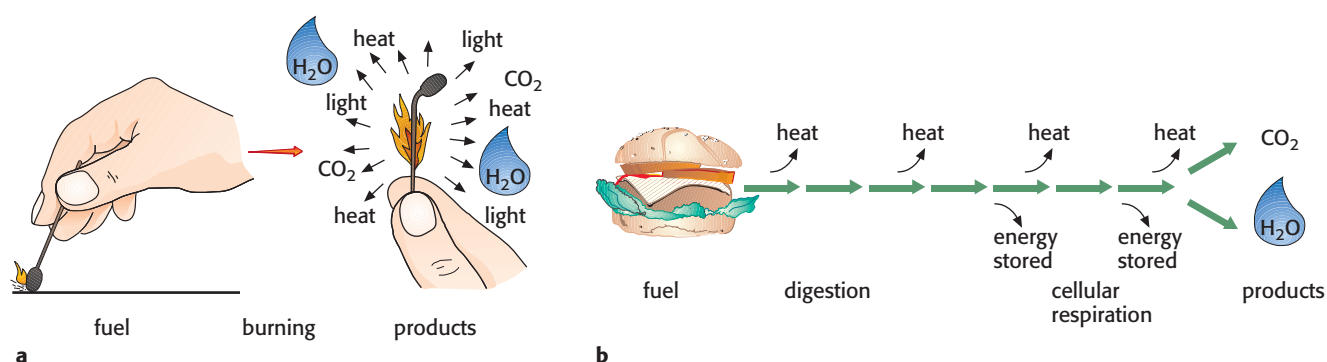


Figure 4.8 ▲

Compare the energy release that occurs (a) during burning with that which occurs (b) during cellular respiration. How are they alike? How are they different?

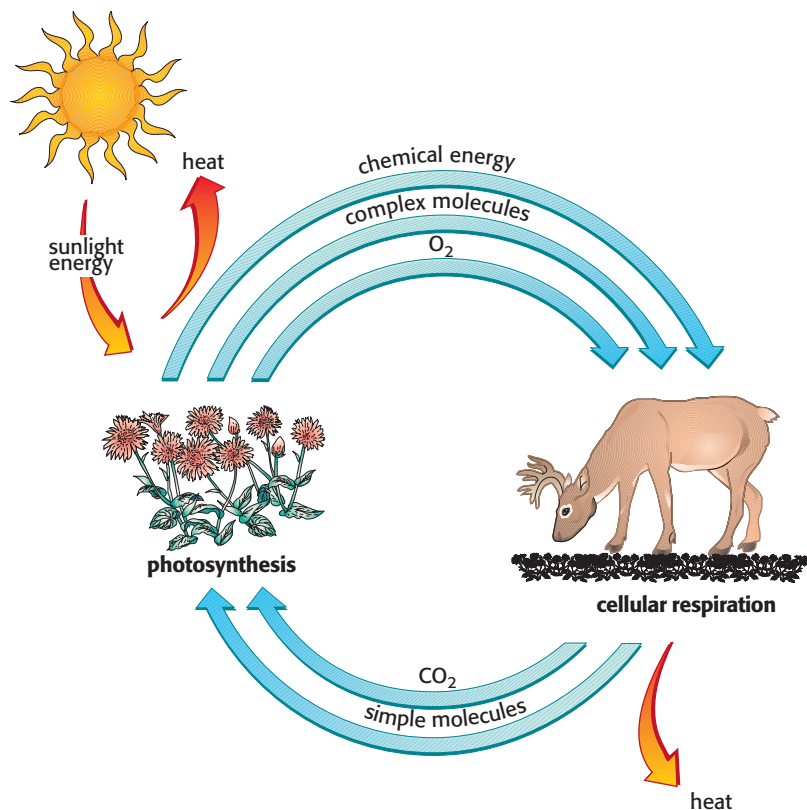


Figure 4.9 ▲

Over evolutionary time, photosynthesis (the process by which cells capture and store energy) and cellular respiration (an energy-releasing process) have been linked. Photosynthetic organisms provided the oxygen-rich atmosphere in which we now live. In the ecosystems of today, end products of photosynthesis provide the materials for cellular respiration, which in turn provides carbon dioxide for continued photosynthesis. How does water fit into this cycle?

4.7

ATP, the Cell's Currency for Energy Transfer

Cellular respiration converts the energy stored in complex molecules into chemical energy stored in smaller, more useful molecules. One of these is **ATP**, adenosine triphosphate. ATP is the most important of several energy-transfer compounds that are found in all organisms. The energy released during respiration is temporarily transferred to molecules of ATP. As you can see in Figure 4.10, each ATP molecule is made up of a main section (A) to which are attached three identical groups of atoms called phosphates (P). The three phosphates together are called the triphosphate group (TP).

As food molecules are broken down to simpler compounds, a great deal of energy is released. The energy is used to make ATP molecules. For example, in Figure 4.8b, ATP molecules are made at the steps labeled “energy stored.” Chemical energy is stored in ATP until it is released by reactions that remove a phosphate from ATP. This energy is used to help the cell do its work. The work may be to move a muscle, to send a nerve impulse, to grow, or to form new compounds. Thus, ATP is a carrier of chemical energy in the cell. Because ATP connects many types of reactions in living systems, it has been referred to as the energy currency of cells.

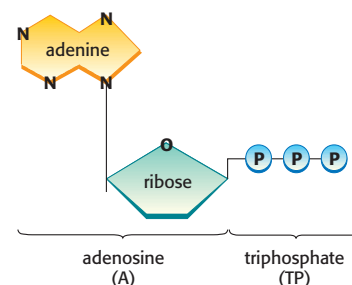


Figure 4.10 ▲

Where is the energy stored in ATP?

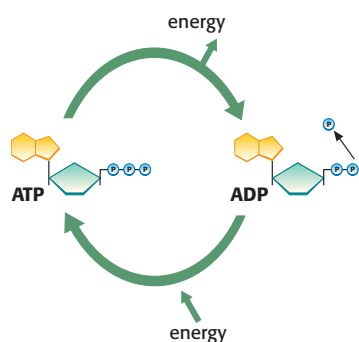


Figure 4.11 ▲

Use this diagram to explain why energy is released and when energy is required in the ATP-ADP cycle.

To see why ATP has been compared to money, imagine foreign tourists who arrive in New York City with only foreign currency. The tourists must pay a fee to change their foreign money into dollars, which they could use for their purchases. In a similar manner, a cell carries out chemical reactions that exchange the chemical energy of food molecules for the chemical energy of ATP. Then ATP pays most of the energy “debts” inside a cell. The “fee” is the energy lost as heat during the conversion.

Each ATP molecule releases energy whenever a phosphate is broken off or transferred to another molecule. The molecule that remains, which has only two phosphate groups, is called **ADP**, adenosine diphosphate. Cells must continually rebuild their ATP supply. As you can see in Figure 4.11, this is accomplished by an ADP-ATP cycle. To make ATP molecules, an ADP molecule, a phosphate group, and chemical energy are required. This energy is derived indirectly from the breakdown of food molecules.

CONCEPT REVIEW

1. In what way is photosynthesis important for all living organisms?
2. What are the two products of photosynthesis?
3. How are the reactions of photosynthesis and cellular respiration different?
4. Do you think there is more energy in one molecule of ATP or one molecule of sugar?
5. Explain the relationship between ATP and ADP.

Life Is Based on Carbon

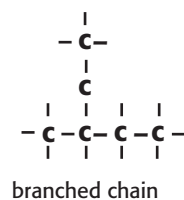
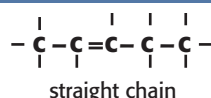


Figure 4.12 ▲

Carbon atoms can bond in several ways. The unconnected lines protruding from some of the carbon atoms show that any one of a number of elements can bond with the carbon in these positions.

4.8

Carbon Is Found in All Living Things

Although organisms are composed of many different chemical elements, carbon is the central element for all living systems. Carbon atoms can join together to form chains or rings, as shown in Figure 4.12. Furthermore, carbon atoms can combine with hydrogen, oxygen, nitrogen, sulfur, and phosphorus to form a vast number of organic compounds. In fact, the atoms of the elements present in organic compounds can be arranged in so many ways that the variety of organic compounds is almost limitless. This variety ensures the uniqueness of each organism.

Organic compounds are the essential building blocks for organisms and are also their major source of chemical energy. Four basic types of carbon-containing molecules are found in all organisms. **Carbohydrates** and **lipids** are important energy-storing compounds. They also form part of the structure of cells. The sugars produced from photosynthesis and used in cellular respiration are carbohydrates. Starch is a large carbohydrate molecule made by joining many individual sugar molecules. Oils and fats are examples of lipids. **Proteins** function as enzymes and form part of the structure of cells. **Nucleic acids** are the hereditary, or genetic, material for all organisms.

All living organisms contain carbohydrates, lipids, proteins, and nucleic acids. In order to get the building blocks needed to make these molecules,

consumers take in foods of plant and animal origin. Those foods provide the materials that organisms use to synthesize their own unique set of molecules.



How are carbon-containing molecules important in the structure (the matter) of living things and in the storage and flow of energy through living systems?

4.9

Carbohydrates Are Used for Energy Storage and Energy Production

Carbohydrates contain the elements carbon, hydrogen, and oxygen. The subunits, or building blocks, of carbohydrates are single sugars, such as glucose and fructose (see Figure 4.13a), which each contain six carbon atoms and are a major source of energy for most organisms. Single sugar molecules are also called monosaccharides. Two monosaccharides may bond together to form a double sugar, or disaccharide, as shown in Figure 4.13b. The most familiar disaccharide is sucrose, commonly called cane, beet, or table sugar. Sucrose is formed by a chemical reaction that combines a glucose molecule with a fructose molecule.

In synthesis reactions, many glucose molecules may bond together to build complex carbohydrates, called polysaccharides, such as starch and **cellulose**. Portions of these molecules are represented in Figure 4.13c. Starch is an energy-storage compound in many plants and an important food source for humans. Food and nutrition will be discussed in Chapter 15. Cellulose, a major part of wood and cotton fibers, gives the cell walls surrounding plant cells their rigidity. In human liver and muscle cells, carbohydrates are stored as glycogen, also called animal starch. Molecules of starch, cellulose, and glycogen consist of thousands of glucose units and have no fixed size.

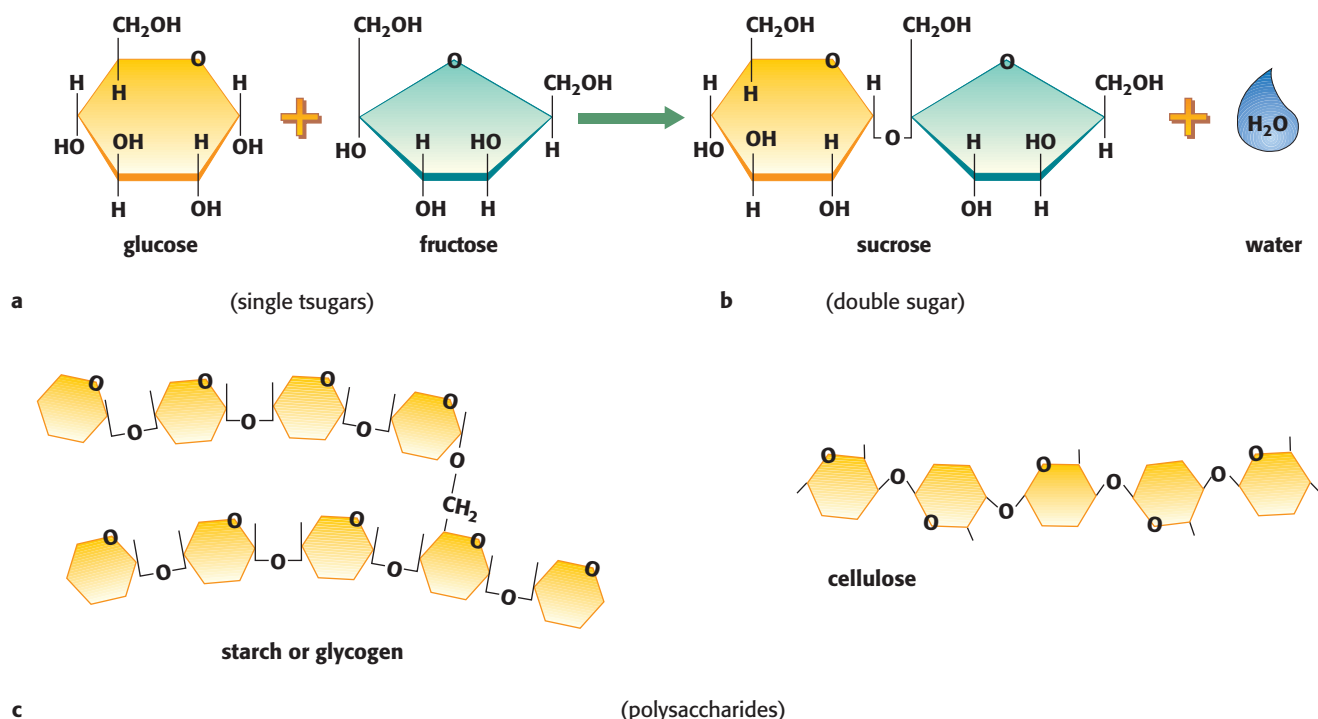


Figure 4.13 ▲

Single sugars (a) can combine to form double sugars (b). Polysaccharides such as starch, glycogen, and cellulose (c) are formed by linking together many glucose units. Note that in these ring diagrams, each point of the ring is understood to be a carbon atom (unless an oxygen (O) is shown). Appendix Three describes the conventions used to depict carbon-based molecules.

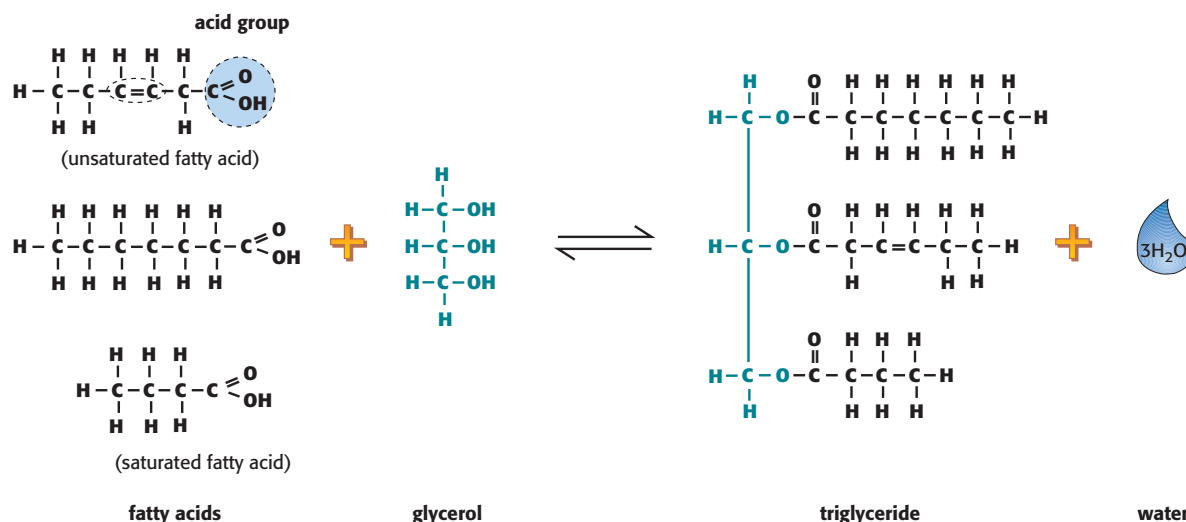


Figure 4.14 ▲

A triglyceride molecule consists of three fatty acids (look at the far left of the diagram) joined to a glycerol molecule. The fatty acids in a triglyceride may be the same or different. You can see a similarity in the structures of these fatty acids: all have a COOH group (note the blue circle in the unsaturated fatty acid). What difference can you see between unsaturated and saturated fatty acids? What molecule is formed as a by-product of the synthesis of a triglyceride?

4.10

Lipids Are Efficient Energy-Storage Compounds

Like carbohydrates, lipids are composed of carbon, hydrogen, and oxygen atoms. However, lipids contain fewer oxygen atoms than carbohydrates. Simple fats, or triglycerides, are the lipids most common in human diets and bodies. These molecules are made from two building blocks: glycerol and fatty acids. Glycerol is a three-carbon sugar. Fatty acids are chains of carbon and hydrogen with an acid grouping on one end (see Figure 4.14). Cells can form both glycerol and fatty acids from glucose.

Both carbohydrates and lipids are important energy-storage compounds in organisms. A gram of fat, however, contains more than twice as much chemical energy as a gram of carbohydrate. Therefore, fats are more efficient storage compounds. As animals prepare for winter when food is scarce, they eat large amounts of food. Much of this food energy is converted into fat, and the fat levels in their bodies increase dramatically.

Lipids are also essential structural components of all cells. Lipids include plant waxes and **cholesterol**, in addition to simple fats. The chemical structure of cholesterol is illustrated in Figure 4.15. Cholesterol is a structural component of cells and is used by the body to make hormones and other important compounds. However, excess cholesterol in the blood has been linked to heart disease.

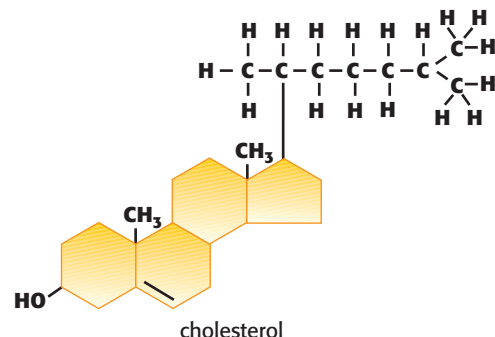
4.11

Proteins Function as Enzymes and Structural Components of Cells

Proteins are a diverse group of molecules. Some proteins, called enzymes, function as catalysts to speed up chemical reactions, such as those for

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◀ **Figure 4.15**

Some of the cholesterol, a type of lipid, produced in our bodies is converted into vitamin D (required for strong bones and healthy teeth).

cellular respiration and the building of other molecules. Some proteins form the structural components of cells. Specialized cells with certain kinds of proteins build body parts such as muscle, bone, and feathers.

The building block of a protein molecule is an **amino acid**, shown on the left side of Figure 4.16a. Amino acids always contain four different atoms: carbon (C), hydrogen (H), oxygen (O), and nitrogen (N). There are two amino acids that also contain sulfur (S). Twenty different amino acids can be found in protein molecules.

Green plants can synthesize all of these amino acids from simple materials. Animals cannot. Animals must get some amino acids, called essential amino acids, from the food they eat. Unfortunately, not every type of food contains all the needed essential amino acids. Therefore, animals must have a balanced diet containing different protein sources. Without it, protein-deficiency diseases may occur.

To synthesize a protein, amino acids must be linked together. First, two amino acids are linked together to form a dipeptide, as shown in Figure 4.16a. A long chain of amino acids is a **polypeptide**, illustrated in

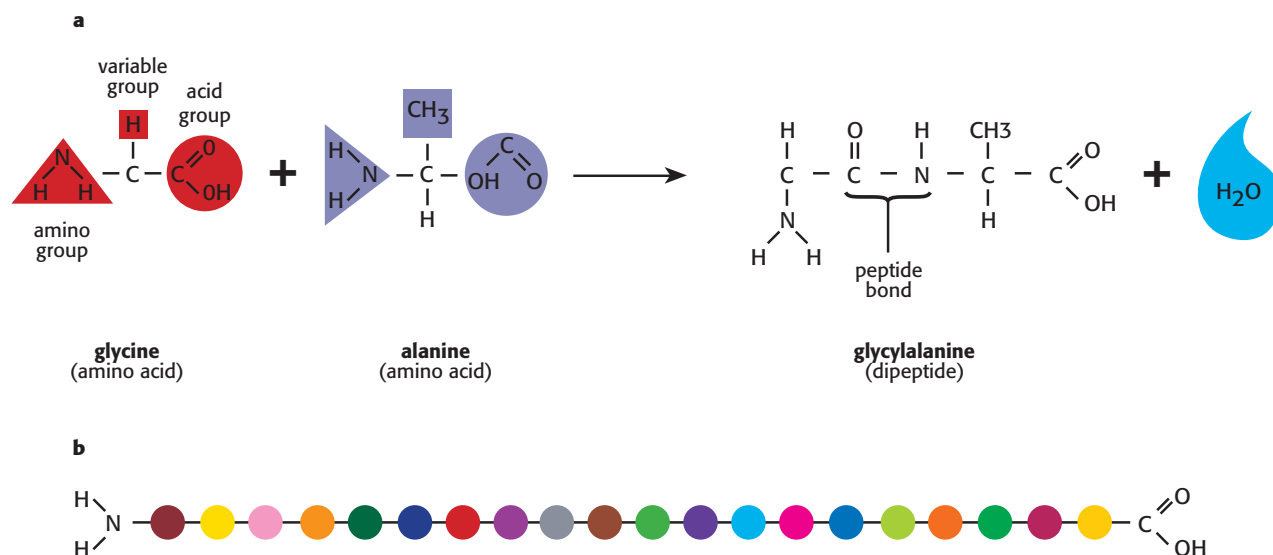


Figure 4.16 ▲

(a) The parts of an amino acid are indicated on the glycine molecule. Can you identify these parts on the alanine molecule? The formation of a peptide bond between the two amino acids creates what is called a dipeptide. Polypeptide chains (b) are composed of many amino acids, linked together by peptide bonds. In this diagram, the amino acids are shown as little balls connected by peptide bonds (shown as solid lines), just to give you the idea of what a chain of amino acids might look like.

Figure 4.17 ▶

A single polypeptide chain may coil, like a spring, giving it a three-dimensional structure (a). For simplicity, the string of amino acids may be drawn as a flat ribbon, so that the coil would look as shown in (b). Using a convention similar to a ribbon diagram, but with a tube around the coil, the shape of a folded protein, such as myoglobin, would look like (c).

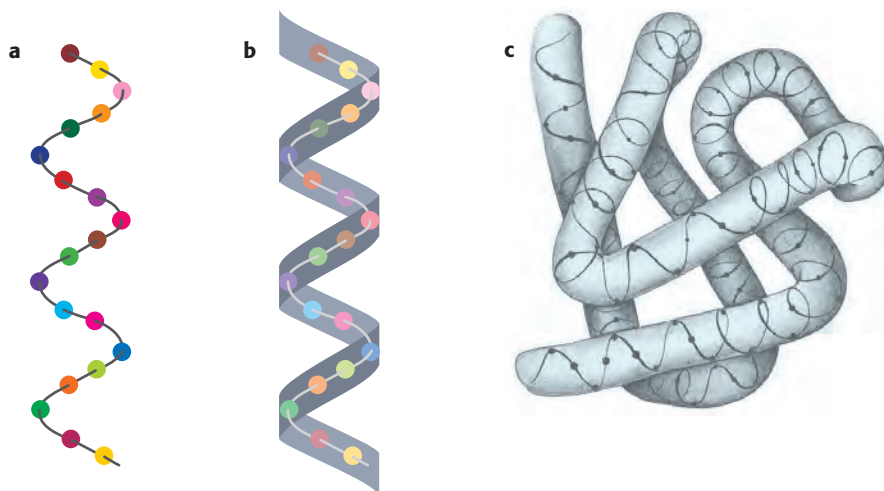


Figure 4.16b. Proteins vary considerably in the number of amino acids they contain. Additionally, many proteins are made of only one polypeptide chain, while others are made of two or more polypeptide chains joined together in some way. As shown in Figure 4.17, polypeptide chains are coiled and folded into complex three-dimensional structures. The structure and shape of a protein, such as the myoglobin in Figure 4.17c, determines how it will function.

Living organisms make thousands of different kinds of proteins from only 20 amino acids. These amino acids are joined by peptide bonds in different sequences and numbers to form polypeptide chains of sizes from small to large. A protein may be a single polypeptide chain, while another protein may be composed of more than one polypeptide chain. Given the diversity of structures that living systems exhibit and the many chemical reactions needed for life, we should not be surprised by the large number of possible proteins made by living things.

4.12

Enzymes Catalyze Chemical Reactions

Most enzymes are large, complex proteins. Enzymes participate in cellular reactions that would otherwise require added energy, such as heat, to take place. In living systems, enzymes allow chemical reactions to take place at normal cell temperatures. Enzymes function as catalysts: they promote reactions but are not used up in the reactions. Some enzymes are needed in only small amounts, because one enzyme molecule can catalyze (speed-up) its chemical reaction many times in a given time period.

As shown in Figure 4.18a, the specific reaction catalyzed by an enzyme depends on the molecule's structure and the shape of a small area of the enzyme known as the **active site**. This region, formed by the folding of the polypeptide chain or chains that make up the enzyme, can attract and hold only specific molecules. The molecules on which an enzyme acts are known as **substrates**. Some enzymes bind a very limited number of substrates and are very specific about the chemical reaction they catalyze (for instance, the enzyme that makes sucrose from glucose and fructose). Other enzymes may bind a series of substrates that share some common feature and catalyze a more general chemical reaction (for instance, the enzyme that links amino acids during protein formation).

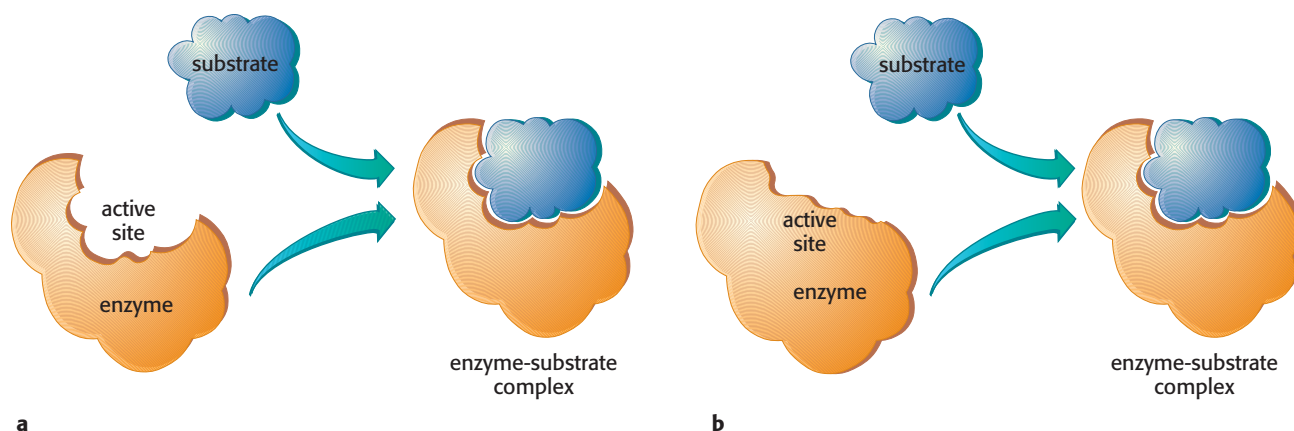


Figure 4.18 ▲

(a) A substrate binds to the enzyme at the active site. (b) Sometimes the active site changes shape after the substrate binds, bringing about the necessary fit. The binding produces an enzyme-substrate complex.

To act as a catalyst, an enzyme must participate in a chemical reaction. The reacting molecules combine with the active site of an enzyme, forming an **enzyme-substrate complex** (Figure 4.18b). The enzyme aligns the reacting molecules precisely and permits chemical changes to be completed rapidly. Once the reaction is complete, the new molecules break away, leaving the enzyme as it was before the reaction.

Different enzymes catalyze the various synthesis and decomposition reactions. In a synthesis reaction, Figure 4.19a, two or more substrates combine with the enzyme. The enzyme provides the proper alignment, which enables these small molecules to join into a new molecule. In a decomposition reaction, Figure 4.19b, the substrate combines with the enzyme and is split into two or more smaller molecules. Remember that the energy-releasing steps that occur during cellular respiration (Section 4.6) are decomposition reactions.

Two aspects of enzyme activity are very important to cells. Enzyme reactions are faster as temperatures increase, but only to a certain point. At temperatures that are too high, enzymes may begin to lose their shape. Because fit is so important for proper enzyme action, enzymes that lose their shape no longer function. Enzyme activity also varies with the pH of the solution. Thus, the temperature and the pH must be appropriate for enzymes to act effectively, as you observe in Investigation 4.3.

4.13

Nucleic Acids Contain the Blueprint for Life

Nucleic acids are carbon-containing molecules present in all cells and are vital to cell function. The two types are **RNA**, ribonucleic acid, and **DNA**, deoxyribonucleic acid. RNA is required for the synthesis of proteins. Information stored in DNA determines the genetic, or hereditary, blueprint of the organism. In this way, DNA controls the activities that occur in each cell.

Both DNA and RNA are made up of individual subunits called **nucleotides**. Each nucleotide, in turn, is made up of three smaller molecules linked together: a phosphate group, a 5-carbon sugar, and a nitrogen

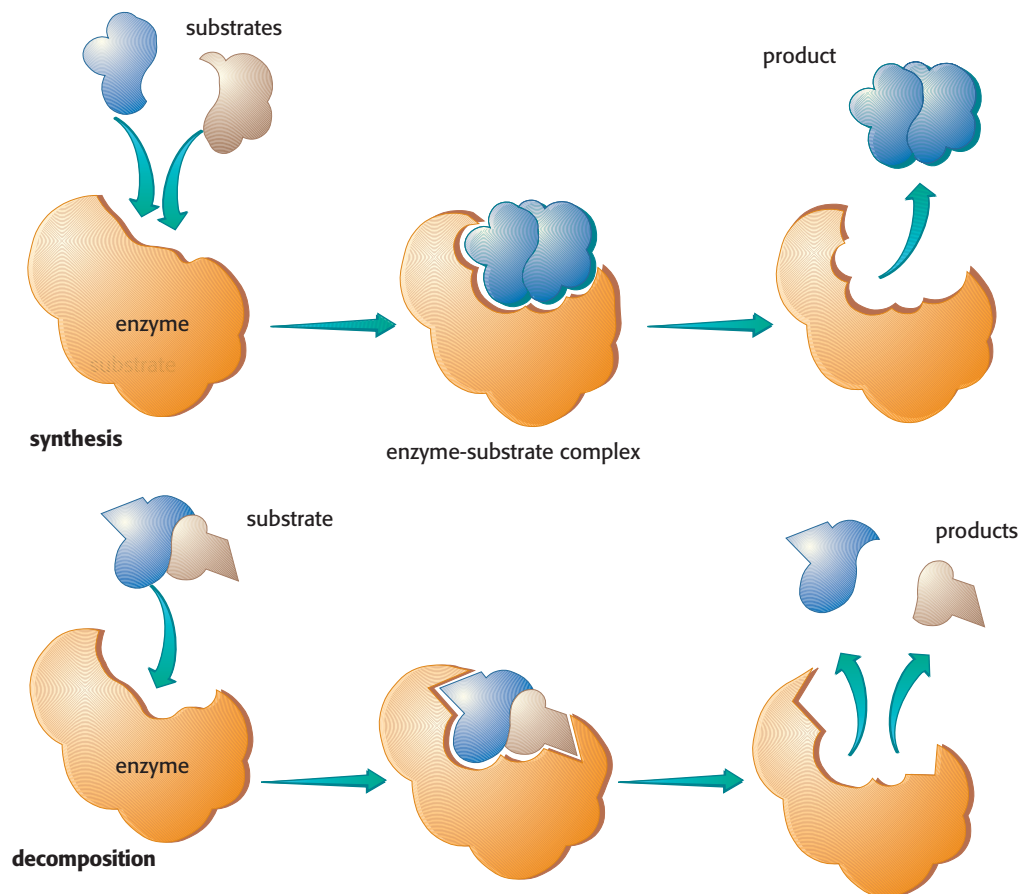


Figure 4.19 ▲

In synthesis, two or more substrate molecules join at the active site forming one larger molecule. In decomposition, the substrate combines with the enzyme and is split into two or more smaller molecules.

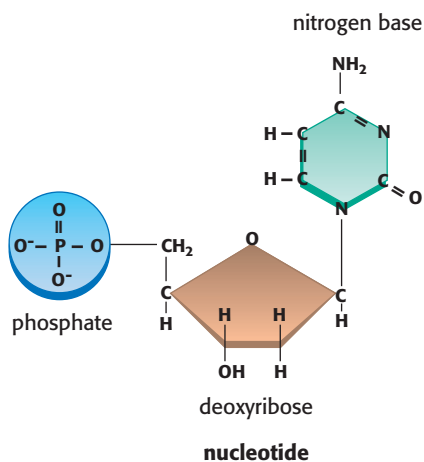


Figure 4.20 ▲

A nucleotide is made up of a 5-carbon sugar (ribose or deoxyribose), a nitrogen base, and a phosphate group.

base (see Figure 4.20). DNA and RNA each contain four nitrogen bases, three of which are common to both molecules. Each base is made up of carbon, hydrogen, oxygen, and nitrogen atoms. RNA nucleotides contain a 5-carbon sugar called ribose. DNA contains a slightly different 5-carbon sugar called deoxyribose, which has one fewer oxygen atom than ribose. Chromosomes, the genetic information found in a cell's nucleus, are each made of two large DNA strands. The two strands are joined in a specific way and coiled to form the double helix as shown in Figure 4.21. RNA molecules are single-stranded and are usually smaller.

Information is stored in DNA as the sequence of nitrogen bases that make up each DNA strand. This sequence is the information that, in turn, determines the sequence of amino acids in proteins. This sequence information also plays a major role in controlling when each protein is made. By controlling the synthesis of enzymes necessary for chemical reactions in the cell, DNA controls the activities of the cell. All the cells in a given individual (a human or other animal, for instance) have the same unique genetic information in their DNA. That individual's unique DNA resulted from the combination of genetic information provided by the individual's parents during sexual reproduction.

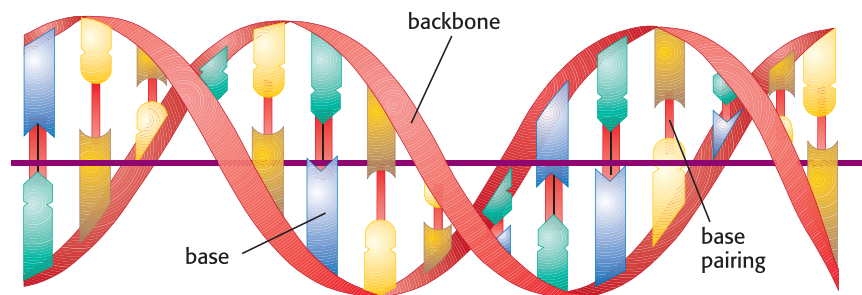


Figure 4.21 ▲

The genetic information in each cell in your body is contained in the nucleotide sequence of DNA. The backbone of the DNA molecule is made up of the deoxyribose and phosphate groups, and is shown as a red ribbon. The various nitrogen bases point to the inside. Two chains of nucleotides are held together by specific pairings of these bases. For example, we have shown the green nitrogen base from Figure 4.20 with a shape that would fit into its matching base. The two chains (the double strand) are coiled around a central axis to form what is called a double helix. We show the axis as a horizontal line to help you visualize the correct twisting.

CONCEPT REVIEW

1. Why is the element carbon so important to living things?
2. What are the building blocks of carbohydrates? Of fats? Of proteins? Of nucleic acids?
3. Name one important function of each of the biological molecules listed in question 2.
4. Why is fat a better storage compound than starch?
5. How do enzymes work to catalyze a chemical reaction?
6. How is it possible for so many different proteins to exist?
7. What role do enzymes play in the release of energy from food?

Carbon Cycling

4.14

Plants Make and Use Carbon-Containing Sugars

Recall from Section 4.5 that plants take up carbon atoms as carbon dioxide from the air. During photosynthesis, they use the energy in sunlight to make sugars from carbon dioxide and water. In this way, the energy from sunlight and the carbon from carbon dioxide are stored in the sugars.

The sugars created during photosynthesis can be used in four ways by the plant, as shown in Figure 4.22. First, the plant may break down the sugar molecules to release the stored energy. This energy may be used by plant cells to carry out their essential activities. Second, a plant may use the sugar molecules for growth. In this case, many sugar molecules are joined together to make the building materials necessary for more cells. Cellulose, for example, is one of these materials. Third, the plant may store sugars for future use. Starch is an important storage compound found in many parts of a plant. When the plant needs energy, starch is first broken



What is the source of matter for living things, and what happens to the matter as it passes through living systems?

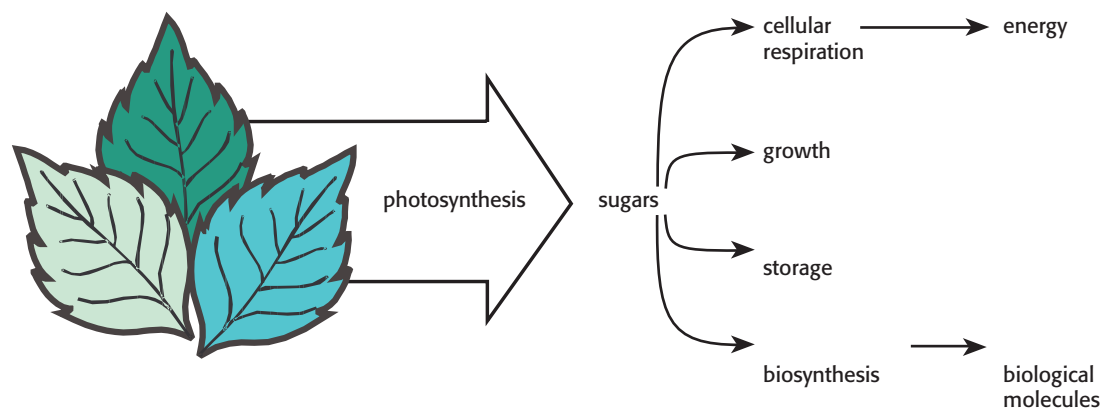


Figure 4.22 ▲

Four ways that plants use the sugars made during photosynthesis

down to individual sugar molecules. During cellular respiration, the sugars are broken down to release energy. Fourth, sugar molecules may be converted into the other biological molecules needed for life.

4.15

Carbon Cycles within an Ecosystem

Topic: carbon cycle/
global warming
Go To: www.scilinks.org
Keyword: GV10E104



When a plant is eaten, the carbon in the plant is passed to a consumer. For the consumer to use the food, it must use decomposition reactions to break the plant's molecules into their smaller building blocks. In addition to producing molecules that the consumer can use, this process also releases energy. Much of the energy released is used for the activities of the consumer. Carbon-containing molecules that are not used to make new molecules needed by the consumer are further broken down, and the carbon is exhaled into the air as carbon dioxide. For example, you take in carbon in all the foods you eat. You return carbon dioxide to the air every time you exhale. A plant also returns carbon dioxide to the air when it uses its own sugars as a source of energy. When another plant takes in this carbon dioxide during photosynthesis, the cycle of carbon through the community is complete.

Carbon dioxide also is returned to the air by decomposers, which break down both consumers and producers. Similar to what is described above, decomposers derive energy and carbon from the organisms on which they act to maintain themselves. Carbon that is not used is returned to the air as carbon dioxide. Eventually, almost all the carbon that is taken in by plants during photosynthesis is returned to the air by the activity of decomposers.

During the past tens of millions of years, many energy-rich plants were buried before decomposers could act on them. Consequently, the molecules in the plants slowly changed over long periods of time. They were converted to fuels, like coal, oil, and natural gas. When these fossil fuels are burned, energy is released, and the carbon in the fuels is returned to the air as carbon dioxide. So even the energy obtained from fuels is a result of photosynthesis. The process in which carbon is passed from one organism to another, then to the abiotic community, and finally back to the plants is called the **carbon cycle** (see Figure 4.23). Some of the other cycles found within ecosystems—the water cycle, the sulfur cycle, and the nitrogen cycle—are described in later chapters.

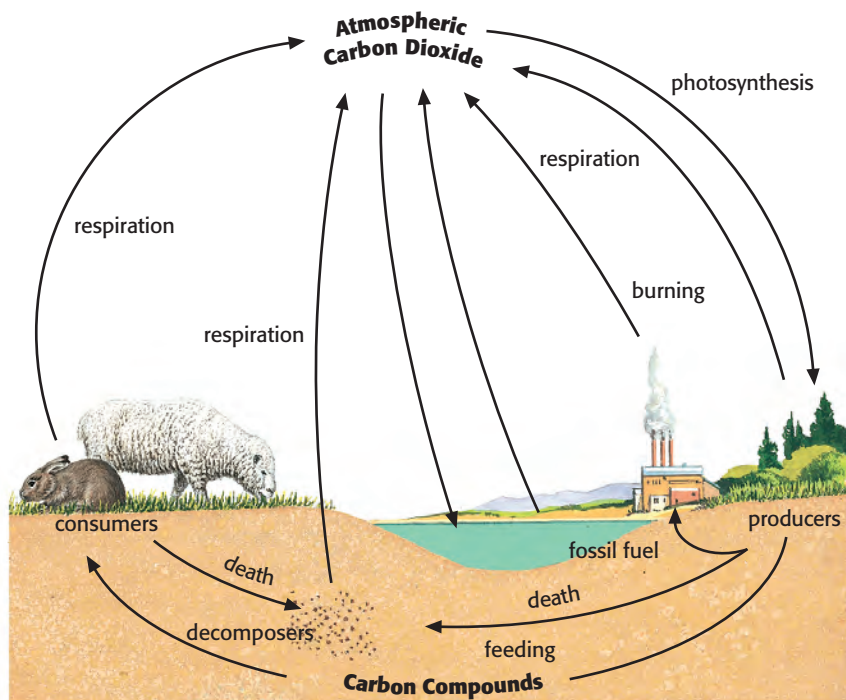


Figure 4.23 ▲

Where would you place humans in the carbon cycle?

CONCEPT REVIEW

1. Of the four ways a plant uses the sugars it makes, which is the only way that does not add material to the plant?
2. How are producers, consumers, and decomposers involved in the carbon cycle?
3. What is the greenhouse effect and how does it work?
4. Explain why the ultimate fate of a piece of bread you eat is that you will exhale it.

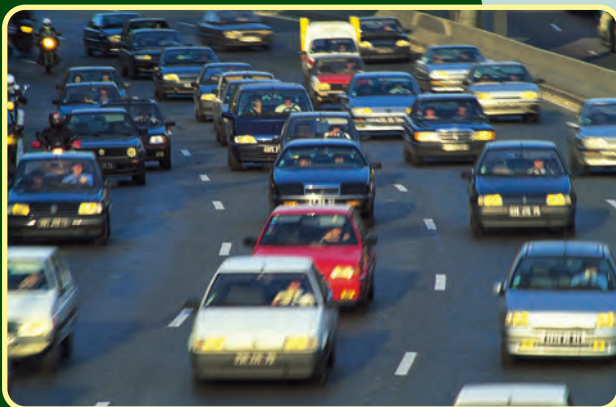
Summary

Energy is needed to do work and to create and maintain order. Without energy, highly organized systems such as living things could not exist. The need for energy is continuous; therefore, organisms must obtain and use energy throughout their lives. ATP is the major energy-transfer molecule in cells. Organisms also must obtain matter to maintain their structure and to grow and reproduce. Plants make sugars from carbon dioxide, water, and light energy in the process of photosynthesis. This process converts light energy into chemical energy, which is stored in the form of carbohydrates. Plants can use this energy to make their own biological molecules, including proteins, lipids, and nucleic acids, all of which contain carbon. Other organisms, like humans, use the energy obtained from eating plant and animal tissues for energy production and to make their own biological molecules. There are two main types of chemical reactions in cells, synthesis and decomposition. All chemical reactions are catalyzed by a class of proteins called enzymes.

BIOLOGY TODAY

The Carbon Cycle and Global Warming

Over the past 100 years, the surface of the earth has warmed by approximately 0.5 C. This effect is called global warming. Scientists believe global warming is mostly due to human technology adding to gases in the atmosphere. Carbon dioxide is one of the gases that compose the earth's atmosphere, and has a great effect on climate. Although some carbon dioxide is released by the cellular respiration of organisms, larger amounts are released when humans burn fossil fuels. Since the industrial Revolution, the amount of carbon dioxide in the atmosphere has increased by about 25 percent.



As early as the 19th century, experts recognized that carbon dioxide in the atmosphere gives rise to a greenhouse effect. Think how the closed windows of a car or the glass in a greenhouse will allow sunlight to stream in but will prevent heat from escaping. Similarly, carbon dioxide and other greenhouse gases, such as methane, ozone, and nitrous oxide, allow sunlight to reach the earth but trap the reflected heat. If there were no greenhouse gases, the earth would be cold and devoid of life. Too great a concentration of such gases, on the other hand, would cause the temperature to rise.

Human activity also interrupts the carbon cycle in two ways. First, the burning of carbon-containing fossil fuels adds carbon dioxide to the atmosphere. Second, the destruction of rain forests and other vegetation leaves less plant life to absorb carbon dioxide. When unharvested plant matter decays and when roots in the exposed soil react with oxygen, still more carbon dioxide enters the atmosphere. Many scientists expect the increased levels of carbon dioxide, other gases, and water vapor to raise the earth's temperature by 1 C to 6 C in the next 100 years. Such an increase could affect global climate (changing rainfall patterns), cause a rise in sea levels (flooding low-lying areas), and change food-producing patterns (bringing famine to some regions). Famine and floods may cause a population to migrate into a new area, adding to existing problems of the population there and creating new ones. The opposing point of view states that the computer models used to predict

the greenhouse effect are so weak they do not account for the warming that has occurred in the last 100 years. Many experts feel that not enough research has been done to tell us what we need to know about interactions between the oceans and the atmosphere. This ignorance limits our ability to predict effects. For example, in February 1990, a federal government study indicated that the temperature in the southeastern United States actually had fallen 1 C during the past 30 years. The report did not disprove that global warming is happening, but it did stimulate debate. You may want to research current studies and bring these into class to discuss with your classmates and teacher.

Applications

1. How would a biologist studying food chains or food webs benefit from understanding the carbon cycle?
2. The proteins in the cells of a wheat plant are different from the proteins in your cells. How can the differences be explained? What must happen when you use wheat as a nutrient for the formation of your proteins?
3. Many botanists will tell you that the concentration of carbon dioxide in the air was much greater during the Carboniferous period (about 295 million years ago), when most of the large coal deposits were being formed, than it is today. What might be the basis for their information?
4. Are animals absolutely necessary for carbon to cycle within a community? Explain. In what ways do you contribute to the carbon cycle?
5. In terms of calories, why do you think seeds (small structures containing young plants) are high in fat content? Examples are the peanut, corn, and sunflower seeds from which we get cooking oils. Why are such seeds good sources of food for humans?

Problems

1. Make two lists: (a) all the ways you use energy in a day, and (b) all the different types of energy you use in a day (for example, light, heat, mechanical, chemical).
2. One hundred years ago, the carbon dioxide in the atmosphere was measured at 0.0283 percent. Today the level is 0.0330 percent. What factors during the last 100 years may have contributed to this increase? What are some possible future consequences if this trend continues?
3. Many fats and cooking oils are called polyunsaturated. Find out what this means in chemical terms.
4. Each day, you come in contact with many basic, acidic, and neutral solutions. You may have seen products that are labeled “pH-balanced” or “buffered.” What does this mean? Make a list of such products or foods and explain how they affect you. Do you use these products or eat these foods because of their acidity or alkalinity, or does it make any difference what their pH is?

Investigation 4.1

Organisms and pH

Chapter 2 discussed the tendency for populations to maintain a relative stability, or homeostasis. Furthermore, the ability of individual organisms and cells to maintain an internal homeostasis is a fundamental characteristic of life. Many factors can affect that stability, for example, the relative concentrations of hydrogen ions (H^+) and hydroxide ions (OH^-). The biochemical activities of living tissues frequently affect pH, yet life depends on maintaining a pH range that is normal for each tissue or system. Using a pH meter or wide-range pH paper, you can compare the responses of several materials to the addition of an acid and a base.

- Before you begin, study the investigation and develop a hypothesis that answers the question, How do organisms survive and function despite metabolic activities that tend to shift pH toward either the acidic or basic end of the scale?

Materials (per team of 4)

4 lab aprons	0.1 M NaOH in dropping bottle
4 pairs of safety goggles	sodium phosphate pH 7 buffer solution
50-mL beaker or small jar	liver homogenate
50-mL graduated cylinder	potato homogenate
forceps (optional)	egg white (diluted 1 : 5 with water)
pH meter or wide-range pH paper	warm gelatin suspension, 2% solution
tap water	data books
3 colored pencils	pens
0.1 M HCl in dropping bottle	



Put on your safety goggles and lab apron.



Procedure

1. In your data book, prepare a table similar to Table 4.1.
2. Pour 25 mL of tap water into a 50-mL beaker.
3. Record the initial pH by using a pH meter or by dipping small strips of pH paper into the water and comparing the color change to a standard color chart.
4. Add 0.1M HCl 1 drop at a time. Gently swirl the mixture after each drop. Determine the pH after 5 drops have been added. Repeat this procedure until 30 drops have been used. Record the pH measurements in your table.



0.1M HCl is an irritant and may destroy clothing. Avoid skin/eye contact; do not ingest. Should a splash or spill occur, call your teacher immediately; flush the area with water for 15 minutes; rinse mouth with water.



Table 4.1 Testing pH

Solution Tested	Tests with 0.1M HCl							Tests with 0.1M NaOH						
	0	5	10	15	20	25	30 drops	0	5	10	15	20	25	30 drops
tap water														
liver														
potato														
egg white														
gelatin														
buffer														

- Rinse the beaker thoroughly and pour into it another 25 mL of tap water. Record the initial pH of the water and add 0.1M NaOH drop by drop, recording the pH probe changes in exactly the same way as for the 0.1M HCl.

0.1M NaOH is an irritant and may destroy clothing. Avoid skin/eye contact; do not ingest. Should a splash or spill occur, call your teacher immediately; flush the area with water for 15 minutes; rinse mouth with water.



- Using the biological material assigned by your teacher, repeat Steps 2–5. Record the data in your table.
- Test the buffer solution (a nonliving chemical solution) using the same method outlined in Steps 2–5. Record the data in your table.
- Wash your hands thoroughly before leaving the laboratory.

Discussion

- Summarize the effects of HCl and NaOH on tap water.
- What was the total pH change for the 30 drops of HCl added to the biological material? What was the total pH change for the 30 drops of NaOH added? How do these data compare with the changes in tap water?
- In your data book, prepare a simple graph of pH versus the number of drops of acid and base solutions added to tap water. Plot two lines: a solid line for changes with acid and a dashed line for changes with base. Using different colored solid and dashed lines, add the results for your biological material. Compare your graph with the graphs of teams that used a different biological material. What patterns do the graphs indicate for biological materials?

4. How do biological materials respond to changes in pH?
5. Use different colored solid and dashed lines to plot the reaction of the buffer solution on the same graph. How does the buffer system respond to the HCl and NaOH?
6. Is the pH response of the buffer system more like that of water or of the biological material?
7. How does the reaction of the buffer solution serve as a model for the response of biological materials to pH changes?
8. Would buffers aid or hinder the maintenance of homeostasis within a living cell in a changing environment?
9. What does the model suggest about a mechanism for regulating pH in an organism? Your answer should allow you to evaluate your original hypothesis.

investigation 4.2

Compounds in Living Organisms

The compounds that your body needs for energy and building materials are carbohydrates, proteins, fats, vitamins, and other nutrients. These compounds are present in the plants and animals you use as food. In this investigation, you will observe tests for specific compounds and then use those tests to determine which compounds are found in ordinary foods.

Materials (per team of 4)

4 pairs of safety goggles	1% silver nitrate solution in dropping bottle
4 lab aprons	isopropyl alcohol (99%) in screw-top jar
4 pairs of plastic gloves	Benedict's solution in dropping bottle
250-mL beaker	apple, egg white, liver, onion, orange, potato, or other foods of your choice
10-mL graduated cylinder	brown wrapping paper
6 18-mm $\times$ 150-mm test tubes	hot plate
test tube clamp	data books
Biuret solution in dropping bottle	pens
indophenol solution in dropping bottle	
Lugol's iodine solution in dropping bottle	
bottle	



Put on your safety goggles, lab apron, and gloves. Tie back long hair.



Procedure

Part A: Test Demonstration

1. In your data book, prepare a table similar to Table 4.2.

Table 4.2 Reagent Tests of Known Food Substances

Food Substance	Reagent Test	Results
gelatin	Biuret solution	
glucose	Benedict's solution	
starch	Lugol's iodine solution	
vitamin C	indophenol solution (0.1%)	
sodium chloride	silver nitrate solution (1%)	
butter or vegetable oil	brown paper	

2. Scientists use special chemical solutions, or reagents, to detect the presence of certain compounds. Observe the six reagent tests your teacher performs. In your table, describe the results of each test.

Part B: Compounds in Foods

3. In your data book, prepare a table similar to Table 4.3. Then, record the presence (+) or absence (–) of each substance in the foods you test.

The reagents you will use in this procedure may be corrosive, poisonous, and/or irritants, and they may destroy clothing. Avoid skin and eye contact; do not ingest. Should a splash or spill occur, call your teacher immediately; flush the area with water for 15 minutes; rinse mouth with water.



Irritant



Corrosive



Poison!



Warning

4. Predict what substances you will find in each sample your teacher assigns to you. Then, test the samples as your teacher demonstrated or as described in Steps 5–10. Record the result of each test in your data book, using a + or –.

Table 4.3 Analysis of Compounds in Common Foods

Substance		Protein	Glucose	Starch	Vitamin C	Chloride	Lipid
egg	prediction						
	test results						
potato	prediction						
	test results						
etc.	prediction						
	test results						

5. Protein test: Place 5 mL of the assigned food in a test tube. Add 10 drops of Biuret solution.
6. Glucose test: Add 3 mL of Benedict's solution to 5 mL of the assigned food. Place the test tube in a beaker of boiling water and heat for 5 minutes.



Use test tube clamps to hold hot test tubes. Boiling water will scald, causing second-degree burns. Do not touch the beaker or allow boiling water to contact your skin. Avoid vigorous boiling. Should a burn occur, call your teacher immediately; place burned area under cold, running water.

7. Starch test: Add 5 drops of Lugol's iodine solution to 5 mL of the assigned food.
8. Vitamin C test: Add 8 drops of indophenol to 5 mL of the assigned food.
9. Chloride test: Add 5 drops of silver nitrate solution to 5 mL of the assigned food.
10. Fat test: Rub the assigned food on a piece of brown wrapping paper. Hold the paper up to the light. Food that contains fat makes a translucent, greasy spot on the paper. When food contains only a small amount of fat, it may not be detected by this method. If no fat has been detected, place the assigned food in 10 mL of a fat solvent such as isopropyl alcohol (99%). Allow the food to dissolve in the solvent for about 5 minutes. Then, pour the solvent on brown paper. The spot should dry in about 10 minutes. Check the paper.

Isopropyl alcohol is flammable; its vapors may explode. Keep away from heat and sparks. Extinguish any open flames in the area.



11. Wash your hands thoroughly before leaving the laboratory.

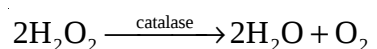
Discussion

1. How did your predictions compare with the test results?
2. Which of your predictions was correct?
3. Which foods contained all the compounds for which you tested?
4. On the basis of your tests, which food could be used as a source of protein? Glucose? Starch? Vitamin C? Fat?
5. How might the original colors of the test materials affect the results?

Investigation 4.3

Enzyme Activity

In this investigation, you will study several factors that affect the activity of enzymes. The enzyme you will use is catalase, which is present in most cells and found in high concentrations in liver and blood cells. You will use liver homogenate as the source of catalase. Catalase promotes the decomposition of hydrogen peroxide (H_2O_2) in the following reaction:



Hydrogen peroxide is formed as a by-product of chemical reactions in cells. It is toxic and would kill cells if not immediately removed or broken down.

Materials (per team of 3)

3 pairs of safety goggles	forceps
3 lab aprons	square or rectangular pan
50-mL beaker	buffer solutions: pH 5, pH 6, pH 7, pH 8
2 250-mL beakers	stock catalase solution
10-mL and 50-mL graduated cylinders	fresh 3% H_2O_2
6 18-mm × 150-mm test tubes	ice
test tube rack	water bath at 37° C
nonmercury thermometer	data books
filter-paper disks	pens
reaction chamber	

Put on your safety goggles and lab apron. Tie back long hair.



Procedure

As shown in Figure 4.24, the reaction chamber is a 25-mL square glass bottle equipped with a 1-hole rubber stopper into which a dropping pipet has been inserted. In all experiments, make certain that your reaction chamber is scrupulously clean. Catalase is a potent enzyme, and if the chamber is not washed thoroughly, enough will adhere to the sides to make later tests inaccurate. Measure all substances carefully. Results depend on comparisons between experiments, so the amounts measured must be equal or your comparisons will be valueless. Before you do the experiment, read the instructions completely. Make sure that you have all the required materials on hand, that you understand the sequence of steps, and that each member of your team knows his or her assigned function.



Figure 4.24 ▲

This apparatus will allow you to measure O_2 production in a reaction between catalase and hydrogen peroxide.

Part A: The Time Course of Enzyme Activity

1. Prepare a table in your data book similar to Table 4.4.
2. Obtain a small amount of stock catalase solution in a 50-mL beaker.
3. Obtain a reaction chamber and a number of filter-paper disks.
4. Prepare a disk for use in the reaction chamber by holding it by its edge with a pair of forceps and dipping it into the stock catalase solution for a few seconds. Drain excess solution from the disk by holding it against the side of the beaker before you transfer it to the reaction chamber. Prepare 4 catalase-soaked filter-paper disks and place each one high on one interior side wall of the reaction chamber. (They will stick to the side wall.)

Table 4.4 Catalase Activity under Various Conditions

Experiment	mL O ₂ Produced/30 sec																			
reading	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
(Part A) full concentration																				
(Part B) ¾ concentration																				
etc.																				

5. Stand the reaction chamber upright and carefully add 10 mL of 3% hydrogen peroxide (H₂O₂) solution. *Do not allow the peroxide to touch the filter-paper disks.*

Hydrogen peroxide (H₂O₂) is a reactive material. Avoid skin/eye contact; do not ingest. Should a splash or spill occur, call your teacher immediately; flush the area with water for 15 minutes; rinse mouth with water.



- Put the stopper on the chamber and seal it tightly.
- Fill a pan almost full with water.
- Lay the 50-mL graduated cylinder on its side in the pan so that it fills with water completely. If any air bubbles are present, carefully work these out by tilting the cylinder slightly. Turn the cylinder upside down into a vertical position, keeping its mouth underwater at all times.
- Making certain the side with the disks is at the top, carefully place the reaction chamber on its side in the pan of water.
- Move the graduated cylinder so that its mouth lies directly over the tip of the dropping pipet extending from the reaction chamber, as shown in Figure 4.24. One member of the team should hold it in this position for the duration of the experiment.
- Rotate the reaction chamber 180° on its side so that the H₂O₂ solution comes into contact with the soaked disks.
- Measure the gas levels in the graduated cylinder at 30-second intervals for 10 minutes. Record the levels in your data table.

Part B: The Effect of Enzyme Concentration on Enzyme Activity

13. Test $\frac{3}{4}$, $\frac{1}{2}$, and $\frac{1}{4}$ concentrations of enzyme solution, using the procedure for Part A with the following changes:
 - a. $\frac{3}{4}$ concentration: Use 3 catalase-soaked disks instead of 4.
 - b. $\frac{1}{2}$ concentration: Use 2 catalase-soaked disks and a 10-mL graduated cylinder instead of a 50-mL graduated cylinder.
 - c. $\frac{1}{4}$ concentration: Use 1 catalase-soaked disk and a 10-mL graduated cylinder.
14. Record all data in your data table.

Part C: The Effect of Temperature on Enzyme Activity

15. Add 10 mL of 3% H_2O_2 to each of two test tubes. Place one test tube in a beaker of ice water and the other in a beaker with water maintained at 37°C .
16. When the temperature of the chilled H_2O_2 reaches approximately 10°C , repeat Part A with the following changes:
 - a. In Step 5, use 10 mL of chilled 3% H_2O_2 .
 - b. In Step 7, add ice to the pan to chill the water to approximately 10°C .
17. When the temperature of the warmed H_2O_2 reaches approximately 37°C , repeat Part A with the following changes:
 - a. In Step 5, use 10 mL of warmed 3% H_2O_2 .
 - b. In Step 7, fill the pan with water warmed to approximately 37°C .
18. Record the data in your data table.

Part D: The Effect of pH on Enzyme Activity

19. Label 4 test tubes *pH 5*, *pH 6*, *pH 7*, and *pH 8*, respectively. Add to each of these 8 mL of 3% H_2O_2 .
20. Add 4 mL of pH 5 buffer solution to the pH 5 test tube, shaking well to ensure mixing. Do the same for the other buffer solutions.
21. Repeat Part A for each pH value, substituting the buffered 3% H_2O_2 solutions.
22. Record the results in your data table.
23. Wash your hands thoroughly before leaving the laboratory.

Discussion

1. In your data book, plot the data of Part A on a graph. Label the horizontal axis *Time (sec)*, and label the vertical axis *mL O_2 Produced*. Does the action of catalase change through time?
2. Plot the data of Part B on the graph used for Part A, and label the concentrations on the graph. Based on these data, how does enzyme activity vary with concentration?
3. Copy the graph for Part A, and plot the data from Part C on it. Based on these data, how does temperature affect enzyme action?

4. Plot the results of all four runs of Part D on a third graph. How does pH affect enzyme action?
5. What is a buffer? Would Parts A, B, and C have been different if buffers had been used in them too? If so, how?
6. Summarize the general conditions necessary for effective enzyme action. Are these conditions the same for each enzyme? Why?
7. How would you design an experiment to show how much faster H_2O_2 decomposes in the presence of catalase than it does without the enzyme?
8. Since the liver from which you obtained catalase was dead, why is the enzyme still active?

GLOSSARY



A

abiotic (AY by OT ik) **factor**: a physical or nonliving component of an ecosystem. p. 32

abscisic (ab SIS ik) **acid**: a plant hormone that protects a plant in an unfavorable environment by promoting dormancy in buds and seeds and closing of stomates. p. 554

absorption: the movement of water and of substances dissolved in water into a cell, tissue, or organism. p. 420

absorption spectrum: the characteristic array of wavelengths (colors) of light that a particular substance absorbs. p. 545

acid deposition: The falling of acids and acid-forming compounds from the atmosphere on the earth's surface; commonly known as acid rain. p. 648

acidic: having a pH of less than 7, reflecting more dissolved hydrogen ions than hydroxide ions. p. 90

acquired characteristics: characteristics acquired during the life of an organism; once thought to be heritable. p. 241

actin: a protein in a muscle fiber that, together with myosin, is responsible for muscle contraction and relaxation. p. 484

action spectrum: a representation of the rate of an activity, especially photosynthesis, under different wavelengths of light at a given light intensity. p. 543

active site: the specific portion of an enzyme that attaches to the substrate through weak chemical bonds. p. 100

active transport: the movement of a substance across a biological membrane against its concentration gradient with the help of energy input and specific transport proteins. p. 133

adaptation: in natural selection, a hereditary characteristic of some organisms in a population that improves their chances for survival and reproduction in their environment compared with the chances of other organisms in the population. p. 240

adaptive radiation: the emergence of numerous species from a common ancestor introduced to an environment presenting a diversity of conditions. p. 248

adenosine diphosphate: see *ADP*.

adenosine triphosphate: see *ATP*.

addiction: the continued, compulsive abuse of drugs in spite of negative health or social consequences. p. 504.

ADP: adenosine diphosphate (uh DEN oh seen dy FOS fayt); the compound that remains when a phosphate group is transferred from ATP to a cell reaction site requiring energy input. p. 96

adrenal cortex: the outer portion of the adrenal gland. p. 499

adrenal medulla: the central portion of the adrenal gland that secretes epinephrine. p. 499

aerobic (eh ROH bik): occurring or living in the presence of free or dissolved oxygen. p. 271

agglutinate (uh GLOO tin ayt): to unite in a mass; clump. p. 464

aggression: forceful or hostile behavior. p. 577

algae: unicellular or multicellular photosynthetic organisms lacking multicellular sex organs. p. 326

alkaline: basic; having a pH greater than 7, reflecting more dissolved hydroxide ions than hydrogen ions. p. 90

allele (al LEEL): one of two or more possible forms of a gene, each affecting the hereditary trait somewhat differently. p. 196

alpine tundra: a biome roughly similar to arctic tundra that occurs above the timberline on mountains. p. 629

alternation of generations: a reproductive cycle in which a haploid (*n*) phase, the gametophyte, gives rise to gametes that, after fusion to form a zygote, produce a diploid (*2n*) phase, the sporophyte; spores from the sporophyte give rise to new gametophytes. p. 356

alveoli (al VEE oh ly): air sacs in a lung. p. 465

amino (uh MEEN oh) **acid**: an organic compound composed of a central carbon atom to which are bonded a hydrogen atom, an amino group (—NH_2), an acid group (—COOH), and one of a variety of other atoms or groups of atoms; amino acids are the building blocks of polypeptides and proteins. p. 99

ammonia: (1) a toxic nitrogenous waste excreted primarily by aquatic organisms, p. 304; (2) a gas in the earth's early atmosphere. p. 297

amniocentesis (AM nee oh sen TEE sus): a technique used to detect genetic abnormalities in a fetus through the presence of certain chemicals or defects in fetal cells in the amniotic fluid; the fluid is obtained through a needle inserted into the amniotic sac. p. 179

amnion: a sac or membrane, filled with fluid, that encloses the embryo of a reptile, bird, or mammal. p. 177

amniotic fluid: the liquid that bathes an embryo or fetus. p. 179

amphibian: any of the various ectothermic, smooth-skinned vertebrate organisms, belonging to the class Amphibia, that characteristically hatch as aquatic larvae with gills and that develop into adult forms that use lungs for gas exchange. p. 398

anaerobic (an eh ROH bik): occurring or living in conditions without free oxygen. p. 285

anaphase: the stage in mitosis in which chromosomes on the spindle separate and are pulled toward opposite ends of the cell. p. 138

Animalia (an ih MAYL yuh): the animal kingdom. p. 277

Annelida (an NEL ih duh): the phylum that includes segmented worms, such as earthworms and leeches. p. 394

annelids (AN ih lidz): worms belonging to the phylum Annelida. p. 394

anorexia nervosa (an oh REX ee uh ner VOH suh): a condition characterized by abnormal loss of appetite and induced self-starvation to reduce body weight. p. 437

anterior: situated toward the front; toward a head end. p. 388

anther: the enlarged end of a stamen, inside which pollen grains with male gametes form in a flower. p. 358

Anthophyta (an THOF ih tuh): the phylum containing the flowering plants. p. 370

anthropologist (an thruh PAH loh jist): a scientist who studies humans—human evolution, variability,

and both past and present cultures and behavior. p. 613

antibody: a blood protein produced in response to an antigen, with which it combines specifically; antibodies block the ability of pathogens or foreign material to injure the body. p. 306

antigen: any material, usually a protein, that is recognized as foreign and elicits an immune response. p. 458

anus (AY nus): the outlet of the digestive tube. p. 421

aorta: the main artery of the circulatory system; blood that has been oxygenated in the lungs and has been returned to the heart enters the aorta to be carried to all other parts of the body. p. 452

Apicomplexa (ap ih kum PLEX suh): the phylum containing the sporozoans. p. 331

appendage (uh PEN dij): a structure attached to the main part of a body; in animals, a tentacle, a leg, a flipper, a wing, etc. p. 389

aquatic (uh KWAH tik): describing a water environment or organisms that live in water. p. 388

arboreal: adapted for living in or around trees, as are monkeys and some apes. p. 609

archaeobacteria (AR kee bak TIR ee uh): the more ancient of the two major lineages of prokaryotes, represented today by a few groups of bacteria inhabiting extreme environments; commonly referred to as Archaea. p. 297

archaeology: the systematic study of the human past; locating and interpreting the cultural products of prehistoric humans. p. 620

arctic tundra: biome at the northernmost limits of plant growth, where plant forms are limited to low, shrubby, or matlike vegetation. p. 629

artery: a vessel that transports blood away from the heart. p. 452

arthropod: any of the numerous invertebrate organisms of the phylum Arthropoda. p. 395

Arthropoda (ar THRAP uh duh): the phylum that includes insects, crustaceans, arachnids, and others; an alternate classification scheme, as shown in Appendix Four, "The Catalog of Living Things," divides this phylum into three phyla, the crustaceans, the chelicerates (horseshoe crabs, mites, spiders, etc.), and the mandibulates (insects). p. 395

artificial selection: the selective breeding of domesticated plants and animals to encourage the occurrence of desirable traits. p. 240

Ascomycota (AS koh my KOH tuh): the phylum containing the sac fungi. p. 335

ascus (AS kus): a reproductive structure formed by sac fungi when two hyphae conjugate. pp. 186, 336

asexual reproduction: any method of reproduction that requires only one parent or one parent cell. p. 153

atherosclerosis (ATH uh roh skleh roh sis): a chronic cardiovascular disease in which plaques develop on inner walls of arteries, restricting the flow of blood. p. 433

atom: the smallest particle of an element; in turn, an atom is made of smaller particles that do not separately have the properties of the element. p. 13

ATP: adenosine triphosphate (uh DEN oh seen try FOS fayt); a compound that has three phosphate groups and is used by cells to store energy. p. 95

atrium (AY tree um; plural atria): a chamber of the heart that receives blood from the veins. p. 453

australopithecine (AH strahl oh PITH uh seen): any of the earliest known species of hominids that walked erect and had humanlike teeth but whose skull, jaw, and brain capacity were more apelike; may include several species. p. 610

autoimmune: a response in which antibodies are produced against some of the body's own cells. p. 461

autonomic nervous system: a division of the nervous system that controls involuntary activities of the body such as blood pressure, body temperature, and other functions necessary to the maintenance of homeostasis. p. 492

autosome: a chromosome that is not directly involved in determining sex. p. 202

autotroph (AWT oh trohf): an organism able to make and store food, using sunlight or another non-living energy source. p. 275

auxin (AWK sin): a plant hormone produced in an actively growing region of a plant and transported to another part of the plant, where it produces a growth effect. p. 553

axon: a structure that extends out from a neuron and conducts impulses away from the cell body. p. 488

B

Bacillariophyta (buh SIL er ee OFF ih tuh): the phylum containing the diatoms. p. 327

basic: alkaline; having a pH greater than 7, reflecting more dissolved hydroxide ions than hydrogen ions. p. 90

basidia (buh SID ee uh): specialized reproductive cells of basidiomycetes, often club-shaped, in which nuclear fusion and meiosis occur. p. 337

Basidiomycota (buh SID ee oh my KOH tuh): the phylum containing the club fungi. p. 337

B cell: a type of lymphocyte that develops in the bone marrow and later produces antibodies. p. 458

bilateral symmetry (by LAT er ul SIM eh tree): a body having two corresponding or complementary halves. p. 388

bile: a secretion of the liver stored in the gall bladder and released through a duct to the small intestine; breaks large fat droplets into smaller ones that enzymes can act upon more efficiently. p. 419

binomial nomenclature (by NOH mee ul NOH men klay chur): the two-word naming system used in systematics or taxonomy. p. 271

biocide: a poisonous substance produced and used to kill forms of life considered to be pests to humans or that spread diseases. p. 70

biodiversity: the diversity of different species and the genetic variability among individuals within each species. p. 71

biology: the study of living organisms and life processes. p. 7

biomass: the dry weight of organic matter composing a group of organisms in a particular habitat. p. 669

biome: the distinctive plant cover and the rest of the community of organisms associated with a particular physical environment; often the biome is named for its plant cover. p. 626

biosphere (BY oh sfir): the outer portion of the earth (air, water, and soil) where life is found. p. 16

biosynthesis (by oh SIN thuh sis): the process of putting together or building up the large molecules characteristic of a particular type of cell or tissue. p. 427

biotic (by OT ik): living or recently living; a biotic factor is an organism or its remains in an ecosystem. p. 32

bipedal: capable of walking erect on the hind limbs, freeing the hands for other uses. p. 610

birthrate: the rate at which reproduction increases the population; often expressed as new individuals per 1,000 or 10,000 in the population. p. 31

blade: the broad, expanded part of a leaf. p. 514

blastocyst: the mammalian embryonic stage that corresponds to the blastula of other animals. p. 177

blastula (BLAS choo luh): an animal embryo after the cleavage stage, when a pattern of cell movements toward the outside of the ball of cells results in a fluid-filled cavity inside. p. 172

blood pressure: the fluid pressure created by heart contractions; allows blood to circulate. p. 454

brachiopods (BRAY kee oh podz): marine invertebrates with dorsal and ventral shells and a pair of tentacled structures on either side of the mouth. p. 598

Brain stem: the major route by which the forebrain sends information to, and receives information from, the spinal cord and peripheral nerves. p. 491

Bryophyta (bry OFF ih tuh): the phylum containing the bryophytes. p. 361

bryophytes (BRY oh fyts): the mosses, liverworts, and hornworts; a group of nonvascular plants that inhabit land but lack many of the terrestrial adaptations of vascular plants. p. 355

bulimia (buh LEE mee uh): an abnormal craving for food beyond the body's needs; frequently expressed as gorging followed by forced vomiting. p. 437

bundle-sheath cells: tightly packed cells surrounding veins in the leaves of C-4 plants that receive a rearranged 4-carbon acid in the first stage of C-4 photosynthesis; within the bundle sheath cells, carbon dioxide is released and reincorporated by an enzyme into PGA. p. 551

C

C-4 plants: plants with a photosynthetic pathway that incorporates carbon dioxide into 4-carbon compounds before beginning the Calvin cycle. p. 551

callus: a mass of dividing, undifferentiated cells at the cut end of a shoot or in a tissue culture, from which adventitious roots develop. p. 558

calorie: the amount of heat required to raise the temperature of one gram of water 1° C. p. 41

Calvin cycle: the cycle (named for its discoverer) by which carbon dioxide is incorporated in sugars during photosynthesis; uses chemical energy previously converted from light energy. p. 544

CAM: crassulacean (kras yoo LAY see un) acid metabolism; an adaptation for photosynthesis in arid conditions, in which carbon dioxide entering open stomates at night is converted into organic acids, which release carbon dioxide during the day when the stomates are less open. p. 552

cambium (KAM bee um): a layer of meristem tissue in the stems and roots of plants that produces all growth in diameter, including new xylem and phloem cells. p. 519

cancer: malignancy arising from cells that are characterized by profound abnormalities in the plasma membrane and in the cytosol, and by abnormal growth and division. p. 182

capillary (KAP ih layr ee): a microscopic blood vessel that penetrates the tissues and that has walls consisting of a single layer of cells that allows exchange between the blood and tissue fluids. p. 452

carbohydrate (kar boh HY drayt): an organic compound made of carbon, hydrogen, and oxygen, with the hydrogen and oxygen atoms in a 2:1 ratio; examples are sugars, starches, glycogen, and cellulose. p. 96

carbon cycle: the biogeochemical cycle in which carbon compounds made by some organisms are digested and decomposed by others, releasing the carbon in small inorganic molecules that can be used again by more organisms to synthesize carbon compounds. p. 104

carbon-14 dating: a technique to date fossils that uses the known disintegration rate of radioactive carbon; the amount of carbon-14 remaining in fossils indicates their age. p. 595

cardiac (KARD ee ak) **muscle:** a specialized type of muscle tissue found only in the heart. p. 484

cardiovascular disease: disease of the heart and/or blood vessels, such as atherosclerosis. p. 433

cardiovascular fitness: the relative state of health or fitness of the lungs, heart, and blood vessels. p. 487

carnivore (KAR nih vor): any organism that eats animals; a meat-eater, as opposed to a plant-eater, or herbivore. p. 62

carpel (KAR puh1): the female reproductive organ of a flower, consisting of the stigma, style, and ovary. p. 358

carrying capacity: the maximum population size that can be supported by the available resources of a given area. p. 34

cartilage: a tough, elastic connective tissue that makes up the skeleton of cartilaginous fishes, but that in other vertebrates is replaced mostly by bone as the animal matures. p. 397

catalyst (KAT uh list): a chemical that promotes a reaction between other chemicals and may take part in the reaction but emerges in its original form. p. 91

cell cycle: an ordered sequence of events in the life of a dividing cell, composed of the M, G₁, S, and G₂ phases. p. 135

cell membrane: the membrane at the boundary of every cell that serves as a selective barrier to the passage of ions and molecules. pp. 128

cell theory: the theory that organisms are composed of cells and their products and that these cells all are derived from preexisting cells. pp. 122, 124

cellular respiration (SEL yoo ler res pih RAY shun): the series of chemical reactions by which a living cell breaks down food molecules and obtains energy from them. p. 94

cellulose (SEL yoo loh): a carbohydrate found in cell walls. p. 97

cell wall: a nonliving covering around the plasma membrane of certain cells, as in plants, many algae, and some prokaryotes; in plants the cell wall is constructed of cellulose and other materials. p. 130

central nervous system: the brain and spinal cord in vertebrates. p. 490

centriole (SEN tree ohl): one of two structures in animal cells, composed of cylinders of nine triplet microtubules in a ring; centrioles help organize microtubule assembly during cell division. p. 130

centromere (SEN troh meer): the specialized region of a chromosome that holds two replicated chromosomal strands together and that attaches to the spindle in mitosis. p. 157

cerebellum (ser eh BEL um): the part of the brain in vertebrates that is associated with regulating muscular coordination, balance, and similar functions. p. 491

cerebrum (seh REE brum): the largest portion of the brain in humans and many other animals; controls the higher mental functions such as learning. p. 490

chancre (SHAN ker): an ulcer located at the initial point of entry of a pathogen; a dull red, hard lesion that is the first manifestation of syphilis. p. 312

chaparral (shap uh RAL): a scrubland biome of dense, spiny evergreen shrubs found at midlatitudes along the coast where cold ocean currents circulate offshore; characterized by mild, rainy winters and long, hot, dry summers. p. 642

chelicerates (chih LIS er ayts): arthropods possessing paired appendages near the mouth that are modified for grasping. p. 395

chemical bond: the attraction between two atoms resulting from the sharing or transfer of outer electrons from one atom to another. p. 89

chemical energy: energy stored in the structure of molecules, particularly organic molecules. p. 12

chemoautotroph: the eubacteria that use inorganic molecules (sulfur, iron, or other minerals) in the environment to synthesize organic molecules and to create their own stores of chemical energy; compare

to photoautotrophic organisms, which use the energy from sunlight. p. 303

chemosynthesis (KEE moh SIN thih sis): a pathway that uses energy from the oxidation of inorganic substances to drive the formation of organic molecules. p. 303

chemosynthetic: eubacteria that use chemosynthesis to obtain energy from inorganic molecules in the environment (as opposed to photosynthetic organisms that use light energy in the process of photosynthesis to synthesize organic compounds and to create stores of their own chemical energy). p. 303

chitin (KYT in): a hard organic substance secreted by insects and certain other invertebrates as the supporting material in their exoskeletons. pp. 274, 334

chlorophyll (KLOR uh fil): the green pigments of plants and many microorganisms; converts light energy (via changes involving electrons) to chemical energy that is used in biological reactions. p. 93

Chlorophyta (kloh ROF it uh): the phylum containing the green algae. p. 326

chloroplast (KLOR oh plast): an organelle found only in plants and photosynthetic protists; contains chlorophyll that absorbs light energy used to drive photosynthesis. pp. 130

cholesterol (koh LES ter ol): a lipid that is associated particularly with animal plasma membranes and is linked to deposits in blood vessels and to corresponding disorders of the heart. p. 98

Chordata (kohr DAH tuh): the phylum containing the chordates. p. 397

chordates: a diverse phylum of animals that possess a notocord, a dorsal hollow nerve cord, a tail, and pharyngeal gill slits at some stage of the life cycle. p. 397

chorion (KOR ee on): an embryonic membrane that surrounds all the other embryonic membranes in reptiles, birds, and mammals. p. 177

chorionic villi sampling (CVS): a procedure by which a small piece of membrane surrounding a fetus is removed and analyzed to detect genetic defects. p. 178

chromatid (KROH muh tid): one of two strands of a replicated chromosome before their separation during mitosis or meiosis. p. 157

chromatography: various techniques that scientists can use to separate mixtures of molecules based on their mass, charge, or ability to bind to other molecules. p. 219

chromosome (KROH moh sohm): a long, thread-like group of genes found in the nucleus of all eukaryotic cells and most visible during mitosis and meiosis, chromosomes consist of DNA and protein. p. 129

chromosome theory of heredity: the ideas that both eggs and sperm make equal genetic contributions to a new organism, that genes are located in the nucleus of both gametes, and that chromosomes contain the genes. p. 207

cilia (SIL ee uh): short, hairlike cell appendages specialized for locomotion and formed from a core of nine outer doublet microtubules and two inner single microtubules. p. 331

ciliates: unicellular, heterotrophic organisms that move by means of cilia. p. 331

Ciliophora (sil ee OFF er uh): the phylum containing the ciliates. p. 331

class: the third largest grouping, after kingdom and phylum or division, in the biological classification system. p. 269

cleavage (KLEE vaj): the process of cell division in animal cells, characterized by rapid cell divisions without growth that occur during early embryonic development and that convert the zygote into a ball of cells. p. 172

climatogram: a graph of monthly measurements of temperature and precipitation for a given area during a year. p. 628

clone: a lineage of genetically identical individuals. p. 555

closed circulatory system: a type of internal transport in which blood is confined to vessels. p. 404

closed population: a population in which there is no immigration or emigration; a completely isolated population. p. 47

clotting factors: the proteins involved in the sequence of events that results in the clotting of blood (usually, the sealing of a wound). p. 455

club fungi: fungi belonging to the phylum Basidiomycota and possessing basidia, on which spores are produced. p. 337

Cnidaria: the phylum containing cnidarians. p. 391

cnidarians (nih DAR ee unz): radially symmetrical, stinging-tentacled animals that possess nerve networks and digestive sacs. p. 391

CoA: an enzyme present in all cells and necessary for cellular respiration and fatty acid metabolism. p. 424

coacervate (koh AS er vayt): a cluster of proteinlike substances held together in a small droplet within a

surrounding liquid; used as a model for a precell to investigate the formation of the first life on the earth. p. 283

codominance: a condition in which both alleles in a heterozygous organism are expressed. p. 200

codon: the basic unit of the genetic code; a sequence of three adjacent nucleotides in DNA or mRNA. p. 212

coevolution: the evolution of two different species interacting with each other and reciprocally influencing each other's adaptations. p. 251

cohesion-tension: the process by which water is raised upward in a column in the xylem of plants due to the force holding the water molecules together and by the continuing evaporation of water from the top of the column, in leaves. p. 520

collecting duct: the part of the kidney where filtrate from the nephrons is collected and where the filtrate is concentrated and can be called urine. p. 468

communication: the exchange of thoughts, messages, or information by vocalizations, signals, or writing. p. 573

community: all the organisms that inhabit a particular area. p. 8

companion cell: a specialized elongated cell in the phloem of flowering plants that is associated with a sieve cell. p. 519

competition: interaction between members of the same population or of two or more populations to obtain a mutually required resource in limited supply. p. 64

complement system: a complex group of serum proteins that can destroy antigens. p. 460

compound: a substance formed by chemical bonds between atoms of two or more different elements. p. 13

concentration: the amount (often with reference to the number of molecules or ions) of a substance in a specified volume of liquid or air; the process of increasing the amount of a substance in a volume of liquid, as in the kidneys during formation of urine. pp. 132, 468

concentration gradient: a difference in the concentration of certain molecules over a distance. p. 132

conditioning: training that modifies a response so that it becomes associated with a stimulus different from the stimulus that originally caused it. p. 587

Coniferophyta: the phylum containing conifers. p. 367

conjugation: the process by which sexual exchange and reproduction take place in many microscopic organisms, principally protists and fungi. p. 297

consumer: a heterotroph; an organism that feeds on other organisms or on their organic wastes. pp. 8, 275

continental drift: a hypothesis proposed by Wegener in 1912 suggesting that the earth's land-masses had at one time been joined in a supercontinent, Pangaea, that has broken up to form the present continents. Continental drift is now considered to be part of a broader theory of plate tectonics. p. 599

control: in an experiment, the control is the individual, thing, or group designated to receive no treatment (the unchanged group); all other groups are compared against this one. p. 24

convergent evolution: the independent development of similarity between species as a result of their having similar ecological roles and selection pressures. p. 250

cooperative behavior: behavior that increases the reproductive fitness of the performing individual and of the recipient. p. 580

cornea (KOR nee uh): the transparent outer layer of the vertebrate eye. p. 175

corpus luteum (KOR pus LOOT ee um): the structure that forms from the tissues of a ruptured ovarian follicle and secretes female hormones. p. 163

cortex: (1) the outer layers of the adrenal gland, p. 499; (2) a layer of cells under the epidermis or bark of some plant stems and roots. p. 518

cotyledons (kot ih LEE dunz): the single (monocot) or double (dicot) seed leaves of a flowering plant embryo. p. 371

cravings: an intense desire for drugs of abuse that occurs after a user takes drugs for a period of time. p. 504

creatine phosphate (KREE uh tin FOS fayt): an energy storage compound used by muscle cells of vertebrates to replenish ATP supplies; replenished by the breakdown of glycogen. p. 485

crossing-over: during prophase I of meiosis, the breakage and exchange of corresponding segments of chromosome pairs at one or more sites along their length, resulting in genetic recombination. p. 157

crustaceans: includes aquatic organisms such as lobsters, shrimp, and crabs, as well as terrestrial sow

bugs and pill bugs; phylum Crustacea formerly of the phylum Arthropoda. p. 395

cultural adaptation: an adaptation to new pressures or situations resulting from cultural innovation. p. 700

culture: a system of learned behaviors, symbols, customs, beliefs, institutions, artifacts, and technology characteristic of a group and transmitted by its members to their offspring. p. 696

cuticle: in plants, a noncellular, waxy outer layer covering certain leaves and fruits. p. 355

cyanobacteria (SY an oh bak TIR ee uh): the blue-green bacteria, which carry on oxygen-producing photosynthesis much like plants, but without membrane-enclosed chloroplasts isolating their chlorophyll. p. 302

cytokinesis (syt oh kih NEE sus): the division of the cytoplasm of a cell after nuclear division. pp. 136

cytokinin (syt oh KY nin): a plant hormone that promotes cell division, stem and root growth, chlorophyll synthesis, and chloroplast development. p. 554

cytoplasm (SYT oh plaz um): the entire contents of the cell, except the nucleus, bounded by the plasma membrane. p. 128

cytoskeleton: a network of microtubules, microfilaments, and intermediate filaments that run throughout the cytoplasm and serve a variety of mechanical and transport functions. pp. 130

D

data (singular, datum): observations and experimental evidence bearing on a biological question or problem. p. 17

decomposer: an organism that lives on decaying organic material, from which it obtains energy and its own raw materials for life. p. 8

decomposition (de kom poh ZISH un): the process of taking molecules apart; heat and chemicals are the chief agents. p. 89

deforestation: the removal of trees from a forested area without adequate replanting. p. 647

dendrite: a structure that extends out from a neuron and transmits impulses toward the cell body. p. 488

denitrifying (dee NY trih fy ing) **eubacteria:** bacteria that break down nitrogen compounds in the soil and release nitrogen gas to the air. p. 305

density: the number of individuals in a population in proportion to the size of their environment or living space. p. 33

dental caries: cavities; tooth decay caused, in part, by lactic acid bacteria. p. 308

dental plaque: a film composed of eubacteria in a sugar matrix on the surface of teeth. p. 308

deoxyribose (dee OK sih RY boh): a sugar used in the structure of DNA; it contains one fewer oxygen atom than does ribose. p. 102

depressant: a drug that slows the functioning of the central nervous system. p. 501

desert: a biome characterized by lack of precipitation and by extreme temperature variation; there are both hot and cold deserts. p. 637

desertification: the conversion of rangeland or cropland to desertlike land with a drop in agricultural productivity; usually caused by a combination of overgrazing, soil erosion, prolonged drought, and climate change. p. 647

development: (1) cell division, growth, and differentiation of cells from embryonic layers into all the tissues and organs of the body; (2) later changes with age, including reproductive maturity with its effects on appearance and body function. p. 172

diabetes mellitus (MEL luh tus): a disease resulting from insufficient insulin secretion by the pancreas or impairment of insulin receptors on body cells; characterized by abnormal absorption and use of glucose. p. 496

diaphragm (DY uh fram): (1) the sheet of muscle that separates the chest and abdominal cavity in mammals and, along with rib muscles, is important in breathing, p. 465; (2) a caplike rubber device inserted in the vagina and used as a contraceptive. p. 165

diatom (DY uh tom): any of a large group of algae with intricate, patterned, silica-containing shells made in two halves; unusually shaped pores create the patterns. p. 327

dicot (DY kot): flowering plant that has two embryonic seed leaves, or cotyledons. p. 373

differentiation: specialization, as when developing cells become ordered into certain tissues and organs. p. 172

diffusion (dih FYOO zhun): the movement of a substance down its concentration gradient from a more-concentrated area to a less-concentrated area. pp. 132, 144

digestion: the process by which larger food molecules are broken down into smaller molecules that can be absorbed. p. 392

dinoflagellate: any of the numerous, chiefly marine, protozoans characteristically possessing two flagella; one of the major types of plankton. p. 329

dipeptide (dy PEP tyd): two amino acid molecules bonded to one another; the dipeptide may be the start of a chain for a protein or a product of digestion of a protein and a polypeptide. p. 99

diploid (DIP loyd): a cell containing both members of every chromosome pair characteristic of a species ($2n$). p. 156

dispersal: (1) the spreading of organisms from a place of concentration, p. 35; (2) the scattering of spores and seeds that promotes spreading of non-motile organisms. p. 36

divergent evolution: evolutionary change away from the ancestral type, with selection favoring newly arising adaptations. p. 250

DNA: deoxyribonucleic (dee OK sih ry boh noo KLEE ik) acid; the hereditary material of most organisms; DNA makes up the genes; these nucleic acids contain deoxyribose, a phosphate group, and one of four bases. p. 101

dominance hierarchy: a linear pecking order of animals in which position dictates characteristic social behaviors. p. 577

dominant: a trait that is visible in a heterozygous organism. p. 195

dormant: inactive but alive or viable. p. 341

dorsal: in animals, situated toward the top or back side. p. 388

drugs: a chemical compound or substance that can alter the structure and function of the body. Psychoactive drugs affect the function of the brain, and some of these may be illegal to use and possess. Some drugs are medications that are used to treat specific health problems. p. 501

E

ecology: the study of living and nonliving components of the environment and of the interactions that affect biological species. p. 7

ecosystem (EE koh sis tum): a biological community in its abiotic environment. p. 62

ectoderm (EK toh derm): the outer layer of cells in the gastrula stage of an animal embryo. p. 173

effector: a muscle or gland activated by nerve impulses or hormones. p. 490

electron (ee LEK trahn): a negatively charged particle that occurs in varying numbers in clouds surrounding the nuclei of atoms. p. 88

electron transport system: the process in which electrons are transferred from one carrier molecule to another in photosynthesis and in cellular respiration.

tion; results in storage of some of the energy in ATP molecules. p. 423

electrophoresis: any of several techniques for separating large molecules, such as proteins or DNA fragments based on their ability to move through a gel medium subjected to an electric field. p. 219

element: a substance composed of atoms that are chemically identical—alike in their proton and electron numbers. p. 13

embryo: an organism in its earliest stages of development. p. 172

emigration (em uh GRAY shun): departure of individuals from a population; decreases the size of the population. p. 32

emphysema (em fuh SEE muh): a lung condition in which the air sacs dilate and the walls atrophy, resulting in labored breathing and susceptibility to infection. p. 466

endocrine (EN doh krin) **gland:** a ductless gland that secretes one or more hormones into the bloodstream. p. 494

endocrine system: the system of glands that secrete their products from their cells directly into the blood. p. 494

endoderm (EN doh derm): an inner layer of cells, as in an embryo. p. 173

endoplasmic reticulum (en doh PLAZ mik reh TIK yoo lum): an extensive membranous network in eukaryotic cells composed of ribosome-studded (rough) and ribosome-free (smooth) regions. p. 129

endoskeleton (EN doh SKEL eh tun): a hard skeleton buried in the soft tissues of an animal, such as the spicules of sponges and bony skeletons of vertebrates. p. 409

endosperm (EN doh sperm): a nutrient-rich structure, formed by the union of a sperm cell with two polar nuclei during double fertilization, that provides nourishment to the developing embryo in seeds of flowering plants. p. 359

endospore (EN doh spor): a thick-walled spore of a particular type, like that produced by the anaerobic bacterium that causes botulism. p. 297

energy: the ability to do work or to cause change; see *chemical energy*. p. 91

energy pyramid: a graphic representation of the energy available for use by producers and consumers as levels of a pyramid: at the bottom, with the greatest amount of available energy, are the producers, followed by primary consumers, secondary consumers, and top-level consumers; only about 10 per-

cent of the energy available at the preceding level is available for use at the next higher level. p. 68

environment (en VY run ment): everything living and nonliving in an organism's surroundings, including light, temperature, air, soil, water, and other organisms. p. 32

enzyme (EN zym): a protein or part-protein molecule made by an organism and used as a catalyst in a specific biochemical reaction. p. 91

enzyme-substrate complex: an enzyme molecule together with the molecules on which it acts, correctly arranged at the active site of the enzyme. p. 101

epinephrine (ep ih NEF rin): an adrenal hormone, also called adrenaline, that speeds up heart rate and raises blood sugar level and blood pressure, the fight-or-flight hormone that is secreted during a sudden fright or emergency. p. 499

epiphyte (EP ih fyt): a plant that takes its moisture and nutrients from the air and from rainfall and that usually grows on a branch of another plant; not a parasite. p. 634

esophagus: the tubular portion of the digestive tract that leads from the pharynx to the stomach. p. 418

essential nutrient: a nutrient that an organism cannot synthesize, or cannot synthesize in the quantities it requires; plants obtain these nutrients from the soil, animals from food they ingest. p. 431

estivation (es tih VAY shun): a physiological state, characterized by decreased metabolism and inactivity, that permits survival during long periods of elevated temperature and diminished water supplies. p. 639

estrogen (ES troh jen): a hormone that stimulates the development of female secondary sexual characteristics. p. 163

ethylene (ETH ih leen): a gaseous plant hormone that promotes fruit ripening while inhibiting further plant growth in roots and stems. p. 554

eubacteria (YOO bak TIR ee uh): the bacterial group including the cyanobacteria but not the archaeobacteria; sometimes called the "true bacteria"; they differ from archaeobacteria in their ribosomal RNA and tRNA, and in other ways. p. 297

euglenoids: a small group of freshwater flagellates similar to the organisms of the genus *Euglena*; many contain chloroplasts, others absorb organic substances or ingest prey; all lack rigid cell walls. p. 329

eukaryote (yoo KAIR ee oht): an organism whose cells have a membrane-enclosed nucleus and organelles; a protist, fungus, plant, or animal. p. 125

eutrophic (yoo TROH fik): characterizing a body of water that is nutrient-rich, leading to population explosions of photosynthetic organisms and then of decomposers, which deplete the dissolved oxygen and cause fishes and other aquatic organisms to die. p. 681

excretion (ek SKREE shun): the elimination of wastes, especially by-products of body metabolism, by organisms. p. 405

exon (EKS on): a segment of DNA that is transcribed into RNA and translated into protein, specifying the amino acid sequence of a polypeptide; characteristic of eukaryotes and some prokaryotes. p. 215

exoskeleton (EK soh SKEL eh tun): a hard encasement deposited on the surface of an animal, such as the shell of a mollusk, that provides protection and points of attachment for muscles. p. 408

extensor: a muscle that extends a limb or skeletal part. p. 487

extinct: no longer surviving as a species. p. 73

F

F₁: the first filial, or hybrid, offspring in a genetic cross-fertilization. p. 195

F₂: offspring resulting from interbreeding of the hybrid F₁ generation. p. 195

family: the fifth largest grouping after kingdom, phylum or division, class, and order, in the biological classification system; a group of related genera. p. 268

famine (FAM in): severe shortage of food, causing widespread hunger and starvation within a population. p. 40

feces (FEE seez): the waste material expelled from the digestive tract. p. 421

feedback system: a relationship in which one activity of a body system affects another, which in turn affects the first, yielding a regulatory balance. p. 495

fermentation (fer men TAY shun): the incomplete breakdown of food molecules, especially sugars, in the absence of oxygen. p. 427

fertilization: the union of an egg nucleus and a sperm nucleus. p. 156

fetus: a vertebrate embryo in later stages of development when it has attained the recognizable structural plan and features of its type. p. 179

fibrin (FY brin): an insoluble, fibrous protein that forms a network of fibers around which a blood clot develops. p. 456

fibrinogen (fy BRIN oh jen): a soluble blood protein that is changed into its insoluble form as fibrin during the blood-clotting process. p. 456

fight-or-flight response: a response of the neuroendocrine system to stressors in which the body prepares to fight or flee; includes the secretion of epinephrine that speeds up heart rate and elevates blood pressure. p. 500

filtration: in vertebrate kidneys, filtration occurs when blood pressure forces the blood into the glomerulus of the nephron where blood cells and plasma proteins are separated from the blood's water, nitrogenous wastes, and ions; most of the liquid filtrate is reabsorbed, but some wastes are secreted from the body in the urine. p. 468

flagella (fluh JEL uh): singular, flagellum; the long cellular appendages specialized for locomotion and formed from a core of nine outer doublet microtubules and two single inner microtubules; many protists and certain animal cells have flagella. p. 274

flame cell: in planarians, a cell with cilia in a network connected by tubules; absorbs fluid and wastes and moves fluid through the tubules to eliminate excess water. p. 406

flatworm: any member of the phylum Platyhelminthes. p. 392

flexor: a muscle that bends a joint; its action is opposite to that of an extensor. p. 487

follicle: in mammals, an ovarian sac from which an egg is released. p. 163

follicle-stimulating hormone (FSH): a substance secreted by the anterior lobe of the pituitary that stimulates the development of an ovarian follicle in a female or the production of sperm cells in a male. p. 163

food: a substance containing energy-rich organic compounds made by organisms and used as a source of energy and matter for life. p. 7

food chain: the transfer of food from one feeding level to another, beginning with producers. p. 8

food web: food chains in an ecosystem taken collectively, showing partial overlapping and competition for many food organisms. p. 9

foraminiferan (FOR am ih NIF er un): any of the unicellular microorganisms of the order Foraminifera, characteristically possessing a calcareous shell with perforations through which numerous pseudopodia protrude. p. 330

fossil: a cast of an organism preserved in rock that formed where it died; the organism itself in ice, vol-

canic glass, or amber; or the skeleton preserved in deposits. p. 267

Fungi (FUN jy): a kingdom of heterotrophic organisms that develop from spores; many are decomposers; some are parasites of other organisms. p. 277

G

G₁ (Gap 1, or in this text, Growth 1): the first growth phase of the cell cycle, starting just after offspring cells form. p. 135

G₂ (Gap 2 or in this text, Growth 2): the second growth phase of the cell cycle, beginning after DNA synthesis. p. 136

Gaia hypothesis: the hypothesis which proposes that the connections between living organisms and nonliving environment qualify our planet as a single, complex living organism. p. 285

Galápagos Islands: a group of volcanic islands west of Ecuador; formed only 5 million years ago; life could not have arisen there, so the organisms that inhabit these equatorial islands must have come from mainland South America and achieved their present diversity through adaptation and evolution. p. 238

gamete (GAM eet): a sex cell, either an egg cell or a sperm formed by meiosis, having half the number of chromosomes as body cells. p. 154

gametophyte (guh MEET oh fyt): the gamete-producing generation in a plant species that undergoes alternation of generations. p. 356

ganglion: a grouping of nerve cells where nerve impulses are exchanged; in more complex organisms, these are in areas of the body other than the brain or spinal cord. p. 407

gastric juice: mixed secretions of the glands in the stomach wall; in humans, principally mucus, hydrochloric acid, and protein-fragmenting enzymes. p. 419

gastrula (GAS truh luh): an early embryo at the stage when infolding of cells from the outside occurs. p. 172

gastrulation: the formation of the gastrula stage of an embryo; the stage at which the embryo acquires three layers. p. 172

gene: the fundamental physical unit of heredity, which transmits a set of specifications from one generation to the next; a segment of DNA that codes for a specific product. p. 129

gene flow: the loss or gain of alleles in a population due to the emigration or immigration of fertile individuals. p. 246

gene pool: the total aggregate of genes in a population at any one time. p. 244

genetic drift: changes in the gene pool of a small population due to chance. p. 246

genome: the total genetic content or complement of a haploid cell from any given species. p. 216

genotype (JEE noh typ): the genetic makeup of an organism. p. 196

genus (JEE nus): the next largest grouping after kingdom, phylum or division, class, order, and family in the biological classification system; a group of related species. p. 268

gibberellin (jib uh REL en): a plant hormone that stimulates elongation of the stems, triggers the germination of seeds, and with auxin, stimulates fruit development. p. 553

gills: the respiratory organs chiefly of aquatic organisms such as fish; the chief excretory organs in many ocean fish. p. 404

gizzard: a muscular sac in the digestive system of birds, earthworms, and other animals that mechanically changes food by grinding it against sand particles. p. 403

glomerular capsule: the cup-shaped portion of the nephron enclosing a mass of capillaries (the glomerulus); the site of filtration in the kidneys. p. 468

glomerulus (glah MER yoo lus): a ball of capillaries surrounded by a capsule in the nephron and serving as the site of filtration in the kidneys. p. 468

glucagon (GLOO kuh gahn): a pancreatic hormone that acts to raise the blood glucose level. p. 495

glycerol: a 3-carbon alcohol molecule that combines with fatty acids to form fats and oils. p. 98

glycogen: the chief carbohydrate used by animals for energy storage. p. 97

glycolysis (gly KAWL uh sis): the initial breakdown of a carbohydrate, usually glucose, into smaller molecules at the beginning of cellular respiration. p. 423

Golgi (GOHL jee) **apparatus**: an organelle in eukaryotic cells consisting of stacked membranes that modifies and packages materials for export from the cell. pp. 127, 129

grana (GRAY nuh): singular, granum; stacks of thylakoids within a chloroplast. p. 542

gravitropism (grav ih TROH piz um): a positive or negative response of a plant or animal to the acceleration force of gravity. p. 557

guard cells: a pair of cells that surround a stomate in a leaf's epidermis; turgor pressure in the guard cells

regulates the opening and closing of the stomate.
p. 515

gut: the alimentary canal, or portions thereof, especially the stomach and intestines. p. 418

H

habitat (HAB ih tat): place where an organism lives; even in the same ecosystem, different organisms differ in their habitats. p. 64

half-life: in radioisotopes, the time required for half of a specified quantity to decay. p. 594

halophile (HAL uh fyl): an organism that requires a salty environment; usually refers to a type of archaeobacteria. p. 300

haploid (HAP loyd): a cell containing only one member (n) of each chromosome pair characteristic of a species. p. 156

hemoglobin (HEE moh gloh bin): the pigment in red blood cells responsible for the transport of oxygen. p. 455

hemophilia: an X-linked recessive human trait; a disorder in which blood does not clot properly. p. 456

herbaceous (her BAY shus): herblike; without woody tissues. p. 373

herbivore (HER bih vor): a plant-eating consumer; one of the class of consumers most closely associated with producers. p. 62

heterotroph (HET eh roh trohf): an organism that obtains carbon and all metabolic energy from organic molecules previously assembled by autotrophs; a consumer. p. 275

heterotroph hypothesis: the hypothesis that the first life-forms used the supply of naturally occurring organic compounds for food. p. 284

heterozygous (HET er oh ZY gus): having two different alleles for a given trait. p. 197

hibernation: a physiological state that permits survival during long periods of cold and diminished food, in which metabolism decreases, the heart and respiratory system slow down, and body temperature is maintained at a lower level than normal. p. 581

histamine: a substance released by injured cells that causes blood vessels to dilate during an inflammatory response. p. 462

homeostasis (hoh mee oh STAY sis): a fundamental characteristic of living systems; maintenance of stability of numbers of individuals within a population (social); the tendency of an organism to maintain a

stable, constant internal environment (physiological). pp. 35, 479

hominid (HOM ih nid): a primate of the family Hominidae, which includes modern humans, earlier subspecies, and *australopithecines*. p. 610

***Homo erectus*:** an extinct tool-using human species that lived from 1.6 million to 300,000 years ago; the first undisputed human species. p. 610

***Homo habilis*:** a fossil hominid, larger than an australopithecine, thought to be between 1.6 and 2 million years old. p. 610

homologies (hoh MOL uh jeez): likeness in form, as a result of evolution from the same ancestors. p. 267

Homo sapiens neanderthalensis (nee an der tal EN sis): a subspecies of modern humans that lived in Europe Africa and Asia from about 100,000 to 35,000 years ago; their relationship to modern humans is debated. p. 611

***Homo sapiens sapiens*:** a subspecies of anatomically modern humans composed of present-day human groups. p. 611

homozygous (HOH moh ZY gus): having two identical alleles for a given trait. p. 197

hormone: a substance, secreted by cells or glands, that has a regulatory effect on cells and organs elsewhere in the body; a chemical messenger. p. 162

host: an organism that serves as a habitat or living food source, or both, for another organism. p. 305

hybrid: having different alleles for a given trait, one inherited from each parent; heterozygous. p. 197

hyphae (HY fee): threadlike growth of a fungus; in an irregular mass they compose the mycelium of many fungi; in an orderly and tightly packed arrangement they compose the body of a mushroom or bracket fungus. p. 334

hypoglycemia (hy poh gly SEE mee uh): low blood sugar level. p. 496

hypothalamus: a specialized part at the base of the brain; in humans it links the nervous system to what is called the endocrine system (the endocrine system controls the hormones that regulate many body functions). p. 162

hypothesis (hy POTH uh sis): a statement suggesting an explanation for an observation or an answer to a scientific problem. p. 17

I

immigration (im uh GRAY shun): arrival of new individuals into a population; increases the size of a population. p. 32

immune response: the body's response against specific pathogens or foreign materials; results in the production of proteins, called *antibodies*. p. 458

immune system: the body's specific defense system; a response to foreign material occurs in the lymphatic system, the bone marrow, the thymus, tonsils, spleen, and appendix; these tissues produce cells which then produce antibodies or a cellular defense against an antigen. p. 458

immunity: disease resistance, usually specific for one disease or pathogen. p. 306

imperfect fungi: any of the fungi not belonging to other phyla, in which the method of reproduction, if known, is asexual; a taxonomic grouping of convenience. p. 337

incomplete dominance: a situation in which the phenotype of a heterozygous offspring is intermediate to the phenotype of the parents. p. 200

incubation period: the time from the entry of an infectious agent into an organism up to the time of the first appearance of disease signs or symptoms. p. 312

industrialized agriculture: using large inputs of energy primarily derived from fossil fuels to produce large quantities of crops and livestock. p. 698

infectious disease: a disease caused by viruses or microorganisms that can be transmitted directly from an affected individual to a healthy individual. p. 305

inflammatory response: occurs when injured tissue releases chemical signals that cause capillaries to become leaky, allowing white blood cells into the area of injury (causing swelling and reddening of the injured area); the white blood cells engulf pathogens. p. 458

ingestion: the process of taking a substance from the environment, usually food, into the body. p. 402

innate behavior: behavior that is genetically determined, as in the organization of an ant society; also called *instinctive behavior*. p. 572

instinct: the capacity of an animal to complete a fairly complex, stereotyped response to a key stimulus without having prior experience. p. 572

insulin (IN suh lin): a pancreatic hormone that promotes cell absorption and use of glucose; impairment of its secretion or its action results in diabetes. p. 495

interneuron: associative neuron; a neuron located between a sensory neuron and a motor neuron. p. 489

interphase (IN ter fayz): a normal interval between successive cell divisions when the only evidence of future divisions is that chromosomes begin to be

replicated; a cell at work, rather than a cell dividing. pp. 135, 139

intertidal zone: the shallow zone of the ocean where land meets water; also called the *littoral zone*. p. 676

intestinal juice: secretions of the glands in the small intestinal wall containing enzymes that act on dipeptides and double sugars. p. 420

intron (IN tron): a segment of DNA that is transcribed into precursor mRNA but then removed before the mRNA leaves the nucleus. p. 215

ion (EYE on): an atom or molecule that has either gained or lost one or more electrons, giving it a positive or negative charge. p. 89

ionization: the conversion of a nonionic substance, such as water, into ions. p. 90

J

joint: a point of movement, or of fixed calcium deposits preventing movement, marking where two bones meet in the skeleton. p. 486

K

karyotype: a method of organizing the chromosomes of a cell in relation to number, size, and type. p. 202

kcal: kilocalorie; a measure of food energy equal to 1,000 calories. p. 41

kidney: an organ that regulates water and salt levels, filters water and wastes from the blood, and gets rid of the end products as urine. p. 467

killer T cell: lymphocytes that are produced in the bone marrow but mature in the thymus; these cells recognize and destroy infected cells, limiting the spread of the infection. p. 458

kingdom: the largest grouping in the biological classification system. p. 269

Krebs cycle: the cycle in cellular respiration that completes the breakdown of intermediate products of glycolysis, releasing energy; also a source of carbon skeletons for use in biosynthesis reactions. p. 423

L

larval (LAR val): an immature stage of development in offspring of many types of animals. p. 397

latent: present but not evident or active. p. 312

learned behavior: behavior developed as a result of experience. p. 572

lens: in the eye, a transparent tissue layer behind the iris that focuses light rays entering through the pupil to form an image on the retina. p. 175

lenticel (LENT ih sel): an opening in the surface of a plant stem through which air can diffuse. p. 517

lichen (LY kin): an alga and a fungus that live in symbiosis, forming a distinctive structure, or thallus, that may be low and crusty, leafy, or bushy; lichens are pioneers on rock or other surfaces. p. 64

life cycle: all the events that occur between the beginning of one generation and the beginning of the next generation. p. 152

ligaments: a cord or sheet of connective tissue by which two or more bones are bound together at a joint. p. 486

light reactions: the energy-capturing reactions in photosynthesis. p. 544

limiting factor: an environmental condition such as food, temperature, water, or sunlight that restricts the types of organisms and population numbers that an environment can support. p. 32

lipid (LIP id): a fat, oil, or fatlike compound that usually has fatty acids in its molecular structure; an important component of the plasma membrane. p. 96

luteinizing hormone (LH): a hormone secreted by the anterior lobe of the pituitary gland that controls the formation of the corpus luteum in females and the secretion of testosterone in males. p. 163

Lycophyta (ly KOF ih tuh): the phylum containing the club mosses. p. 362

lymph (LIMF): the fluid transported by the lymphatic vessels. p. 421

lymphatic (lim FAT ik) **system:** a system of vessels through which body lymph flows, eventually entering the bloodstream where the largest lymph duct joins a vein. p. 421

lymph node: a tiny, twisted portion of a lymph vessel in which white blood cells attack any pathogenic organisms in the lymph and engulf any foreign particles. p. 456

lymphocyte (LIM foh syt): a type of small white blood cell important in the immune response. p. 458

lymphokine (LIM foh kyn): any of a class of proteins by which the cells of the vertebrate immune system communicate with one another. p. 459

lymph vessel: a vessel in which lymph from the body tissues, or from villi in the intestine, flows until it enters the largest lymph duct, which empties into a vein. p. 456

lysosome (LY soh zohm): a cell vesicle that contains digestive enzymes. pp. 126, 130

M

macronucleus: the larger of two types of nuclei in ciliates; one or more of the macronuclei may be present in each organism. p. 332

macronutrient: a nutrient required in large amounts by a plant or other organism. p. 524

macrophage (MAK roh fayj): a large white blood cell that ingests pathogens and dead cells. p. 458

mammary glands: the organs in female mammals, consisting of clusters of milk-producing cells with small ducts terminating in a nipple or teat. p. 400

marsupials: a group of mammals, such as koalas, kangaroos, and opossums, whose young complete their embryonic development inside a maternal pouch called a marsupium. p. 400

mating behavior: the behaviors, including courtship rituals and displays, that lead to mating; such behavior usually is specific for each species. p. 577

medulla (meh DUL lah): a part of the brain stem in vertebrates. p. 491

meiosis (my OH sis): two successive nuclear divisions (with corresponding cell divisions) that produce gametes (in animals) or sexual spores (in plants) having one-half of the genetic material of the original cell. p. 156

memory cell: B- or T-lymphocyte, produced in response to a primary immune response, that remains in the circulation and can respond rapidly if the same antigen is encountered in the future. p. 458

menopause (MEN oh pahz): in human females, the period of cessation of menstruation, usually occurring between the ages of 45 and 50. p. 164

menstrual cycle: the female reproductive cycle that is characterized by regularly recurring changes in the uterine lining. p. 162

menstruation: periodic sloughing of the blood-enriched lining of the uterus when pregnancy does not occur. p. 164

meristem (MER ih stem): plant cells at the growing tips of roots and stems and in buds and cambium that divide and produce new cells that can differentiate into various plant tissues. p. 527

mesoderm (MEZ oh derm): in most animal embryos, a tissue layer between the ectoderm and

endoderm that gives rise to muscle, to organs of circulation, reproduction, and excretion, to most of the internal skeleton (if present), and to connective tissue layers of gut and body covering. p. 173

mesophyll (MEZ oh fil): the green leaf cells between the upper and lower epidermis of a leaf; the primary site of photosynthesis in leaves. p. 514

mesosome (MEZ oh soh-m): an infolding of the plasma membrane of a prokaryotic cell. p. 296

metabolism (meh TAB oh liz um): the sum of all the chemical changes taking place in an organism. p. 131

metamorphosis (met uh MOR puh sis): in the life cycles of many animals, marked changes in body form and functions that transform young or immature stages to adults. p. 396

metaphase: the stage in mitosis in which replicated chromosomes move to the center of the spindle and become attached to it. p. 136

metastasize: to spread, as in the spread of cancer cells. p. 183

methanogen (meh THAN uh jen): a methane-producing archaeobacterium. p. 300

miconucleus: the smaller of two types of nuclei in ciliates; one or more micronuclei may be present in each organism. p. 332

miconutrient: a nutrient required in only small amounts by a plant or other organism. p. 524

miconorganism: an organism too small to be seen with the unaided human eye. p. 8

miconosphere: a cooling droplet from a hot-water solution of polypeptides; the droplet forms its own double-layered boundary as it cools; used as a model for precells to study the formation of the first life on the earth. p. 283

miconutubule: a hollow rod of protein found in the cytoplasm of all eukaryotic cells, making up part of the cytoskeleton and involved in cell contraction. p. 130

midlatitude forest: a biome located throughout midlatitude regions where there is sufficient moisture to support the growth of large trees, mostly of the broad-leaved deciduous type; also called *temperate forest*. p. 632

mitochondria (my toh KON dree uh): the cell organelles in eukaryotic cells that carry on cellular respiration, releasing energy from food molecules and storing it in ATP. pp. 129, 130

mitosis (my TOH sis): the replication of the chromosomes and the production of two nuclei in one cell; usually followed by cytokinesis. pp. 136, 148

mixed-grass prairie: the biome composing the central Great Plains that contains both short and tall grasses and is characterized by low precipitation, low winter temperatures, and relatively high elevation. p. 636

molecule (MOL uh kyool): a particle consisting of two or more atoms of the same or different elements chemically bonded together. p. 13

mollusc: any invertebrate of the phylum Mollusca, typically having a hard shell that wholly or partly encloses a soft, unsegmented body; includes chitons, snails, bivalves, squid, octopuses, and similar animals. p. 394

Mollusca (muh LUS kuh): the phylum containing molluscs. p. 394

monocot (MON oh kot): a subdivision of flowering plants whose members have one embryonic seed leaf, or cotyledon. p. 373

monotremes: a group of egg-laying mammals, represented by the platypus and echidnas. p. 400

morphology: the shape, form, and structure of an organism or its parts. p. 172

mortality (mor TAL ih tee): death rate, measured as the proportion of deaths to total population over a given period; often expressed as number of deaths per 1,000 or 10,000 individuals. p. 31

motile (MOH tuhl): capable of movement from place to place, characteristic of most animals. p. 388

motor neuron: a specialized neuron that receives impulses from the central nervous system and transmits them to a muscle or gland. p. 490

multicellular: composed of many cells, as contrasted with a single-celled organism. p. 122

multifactorial inheritance: a pattern of inheritance in which characteristics are determined by at least several genes with a large number of environmental variables. p. 201

multiple alleles: the existence of several known alleles for a gene. p. 200

mutation (myoo TAY shun): a chemical change in a gene, resulting in a new allele; or, a change in the portion of a chromosome that regulates the gene; in either case the change is hereditary. p. 203

mycelium (my SEE lee um): the densely branched network of hyphae in a fungus. p. 334

mycoplasma (my koh PLAZ muh): eubacteria that lack cell walls; probably the smallest organisms capable of independent growth. p. 301

mycorrhizae (my koh RY zee): symbiotic associations of plant roots and fungi. p. 339

myosin: a protein that, together with actin, is responsible for muscular contraction and relaxation. p. 484

Myxomycota (mik soh my KOH tuh): the phylum containing the slime molds. p. 332

N

NAD⁺: nicotinamide adenine dinucleotide (nik uh TEE nuh myd AD uh neen DY NOO klee oh tyd); an electron and hydrogen carrier in cellular respiration. p. 424

NADP⁺: nicotinamide adenine dinucleotide phosphate; a hydrogen-carrier molecule that forms NADPH in the light reactions of photosynthesis. p. 546

natural selection: a mechanism of evolution whereby members of a population with the most successful adaptations to their environment are more likely to survive and reproduce than members with less successful adaptations. p. 240

nectar: a secretion, mainly a sugar solution, produced by small glands in the petals of many flowers. p. 370

Nematoda (nee muh TOH duh): the phylum containing the unsegmented worms. p. 393

nephron (NEF rahn): the functional unit of a kidney, consisting of a long, coiled tubule, one end of which forms a cup that encloses a mass of capillaries and the other end of which opens into a duct that collects urine; the entire nephron is surrounded by a network of capillaries. p. 468

nerve: a bundle of nerve fibers; the cell bodies from which the fibers extend usually are located together at one end of the fiber. p. 488

nerve impulse: a wave of chemical and electrical changes that passes along a nerve fiber in response to a stimulus. p. 488

nervous system: a coordinating mechanism in all multicellular animals, except sponges, that regulates internal body functions and responses to external stimuli; in vertebrates, it consists of the brain, spinal cord, nerves, ganglia, and parts of receptor and effector organs. p. 407

neural tube: the structure formed in the embryo that eventually gives rise to the brain and spinal cord. p. 173

neuron (NOO rahn): a nerve cell; a name usually reserved for nerve cells in animals that have a com-

plex brain and specialized associative, motor, and sensory nerves. p. 488

neurotransmitter (NOOR oh trans MIT er): a chemical messenger, often similar to or identical with a hormone, that diffuses across the synapse and transmits a nerve impulse from one neuron to another. p. 488

neutral: a solution in which the concentrations of hydrogen and hydroxide ions are equal. p. 91

neutron (NOO trahn): a particle carrying no electrical charge; found in the nuclei of all atoms except those of hydrogen. p. 88

niche (NITCH): the sum total of all the adaptations an organism uses to survive in its environment; this includes its role in the community, what it eats, and what interactions it has with other organisms and with its environment. p. 64

nitrifying (NY trih fy ing) **eubacteria**: bacteria that use ammonium ions to produce nitrite and nitrate ions. p. 304

nitrogen-fixing eubacteria: bacteria that take in free nitrogen from the atmosphere and use it to produce ammonia; subsequent reactions by other bacteria produce ammonium ions and nitrates, from which plants obtain their nitrogen. p. 304

nodule (NOD yool): a rounded growth of tissue that usually contains microorganisms or some other agent associated with the growth; in certain plants, nitrogen-fixing bacteria live in nodules on the plant roots. p. 304

norepinephrine: a hormone secreted by the adrenal medulla in response to nerve signals from the sympathetic division of the autonomic nervous system. p. 499

notochord (NOH toh kord): in chordates, a flexible, dorsal, rodlike structure that extends the length of the body; in vertebrates it is replaced in later stages of development by the vertebrae. p. 397

nuclear membrane: the membrane in eukaryotes that encloses the genetic material, separating it from the cytoplasm. p. 129

nucleic (noo KLEE ik) **acid**: DNA or RNA; an organic compound composed of nucleotides and important in coding instructions for cell processes. p. 96

nucleoid (NOO klee oyd): a region in a prokaryotic cell consisting of a concentrated mass of DNA. p. 296

nucleotide (NOO klee oh tyd): a subunit or building block of DNA or RNA, chemically constructed

of a 5-carbon sugar, a nitrogen base, and a phosphate group. p. 101

nucleus (NOO klee us): in atoms, the central core, containing positively charged protons and (in all but hydrogen) electrically neutral neutrons, p. 71; in eukaryotic cells, the membranous organelle that houses the chromosomal DNA. pp. 88, 125

nutrient: (1) a food substance usually digested or not requiring digestion in a form, that is interchangeable among organisms, p. 87; (2) certain chemicals used by plants. p. 524

O

omnivore (OM nih vor): a consumer organism that feeds partly as a herbivore and partly as a carnivore, eating plants, animals, and fungi. p. 62

oncogene: a gene found in viruses or as part of the normal genome that is crucial for triggering cancerous characteristics. p. 183

open circulatory system: a system in which the blood does not travel through the body completely enclosed in vessels; the return to the heart is usually through open spaces, or sinuses, as in the grasshopper. p. 405

open population: a population that gains members by immigration or loses them by emigration, or both. p. 35

opportunistic infections: infections that occur in organisms with weakened immune responses; normally these infections would be repelled by healthy immune systems. p. 313

order: the fourth largest grouping, after kingdom, phylum or division, and class, in the biological classification system; a group of related families. p. 269

organelle (or guh NEL): an organized structure within a cell, with a specific function; a chloroplast and a mitochondrion are examples. p. 125

organic compounds: compounds built of carbon combined with other elements. p. 88

osmosis (os MOH sis): the movement of water across a selectively permeable membrane. p. 132

ova (singular, *ovum*): the mature female gamete. p. 154

ovaries (singular, *ovary*): the primary reproductive organs of a female; egg-cell-producing organs. p. 160

oviduct: a tube leading from an ovary to the uterus. p. 163

ovulation: in vertebrates, the release of one or more eggs from an ovary. p. 161

ovule (OHV vool): a structure that develops in the plant ovary and contains the female egg. p. 358

ovum: a female gamete, or egg. p. 154

P

P: the parental organisms in a genetic cross. p. 195

paleontologist (pay lee un TOL uh jist): a specialist who studies extinct organisms through fossils. p. 594

palisade layer: the layer of tightly packed and column-shaped mesophyll cells containing many chloroplasts. p. 514

pancreatic (pan kree AT ik) **juice:** fluid secreted by the pancreas; converts the acidic food mixture to a basic pH and contains enzymes that break down proteins, fats, and carbohydrates. p. 420

Pangaea (pan GEE uh): in the Triassic period, the supercontinent formed by the four major continents; the breakup of Pangaea affected the distribution and evolution of organisms. p. 600

parallel evolution: the type of evolution that occurs when organisms from a single species become so different that they no longer can interbreed, yet both groups continue to evolve in a similar direction; the ostrich and the rhea are the result of parallel evolution. p. 250

parasitism (PAIR uh sih tiz um): an ecological niche in which one organism is the habitat and the food for another, which lives and feeds on the host organism, usually without killing it. p. 65

parasympathetic division: in vertebrates, one of the two divisions of the autonomic nervous system; stimulates resting activities, such as digestion, and restores the body to normal after emergencies. p. 492

passive transport: the diffusion of a substance across a biological membrane through a transport protein in the membrane. p. 133

pathogen: a disease-causing organism. p. 305

penicillin: any of several antibiotic compounds obtained from penicillium mold and used to prevent or treat a wide variety of diseases and infections. p. 242

penis: in vertebrates, the male organ through which sperm are passed to the female and through which nitrogenous wastes from the kidneys—in the form of urine—are discharged outside the body. p. 160

peptidoglycan (PEP tid oh GLY kan): a substance found only in eubacteria cell walls that consists of modified sugars cross-linked by short polypeptides. p. 298

peripheral nervous system: the sensory and motor neurons that connect the central nervous system to the rest of the body. p. 490

peristalsis (per ih STAWL sis): rhythmic waves of contraction of smooth muscle that push food along the digestive tract. p. 418

permafrost: the sublayers of soil that remain frozen through the summer thaw in the tundra of northern latitudes. p. 629

petal: one of the leaflike, often brightly colored structures within the ring of green sepals in a developing flower; in the mature flower the petals may form their own ring or fuse to form a cuplike or tubular structure. p. 358

petiole (PET ee ohl): the slender structure at the base of a leaf that attaches it to a plant stem. p. 514

pH scale: a scale from 0 to 14 reflecting the concentration of hydrogen ions; the lower numbers denote acidic conditions, 7 is neutral, and the upper numbers denote basic or alkaline conditions. p. 90

Phaeophyta (fay OFF it uh): the phylum containing the brown algae. p. 328

phenotype (FEE noh typ): the expression of a genotype in the appearance or function of an organism; the observed trait. p. 197

pheromone (FAYR uh mohn): a chemical signal functioning in communication between animals and acting much like hormones to influence physiology and behavior. p. 186

phloem (FLOH em): a portion of the vascular system in plants, consisting of living cells arranged into elongated tubes that transport sugar and other organic nutrients throughout the plant. p. 518

photoperiodism (foh toh PIH ree ud iz um): a physiological response to day length, such as in flowering plants. p. 558

photorespiration: a metabolic pathway that uses oxygen, produces carbon dioxide, generates no ATP, and slows photosynthetic output; generally occurs on hot, dry, bright days, when stomates are nearly closed and the oxygen concentration in the leaf exceeds that of carbon dioxide. p. 550

photosynthesis: the process by which living cells that contain chlorophyll use light energy to make organic compounds from inorganic materials. p. 12

photosystems (PS) I and II: the light-harvesting units in photosynthesis, located in the thylakoid membranes of the chloroplast. p. 545

phototropism (foh toh TROH piz um): movement or growth curvature toward light. p. 556

phylum (FY lum): the second largest grouping, after kingdom, in the biological classification system, for all organisms except plants, which are classified in divisions. p. 269

phytoplankton (FYT oh PLANK ton): very small aquatic organisms, many microscopic, that carry on photosynthesis. p. 663

pigment: any coloring matter or substance. p. 545

pith: cells at the center of the young stems of many plants; in some plants the pith disappears as the stems age. p. 519

pituitary (pih TOO ih ter ee) **gland:** a part of the brain that produces and secretes hormones that regulate a variety of body functions. The pituitary also stores and then releases two hormones produced by cells in the hypothalamus. p. 163

placenta (pluh SEN tuh): a structure in the pregnant uterus for nourishing a fetus with the mother's blood supply, formed from the uterine lining and embryonic membranes. p. 177

plankton (PLANK ton): very small aquatic organisms, many microscopic, that usually float or feebly swim near the surface. p. 662

Plantae (PLAN tee): the plant kingdom, containing multicellular, autotrophic eukaryotes; all members have cellulose-containing cell walls and chloroplasts; reproduction may be sexual or asexual. p. 275

plaque: an abnormal change that occurs on inner arterial walls when lipids, such as cholesterol, infiltrate a matrix of smooth muscle; plaques are a product of atherosclerosis. p. 433

plasma (PLAZ muh): the liquid portion of the blood in which the cells are suspended. p. 454

plasma cell: an antibody-producing cell that is formed as a result of the proliferation of sensitized B-lymphocytes. p. 459

plasma membrane: see *cell membrane*.

plasma proteins: proteins dissolved in the liquid portion of the blood; there are several different kinds of proteins in the plasma, performing functions such as blood clotting, defense against pathogens (this is the immune system), and maintenance of blood osmotic pressure and pH balance. p. 454

plasmid: in prokaryotes, a small ring of DNA that carries accessory genes separate from those of the bacterial chromosome. p. 216

plasmodium (plaz MOHD ee um): the motile sheet-like stage of life formed by the fusion of many amoeba-like slime molds. p. 332

platelet (PLAYT let): a small plate-shaped blood factor that contributes to blood clotting at the site of a wound; platelets release substances that begin formation of a network in which the platelets are caught, forming a clot. p. 455

plate tectonics: the theory and study of the great plates in the earth's crust and their movements, which produce earthquakes, seafloor spreading, continental drift, and mountain building. p. 601

Platyhelminthes (plah tih hel MIN theez): the phylum containing bilaterally symmetrical, somewhat flattened worms. p. 392

pollen grain: a haploid spore produced by a flowering plant; it gives rise to sperm nuclei. p. 358

pollen tube: a tube that develops from a germinating pollen grain and penetrates the carpel until it reaches the ovary; sperm nuclei pass through the tube. p. 359

pollination: the placement of pollen onto the stigma of a carpel by wind or animal vectors, a prerequisite to fertilization. p. 359

polypeptide (POL ee PEP tyd): a long chain of chemically bonded amino acids. p. 99

population: a group of organisms of one species that live in the same place at the same time. p. 30

Porifera (poh RIH fer uh): the phylum containing sponges and their relatives. p. 390

posterior: situated toward the rear, or coming last; the tail end in most animals. p. 388

potassium-40 dating: a radiometric dating technique that involves measuring the relative amounts of potassium-40 to argon-40 in a volcanic rock sample; the ratio is compared to the known half-life of potassium-40, thus yielding an estimate of the age of the rocks. p. 594

predator-prey relationship: the relationship between organisms in which one, the predator, feeds on the other, the prey. p. 64

pressure-flow: the hypothesis that food is transported through the phloem as a result of differences in pressure. p. 520

primary growth: growth in the length of plant roots and stems. p. 526

principle of independent assortment: the inheritance of alleles for one trait does not affect the inheritance of alleles for another trait. p. 199

principle of segregation: during meiosis, chromosome pairs separate into different gametes such that each of the two alleles for a given trait appears in a different gamete. p. 196

probability: the chance that any given event will occur. p. 194

producer: an autotroph; any organism that produces its own food using matter and energy from the non-living world. p. 8

productivity: the amount of available solar energy converted to chemical energy by producers during any given period. p. 669

progesterone (proh JES tuh rohn): a female hormone secreted by the corpus luteum of the ovary and by the placenta that acts to prepare and maintain the uterus for pregnancy and to prepare the breasts for lactation. p. 163

Prokaryotae (proh kayr ee OH tee): the kingdom of bacteria; their cells are prokaryotic and lack membrane-enclosed organelles such as nuclei and mitochondria. This kingdom is often called kingdom Bacteria and was called kingdom Monera. p. 275

prokaryote (pro KAIR ee oht): an organism whose cells do not have membrane-enclosed organelles, such as nuclei, mitochondria, and chloroplasts; a bacterium. pp. 125

prophase: the stage in mitosis during which replicated strands of chromosomes condense to become thicker and shorter, the nuclear envelope begins to disappear, and a spindle forms. p. 139

protein (PROH teen): an organic compound composed of one or more polypeptide chains of amino acids; most structural materials and enzymes in a cell are proteins. p. 96

prothrombin (proh THROM bin): a plasma protein that functions in the formation of blood clots. p. 455

prothrombin activator: in the clotting process, a substance that catalyzes the conversion of prothrombin to thrombin. p. 455

Protocista (proh toc TIST uh): a kingdom of mostly aquatic organisms whose cells are eukaryotic, but that are mostly microscopic; exceptions in size include the larger seaweeds such as kelp. This kingdom was formerly named Protista. p. 278

proton (PRO tahn): a particle bearing a positive electrical charge, found in the nuclei of all atoms. p. 88

proto-oncogene: the normal cellular version of a gene, which, if the DNA is altered, can become an oncogene capable of causing cancer. p. 183

pseudopod (SOO doh pod): literally, a false foot; a term used to describe an amoebalike extension of a cell or unicellular organism; pseudopods are used in locomotion and obtaining food, or, as in white

blood cells, in engulfing bacteria and foreign particles. p. 330

psychoactive (sy koh AK tiv) **drug**: a drug that affects the mind or mental processes. p. 501

Pterophyta (ter OFF ih tuh): the phylum containing the ferns. p. 364

puberty: the stage of development in which the reproductive organs become functional. p. 161

pulmonary artery: one of two major arteries leaving the heart (the aorta is the other); the pulmonary artery carries the blood from the right side of the heart to the lungs, where the blood picks up oxygen. p. 452

punctuated equilibria: a theory of evolution positing spurts of relatively rapid change followed by long periods of stasis. p. 248

pyloric valve: the valve located between the stomach and the small intestine that regulates the passage of food from the stomach. p. 419

R

radial (RAYD ee ul) **symmetry**: correspondence in size, shape, and position of parts as though they all radiated equally from a center point, or from a center line or axis. p. 388

rate: change per unit of time; the amount of change measured over a period of time, divided by the length of time. p. 31

ray cell: any of the cells in the stems of woody plants that form a channel allowing the passage of material laterally back and forth between the xylem and the phloem. p. 528

reabsorption: in the kidney; occurs in capillaries outside the glomerulus (in the renal tubule); water and some dissolved substances that had been filtered from the blood are returned (reabsorbed) back into the filtered blood. p. 468

receptor: a specialized sensory cell, as in the eye or the skin, that is sensitive to a particular type of stimulus. p. 489

recessive: a term used to describe an allele or trait that is masked by a dominant allele or trait. p. 195

recombinant DNA: DNA that incorporates parts of different parent DNA molecules, as formed by natural recombination mechanisms or by recombinant DNA technology. p. 216

reduction division: the first meiotic division, in which the chromosome number is reduced from diploid ($2n$) to haploid (n). p. 157

reflex: an involuntary reaction or response to a stimulus. p. 490

renal tubule: leading away from the glomerulus; the place where reabsorption takes place. p. 468

replication: the process of making a copy of the chromosome in a cell nucleus, and other genes in certain organelles outside the nucleus—particularly chloroplasts and mitochondria; the process is unlike duplication in that each gene and each chromosome in the double set is partly new but also includes part of the old gene or chromosome. p. 136

reproductive isolation: the state of a population or species in which successful mating outside the group is impossible because of anatomical, geographical, or behavioral differences. p. 235

reptile: any of the ectothermic, usually egg-laying vertebrates that belong to the class Reptilia; includes snakes, lizards, crocodiles, turtles. p. 397

resistance: relative immunity; the ability of a host organism to destroy a pathogen or prevent the disease symptoms it causes. p. 305

resource: in ecology, an environmental supply of one or more of an organism's requirements (light energy, food energy, water, oxygen or carbon dioxide, living space, protective cover, and so on); in a human society, a resource may be anything useful. p. 34

retina (REH tin uh): the photosensitive layer of the vertebrate eye that contains several layers of neurons and light receptors (rods and cones); the retina receives the image formed by the lens and transmits it to the brain via the optic nerve. p. 175

retrovirus: certain RNA viruses that must make copies of DNA from their RNA before they can reproduce. p. 311

reverse transcriptase: an enzyme that transcribes RNA into DNA, found only in association with retroviruses. p. 311

Rh factor: marker on red blood cells; a woman with no Rh markers (Rh⁻) will develop antibodies to Rh factors during a pregnancy in which the fetus is Rh⁺; these antibodies may harm the blood supply of a following pregnancy. p. 464

rhizoid (RY zoid): the threadlike structure that in nonvascular plants absorbs water and nutrients from the soil and helps hold the plants in place. p. 362

Rhodophyta (roh DOF it uh): the phylum containing the red algae. p. 328

rhodopsin: a light-absorbing purplish protein pigment; in the retina of the eye, it transforms light into a signal that is transmitted to the brain; in extreme halophiles, bacterial rhodopsin is adapted to carry out photosynthesis (in place of chlorophyll). p. 300

ribose (RY boh): a 5-carbon sugar found in RNA molecules. p. 102

ribosome (RY boh sohm): a cell organelle constructed in the nucleus, consisting of two subunits and functioning as the site of protein synthesis in the cytoplasm. p. 130

ritual: a detailed method of procedure that is faithfully or regularly followed. p. 576

RNA: ribonucleic (ry boh noo KLEE ik) acid; the hereditary material of certain viruses, and the material coded by the DNA of other cells to carry out specific genetic functions, for example, messenger RNA and transfer RNA. p. 101

root cap: a layer of protective cells that covers the growing tip of a plant root. p. 527

root hair: a hairlike extension of an epidermal cell of a plant root that absorbs water and nutrients. p. 523

roundworm: an unsegmented, cylindrical worm having a digestive tube with two openings; a nematode. p. 393

rubisco (roo BIS koh): ribulose biphosphate carboxylase (RY byoo lose BIS fos fayt kar BOX uh lays); an enzyme that catalyzes the initial incorporation of carbon dioxide in the Calvin cycle. p. 550

rumen (ROO men): an enlargement of the digestive tract of many herbivorous mammals, in which microorganisms that can digest cellulose live. p. 300

S

S phase (synthesis): the synthesis phase of the cell cycle during which DNA is replicated. p. 136

sac fungi: fungi belonging to the phylum Ascomycota, in which sexual spores are formed in a saclike structure, the ascus. p. 335

sarcodines: microscopic, or almost microscopic, protists that move by using pseudopods; many produce intricate shells or skeletal structures; includes amoebas, foraminiferans, and radiolarians. p. 330

saturated fat: a fat containing fatty acids with no double carbon bonds; usually solid at room temperature. p. 431

savanna (suh VAN uh): a tropical grassland biome with scattered individual trees and large herbivores; water is the major limiting factor. p. 639

scavenger (SKAV en jer): a consumer organism that feeds on the dead carcasses of other consumer organisms it did not kill. p. 66

scrotum: a pouch of skin that encloses the testes. p. 160

scurvy: a disease caused by a deficiency of vitamin C, characterized by spongy, bleeding gums, bleeding under the skin, and extreme weakness. p. 306

secondary growth: growth in girth or diameter of plant and root. p. 528

secondary sexual characteristics: differences in appearance or behavior brought about by male or female hormones; in many animal species, males are larger or more colorful. p. 579

secretion: in the kidney, takes place near the end of the renal tubule, unfiltered wastes are passed from the blood (secreted) into the filtrate, a process that adjusts the blood pH. p. 468

seed: an embryonic plant, along with food storage tissue (endosperm), both enclosed within protective coatings formed of tissues from an ovule in the parent plant. p. 360

seed coat: the tough, protective outer covering of a seed. p. 526

semen (SEE men): in mammalian males, the thick fluid in which sperm are transported. p. 166

sensory neuron: a neuron that receives impulses from a sensory organ or receptor and transmits them toward the central nervous system. p. 489

sepal (SEE pul): one of the leaflike structures that encloses and protects a flower bud; in the mature flower sepals are on the underside, next to the stem; they often are green. p. 358

sessile (SES il): not free to move about in the environment; sessile animals usually are attached by the base to an object in the environment. p. 388

sex chromosome: one of a pair of chromosomes that differentiates between and is partially responsible for determining the sexes. p. 202

sexual reproduction: reproduction involving the contribution of genetic material from two parents. p. 153

sexual selection: selection based on variation in secondary sexual characteristics, leading to the enhancement of individual reproductive fitness. pp. 246, 579

short-grass prairie: a grassland biome that stretches from the central Great Plains to the Rocky Mountains; grasses usually are less than 0.5 m tall. p. 636

sieve cell: a type of phloem cell in plants that forms a column. p. 519

skeletal muscle: a type of muscle tissue found in muscles attached to skeletal parts and responsible for voluntary muscle movement. p. 484

slash-and-burn cultivation: cutting down trees and other vegetation in a patch of forest, leaving the cut material to dry, and then burning it; the ashes add plant nutrients to the nutrient-poor soils of most tropical forest areas. p. 697

slime molds: members of the phylum Myxomycota; slime molds form amoebalike colonies, are heterotrophic, and reproduce by spores. p. 332

small intestine: a digestive organ of vertebrates and some invertebrates; in vertebrates it is located between the stomach and the large intestine and is the organ in which the digestive processes are completed. p. 419

smooth muscle: the type of muscle tissue found in the walls of hollow internal organs. p. 484

social behavior: animal behavior that shows evidence of differing individual roles in the organization of a group and of cooperation or division of labor in tasks. p. 576

somatic nervous system: those nerves leading from the central nervous system to skeletal muscles. p. 492

speciation: an evolutionary process involving reproductive isolation of a population from others of its species; a new species has been formed when interbreeding is no longer possible between individuals of the isolated population and those of the parent species. p. 246

species (SPEE sheez): a group of organisms that can interbreed with others of the same type; individuals within a species possess similar anatomical characteristics. p. 73

sperm cell: a male gamete, usually motile in swimming movements; its motility increases its chance of encountering and fertilizing an egg. p. 154

Sphenophyta (sfen OFF ih tuh): the phylum containing horsetails. p. 363

sphincter (SFINK ter): a circular muscle that functions to close an opening of a tubular structure. p. 419

spina bifida (SPY nuh BIH fih duh): a birth defect resulting from the failure of the neural tube to close properly during formation of the spinal cord and brain. p. 176

spinal cord: a complex band of neurons that runs through the spinal column of vertebrates to the brain. p. 490

spongy layer: a layer of round, chloroplast-containing mesophyll cells surrounded by air spaces. p. 514

sporangia (spoh RAN jee uh): spore-producing structures formed in one stage of the life cycle of many organisms, but not animals. p. 332

spores: one-celled reproductive bodies that are usually resistant to harsh environmental conditions and may remain dormant, in a dry covering, for long periods; in some organisms, spores are asexual and may initiate the growth of a new organism under favorable conditions; in other organisms, spores are sexual and must unite with those of the other sex before producing a new organism. p. 190

sporophyte (SPOR oh fyt): the spore-producing generation in a plant species that undergoes alternation of generations; in some species, the sporophyte is reduced to a dependent structure that grows from the gametophyte plant. p. 357

sporozoans: usually nonmotile, heterotrophic, parasitic protists of the phylum Apicomplexa, with complex life cycles. p. 331

stamen (STAY men): the pollen-producing male reproductive organ of a flower, consisting of an anther and filament. p. 358

sterile: not capable of reproducing. p. 236

stigma: the tip of the carpel in a flower; it secretes a sticky substance that traps pollen. p. 358

stimulant: a drug that increases the activity of the central nervous system. p. 504

stimuli: the plural of stimulus. p. 407

stimulus (STIM yoo lus): a change or signal in the internal or external environment that causes an adjustment or reaction by an organism. p. 488

stomach: the digestive organ located between the esophagus and the small intestine. p. 419

stomate (STOH mayt): the opening between two guard cells in the epidermis of a plant leaf; gases are exchanged with the air through stomates. p. 355

strata (STRAYT uh; singular, *stratum*): layers, usually of deposited earth sediments carried by erosion; many strata become mineralized into rock layers. p. 594

stress: a physiological response to factors causing disruptive changes in the body's internal environment. p. 501

stressor: a factor capable of stimulating a stress response. p. 501

stroma (STROH muh): the colorless substance in a chloroplast surrounding the thylakoids; the enzymes of the Calvin cycle also are in the stroma. p. 542

stromatolite (stroh MAT uh lyt): a rock made of banded domes of sediment in which are found the most ancient forms of life, fossil prokaryotes dating back as far as 3.5 billion years. p. 281

subsistence agriculture: producing only enough food to feed oneself and family members; in good years, enough may be left over to sell or store. p. 697

substrate (SUB strayt): a molecule on which enzymes act. p. 100

succession: the replacement of one community by another in a progression to a climax community. p. 642

succulent: in botany, a type of plant with thick, fleshy, water-storing leaves or stems. p. 516

surface receptor: a protein-containing molecule on the outside membrane of a cell that binds to a specific molecule; for example, in a cell such as a lymphocyte, the receptor binds to a specific antigen, a step in the immune response. p. 458

sustainable agriculture: a method of growing crops and raising livestock based on organic fertilizers, soil conservation, water conservation, biological pest control, and minimal use of nonrenewable energy sources. p. 706

symbiosis (sim by OH sis): an ecological relationship between organisms of two different species that live together in direct contact. p. 64

symmetry: correspondence in form and arrangement of parts on opposite sides of a boundary. p. 388

sympathetic division: a division of the autonomic nervous system of vertebrates that functions in an alarm response; increases heart rate and dilates blood vessels while placing the body's everyday functions on hold; mobilizes the body for response to stressors, danger, or excitement. p. 492

synapse (SIN aps): an open junction between neurons, across which an impulse is transmitted by a chemical messenger, a neurotransmitter. p. 488

synthesis (SIN thih sis): the process of putting together or building up; applicable to ideas, chemical compounds, and so on. p. 89

T

taiga: (TY guh): the coniferous or boreal forest biome, characterized by much snow, harsh winters, short summers, and evergreen trees. p. 631

tall-grass prairie: a grassland biome found at the western edge of the deciduous forest in the United States; grasses may grow 1.5 to 2 m tall. p. 636

target organ: a specific organ on which a hormone acts. p. 495

taxonomy (tak SAHN uh mee): the study of species and their classification by genus, family, order, class, phylum (or division), and kingdom. p. 266

T cell: a lymphocyte that matures in the thymus, stimulated by the presence of a particular antigen; it differentiates and divides, producing offspring cells (killer cells) that attack and kill the cells bearing the antigen. p. 458

telophase: the final stage in mitosis; two new cell nuclei are completed as nuclear envelopes form around the two clusters of chromosomes at opposite ends of the cell, and the cell itself divides. p. 137

tendon: a cordlike mass of white fibrous connective tissue that connects muscle to bone. p. 487

terrestrial (ter ES tree uhl): living on land. p. 389

territoriality: the behavior pattern in animals consisting of the occupation and defense of a territory. p. 578

testes: the primary reproductive organs of a male; sperm cell-producing organs. p. 160

thermoacidophiles (THER moh a SID uh fylz): archaebacteria requiring high temperatures and/or acidic conditions for life. p. 299

thermocline (THER moh klyn): a layer in a thermally stratified body of water that separates upper, oxygen-rich and nutrient-poor warm water from lower, oxygen-poor and nutrient-rich cold water. p. 665

threat display: a behavior in which an animal attempts to make itself appear larger or fiercer than it actually is in an attempt to discourage intruders. p. 578

thrombin: a blood protein that is important in the clotting process. p. 456

thylakoid (THY luh koyd): a flattened sac in a chloroplast; many of the thylakoids are arranged in stacks known as grana; the pigments and enzymes for the light reactions of photosynthesis are embedded in the sac membrane. p. 542

thyroid gland: an endocrine gland in the neck region of most vertebrates that controls the rate of cell metabolism in the body through one of its hormones, thyroxine. p. 499

thyroxine (thy ROK sin): a principal hormone of the thyroid gland; regulates the rate of cell metabolism. p. 499

tolerance: the ability to withstand or survive a particular environmental condition. pp. 504, 582

toxin: a naturally occurring chemical or substance that is poisonous to an organism. p. 727

trachea (TRAY kee uh): the windpipe of an air-breathing vertebrate, connecting the air passage in the throat with the lungs. p. 465

tracheid (TRAY kee id): a water-conducting and supportive element of xylem composed of long, thin cells with tapered ends and hardened walls. p. 519

transpiration (trans pih RAY shun): the loss of water to the atmosphere by a plant through the stomates in its leaves. p. 515

trimester: a period or term of three months; the gestation period of humans usually is divided into trimesters. p. 180

tropical deciduous forest: a tropical forest biome with wet and dry seasons and constant temperatures. p. 635

tropical rain forest: the most complex of all communities, located near the equator where rainfall is abundant and harboring more species of plants and animals than any other biome in the world; light is the major limiting factor. p. 634

tropism (TROH piz um): a change in the orientation of a plant, or part of a plant, in response to light, gravity, or other environmental factors. p. 556

true breeding: organisms that are genetically identical; homozygous. p. 195

tumor: a mass that forms within otherwise normal tissue, caused by the uncontrolled growth of a transformed cell. p. 183

turgor (TER ger) **pressure:** pressure exerted by plant cells against their cell walls whenever the plant is adequately supplied with water. p. 515

U

ultrasound: high frequency sound waves; a method used to determine some fetal abnormalities. p. 178

ultraviolet light: the range of radiation wavelengths just beyond violet in the visible spectrum, on the border of the X-ray region. p. 543

umbilical (um BIL ih kul) **cord:** in placental mammals, a tube connecting the embryo with the placenta. p. 177

unicellular: one-celled. p. 122

Uniramia (yoo nih RAY mee uh): the subphylum containing animals with three distinct body parts and one pair of antennae; includes millipedes, centipedes, and insects. p. 395

unsaturated fat: a fat containing fatty acids with one or more double-bonded carbon atoms; each double bond in the carbon chains reduces by one the number of hydrogen atoms that can be bonded to the carbons; unsaturated fats usually are liquid at room temperature. p. 431

uranium-235 dating: a radiometric dating technique in which the decay of uranium into lead isotopes is measured; used to date rocks 2 billion years old. p. 594

urban wildlife: wildlife living in urban and suburban areas, including raccoons, skunks, pigeons, songbirds, raptors, mice, rats, and similar animals. p. 585

urea (yoo REE uh): a nonprotein nitrogenous substance produced as a result of protein metabolism. p. 407

ureter (YOOR ee ter): a muscular tube that carries urine from the kidney to the urinary bladder. p. 467

urethra (yoo REE thruh): the tube through which urine is carried from the bladder to the outside of the body in vertebrates. pp. 467–468

uric (YOOR ik) **acid:** the insoluble precipitate of nitrogenous waste excreted by land snails, insects, birds, and some reptiles. p. 407

urinary bladder: an organ that stores urine before it is discharged from the body through the urethra. p. 467

urine: in vertebrates, a liquid waste material, carrying nitrogenous compounds and other salts, secreted by the kidneys. p. 468

uterus: a hollow muscular organ, located in the female pelvis, in which a fetus develops. p. 162

V

vaccine: a substance that contains antigens and is used to stimulate the production of antibodies. p. 306

vacuole (VAK yoo ohl): a membrane-enclosed structure in the cytoplasm of a cell or a unicellular organism; different types of vacuoles serve different functions. pp. 127, 130, 402

vagina: a tubular organ that leads from the uterus to opening of the female reproductive tract. p. 162

valve: a membrane or similar structure in an organ or passage, such as an artery or vein, that retards or prevents the return flow of a bodily fluid. p. 453

variable: a factor that can change during an experiment; a scientist conducting an experiment will

allow only one factor (variable) to change while holding all other factors constant. p. 24

variation: small differences among individuals within a population or species that provide the raw material for evolution. p. 237

vascular tissue: plant tissues specialized for the transport of water and nutrients; also for support. p. 355

vegetative reproduction: asexual reproduction by plants that also may reproduce sexually; examples include potato plants from eyes and grass plants from runners. p. 153

vein: (1) a vessel that carries blood toward the heart. p. 452; (2) a continuation of the vascular tissues of the stem and root in a plant leaf. p. 514

ventral: in animals, situated toward the lower or belly side. p. 388

ventricle (VEN trih kul): one of two lower chambers of the heart that pump blood out of the heart. p. 453

vertebrae (VER teh bray): an articulated bone; the vertebrae make up the backbone, or spinal column, of vertebrates. p. 397

vertebrate: a chordate animal with a backbone; mammals, birds, reptiles, amphibians, and various classes of fishes are examples. p. 397

vesicle: a small, intracellular membrane-enclosed sac in which various substances are transported or stored. p. 129

vessel: in plants, a type of water-conducting xylem cell. p. 519

villi (VIL eye): (1) fingerlike projections of the small intestine that increase surface area. p. 420; (2) fingerlike projections of the chorion that together with the uterine lining form the placenta. p. 177

virulence (VIR yuh lents): the relative ability of a pathogen to overcome body defenses and cause disease. p. 305

virus: a submicroscopic pathogen composed of a core of nucleic acid surrounded by a protein coat that can reproduce only inside a living cell. p. 322

W

wetland: land that stays flooded all or part of the year with freshwater or salt water; includes coastal and inland wetlands. p. 677

X

X-linked trait: a trait determined by a gene carried on the X chromosome. p. 204

xylem (ZY lem): conducting tissue that transports water and dissolved nutrients in vascular plants. p. 518

Z

zooplankton (ZOH oh PLANK ton): very small, feebly swimming aquatic organisms that are herbivorous or carnivorous or both. p. 663

Zygomycota (ZY goh my KOH tuh): the phylum containing conjugation fungi. p. 335

zygospore (ZY goh spor): a zygote that forms a spore; produced in some fungi and many plants following the union of sexual cells or nuclei. p. 335

zygote (ZY goht): the diploid product of the union of haploid gametes in conception; a fertilized egg. p. 156

INDEX

Note: Illustrations and tables are referenced in *italics*.

A

- A. *pratensis*, 37
 Aardvark, 776
 Abiotic environment, 32; carrying capacity and, 34–35; comparative study, 78–80
 Abiotic factors, 785; ecosystems and, 583, 626–27; ocean and, 670–72; population size and, 32–33; tree growth and, 67
 ABO blood group, 462, 464
 ABO blood type, 200, 201
 Absciscic acid, 554, 785
 Absorption, 785; in flowering plants, 523–26; in small intestine, 420–21
 Absorption spectrum, 785
 Acadian flycatcher, 633
 Acanthocephala, 765
Accipiter cooperi, 170–71
Acetabularia, 327
 Acetyl CoA, 424
 Acid deposition, 648, 649, 785
 Acid rain, 648, 699, 704–5, 704; seed germination and, 83–85
Acidianus infernos, 299
 Acidic, 785
 Acids, inorganic, 731–732
 Acorn worms, 771
 Acquired characteristics, 785
 Actin, 484, 785
 Actinobacteria, 758
 Actinophrys, 742, 762
 Actinopoda, 762
Actinosphaerium, 742
 Action spectrum, 785
 Active site, 100, 101, 785
 Active transport, 133, 134, 404, 785; in leaf, 520; roots and, 524–26
 Adaptations, 240, 785
 Adaptive behavior, 573
 Adaptive radiation, 248, 248, 785
 Adder's tongue, 779
 Addiction, 504
 Adenine, 208
 Adenosine diphosphate. *See* ADP
 Adenosine triphosphate. *See* ATP
 Adenovirus, 308
 ADP, 96, 785
 ADP-ATP cycle, 96, 96
 Adrenal cortex, 499, 500, 785; hormones and, 497
 Adrenal glands, 495, 496, 499
 Adrenal medulla, 499, 500, 785; hormones and, 497
 Advanced Spatial Disorientation Demonstrator (ASDD), 470
Aepyceros melampus, 776
 Aerobic, 785
 Aerobic respiration, 425–26
 Aerospace Medical Association, 503
 Aerospace Physiology Department, 470
 Africa: famine in, 43; first humans in, 610–14; savanna in, 639, 640
 African elephant, 776
 African sleeping sickness, 306; parasite that causes, 330, 330
Agardhiella, 761
 Agave, 781
 Age of Reptiles, 280, 280
 Agent Orange, 553
 Agglutinate, 464, 785
 Aggression, 785
 Agriculture: animal-powered, 697; crop rotation, 706–7, 707; establishment of, 696–98; industrialized, 698, 698; slash-and-burn, 42, 696–97; subsistence, 697; sustainable, 706–7, 707
 AIDS: condoms for prevention of, 165; as deadly disease, 313–14; destroying cells of, 314; from eubacteria, 312; prospects for treatment of, 314–15; screening for, 321–23
Ailuropoda melanoeuca, 267
 Air circulation, climate and, 627–28
 Air pollution, control of, 705
 Alanine, 99, 213
 Alaska, 294–95; Prince William Sound, 702; tundra in, 629
 Albatross, 773
 Alcohol, 504
 Algae, 65, 785; aquatic, 540–41; brown, 328–29, 328, 674–75, 676, 761; colonial, 326; conjugating green, 762; green, 326–27, 762. *See also* Green algae; mixed, 326; multicellular, 326, 355; as photosynthetic protists, 326; red, 328–29, 328; unicellular, 326
 Alismataceae, 781
 Alkaline, 785
Alleena mexicana, 393
 Alleles, 196, 785; multiple, 200
 Allergies, immune system and, 462
 Alligator, 63, 773; in Everglades, 72, 72
Alouatta, 775
 Alphafetoprotein (AFP), 178
 Alpine lupine, 645
 Alpine slide mystery, 475–77
 Alpine tundra, 629, 785
Alternaria, 777
 Alternation of generations, 356, 785
 Altitude, vegetation in, 630
 Alveoli, 465–66, 785
 Amanita, 337
Amanita muscaria, 337
 Amaryllaceae, 781
 Amaryllis family, 781
Ambystoma opacum, 398
 American eel, 772
 Amino acid, 99, 785–86; essential, 436–37; excretion in, 407; in polypeptide chains, 100; protein formation and, 212
 Ammonia, 281, 786; in excretion, 405
 Amniocentesis, 178, 179, 180, 786
 Amnion, 177, 786
 Amniotic fluid, 179, 786
Amoeba, 742, 759; classification of, 279; as sarcodine, 330, 330
 Amoebic dysentery, 306, 330
 Amphibia, 772
 Amphibians, 772, 786; in Carboniferous period, 607; as chordates, 398; examples of, 398; reproductive system of, 411
Anabaena, 745; classification of, 279
Anabaena circinalis, 276
Anacystis, 744
 Anaerobic, 786
 Anaerobic bacteria, 285
 Anaerobic respiration, 427–28
 Anaphase, 136, 137, 786
 Anaphase I, 157, 157
 Anaphase II, 157, 158
 Anemones, 676
Anhinga anhinga, 232–33
 Animal cell: cytokinesis in, 138; generalized, 126; water concentration and, 133
 Animal development, 177–82

- Animalia kingdom, 269, 276, 277, 277, 786; catalog of, 763–75
 Animal-powered agriculture, 697
 Animals: adaptation of, 388–400; adjustment to environment changes, 580; annelids, 394–97; appearance through history, 390; aquatic, 388–89; arboreal, 635, 635; of arctic tundra 630, 630; arthropods, 394–97; cellular respiration in, 403–4; chordates, 397–400; circulatory system of, 405; classification of (examples), 266–72, 290; cnidarians, 390–92; cooperative behavior among, 580; in deciduous forests, 632, 632; digestion in, 402–5; digestive cavities of, 402; diversity of, 277, 390–400; evolutionary descent of, 597; examples of diversity among, 388; excretory systems in, 405–7; flatworms, 392; in food chain, 8–11; grassland, 636, 637; hierarchical societies of, 577–78; human activity and, 584–86; interactions of river, 62–64, 63; invertebrate, fluid transport in, 405; least complex, 390–92; mollusks, 393–94; motile, 388; muscles and skeletons of, 408–9; nervous systems of, 407–8; nervous systems in five diverse, 408; parasites of, 331, 392; reproductive success of, 409–11; roundworms, 393–94; secondary sexual characteristics in, 409; sessile, 388; size and complexity in, 389; sponges, 390–92; terrestrial, 389; territoriality of, 578–79; varying sizes of, 389
Ankistrodesmus, 744
 Annelida, 394, 769, 786
 Annelids, 394–97, 663, 786; circulatory system of, 405; excretory system in, 406; nervous system of, 407, 408
 Anoplura, 767
 Anorexia nervosa, 437–38, 786
 Ant, 397
 Antarctic: absence of polar bears from, 37–38; hole in ozone layer over, 16
 Anteaters, 775
Antedon dentate, 771
 Antelopes, 776
 Anterior, 388, 786
 Anthers, 195, 786
 Anthoceroophyta, 778
Anthoceros, 778
Anthoceros punctatus, 361
 Anthophyta, 355, 370, 781, 786
 Anthozoa, 763
 Anthropologist, biological, 613, 786
Anthus trivialis, 37
 Antibiotic resistance, 242–43
 Antibodies, 306, 786; monoclonal, 463, 463
 Antigens, 458, 786
 Antihistamines, 462
Antirrhinum, 784
 Ants, 60, 61, 768
 Anus, 421, 786
 Anza-Borrego Desert State Park, 624–25
 Aorta, 452, 452, 453, 786
 AFP. *See* Alphafetoprotein
 Apes, 775
Aphelocoma coerulescens, 580
 Aphids, 60, 61, 767
 Aphragmabacteria, 758
 Apiaceae, 782
 Apicomplexa, 760, 786
 Appendages, 389, 786
 Aquatic, 786
 Aquatic algae, 540–41
 Aquatic animals, 388–89; gills in, 404, 404
 Aquatic ecosystems, 661–93; human influences on, 677–84; sewage and industrial wastes, 680–81. *See also* Flowing freshwater ecosystems; Standing freshwater ecosystems; Oceans
 Aquatic organisms; effects of salinity on, 689–91; streams and, 667–68
Aquilegia coerulea, 783
Arabidopsis thaliana, 217
 Arachnida, 766
 Arachnids, 395
 Arboreal, 786
 Arboreal animals, in rain forests, 635, 635
 Arboreal primates, 609
 Archaea, 757
 Archaeobacteria, 297, 757, 786; as different, 298; eubacteria, eukaryotes, and, 299; thermoacidophilic, 299; types of, 299–300
 Archaeological interpretation, 620–23
 Archaeologists, 620
 Archaeology, 786
Archaeopteryx, 232–33
 Arctic: hole in ozone layer over, 16; polar bears in, 37–38
 Arctic Circle, 629
 Arctic tundra, 629, 786
Arcyria, 759
Ardipithecus, 615
Arecella, 742
 Arginine, 213
 Argon-40, 594
Argyrolepecus hemigymnus, 674
 Armadillos, 775
 Arrow worms, 771
 Arrowhead, 781
 Arrowleaf plant, 581
 Arteries, 452, 453, 786
 Arteriosclerosis, 435
 Arthropoda, 395, 786
 Arthropods, 394–97, 786; appendages on, 395, 395; insects as, 396–97, 397; skeletons of, 408–9; varieties of, 396
 Artificial selection, 240–41, 240, 786
 Artiodactyla, 776
Ascaris, 775
 Ascomycota, 335, 777, 786
Ascomyllum, 761
 Ascospores, 336
 Ascus, 186, 336, 787
 Asexual reproduction, 153–54, 787
 Asparagine, 213
 Aspartate, 213
Aspergillus, 338
Asplanchna, 765
 Asses, 776
 Aster, pollination of, 371
 Asteraceae, 782
 Asteroidea, 771
 Atherosclerosis, 433, 433, 435, 787
 Atmosphere, conditions in early, 281, 282
 Atomic testing, aftereffects of, 642
 Atoms, 14, 787; chemical bonds in, 88–89; defined, 13; in matter, 88; oxygen, 88, 88
 ATP, 95, 96, 422, 787; active transport and, 133, 134; anaerobic respiration and, 427–28; electron transport system and, 426–27; energy from, 546; formation of, 545; glycolysis and, 423–24, 424; in energy transfer, 95–96; Krebs cycle and, 425–26, 425; muscle contractions and, 484–85
 Atrium, 453, 453, 454, 787
 Audobon Center for Research of Endangered Species (ACRES), 273
Aurelia, 763
Aurelia aurita, 582, 583
 Aureomycin, 339
 Australian lungfish, 607
Australopithecine, 610, 610, 787
Australopithecus boisei skull, 611
 Autogenesis hypothesis, 333
 Autoimmune, 787
 Autoimmune diseases, 461–62
 Autonomic nervous system, 492, 494, 787
 Autosomes, 202, 787
 Autotroph, 275, 787; evolution of, 285
 Autotrophic protists, 326–29; algae as, 326; brown algae as, 328–29; ciliates, 331–32; diatoms as, 327–28; green algae, 326–27; red algae as, 328–29; sarcodines as, 330–31; slime molds, 332–34; sporozoans as, 331
 Auxins, 553, 553, 554, 558, 787; interaction of cytokinins and, 555
 Aves, 773
 Axons, 488, 787

B

- B cells, 458–59, 458, 787
 Baboon, 774
 Bacillariophyta, 327–28, 787
 Bacteria, 758; aerobic, controlling water pollution with, 684; anaerobic, 285; chemosynthetic, 673–74; gram-negative, 758; gram-positive, 758;

- nitrogen-fixing, 276; penicillin resistance and, 242, 243; in ponds, 663; purple photosynthetic, 276; wall-less, 758
Bacteria kingdom, 757–58
Bacterial virus, 309
Bacteriophage, 308, 309
Badgers, 636, 637
Badhamia, 759
Baker's yeast, 186
Balaenoptera musculus, 775
Bald cypress, 780
Bald eagle, flying ability of, 574
Banded tulip snail, 770
Barbiturates, 501, 504
Bark, 528, 529
Barnacles, 676, 676, 768
Barr body, 205, 205
Barred owl, 773
Basic, 787
Basidia, 337, 787
Basidiomycota, 337, 777, 787
Bath sponge, 763
Batrachospermum, 745
Bats, 774; fossil, 594
Bay of Fundy, Nova Scotia, 676
Beadle, George W., 211
Bean seedling, 527
Bear Creek Nature Center, 74
Bears, 775; in Carnivora order, 269; giant panda and, 267; grizzly, 386–87, 584
Beavertail cactus, 624–25
Beech, southern (silver), 599
Bees, 768; bee dance, 573–74; flowers and, 24–27
Beetles, 767; ladybird, 30, 30
Behavior: categories of, 572–76; cooperative, 580; innate, 572; learned, 572; mating, 576; selection and, 572–80; social, 576–77
Benzene, 682
Bighorn sheep, adaptation of, 584, 584
Bilateral symmetry, 388, 388, 787
Bile, 420, 787
Binomial nomenclature, 271–72, 787
Biochemical homologies, 267
Biochemical trees, 268
Biocides, 70, 787
Biodegradation, 702
Biodiversity, 71–73, 787; in danger, 644; preserving, 273; value of, 73, 75
Bioethical decisions, 707
Biological activity, energy required for, 11–12
Biological anthropologist, 613
Biological classification, 266–72; based on homologies, 266–67; binomial system, 270–72; as changing, 278–79; class, 269; family, 268; genus, 268; kingdom, 269; order, 269; phylum, 269; seeing relationships with, 266
Biological events, major, 754
Biological illustrator, 375
Biologists, molecular, 216
Biology, 787; Darwin's impact on, 241–43; defined, 7; study of, 3
Bioluminescence, 673
Biomass, 669, 787
Biomes, 787; chaparral, 640–41; climate, ecosystems and, 626–28; defined, 626; earth's major, 626; effect of fire on, 656–59; grassland, 635–36; human influence on, 646–49; with low precipitation levels, 635–39; midlatitude deserts, 637–39; midlatitude forests, 632–33; savannas, 639; solar energy levels and, 629–35; taiga, 631; tropical rain forests, 634–35; tundra, 629–31; with variable precipitation, 639–41
Bioremediation, 702
Biosphere, 787; defined, 16; diversity and adaptation in, 263–413; as home to living things, 15–19; ordering life in, 265–93; patterns in, 569–91; water cycles in, 666, 666
Biosynthesis, 427, 428, 787; genes and, 210–11
Biotechnology, 215–20, 706; genetic engineering, 216–20; new tools of, 215–16
Biotic, 787
Biotic environment, 32; carrying capacity and, 34–38
Bipedal, 787
Birds, 773; as chordates, 398; competition among, 80–82; digestion in, 403; embryo development of, 177; examples of, 399; flight behavior in, 573, 574; in food chain, 8–11, 9, 10; gizzard, 403
Birth control, 165
Birthrate, 31, 787
Bison, 636
Biston betularia, 242
Bivalvia, 766
Black-footed ferret, 644, 644
Black-nosed dace, 772
Black-tailed jackrabbits, 637
Blade, 787
Blastocyst, human, 177, 177, 787
Blastula, 172, 173, 788
Blepharisma, 745
Blood: ABO group system, 462, 464; glucose in, 469; glucose levels in, 495–96; kidneys and, 467–68; materials in urine vs., 480; respiratory gases in, 467
Blood cells: in plasma, 454–55; red. *See* Red Blood cells; white, 455
Blood clot, 450–51
Blood clotting, 455–56; fibrin strands in, 455
Blood lily, mitosis in, 137
Blood pressure, 454, 788
Blue crab, 769
Blue spruce, 780
Blue whale, 775
Bluebird, western, 399
Blue-footed booby, 82
Bluegrass, 782
Blue-green mold, 777
Blueheaded wrasse, 154, 155, 156
Body mass index (BMI), 443–46
Boletus mushroom, 341
Bones: in human body, 486; skeleton of, 409
Bony fishes, 397–98, 398, 772
Boobies, 82; blue-footed, 579
Boron, required by plants, 525
Bossiella, 328
Botrychium, 779
Bougainvillea, 370
Boveri, Theodore, 207
Bovine spongiform encephalopathy (BSE), 310
Box turtle, 773
Brachiopoda, 768, 770
Brachiopods, 598, 598, 788
Bracket fungi, 337, 777
Brain: internal temperature control and, 472–73; major parts of human, 492; slow infections of, 310
Brain coral, 763
Brain stem, 491, 492
Brassicaceae, 783
Brazil: conservation system in, 76; slash-and-burn agriculture in rain forest, 697
BRCA1 gene, 185
BRCA2 gene, 185
Bread mold, 777
Breast cancer genes, 185
Breathing; processes in, 466; respiration and, 94, 465–66
Brine shrimp, 581, 768
Bristletails, 766
Brittle stars, 771; fossils, 592–93
Broad-tailed hummingbird, 773
Brooks, 667, 667
Brown algae, 328–29, 328, 674–75, 676, 761. *See also* Phaeophyta
Brown pelican, 399, 773
Bryophyta, 361, 778, 788
Bryophytes, 355, 788; classes of, 361; seedless vascular plants and, 361–65; varieties of, 361; water evaporation and, 356–57
Bryozoa, 770
Buds, on stems, 517, 517
Bulimia, 437–38, 788
Bullfrog, scientific name of, 270–71
Bulrushes, 684
Bumblebees, toad and, 572
Bundle-sheath cells, 551, 788
Burrowing sea anemone, 392
Bursaria, 742
Butter-and-eggs, 784
Buttercup, 784; flower structure of, 358
Buttercup family, 784
Butterflies, 277, 767; mimicry and, 575

C

- C. sulphurea*, 236
 C-3 plants, 551–52, 552
 C-4 plants, 551–52, 552, 791
 Cactus, 251; beavertail, 624–25
 Caecilian, 772
 Calamites, 364
 Calcium, 747; required by plants, 525
 California: Anza-Borrego Desert State Park, 624–25; condor, 76; salamander distribution in, 256–61
 Callus, 788
 Calories, 41, 429, 788. *See also* Kilocalories
 Calorimeter, 439, 440
Calpidium campylum, 760
 Calvin cycle, 544, 544, 546, 788; sugar formation in, 546–47, 546
 CAM, 552, 788
 Cambium, 528, 788; vascular, 519, 528
 Cambrian period, 598, 604; aquatic communities in, 603, 604, 606
 Camels, 776
 Camouflage, 575, 575
Camponotus, 397
 Cancer, 788; development of, 182; division of, 183–84; in red blood cells, 183
 Cancer cells, 463; during division, 140; growth of, 138
 Canidae, 268, 269
Canis, 268
 Canopy, 632, 634
 Canyon tree frog, 575, 575
 Cape Hatteras, 628
 Capillaries, 452, 454, 788
 Carbohydrates, 96, 97, 420, 434–36, 788; complex, 429; refined, 430
 Carbon: atoms of, 88, 96; in carbohydrates, 96; in lipids, 96, 98; in living things, 96–97; cycling of, 103–5
 Carbon cycle, 788; defined, 104; within ecosystem, 104; global warming and, 106; humans and, 105; in plants, 103–4
 Carbon dioxide, 281, 425; in blood-stream, 467; Calvin cycle and, 546–47, 546; deforestation and, 647; exercise and production of, 478–79; fossil fuels and, 699; in leaves, 515; movement in leaf structure, 514–15; photosynthesis and, 93
 Carbon pathway, 425
 Carbon-14, 595, 595, 788
 Carboniferous period, 604, 606–7, 606
Carchesium, 745
 Cardiac muscle, 484–85, 484, 788
 Cardiovascular disease, 435, 788; assessing risk for, 443–49
 Cardiovascular fitness, 788
 Carnivora, 269, 775
 Carnivores, 62, 788; aquatic, 774
 Carpel, 358, 788
 Carrot, wild, 782
 Carrying capacity, 34–38, 788; defined, 34; of earth, 39–40
 Cartilage, 397, 486, 788; skeleton of, 409
 Cartilaginous fishes, 397, 398, 772
Castilleja rhexifolia, 236
 Catalase, 113, 114
Catalog of Living Things, A, 279, 757–84
 Catalysts, 91, 787
 Caterpillar, 397, 397; gypsy moth, 7
 Cats, 775
 Cattle, 776
 Cecropia moth, life cycle of, 397
 Cell, 121–49; active transport in, 133, 133; cancer, 182–84, 463; differentiation, 173–74. *See also* Differentiation; diffusion in, 132, 132; diploid, 156; division of, 135–39; eukaryotes, 125, 125, 126–27, 128; functions of, 131–34; generalized animal, 126; generalized plant, 127; haploid, 156; interactions between, 175–76, 175; life cycle of, 135–36, 135; life in single, 344–48; microscopes to study, 124–25; observing, 141–44; passive transport in, 133, 134; prokaryotes, 125, 125, 128; reproductive, formation of, 154–58; specialization of, 138–39; structure of, 128–31; as unit of life, 6, 122–28
 Cell cycle, 135–36, 135, 788; events in, 139
 Cell membrane, 126, 128, 788; transport of material and, 134
 Cell size, diffusion and, 146–47
 Cell structure, as evidence for relatedness, 272–74
 Cell theory, 122–24, 789; development of, 123
 Cell wall, 127, 130, 789
 Cellular metabolism, Krebs cycle in, 427
 Cellular respiration, 94, 422–28, 465–67, 789; in animal cells, 403–4; energy release during, 94, 94; in flowering plants, 515; heat as by-product of, 471; photosynthesis and, 93, 94; stages of, 423; 3-carbon sugar and, 547. *See also* Respiration
 Cellular slime molds, 759
 Cellulose, 97, 103, 789; fibers in leaves, 515
 Celsius, comparison of Fahrenheit and, 726
 Cenozoic era, 605, 607–8; animals in, 608; landscapes in, 608
 Center for Reproduction of Endangered Species (CRES), 273
 Centers of origin, 696
 Centipedes, 395, 396, 766, 768
 Central nervous system (CNS), 490–91, 789; defined, 490; peripheral nervous system and, 492; psychoactive drugs and, 501, 504–5
 Centrioles, 126, 130, 789; before mitosis, 138
Centrocercus urophasianus, 579
 Centromere, 157, 789
 Century plants, 624–25, 781
 Cephalochordata, 772
 Cephalopoda, 770
 Cercaria, 410
 Cerebellum, 491, 492, 789
 Cerebratulus, 764
 Cerebrum, 490, 789
 Cestoda, 764
 Cetacea, 775
 Chaetognatha, 771
Chaetomotus, 765
 Chameleon, 773
 Chancre, 312, 789
 Channel Islands, 675
 Chaos, 743
 Chaparral, 640–41, 640, 789
 Chara, 354–55, 354
 Chase, Martha, 207; experiments of, 208
 Cheetah, 118–19; possible extinction of, 249
 Chelicerata, 766
 Chelicerates, 395, 396, 789
 Chemical bonds, 88–89, 789
 Chemical digestion, 403
 Chemical energy, 789; defined, 12; flow of, 13; from food, 93, 94; in food chain, 68; sunlight conversion to, 93
 Chemical reactions, 89–91; in cells, 131–32; enzymes and, 100–101, 101; influence of temperature on rate of, 471
 Chemical safety, 727–33
 Chemical signals, 175, 175
 Chemicals: corrosive, 728, 730–32; reactive, 728, 732–33; toxic, 728, 730
 Chemoautotrophs, 303, 789
 Chemosynthetic bacteria, 675–76
 Chemosynthetic eubacteria, 303, 789
 Chemosynthesis, 789
 Chernobyl: ecosystem around, 702–3; power plant, 703
 Chickens: artificial selection and, 240; dominance relationships among, 578; eggs and sperm of, 155; secondary sexual characteristics in, 409
Chilomonas, 743
 Chilopoda, 768
 Chimpanzee, 774; amino acid sequence in, 267
 Chiroptera, 774
 Chitin, 274, 334, 409, 789
 Chitons, 676, 769
 Chlamydia, 312–13
Chlamydia trachomatis, 313
Chlamydomonas, 278, 327, 743, 762
Chlorella, 333, 744
 Chlorine (Cl), 88–89, 746; atoms, 89; required by plants, 525
Chloroflexus, 758

- Chlorohydra viridissima*, 333
 Chlorophyll, 93, 543, 789
 Chlorophyta, 326–27, 762, 789
 Chloroplasts, 130, 333, 789; in corn leaf, 542; origin of, 286; photosynthesis in, 542; stroma of, 547; thylakoid of, 545
 Cholera, 307
 Cholesterol, 98, 99, 433, 434, 789
 Chondrichthyes, 772
 Chondrus, 761
 Chordata, 269, 397, 789
 Chordates, 789; internal skeletons of, 397–400; skeletons of, 408
 Chorion, 177, 789
 Chorionic villi sampling (CVS), 178, 178, 789
 Chromatids, 157, 789; in mitosis and meiosis, 159
 Chromatium, 302
 Chromatography, 219, 789
 Chromosome 17, 185
 Chromosome 7, 218
 Chromosome 9, 209
 Chromosome theory of heredity, 207, 790
 Chromosomes, 102, 129, 790; abnormal, 204–6; clay models of, 168; deletion in, 206, 206; duplication in, 206, 206; in gametes, 156; genes on, 209–10; inversion in, 206, 206; in mitosis and meiosis, 159; nucleoid, 296; sex, 202; translocation in, 206, 206
 Cicadas, 767
 Cilia, 331, 331, 408, 790
 Ciliates, 331–32, 331, 760, 790
 Ciliophora, 331, 760, 790
 Cincinnati Zoo's Center for Reproduction of Endangered Species (CRES), 273
 Cinnamon fern, 779
 Circulation, 452–57; blood vessels and tissues in, 456, 457; clotting and, 455–56; heart and, 452–54; plasma and, 454–55; temperature and, 412–13
 Circulatory systems, in most animals, 405
 Cirripedia, 768
 Citrate, 425
 Citrus canker, 306–7
 City forester, 521
 Cladophora, 744
 Clam worm, 769
 Clams, 674, 675, 769
 Class, 269, 790
 Classification, taxonomic, 269. *See also* Biological classification
 Clean Air Act of 1990, 705
 Cleavage, 172, 174, 790; stages of, in frog, 172
 Climate: effects on, 627–28; ecosystems, biomes, and, 626–28
 Climate warming, 699
 Climatograms, 628, 651–53, 790
 Climax community, 642
 Climbing fern, 779
 Clone, 173–74, 790
 Cloning: molecular (or gene), 216, 219; plant, 555
Clonorchis sinensis, 764
 Closed circulatory system, 790
 Closed population, 790
Closterium, 326, 744
 Clotting, 455–56
 Clotting factors, 455, 790
 Club fungi, 337, 337, 777, 790
 Club moss, 778; as seedless vascular plants, 362–64
 Cnidaria, 391, 790
 Cnidarian, 790; defined, 391; digestion in, 403; excretion in, 405; jellyfish, 392; as least complex animals, 390–92; nervous system of, 407, 408; night-blooming orange cup corals, 392; reproduction in, 410; sea anemone, 392
 CoA, 424, 790
 Coacervates, 283, 790; formation of complex, 283
 Coal Age, plant growth during, 364
 Coastal waters, 674–75
 Coastal wetlands, 678
 Cobalt, 746
 Cocaine, 504
 Cockroaches, 767; in Carboniferous period, 607
 Codominance, 200, 790
 Codons, 212, 213, 790
 CoenzymeA, 424
 Coevolution, 251–52, 790
 Cohesion-tension, 520, 790
 Coleoptera, 767
 Coleoptiles, oat, 557
Coleps, 745
Coleus, 784
Coleus leaves: accessory pigments in, 544; outer cell layer of, 125; photosynthesis in, 544
 Collard stinkhorn, 278
 Collared peccary, 776
 Collecting duct, 468
 Collins, Francis, 216, 220
 Colorado, Rocky Mountain National Park, 75
Colpidium, 743
 Columbine, 783; hummingbird and, 370, 371
 Comb jellies, 763
 Combustible substances, 728, 729–30
 Commelinaceae, 781
 Communication, 790; innate and learned, 573
 Community, 790; defined, 8; ecosystems in, 62–64; energy flow through, 13, 15; fungi in, 339–42; indirect interactions in, 62; life in, 62–66; matter cycle through, 15; producers and consumers in, 67–69
 Companion cells, 519, 790
 Competition, 64, 80–82, 790
 Complement system, 460, 790; activation of, 460
 Complexity score, 379
 Compositae, 782
 Compound, 790; defined, 13; in living organisms, 110–13; organic, 88
 Compound microscope, 733–38, 733; for biological material, 737–38; care of, 733; high power, 735–36; measuring with, 736; setting up, 734; using, 734–35
 Compound: defined, 13; in living organisms, 110–13; organic, 88
 Concentration, 132, 468, 469, 790
 Concentration gradient, 790
 Conditioned reflex, 573, 573
 Conditioning, 587–89, 790. *See also* Learned behavior
 Condor, California, 76
 Conduction, in flowering plants, 516–22
 Conidiospores, 338
 Coniferophyta, 355, 367, 780, 790
 Coniferous forest: succession in, 643; taiga as, 631, 631
 Conifers, 367–69, 780; examples of, 367
 Conjugating fungi, 335, 777
 Conjugating green algae, 762
 Conjugation, 297, 791
 Consumers, 275, 791; in communities, 67–69; defined, 8; in food chain, 10; stream, 668; top level, 68, 69; types of, 62
 Continental drift, 600, 601, 791
 Contour plowing, 683, 684
 Contraception, 165
 Controls, 24, 791
 Convergent evolution, 250, 791
 Cooper's hawks, 170
 Cooperative behavior, 580, 791
 Coordination, 483–511
 Copepoda, 768
 Copper, 748; required by plants, 524, 525
 Copper rockfish, 398
Coprinus, 777
 Coral, 763; night blooming orange cup, 392
 Coral polyps, 675
 Coral reefs, 674–75; Australian, 568–69; Caribbean, 675
Corallina, 761
Cordaites, 364
 Cork cells, 123
 Corn, 782; chloroplast of leaf, 542; cross sections of leaves of, 234
 Cornea, 175, 791
 Corpus luteum, 163, 791
 Corrosive chemicals, 728, 730–32
 Cortex, adrenal, 499, 500, 791; hormones and, 497
Cosmarium, 326

Cosmodiscus, 760
 Cottontail rabbit, 775
 Cotyledon, 371, 526, 527, 791
 Cougar, 775
 Cow, how to make, 56
 Coyotes, 584, 636; in Carnivora order, 269; scientific name of, 270–71
 Crabs, 396, 674, 675, 769; ghost, 677; land, 676
 Crack cocaine, 504
 Craniata, 772
 Crassulacean acid metabolism (CAM), 552
 Cravings, drug, 504
 Creatine phosphate, 485, 791
 Creosote bush, 638, 641
 Cretaceous period, 605; breakup of Pangaea and, 602
 Creutzfeldt-Jakob disease (CJD), 310
 Crick, F. H. C., 208
 Crickets, 767
 Crinoidea, 771
 Crisis in Gulf of Maine, 691–93
 Crocodiles, 668
 Crop dusting, 70
 Crop rotation, 706–7, 707
 Crops: cultivating combination of, 706; sand covered, 647
 Crossing-over, 157, 244–45, 244, 791; during meiosis, 209
 Cross-pollination, 195
 Cruciferae, 783
 Crustacea, 768
 Crustaceans, 791; as arthropods, 395; examples of, 396; excretory system in, 406; nervous system of, 408; in rivers, 668
 Crustose lichens, 341
 “Crystal genes,” 283
 Ctenophora, 764
 Cucumber beetle, 767
 Cultural adaptation, 700, 791
 Culture, human, 699–700, 791. *See also* Cultural adaptation; Human culture
 Currents, ocean, 672
 Cuticle, plant, 355, 514, 791
 CVS. *See* Chorionic villi sampling
 Cyanobacteria, 276, 302–3, 302, 667, 758, 791; classification of, 279; key to, 742–45; variety among, 343–44
 Cycad, 367
 Cycadophyta, 355, 780
 Cycads, 780
Cycloposthium, 760
 Cyclops, 768
 Cyclostomata, 772
 Cysteine, 213
 Cypress swamp, 678
Cyrtomium balcatum, 234
 Cystic fibrosis (CF), 193; alteration in DNA and, 220; genetic screening and, 218

Cytochrome c, 267
 Cytokines, AIDS and, 315
 Cytokinesis, 136, 138, 158, 791; mitosis and, 148–49
 Cytokinins, 554, 791; interactions of auxins and, 555
 Cytoplasm, 127, 128, 174, 423, 791
 Cytosine, 208
 Cytoskeleton, 126, 130, 791

D

Dacrymyces palmatus, 278
Dactylella drechsei, 341
 Damselflies, 766
 Dandelion, 782; pollen grains from, 358; seeds, 36
Daphnia, 389, 768
 Darwin, Charles, 238–39, 238, 556; artificial selection concept, 240–41; explanatory model of evolution, 253; impact on biology, 241–43; voyage of, 238
Dasyatis americana, 398
Dasychalina cyathina, 391
 Data, 791
Daucus carota, 782
 Day octopus, 394
 DDT, 70–71; food chain and, 71
 Death, a leading causes of, 430
 “Death cap,” 337
 Death rate, 31
 Death Valley, 580, 637
 Deciduous forests, 632–33, 632, 633; climatology of, 755; tropical, 647
 Decomposers, 663, 791; defined, 8; in food chain, 8, 9, 340; fungi as, 8, 334–35
 Decomposition, 89, 791; fungi and, 339, 340
 Deep-sea shrimp, 673
 Deer, 776; carrying capacity for, 35; secondary sexual characteristics in, 409; white-tailed, 633
 Deforestation, 42, 72–73, 698, 791; tropical, 647
 Deinococci, 758
 Deletion, 206, 206
Delphinium, 783
 Dendrites, 488, 791
 Denitrifying eubacteria, 305, 789
 Density, 791
 Dental caries, 308, 792
 Dental plaque, 792
 Deoxyribonucleic acid. *See* DNA
 Deoxyribose, 102, 792
 Depolarized neuron, 489
 Depressants, 501, 504, 750, 792
Dermacenter, 396
 Deserts, 792; climatology of, 755; mid-latitude, 637–39; plants in hot vs. cool, 638
 Desertification, 647–48, 792
Desmidium filamentous alga, 326
Desulfovibrio, 758
 Development, 792; animal, 177–81; cell differentiation and, 173–74; defined, 172; regulated, 172–76
 Devonian period, 604; land plants and animals in, 604–5; plant fossils from, 341
 Diabetes mellitus, 496, 792
Dianthus, 271
Dianthus caryophyllus, 271, 271
 Diaphragm, 465, 466, 792
 Diatoms, 327–28, 327, 760, 792; in oceans, 672; in ponds, 663; in streams, 667
Diatryma, 608
Diceros bicornis, 776
 Dicot weeds, herbicide for, 553
 Dicots, 373, 374, 782, 792
 Dicotyledons, 373, 782
Dictyophora, 278
Didinium, 745
 Dietary fiber, 436
Dietary Guidelines for Americans, 431
 Differentiation, 172, 792; cell interactions influence, 175–76; development and, 173–74
Diffugia, 743
 Diffusion, 404, 792; cell size and, 146–47; cellular, 132, 132; chemical, 403, 419–20; through membrane, 144–45
 Digestion, 792; in cnidarians, 392; of food, 89; intracellular or extracellular, 402–3; physical, 403
 Dihybrid cross, 199–200, 199, 227–31
Dileptus, 743
 Dinaomastigota, 759
 Dinoflagellates, 329–30, 330, 672, 759, 792
 Dinosaur: as early reptiles, 398; fossil of bipedal, 607; Mesozoic, 596; Triassic, 607
Dioon edule, 367
 Dioxin, 553
 Dipeptide, 99, 792
 Diphtheria, 307
 Diploid, 356, 792
 Diploid cells, 156
 Diploidy, 244–45
 Diplopoda, 768
 Diptera, 767
 Disaccharide, 97
 Discomitochondria, 760
Discorbia vesicularis, 759
 Disease, 305–11; from eubacteria, 306–8; from interrelationships, 305–6; from viruses, 308–11
 Dispersal, 36, 792; barriers to, 36–38; barriers to human, 38–39
 Divergent evolution, 250, 792
 Diversity, variation, evolution, and, 234–39
 DNA, 792; antibodies against, 461–62; cloning and, 173–74; defined, 101; in

- fossils, 596; genes in, 129, 207–9; genetic information in, 194; as genetic material, 207–9; genetic programs in, 182; in mitosis and meiosis, 159; in nucleus, 125; in viruses, 207, 208; meiosis and, 156–57; molecule, 103; nucleotide sequence of, 103; opposite strands of double helix, 209; plasmids, 296; protein synthesis and, 212–14; recombinant, 216; replication and transcription to RNA, 224–46; sequences and classification, 267, 289–93; transcription of, 213
- Dogs, 775; *Canis* genus, 268; scientific name of, 270–71; variations among, 237
- Dolphins, 775
- Dominance hierarchy, 577–78, 790
- Dominant traits, 195–96, 790
- Dormant, 792
- Dorsal, 388, 792
- Double helix, 102, 103; opposite strands of DNA, 209
- Douglas fir, 368; cross sections of leaves of, 234
- Down's syndrome, 204–5; karyotype of, 204
- Dragonfly, 397, 766
- Dragonfly nymph, 668
- Drake Passage, 670
- Draparnaldia*, 762
- Dresser, Betsy, 273
- Drosophila*: in genetic experiments, 207, 207; inheritance patterns with, 203, 204
- Drought, 648
- Drugs, psychoactive, 501, 504–5
- Duchenne muscular dystrophy, 204
- Duck-billed platypus, 774
- Ducklings, learned behavior of, 572–73
- Dugong dugon*, 776
- Dugongs, 776
- Duplication, 206, 206
- E**
- E. coli*, 219, 309, 758
- Earth: compressed history of, 284; limited carrying capacity of, 39–40; major biomes of, 626; managing, 42, 44–45; orbit around sun, 627; organization of matter on, 286–87, 287; personal commitment for managing, 708–9; views from afar, 710–12, 711, 712
- Earthworms, 769; circulatory systems of, 405; reproductive system of, 410–11; respiration of, 405
- Eating disorders, 437
- Echiniderella, 765
- Echinodermata, 771
- Echinoderms, 771
- Echinoidea, 771
- Ecologist, 18; plant, 679
- Ecology, defined, 7, 792
- Ecosystem stability: biodiversity and, 73, 75; human influences and, 69–76; species conservation and, 75–76
- Ecosystems, 792; abiotic factors and, 626–27; boundaries of, 66–67; carbon cycles within, 104, 105; at Chernobyl, 704; climate, biomes, and, 626–28; communities and, 61–85; defined, 62; factors influencing change in, 641; flowing freshwater, 667–69; human culture and, 696; long-term changes in, 654–55; managing human-affected, 695–717; ocean, 670–77; photosynthesis and productivity of, 542–44; reconstructing the past, 594–98; stability of. *See* Ecosystem stability; standing freshwater, 662–66; structure of, 66–69; succession in, 642–45; vent, 674; wetlands, 677–80
- Ecstasy, 504
- Ectoderm, 173, 173, 175, 175, 792
- Ectothiorhodospira mobilis*, 302
- Effector, 490, 792
- Egg cell, fertilization process and, 156, 156
- Eggs, of several organisms, 155
- Eimeria magna*, 760
- Electra*, 770
- Electron microscopes, 124
- Electron transport system, 423, 423, 426–27, 426, 792; photosynthesis and, 545
- Electrons, 88, 792; photosynthesis and, 545
- Electrophoresis, 219, 793
- Elements, 793; defined, 13; in human body, 14; important to humans, 746–47; periodic table of, 741; required by plants, 525; trace, 746–47
- Elephant, 389; African, 76, 776
- Elephantheads, 370
- Elephants, 639, 776
- Elk, 574, 584
- Embryo, 793; in bean seed, 360; developing human, 177–82, 179, 181; development, in flowering plant, 360; development, in vertebrates, 235; mammalian, 177–82, 180, 181
- Embryo transfer, 218
- Emigration, 32, 793
- Emphysema, 466, 793
- Emulsification, 420
- Endocrine glands, 494, 793
- Endocrine system, 494–500, 793; blood glucose levels and, 495–96; composition of, 495; defined, 494; hormones in, 494–95; hypothalamus and, 496–500; pituitary gland and, 496–500
- Endoderm, 173, 173, 793
- Endoplasmic reticulum, 127, 129, 793
- Endoskeleton, 409, 793
- Endosperm, 359, 793; in bean seed, 360
- Endospora, 758
- Endospores, 297, 793
- Endosymbiosis hypothesis, 333
- Energy, 793; biological activity and, 11–12; carbohydrates and, 97; for cell activities, 131–32; chemical, 12, 68; classification of, 91; defined, 92; flow of, 14, 15, 68; food, 41; as foundation of life, 11–15; glycolysis and production of, 423–24; release from food, 94–95, 94; stored, 95; sun, photosynthesis, and, 92–93; storage compounds, 98
- Energy pyramid, 68, 69, 793
- Ensatina eschscholtzii*, 257
- Enteromorpha*, 762
- Environment, 793; abiotic, 32; biotic, 32; defined, 32; degradation of, 700; ethical decisions about, 707–8; human activities and, 41–42; individuals, populations, and, 30–34; photosynthesis and, 548–52; of polar bears and penguins, 37; population size and, 32–33; survival and, 580–86
- Environmental degradation, 700
- Environmental tolerance, 589–91
- Enzymes, 91, 793; activity of, 113–17; chemical reactions and, 98–99, 100–101, 101; digestive, 419; rubisco, 550
- Enzyme-substrate complex, 101, 101, 102, 793
- Eoastrion*, 297
- Ephemeroptera, 766
- Epidermal ectoderm, 173
- Epinephrine, 499–500, 793
- Epipedobates tricolor*, 398
- Epiphytes, 634, 793
- Epistylis*, 745
- Equisetum*, 363, 779
- Erethizon dorsatum*, 775
- Erwinia amylovora*, 307
- Escherichia coli* (*E. coli*), 219, 309, 758
- Esophagus, 418, 793; peristalsis in wall of, 418
- Essential amino acids, 436–37
- Essential nutrient, 793
- Estivation, 639, 793
- Estrogen, 163, 793
- Estuaries, 677; low tide in coastal, 678
- Ethiopia, famine in, 43
- Ethylene, 554, 793
- Eubacteria, 297, 702, 793; anaerobic photosynthetic, 302; archaeobacteria, eukaryotes, and, 299; chemosynthetic, 303; control of, 319–21; denitrifying, 305; as diverse, 301–3; *Escherichia coli*, 309. *See also* *E. coli*; nitrifying, 304–5, 305; nitrogen cycle and, 303–5; as pathogens, 306–8; purple nonsulfur, 302; sexually transmitted diseases from, 312–13; wall types of, 301
- Eubacteria subkingdom, 758
- Eudorina*, 744

Euglena, 329, 330, 744
Euglena gracilis, 760
 Euglenoids, 329, 793
 Eukarya, 759
 Eukaryotes, 125, 793; animals, 387–413;
 archaeobacteria, eubacteria, and, 299;
 cell structure of, 274; fungi. *See* Fungi;
 genes in, 215; in Kingdom charts, 276;
 models of origins, 333; plants, 353–85;
 vs. prokaryote, 274, 274, 275; protists.
 See Protists
 Eukaryotic cells: organelles in, 129–31;
 structure of, 128
 Eukaryotic mRNA, 215
 Euphorbia, 251
Euplates, 745, 760
Eurypharynx pelecyanoides, 674
Eusthenopteron, 597
 Eutrophic, 681, 793–94
 Eutrophication, 699, 702
 Evaporation, of body heat, 471–72
 Everglades National Park, 72, 680
 Evergreens, conifers, 367–69
 Evolution: coevolution, 251; convergent,
 250; defined, 243; divergent, 250;
 diversity, variation, and, 234–39;
 genetics and, 243–52; isolation and
 speciation, 247–50; of land plants,
 354–61; mechanisms of, 245–46; nat-
 ural selection and, 240–43; parallel,
 250; of photosynthesis, 285–86; plate
 tectonics and, 599–603; time and,
 617–19; various patterns of, 250–52
 Excretion, 405–7, 794; kidneys, 467–687;
 nephrons, 468–69
 Exercise: carbon dioxide production and,
 478–79; cardiovascular fitness and,
 487; pulse rate and, 474–75
 Exons, 215–16, 794
 Exoskeletons, 408–9, 794
 Experimental methods, 24–27
 Exposure, 67
 Extensors, 487, 794
 Extinct, 73, 794
 Extinctions, 598; Cheetah, and possibil-
 ity of, 249
 Extracellular digestion, 402–3, 402
 Exxon Valdez oil spill, 294–95, 702
 Eye, human, vision and, 493, 493

F

F₁, 794
 F₂, 794
 Fabaceae, 783
 Fagaceae, 783
 Fahrenheit, comparison of Celsius and,
 726
 Fairy shrimp, 768
 Family, as biological classification, 268,
 794
 Famine, 794; in Africa, 43; defined, 40

Farmers, effect on food web, 70
 Farming, underwater, 675
 Fast-food lunch, analysis of, 430
 Fats, 420; saturated, 429, 430, 431, 434;
 unsaturated, 431, 433
 Fatty acids, 98, 98, 431
 Feather stars, 771
 Feces, 421, 794
 Feedback system, 794
Felis concolor, 775
 Female reproduction, 163; birth control
 and, 165; embryos, 177–82;
 menopause, 164; menstrual cycle and,
 162–64, 164; prenatal diagnosis, 178
 Fermentation, 427, 794
 Fern trees, 73
 Ferns, 779; cinnamon, 779; climbing,
 779; Coal Age, 364, 364; cross sections
 of leaves of, 234; fossil, 594; grape,
 779; leaves from underground stems,
 364–65; Paleozoic seed, 599, 599;
 sword and wood, 277; water, 779;
 whisk, 363, 779
 Fertilization, 156, 794; in vitro, 218, 273;
 sex determination during, 202
 Fetal alcohol syndrome, 180, 182
 Fetus, 794; developing human, 179, 181;
 human, 179, 180
 Fibrin, 455, 456, 794
 Fibrinogen, 455, 456, 794
 Fibronectin, 175
 Fibrous root system, 523, 524
 Field, population density in, 33
 Field mustard, 783
 Field observation, 22–23
 Field sparrow, tolerance of, 583
 Fight-or-flight response, 500, 794
 Figwort family, 784
 Filicinophyta, 779
 Filtration, 468, 469, 794
 Finches: as urban wildlife, 584;
 Galápagos, 238, 239
 Fir trees, 31, 31
 Fire: in chaparral, 641; effect on biomes,
 656–59
 Fire blight, 306, 307
 Fireflies, 767
Fischerella, 302
 Fish: bony, 397–98, 398, 772; cartilagi-
 nous, 397, 398, 772; eggs and sperm of,
 155; flying, 772; gills in, 404, 404; jaw-
 less, 772; reproductive system of, 411
 Flagella, 274, 794
 Flagellates, 329–30, 760; symbiotic, 330
 Flame cells, 406, 406, 794
 Flamingo, 773
 Flammable substances, 728, 729–30
 Flatworms, 392, 764, 794; marine, 393;
 nervous system of, 407, 408; reproduc-
 tive systems in, 410
 Flexors, 487, 794
 Flies, 767; inheritance patterns in, 202–4

Floods, rivers and, 667
 Florida: Everglades National Park, 680;
 Rainbow Springs, 669, 669; Silver
 River, 669
 Florida scrub jays, 580, 580
 Flowering plants, 781; as diverse group of
 land plants, 372–74; embryo develop-
 ment in, 360; fertilization in, 359;
 form and function of, 513–40; growth
 of, 526–28; leaf structure of, 514–16;
 life cycle of, 358–60, 359; mainte-
 nance and coordination of, 541–67;
 photosynthesis in, 542–47; plant
 growth in, 542–47; pollination in, 360;
 pollinators of, 370–71; reproductive
 adaptations of, 358–61; roots and
 absorption in, 523–26; seeds of,
 371–72; stems and conduction,
 516–22; sun and, 7. *See also* Flowers
 Flowers: bees and, 24–27; examples of
 diversity of, 370; insect-pollinated,
 371; wind-pollinated, 371. *See also*
 Flowering plants
 Flowing freshwater ecosystems, 667–69;
 brooks, 667, 667; streams, 667–68. *See*
 also Flowing waters
 Flowing waters, 661; as laboratory, 668–69.
 See also Flowing freshwater ecosystems
 Flukes, 392, 764; life cycle of, 410
 Fluoride, 747
 Flying fish, 772
 Follicle, 163, 794
 Follicle-stimulating hormones (FSH),
 163–64, 794
 Food, 794; chemical energy from, 93, 94;
 digestion of, 89; organisms and, 7;
 serving vs. helping of, 432; uneven
 distribution of, for humans, 40–41
 Food chain, 794; chemical energy in, 68;
 decomposer, 340; decomposers in, 8, 9;
 defined, 8; fungi in, 339, 340; ocean,
 672; organisms in, 8–11
 Food energy, 41; investigation into,
 439–42; lipids as concentrated sources
 of, 431–34; sun and photosynthesis
 supply of, 12
 Food Guide Pyramid, 432
 Food web, 9–11, 10, 794; defined, 9;
 farmers' effect on, 70; matter cycle
 through, 14, 15. *See also* Food chain
 Foraminifera, 759
 Foraminiferans, 330–31, 330, 794
 Forensic anthropology, 613
 Forest: coniferous, 631, 631; deciduous,
 632–33, 632, 633; midlatitude, 632–33
 Fossil fuels, 698, 699
 Fossils, 267, 794–95; brittle star, 592–93;
 dating techniques, 594–95; informa-
 tion from, 596–98; Neanderthal skull,
 612; plant, from Devonian period, 341;
 record of hominids, 615; trace, 268;
 trilobite, 598; variety of, 594

- Fox: in Carnivora order, 269; in food chain, 8–11, 8–10; *Vulpes* genus, 268
 Fox, Sidney, 283–84
Fragilaria, 743, 760
 Freshwater ecosystems: flowing, 667–69; standing, 662–66
 Freshwater mussel, 668
 Fringed basket sponge, 763
 Frog: canyon tree, 575, 575; conversion of tadpole to, 177; differentiated cell experiment with, 174; eggs and sperm of, 155; gastrula development in, 173; life cycle of leopard, 152; mating of, 177; neural groove in embryo of, 176; phantasmal poison, 398; poison arrow, 575; respiration of, 404; scientific name of, 270–71; stages of cleavage in, 172; tadpole stage of, 177; tree, 770
 Fruit flies, 203
 Fruits: as mature ovaries, 373; controlled ripening of, 554; diversity among, 372; seeds and, 383–85
 Fruticose lichens, 341
Fuirena, 781
 Fungi, 65, 795; as decomposers, 8, 334–35; bracket, 337, 777; club, 337, 337, 777; in community, 339–42; conjugating, 335, 777; in food chains, 339; growth of, 349–51; imperfect, 337–38, 338; lichens, 341–42; mycorrhizal, 339, 341; in ponds, 663; predacious, 341; red cup, 336; sac, 335–36, 336, 777; slime mold resemblance, 332, 334; typical, 278
 Fungi kingdom, 276, 277, 278, 777
Fusarium, 777
 Fusion inhibitors, 315
- G**
- G₁, 795
 G₂, 795
 Gaia hypothesis, 285–86, 795
 Galápagos Islands, 82, 238, 795; finches on, 238, 239; giant tortoises of, 152–53
 Galápagos Rift, 673
 Gametes, 795; chromosomes in, 156; in fertilization process, 156; in males vs. females, 160–62; meiosis and, 156–58; as reproductive cells, 154, 156
 Gametophyte, 356, 795; fern, 365; in land plants, 360; of lily, 359
 Gamophyta, 762
 Ganglion, 407, 795
 Gannets, nesting sites of, 578
 Garden of Eden (ocean), 674
 Garden snail, 770
 Garden spider, 766
 Gas exchange, photosynthesis, 561–64
 Gases, volcanic, 281
 Gastric juice, 419, 795
 Gastropoda, 770
 Gastrotricha, 765
 Gastrula, 172–73, 173, 795
 Gastrulation, 795
 Gazelles, 639
 Gene cloning, 216
 Gene flow, 246, 795
 Gene pool, 244, 795
 Genes, 129, 795; biosynthesis directed by, 210–14; breast cancer, 185; on chromosomes, 209–10; crystal, 283; determining biological potential, 194; DNA in, 207–9; as DNA nucleotide chains, 208–9; genetic maps, 210, 210; linked, 209; Mendel's work on, 194–96; oncogenes, 183; proto-oncogenes, 183; tumor suppressor, 184; as unit of heredity, 196–98. *See also* Genetic material
 Genetic code, 234
 Genetic drift, 246, 246, 795
 Genetic engineering, 216–20; recombinant DNA technique of, 219
 Genetic material, hereditary role of, 194–98. *See also* Genes
 Genetic screening, 218, 220
 Genetics, evolution and, 243–52
 Genome, 795
 Genotype, 196–97, 795
 Genus, 268, 795
 Geologic Time Scale, 594, 752
 Geological events, major, 753
 Geranium, tolerance range of, 582
 Ghost crab, 677
 Giant sequoia, 353
 Giardia, 648
 Gibberellins, 553–54, 795
Gigantactis macronema, 674
 Gila monster, 773
 Gills, 404, 404, 795
Ginkgo biloba, 367, 780
 Ginkgophyta, 355, 780
 Giraffes, 639
 Gizzard, 795
 Glaciers, lake formation and, 664
Gladiolus, 781
 Gland: endocrine, 494; pituitary, 163, 496–500; thyroid, 499
Gleocapsa, 302
 Global warming, 19; carbon cycle and, 106
Gloeocapsa, 744, 758
 Glomerular capsule, 468, 795
 Glomerulus, 468, 795
Glossopteris, 599
Glossopteris ferns, distribution map of extinct, 599
 Glucagon, 495–96, 795
 Glucose, 422; blood, hormones and, 495–96; Krebs cycle and breakdown of, 425–26
 Glutamate, 213
 Glutamine, 98, 98, 213, 420, 427
 Glycerol, 795
 Glycine, 213
 Glycine molecule, 99
 Glycogen, 795; muscle contractions and, 485
 Glycolysis, 423, 423, 424, 795; anaerobic respiration and, 427; in production of energy, 423–24
 Glycylalanine, 99
 Gnetophyta, 780
 Goats, 776
 Golgi apparatus, 127, 129, 795; electron micrograph of, 129
Gonium, 744
 Gonorrhea, 312
Gonyaulax, 759
 Gopher, scientific name of, 270–71
 Gopher turtle, scientific name of, 270–71
Gordius, 765
 Gorilla, 774; relationship between chimps and humans, 267
 Goslings, learned behavior of, 572–73
 Gradualism, 250
 Gram-negative eubacteria, 758
 Gram-positive eubacteria, 758
 Grana, 542, 542, 795
Grantia, 763
 Granuloreticulosa, 759
 Grape fern, 779
 Grapes, effect of gibberellic acid on, 554
 Grass family, 782
 Grasses, in food chain, 9, 10
 Grasshoppers, 767; spider and, 6–7, 6; in food chain, 9, 10
 Grassland: climatogram of, 755; savannas, 639, 640; types of, 635–36
 Gravitropism, 557–58, 557, 795
 Great Basin, 637
 Great blue heron, 63
 Great horned owl, 584
 Great Salt Lake, 666
 Grebe, oil-soaked, 683
 Green algae, 327, 762; as ancestors of plants, 326–27; conjugating, 762; in lichen hyphae, 341; multicellular, 354–55, 354; in ponds, 663; unicellular, 122. *See also* Chlorophyta
 Green frog, scientific name of, 270–71
 Green snake, 399
 Green toad, 772
 Greenhouse effect, 106
Gregarina, 331, 760
 Grizzly bears, 386–87, 584
 Ground squirrels, 581; scientific name of, 270–71
 Ground thorn, 641
 Group A streptococcus (GAS), 307
 Growth phase, 135–36, 135
 Growth rate, 35
 Guanine, 208
 Guard cells, 515–16, 515, 795–96
 Gulf of Maine, crisis in, 691–93
 Gulf Stream, 628

Gulls, 578
 Gut, 796
Gymnodinium, 330
 Gypsy moth caterpillar, 7

H

Habitat, 64, 796; preservation of, 75–76
 Hagfish, 772
Haliaeetus leucocephalus, 574
 Half-life, 796
 Hallucinogens, 751, 796
 Halobacteria, 300
Haloferax volcanii, 757
 Halophiles, 300, 757, 796
 Hang fly, 579
Hantzschia, 743
 Haploid, 356, 796
 Haploid cells, 156
 Hares, 775
 Harvestmen, 766
 Harvey, William, 453
 Hat thrower fungus, 278
 Hazardous chemicals: categories of, 728; defined, 727
 Health, dietary habits and, 429–31
 Heart, circulation and, 452–54, 452, 453
 Heart attack, 435, 456
 Heart disease, risk factors for, 433
 Heat, 12, 94; body, 471; heat loss, 471–73
 Hedgehogs, 774
Helianthus, 782
Heliobatus radions, 594
 Heliozoans, 762
 Helleboraceae, 783
 Hellebore family, 783
 Helper T cells, 458, 459, 459
 Helping of food, 432
Hemectyon ferox, 391
 Hemichordata, 771
 Hemiptera, 767
Hemitrachia, 759
Hemitrachia clovata, 332
 Hemlock, 780
 Hemoglobin, 455, 467, 796
 Hemophilia, 456, 796
 Hens, white leghorn, 578
 Hepatophyta, 778
 Herbaceous, 796
 Herbaceous plants, 373
 Herbaceous stems, 517
 Herbivores, 62, 796
 Heredity: chromosome theory of, 207; definition of, 194; genetic variation and, 193; Mendel's identification of unit of, 196–98; role of genetic material in, 194–98; variations, 244
 Herpes, 312
 Hershey, Alfred, 207; experiments of, 208
 Heterotroph hypothesis, 284, 285, 796
 Heterotrophs, 275, 282–84, 796
 Heterozygote, 200
 Heterozygous, 197, 796; red-flowered plants, 244–45, 244
 Hexapoda, 766
 Hibernation, 581, 581, 796
 Hierarchy, dominance, 577–78
 High-fiber diet, 436, 436
Hinnites giganteus, 394
 Hippopotamus, 776
Hippopotamus amphibious, 776
 Hirudinea, 769
 Histamine, 458, 796
 Hister beetle, 767
 Histidine, 213
 Histoclear™, 564
 HIV. *See* Human immunodeficiency virus
 Hoffman, Mike, 613
 Holothuroidea, 771
 Holtzman, Neil A., 218
 Homeostasis, 796; defined, 35; kidney failure and, 469; kidneys and, 479–81; nervous systems and, 492
 Hominids, 610, 696, 796; fossil record of, 615
Homo erectus, 610–11, 796; skull of, 611, 614; stone tools used by, 612
Homo habilis, 610, 611, 796
Homo sapiens, 774; classification of, 279; skull, 614
Homo sapiens neanderthalensis, 611, 612, 796
Homo sapiens sapiens, 612, 614, 796
 Homologies, 266–67, 796
 Homoptera, 767
 Homozygous, 197, 796
 Honeybee, 768; communication by, 574; cooperative behavior of, 581
 Hooke, Robert, 123, 130–31
 Hookworm, 765
 Hormones, 796; as chemical messengers, 494–95; in endocrine system, 495–96; in menstrual cycle, 164; origins and effects of, 497–98; plant, 552–54, 554, 556; reproductive cycles and, 162–66
 Hornworts, 361, 361, 362, 778
 Horsefly, 767
 Horsehair worms, 765
 Horses, 776
 Horseshoe crab, 396, 766
 Horsetails, 362–64, 363, 779
 Host, 305, 796
 Housefly, 767
 Human animal: aerobic respiration in, 425–26; anaerobic respiration in, 427–28; cellular respiration in, 422–28; circulation in, 452–57; circulatory system of, 452; coordination in, 483–511; digestive system in, 419; endocrine system in, 494–500; excretion, 467–69; heart of, 453, 454; immunity in, 457–64; ingestion and digestion in, 418–22; maintenance of internal environment, 451–81; muscular system of, 484–87; nervous system in, 488–94; nutrition for, 429–38; psychoactive drugs and, 501–5; respiration, 465–67; stress and, 501; temperature regulation in, 471–73; vision in, 493. *See also* Humans
 Human body, elements in, 14
 Human cheek lining, cells from, 124
 Human chromosomes, X and Y, 202–4
 Human culture: agriculture and, 696–98; industrial revolution and, 698; population growth and, 700, 701; role in ecosystem, 696; technology and, problems from, 699–700
 Human eye, 493, 493
 Human female: gamete development in, 161–62; ovum production in, 161–62; reproductive system, 163
 Human Genome Project, 216, 217
 Human immunodeficiency virus (HIV), 313
 Human male: gamete development in, 160–61; meiotic division in, 160; reproductive system in, 161
 Human populations, 38–45; barriers to dispersal and, 38–39; earth management and, 42, 44–45; earth's carrying capacity and, 39–40; environmental changes by activities of, 41–42; food distribution and, 40–41; growth of, 39, 53–54
 Human reproduction, 160–66; birth control, 165; developing embryo, 177, 179, 181; developing fetus, 179; fertilization, 166; gamete development, 160–62; hormones and, 162–66
 Human sperm, 150–151, 160
 Humans, 774; activity of, animal behavior and survival and, 584–86; biodiversity and, 73, 75; biosphere and, 16; carbon cycle and, 104, 105; cultural adaptation of, 700. *See also* Human culture; diversity of organisms and, 71–73; eggs and sperm of, 155; elements important to, 746–47; emergence of, 609–14; first, 610–14; as hominids, 610; influence on biomes, 646–49; influences on aquatic ecosystems, 677–84; power to shape environment, 708; as primates, 609–10; reproduction of. *See* Human reproduction; scientific name of, 270–71; species conservation and, 75–76; stability of ecosystems and, 69–71; wastes of, in oceans, 681–83; vitamins important to, 749. *See also* *Homo sapiens*; Human animals; Human females; Human males; Human populations
 Humboldt current, 628
 Hummingbirds, 370, 371; broad-tailed, 773
 Humpback whale, 400

Hyacinth, chromosomes in root tip cell of, 138

Hyacinthus orientalis, 138

Hyaena hyaena, 775

Hybridomas, 463

Hybrids, 197, 796; fertile, 236

Hydra, 763

Hydra viridis, 333

Hydras: gas exchange in, 403, 404; reproduction of, 153; reproduction in, 410, 410

Hydrocarbon-oxidizing eubacteria, 702

Hydrocarbons, 702

Hydrochloric acid, in gastric juice, 419

Hydrodictyon reticulatum, 327

Hydrogen, 281; ions of, 90, 90; in water molecule, 14

Hydrogen atom, 88

Hydrogen peroxide (H_2O_2), 113, 115

Hydrosira, 760

Hydroxide ions, 90, 90

Hydrozoa, 763

Hyena, 639, 775

Hymenoptera, 768

Hyperbaric medicine, 470

Hyphae, 334, 796

Hypoglycemia, 496, 796

Hypothalamus, 162, 796; endocrine system and, 496–500; hormones and, 496, 497–98; thermal receptors and, 472, 472

Hypothesis, defined, 17, 796

I

Ichthyostega, 597

Immigration, 32, 797

Immune response, 457, 458, 797; interactions during specific, 462; to primary and secondary antigen exposures, 461; production of antibodies in specific, 459

Immune system, 458, 797; major cells of, 458; problems in, 461–64; proteins and, 454–55. *See also* Immunity

Immunity, 306, 457–61, 797; nonspecific protection and, 457–58; secondary, 461; specific protection and, 458–61. *See also* Immune system

See also Immune system

Impala, 776

Imperfect fungi, 337–38, 338, 797

Incubation period, 797

In vitro fertilization, 218, 273

Indian paintbrush, 236, 236, 370

Individuals, in populations, 30

Indonesia, water buffalo in, 697

Industrial revolution, 698

Industrialized agriculture, 698, 698, 797

Infections, slow brain, 310

Infectious disease, 797

Inflammatory response, 458, 797

Informatics, 217

Ingestion, 402, 797; digestion and, in humans, 418–22

Inheritance, multifactorial, 201

Inheritance patterns: abnormal chromosomes and, 204–6; dihybrid crosses, 199–200; phenotype of genetic inheritance, 200–201; X-linked traits and, 202–4, 203

Inland wetlands, 677–80

Inland-water ecosystems, 661

Innate behavior, 572, 797

Inorganic acids, 730–31

Insecticides, 70–71

Insectivora, 772

Insects, 766; as arthropods, 396–97, 397; in food chain, 8–11, 8–10

Instinct, 572, 797

Insulin, 495–96, 797

Interactions: indirect, 62; among organisms, 6–11; of populations in community, 62–64

International System of Units (SI), 725–26

Interneurons, 489–90, 797

Interphase, 135, 135, 137, 138, 139, 797

Intertidal zone, 676–77, 797

Intestinal juice, 797

Intestinal villi, 421

Intestine: large, 421–22; small, 420–21

Intracellular digestion, 402–3, 402

Introns, 206, 206, 215, 797

Invertebrates, in Carboniferous period, 607

Iodine, 747

Iodine solution, Lugol's, 143, 563, 738

Ion, 89, 797

Ionization, 90, 797

Iridaceae, 781

Iris, 781

Iris family, 781

Iron, 747; required by plants, 525

Irrigation techniques, 44

Isoleucine, 213

Isopropyl alcohol, 563

Isoptera, 766

J

Jackrabbit, black-tailed, 637

Jacob's ladder, 784

Jawless fish, 772

Jellies, 763; tolerance ranges of, 582–83, 583

Jelly fungus, 278

Jellyfish, 392, 406

Jenner, Edward, 306, 306

Joints, 486, 797

Juniper, 368, 780

Juniperus, 780

Juniperus chinensis pfitzerii, 368

Jurassic period, 592–93, 607; breakup of Pangaea and, 602; diatoms from, 328

K

Kangaroo, great red, 774

Kangaroo family, 401

Kangaroo rat, 639, 639

Kaolinite clays, repeating structure in, 283

Kaposi's sarcoma, 313

Karyotypes, 202, 202, 797; of Down's

Syndrome, 204

Kcal, 797; in common foods, 748

Kelps, 675; beds in Channel Islands, 675

Kidneys, 467–68, 467, 468, 797; homeostasis and, 467–68, 479–81

Killer T cells, 458, 458, 460, 461, 797

Kilocalories 41, 429

King penguin, 773

King, Mary-Clair, 185

Kingdom, 269, 797; classification of organisms from each, 279; of organisms, 272–79, 276. *See also* *A Catalog of Living Things*

Kinorhyncha, 765

Kitten, innate behavior of, 572, 572

Klinefelter's syndrome, 205

Koala, 774; tolerance of, 583, 583

Krebs cycle, 423, 423, 428, 547, 797; breakdown of glucose and, 425–26; in cellular metabolism, 427

L

La Brea tar pits, 607–8

Labiatae, 784

Laboratory: accident procedures in, 723; caution symbols, 721; electrical equipment in, 722; general procedures for, 719–26; glassware, 722; heat in, 722; measurements, 725–26; record keeping in, 723–25; reports, 724–25; safety in, 719–23; specimens in, 722–23

Lactate, 427–28, 428

Lactic acid, 427

Lactose intolerance, 432

Lactuca sativa, 270

Ladybird beetles, population of, 30, 30

Lagomorpha, 775

Lakes, 664–66; mountain, 664; pollution in, 681; salinization of, 666; succession in, 664; thermocline in, 665

Lamarck, Jean Baptiste, 241

Lamiaceae, 784

Laminaria, 761

Lampreys, 772

Lampshells, 770

Lancelets, 772

Land crabs, 676

Landforms, climate and, 627–28

Larch, 780

Large intestine, 421–22

Larix, 780

Larkspur, 783

Larval stage, 397, 797

Latent, 797

Lathyrus odoratus, 783

- Latitude: climate and, 627–28; vegetation in, 630
 Lazuli bunting, 773
 Leaf blades, 514, 514
 Leaf structure: carbon dioxide movements and, 514–15; guard cells and, 515; simple and compound, 514
 Leafhoppers, 767
 Learned behavior, 572, 798. *See also* Conditioning
 Leaves: functions of, 514; structural adaptations of, 534–36; surface of, 515
 Leech, 63, 65, 769
 Leeuwenhoke, Anton van, 123
 Leggit, Marjorie, 375
 Legumes, 783
 Leguminosae, 783
 Lemmings, 35–36, 36
 Lemurs, 774
 Length measurements, 725
 Lens, 798
 Lenticels, 517, 798
 Leopard frog, life cycle of, 152
Lepidodendron, 364
 Lepidoptera, 767
 Leprosy, 307
 Leucine, 213
 Lichens, 64–65, 341–42, 642, 777, 798; crustose, 341; fruticose, 341; reindeer moss as shrubby, 342, 342
 Life cycle, 798; alternation of generations, 356; of cecropia moth, 397; of moss, 357, 380–82; of unicellular green alga, 327; yeast, 186–91, 190
 Life: cells as units of, 122–28; energy for, 92–96; foundations of, 11–15; origin of, 280–87; sequence of events leading to first, 282; in single cell, 344–48; web of, 5–27
 Ligaments, 486, 798
 Light: penetration into water, 671; photosynthesis and, 542–44; satellite images of, 3
 Light reactions, 544, 544, 546, 798; oxygen gas as by-product of, 545–46
 Liliceae, 782
Lilium tigrinum, 782
 Lily, gametophytes of, 359
 Lily family, 782
Limenitis archippus, 575
 Limiting factor, 32, 798
Limulus, 766
Limulus polyphemus, 396
Linaria vulgaris, 784
Lingula, 770
 Linnaeus, Carolus, 271
Linnea borealis, 783
Liochlorophis vernalis, 399
 Lion: mountain, 400; scientific name of, 270–71
 Lipid bilayer, 128
 Lipids, 96, 420, 431–34, 798
 Liver fluke, stained, 764
 Liver, 420
 Liverworts, 361, 361, 362, 778
 Living organisms: as both similar and varied, 234–35. *See also* Living things; Organisms; compounds in, 110–13; as organized systems, 92
 Living things: biosphere as home to, 15–19; carbon in, 96–97; catalog of, 757–84; interactions among, 6–11. *See also* Living organisms; Organisms; matter in, 13–15
 Lobster, 396, 769; spiny, 396
 Locomotion, muscles and skeleton for, 408–9
 Long water cycle, 666
 Los Angeles Zoo, 273
 Louse, 767
 Lovelock, James, 285
Loxodonta africana, 776
 Lucy (australopithecine), 610, 610
 Lugo, Ariel, 18
 Lugol's iodine solution, 143, 563, 738
Lumbricus, 395
 Lungfish, Australian, 607
 Lupus, 462
 Luteinizing hormone (LH), 163–64, 798
Lutjanus apodus, 398
Lycopodium perlatum, 337
 Lycopphyta, 362, 778, 798
Lycopodium, 778
 Lyme disease, 395–96
 Lymph, 421, 456, 798
 Lymph nodes, 456, 798
 Lymph vessels, 456, 798
 Lymphatic system, 421, 456, 457, 798
 Lymphocytes, 458, 798
 Lymphokines, 459, 798
 Lyon, Mary, 205
 Lysine, 213
 Lysosomes, 126, 130, 403, 798
- M**
- Macrocystis pynfera*, 328
 Macronuclei, in ciliates, 332, 798
 Macronutrients, 798; for flowering plants, 524, 525
 Macrophages, 458, 458, 798
 Mad cow disease, 310
 Madagascar periwinkle, 75, 75
 Magma, 602
 Magnesium, 746; required by plants, 525
 Maidenhair tree, 367
 Maine, crisis in Gulf of, 691–93
Malacosteus indicus, 674
 Malacostraca, 769
 Malaria, 306; sporozoans and, 331
 Malthus, Thomas, 238
 Mammalia, 269, 774
 Mammalian embryos, 177–82, 180, 181
 Mammals, 774; adaptive radiation in, 248; as chordates, 399–400; egg-laying, 774; even-toed hoofed, 776; hibernation and, 581; insect-eating, 774; nervous system of, 408; odd-toed hoofed, 776; pouched, 774
 Mammary glands, 400, 798
 Manatees, 400, 585, 776
 Mandibulata, 766
 Manganese, 748; required by plants, 525
Manis, 775
 Maple, cross section of young stem, 122
 Marbled salamander, 398
Marchantia, 778
 Margulis, Lynn, 285, 757
 Marigolds, 373; marsh, 633
 Marine organisms, water salinity, 581
 Marine snow, 673
 Marmoset, 774
Marmota monax, 775
 Marsh marigold, 633
 Marshall, Dave, 74
Marsilea, 779
 Marsupialia, 774
 Marsupials, 401, 603, 798; as chordates, 400
 Masked booby, 82
 Mass measurements, 725–26
 Mating behavior, 576, 798
 Matter: atoms in, 88. *See also* Atoms; cycling of, 14, 15; as foundation of life, 11–15; in living things, 13–15; organization of, 286–87, 287
 Mayapple, 633
 Mayflies, 663, 766
 McGannon, Jim, 521
 MDMA, 504
 Meadow pipit, 37, 37
 Measurement: Celsius vs. Fahrenheit, 726; International System of Units, 725–26; length, 725; mass, 725–26; temperature, 726; volume, 726
 Medulla, adrenal, 491, 499, 500, 798; hormones and, 497
Megazostrodon, 597
 Meiosis, 798; crossing-over during, 209; defined, 156; gametes and, 156–58; vs. mitosis, 159; model of, 168–69
 Membrane: diffusion through, 144–45; of eukaryotic cells, 128–29; nuclear, 129
 Memory cells, 458, 458, 798
 Mendel, Gregor, 194; concept of gene by, 194–96; experiment results, 197; identification of heredity unit by, 196–98; principle of independent assortment, 199
 Menopause, 164, 798
 Menstrual cycle, 162–64, 164, 798
 Menstruation, 798
Mentha, 784
Meolsira, 743

- Mercchantia polymorpha*, 361
 Mercury pollution, 682
 Mergansers, learned behavior of, 572
Mergus merganser, 572
Merismopedia, 744, 758
 Meristems, 527, 798; location of, 527
 Merostomata, 766
 Mesoderm, 173, 173, 798–99
 Mesophyll cells, 514, 551, 551, 799
 Mesosome, 799
 Mesozoic era, fossil from, 596
 Mesquite plants, 638, 638
 Metabolism, 131, 471, 799; hibernation and, 581
 Metamorphosis, 396, 799
 Metaphase, 136, 137, 799
 Metaphase I, 157, 157
 Metaphase II, 157, 158
 Metastasis, 183, 799
 Meteorites, on primitive earth, 283
 Methamphetamines, 504
 Methane, 281, 300
Methanobacterium, 755
Methanobacterium ruminantium, 300
 Methanogens, 300, 300, 757, 799
Methanopyrus kandleri, 757
Methanosarcina barkeri, 757
Methanospirillum hungatei, 300
 Methionine, 213
 Metric system. *See* International System of Units
 Mice, in food chain, 10
Micrasterias, 326
Micrococcus, 758
Microcystis, 744
 Microfossils, oldest known, 280
 Micronuclei, in ciliates, 332, 799
 Micronutrients, 799; for flowering plants, 524, 525
 Microorganisms, 799; defined, 8; distribution of, 317–19
 Microscope: 733–38, 733. *See also* Compound microscope; to study cells, 124–25
 Microspheres, 799; formation of, 284
 Microtubules, 130, 799
 Microvilli, 420
 Midges, 767
 Midlatitude deserts, 637–39
 Midlatitude forests, 632–33, 799
 Midwest, plains of, 646
 Migration, 246
 Miller, Stanley, 282
 Millipedes, 395, 396, 766, 768
 Mimicry, 575
Mimosa pudica, 556, 557
 Mint, 784
 Mint family, 784
 Miracidia, 410
 Mississippi River, 667, 668
 Mistletoe, 65, 66
 Mites, 766
 Mitochondria, 127, 129–30, 333, 799; electron transport system in, 426; origin of, 286
 Mitosis, 136–38, 137, 799; cytokinesis and, 148–49; vs. meiosis, 159
 Mixed-grass prairie, 636, 636, 799
 Mojave Desert, 637
 Mold: black bread, 335; blue-green, 777; slime, 278; water, 762
 Molecular biologists, 216
 Molecular clock hypothesis, 289
 Molecular cloning, 216
 Molecular homologies, 267
 Molecule, 14, 799; defined, 13; regulatory, 174; water, 14
 Moles, 774
 Mollusca, 394, 769, 799
 Molluscs, 799; aquatic, 394; body cavity of, 393–984; excretory system in, 406; in rivers, 668; natural history of, 366
 Molybdenum, 747; required by plants, 525
 Monarch butterfly, 575
 Monera, 276, 757–58
 Monkeys, 269, 774; red howler, 774
 Monoclonal antibodies, 463, 463
 Monocots, 373, 374, 553, 781, 799
 Monocotyledons, 373, 781. *See also* Monocots
 Monocular microscope, 733
 Monoplacophora, 769
 Monosaccharides, 97
 Monotremata, 774
 Monotremes, 401, 799
 Moon jelly, 763
 Moose, as taiga animal, 631
Morchella augusticeps, 336
 Morels, 777; as sac fungi, 336
 Morgan, Thomas Hunt, 203
 Morning glories, inheritance of flower color in, 200
 Morphology, 172, 799
 Mortality, 31, 799
 Mosquitoes, 767; malaria and, 331
 Moss, 277, 778; club, 362–64; differences between land plants and, 360–61, 360; life cycle of, 357, 380–82; moist conditions and, 357; *Polytrichum*, 361; reindeer, 342, 342; reproductive structures of, 380–82; true, 362; water, 667
 Moths, 767; cecropia, 397; life cycle of, 397, 397; mimicry and, 575; pronuba, 252; secondary sexual characteristics in, 409; selection in peppered, 241, 242
 Motile, 388, 799
 Motor neurons, 490, 799
 Mount St. Helens, 601, 645; *Penstemon* colonization of, 645
 Mountain brook, 667
 Mountain goat, 277
 Mountain lake, 664
 Mountain lions, 400; in food chain, 10
 Mourning dove, 773
 Mouse, liver cell nucleus of, 129
 Movement, vertebrate, 486
 Mozambique, famine in, 43
 mRNA: DNA genetic code transcribed in, 213; eukaryotic, 215; formation of, 226
 Multicellular, 799
 Multicellular organisms, 122; reproduction of, 152
 Multifactorial inheritance, 201, 799
 Multiple alleles, 200, 799
 Multiple sclerosis, 462
 Muscles, 408; cardiac, 484–85, 484; flexor-extensor, 487; in human body, 486; muscle fatigue and, 507–9; protein and, 436–37; rib, 465, 466; skeletal, 484, 484, 485; smooth, 484, 484; for support and locomotion, 408–9
 Muscular system: cardiovascular fitness and, 487; muscle contractions in, 484–85; production of movement in, 486–87
 Mushrooms, 8, 777; *Boletus*, 341; as club fungi, 337; poisonous, section on in Chinese biology book, 272; reproductive structures of field, 337
 Musk ox, 630
 Mussels, 674, 769
 Mustard family, 783
 Mustelidae, 268, 269
 Mutations, 244, 244, 799
 Mycelium, 334, 799; fungal, 335
Mycoplasma pneumoniae, 301
 Mycoplasmas, 758, 799
 Mycorrhizae, 339, 341, 341, 799
 Myeloma cells, 463
 Myofibrils, 484
 Myosin, 484, 800
 Myriopoda, 768
 Myxomycota, 332, 759, 800

N

- NAD⁺, 424, 546, 800
 NADH, 424, 424, 427
 NADP⁺, 545, 546, 800
 NADPH, 546–47, 546
Narcissus, 781
 NASA, Flight Research Center, 503
 National Institute of Standards and Technology, 726
 Natural selection, 800; activity on, 254–56; defined, 240; evidence from genetics and, 243–52; evolution and, 240–43; penicillin-resistant bacteria and, 243
Nautilus, 770
Navicula, 743
 Neanderthals, 611–12
Necator americanus, 393
 Necrotizing fasciitis, 307
 Nectar, 370–71, 800
Neisseria gonorrhoea, 312

- Nelkin, Dorothy, 218
 Nematoda, 393, 765, 800
 Nematodes, 339
 Nematomorpha, 765
 Nemertina, 764
 Neopilina, 769
 Nephrons, 468, 800; as blood filter, 468–69
 Nereocystis, 761
 Nerve, defined, 488, 800
 Nerve cells, human, 122
 Nerve impulses, 800; defined, 488; transmission of, 490
 Nervous system, 407–8, 488–94, 800; autonomic, 492, 494; central, 490–91; neurons in, 488–90; parasympathetic, 492, 494; peripheral, 490, 492; somatic, 492; subsystems in vertebrate, 491; sympathetic, 492, 494
 Neural ectoderm, 175, 176
 Neural groove, 176
 Neural tube, 173, 176, 176, 800
 Neurons, 489, 800; defined, 488; interneurons, 489, 490; motor, 490; plasma membrane of, 488, 489; polarized and depolarized, 489; receptors, 489, 490; sensory, 489, 490; transmission of nerve impulses by, 489, 490
 Neurospora crassa, reproduction of, 210–11, 211
 Neurotransmitter, 488, 800
 Neutral, 800
 Neutrons, 88, 800
 New Zealand, Fox Rain Forest in, 73
 Niche, 64, 800
 Nicotinamide adenine dinucleotide (NAD⁺), 424, 546
 Nicotine, 504
 Night crawler, 395
 Nitrate salts, 648
 Nitric acid vapor, 648
 Nitrifying eubacteria, 304–5, 305, 800
 Nitrobacter winogradskyi, 305
 Nitrogen, 281; required by plants, 524, 525
 Nitrogen cycle, 303; eubacteria and, 303–5
 Nitrogen dioxide, 648
 Nitrogen-fixing eubacteria, 800
 Nitrosomonas, 305
 Noctiluca, 759
 Nodosaria raphanus, 759
 Nodules, 304, 800
 Nondisjunction, 205, 205
 Nonmotile organism, 326
 Norepinephrine, 499–500, 800
 North Carolina: Cape Hatteras, 628; cypress swamp in, 678
 Northern Hemisphere, tilt of, 627
 Nostoc, 745, 758
 Nothofagus, 599, 599
 Notochord, 269, 397, 800
 Nuclear explosions, effects of, 641, 642
 Nuclear membrane, 129, 800
 Nucleic acids, 96, 101, 800; in virus, 6, 309–11. *See also* DNA; RNA
 Nucleoid, 296, 800
 Nucleotides, 101, 102, 103, 194–98, 800; genes as chains of DNA, 208–9
 Nucleus, 88, 125, 126, 801; in ciliate, 332
 Nunneley, Sarah A., 503
 Nutrient, 801
 Nutrition, 429–38; carbohydrates, 434–36; dietary habits and, 429–31; eating disorders and, 437–38; lipids and, 431–34; protein, 436–37
 Nyctea scandiaca, 630
- O**
- Oak family, 783
 Oat coleoptiles, 557
 Obelia, 763
 Observation: field, 22–23; hypothesis and, 16–17, 19; powers of, 20–21
 Ocean: coverage on earth, 661; cross section of, 673; human waste in, 681–83; penetration of sunlight in, 671; shore of, 676. *See also* Ocean ecosystem
 Ocean currents: climate and, 628; Humboldt current, 628
 Ocean ecosystems, 670–77; abiotic factors and, 670–72; coastal waters, 674–75; coral reefs, 674–75, 675; intertidal zone, 676–77; life forms in depths of, 672–74, 674; productivity in, 672, 673. *See also* Ocean
 Ochotona, 775
 Octopus, 770; jet propulsion of, 394
 Octopus cyanea, 394
 Ocypode quadrata, 677
 Odonata, 766
 Oil pool, 801
 Oil spills, effects of, 16, 682; Exxon Valdez, 294–95
 Oligochaeta, 769
 Omnivores, 62, 801
 On the Origin of Species (Darwin), 241
 Oncicola, 765
 Oncogenes, 183, 209, 801
 Onion, removing layer of cells from, 142
 Oniscus, 396
 Onychophora, 770
 Oomycota, 762
 Oparin, A. I., 283
 Open circulatory system, 801
 Open populations, 35, 801
 Ophioglossum, 779
 Ophiuroidea, 771
 Opiates, 504
 Opportunistic infections, 801
 Opossum, 774
 Orchard, population density in, 33
 Orchid, 782
 Orchid family, 782
 Orchidaceae, 782
 Order, 269, 801; Primates, 609–10. *See also* Catalog of Living Things, A
 Organ Pipe Cactus National Monument, 262–63
 Organelles, 125, 801; in eukaryotic cells, 129–31
 Organic compounds, 88, 801
 “Organic soup,” 281
 Organism: appropriate habitats for, 644. *See also* Living organisms; complexity score for, 379; Darwin’s observations of, 238–39; dead, fungi decomposition, 334; describing diversity among, 377–79; energy for, 11; interactions among, 576–77; kingdoms of, 272–79; marine, 581; nonmotile, 326; pH and, 108–10; relationships among, 64–66; roles of, 66; sessile, 388; similarities among, 266; species of, 235–37; unicellular and multicellular, 122; varying tolerances of, 582–83
 Organized system, 92
 Organs, in flatworms, 392
 Origin of life: ancestral species, 280–81; evidence from stars, 281–82; evolution of photosynthesis, 285–86; first cells, 282–84; organization of matter and, 286–87
 Ornithorhynchus anatinus, 401
 Orrorin, 615
 Orthocera clavulus, 759
 Orthoptera, 767
 Orycteropus afer, 776
 Oscillatoria, 302, 745
 Osmosis, 132, 133, 801
 Osmotic pressure, 145
 Osteichthyes, 772
 Ostrich, 250, 251
 Ova, 154, 801
 Ovaries, 160, 801; hormones and, 498
 Ovenbirds, 633
 Overgrazing, 648, 698
 Ovibus moschatus, 630
 Oviducts, 162, 801
 Ovis canadensis, 584
 Ovulation, 161, 163, 801
 Ovules, 801; of flowering plant, 358
 Ovum, 801
 Owl: barred, 773; in food chain, 10; great horned, 584
 Oxaloacetate, 425
 Oxygen, 281; anaerobic respiration and, 427; atoms of, 88, 88; in bloodstream, 467; concentration on C-3 and C-4 plants, 552; photosynthesis and, 93, 545–46, 549, 550; in respiration, 426; in water molecule, 14
 Oysters, 769
 Ozone layer, hole in, 16

P

- P, 801
P. camembertii, 338
P. notatum, 338
Pachycerianthus, 392
Pacific hagfish, 772
Paddle-footed worms, 769
Paleoecosystems: Cambrian communities, 603, 604, 606; Carboniferous period, 604, 606–7, 606; Cenozoic era, 605, 607–8, 608; Devonian period, 604–5, 604; Jurassic period, 605, 607; Triassic period, 605, 607, 607
Paleontologists, 366, 591–95, 801
Paleontology, general principle of, 603
Paleozoic period, seed ferns, 599
Paleozoic seas, 598
Palisade layer, 801; of leaf, 514
Palmer, William Jackson, 521
Pan troglodytes, 774
Pancreas, 420; hormones and, 497
Pancreatic juice, 420, 801
Panda, classification of giant, 267, 267
Pandorina, 744, 762
Pangaea, 600, 801; breakup of, 600, 602, 602; formation of, 604–5
Pangolins, 775
Panulirus argus, 396
Papilio rutulus, 767
Papio, 774
Parallel evolution, 250, 801
Paramecium, 742; as ciliates, 331; structures in, 346
Paramecium multimicronucleatum, 332
Paramecium sonneborni, 331
Parasites: in African sleeping sickness, 330, 330; of animals, 331, 392; sporozoans as animal, 331
Parasitism, 65, 66, 801
Parasympathetic division, 801
Parasympathetic nervous system, 492, 494
Parathyroid, hormones and, 497
Paranema, 743
Parsley family, 782
Passive transport, 133, 134, 801
Pasteur, Louis, 123
Pasture: profits, 58–59; story, 57–58
Pathogen, 305, 455, 801; some eubacteria as, 306–8; immune system and, 458; viruses as, 308–11
Pea family, 783
Pea plants: Mendel's, 194–95; self-pollination, 195; seven traits of (Mendel), 196; two generations of Mendel's, 198
“Pecking order,” 577, 578
Pecopteris, 594
Pelican, 399; brown, 773
Penguin: environment of, 37; king, 773
Penicillin, 801; bacteria resistance and, 242, 243
Penicillium, 777
Penicillium roquefortii, 338
Penis, 160, 801; semen and, 166
Penstemon, 645
Peppered moths, 241, 242
Peptidoglycan, 298, 801
Peranema, 760
Peridium, 743
Periodic table of elements, 741
Peripatus, 770
Peripheral nervous system (PNS), 490, 802; central nervous system and, 492
Perissodactyla, 776
Peristalsis, 418, 418, 802
Permafrost, 629, 802
Permian period, 598, 605
Petal, 802
Petiole, 514, 802
Peziza, 336
pH, 83–85; of acid rain, 648; of common substances, 91; of gastric juice, 419; kidneys and regulation of, 468; organisms and, 108–10; scale, 90–91, 90, 802
Phacus, 744, 760
Phaeophyta, 328
Phaeophyta, 761, 802
Phage, 309
Phantasmal poison frog, 398
Phascolarctos cinereus, 583
Phase contrast microscopes, 124
Phenotype, 197, 802; of genetic inheritance, 200–201
Phenylalanine, 213
Pheromones, 186, 802
Philodina, 765
Phloem, 518, 802
Phloem cells, 519, 519, 527, 528; pressure within, 520
Phlox family, 784
Phlox, 784
Pholidota, 775
Phormidium, 745
Phoronida, 770
Phoronis, 770
Phosphates (P), 95
Phosphorous, 746; required by plants, 524, 525
Photoperiodism, 558, 559, 802
Photorespiration, 802; defined, 550; photosynthesis and, 550–52
Photosynthesis, 802; absorption spectra for, 543; action spectrum for, 543; Calvin cycle and, 544, 544; cellular respiration and, 95; in chloroplasts, 542; defined, 12; environmental factors and, 548–49; evolution of, 285–86; food energy and, 12; gas exchange and, 561–64; interdependent reactions in, 544; leaf function and, 514; light and, 542–44; light intensity and rate of, 548; light reactions of, 544, 544, 545; matter cycle and, 14; oxygen concentration and, 552; oxygen gas and, 545–46; photorespiration and, 550–52; plants use of, 547; plants use of sugars and, 104; sugar formation in Calvin cycle, 546–47; sun and, 92–93
Photosynthetic protists, 326
Photosystem molecules, 545, 802
Phototropism, 556–57, 557, 802
Phylum, 269, 802
Physarum, 759
Physarum polycephalum, 332
Physical digestion, 403
Phytoplankton, 802; in lake, 664; in ocean, 672; in pond, 663; sewage and, 681
Picea pungens, 780
Pigeons: conditioned reflex and, 573; as urban wildlife, 584
Pigment, 802
Pigs, 776
Pika, 631, 775
Pilobolus, 278
Pine seedling, 32; environmental factors and, 32
Pine tree: seed development in, 369; as vascular plants, 355; winged seed of, 368
Pineal gland, hormones and, 498
Pinnipedia, 776
Pinnularia, 760
Piñon pine, 369
Pinus edulis, 369
Pinus ponderosa, 367
Pinus strobus, 780
Pisaster ochraceus, 676
Pisaurina mira, 396
Pith, 519, 802
Pits, 519
Pituitary gland, 163, 496–500, 802; hormones and, 498
Placenta, 177, 802
Placental mammals, 401
Planarians, 764; conditioned reflex experiment with, 573; excretory system in, 406, 406
Plankton, 662–63, 663, 802; in Cambrian period, 603; in streams, 667
Plant cell: diffusion of water in, 133; generalized, 127; water concentration and, 133
Plant ecologist, 679
Plant growth: plant hormones and, 552–54; primary, 526–28; secondary, 528; seeds and, 526
Plant hormones, 552–54, 554, 556: types of, 556
Plantae kingdom, 276, 802; catalog of, 778; defined, 275; members of, 277
Plants, C-3, 551–52, 552
Plants, C-4, 551–52, 552
Plants: cactus, 638; carbon-containing sugars and, 103–4; development of new, 555; early cultivation of, 696–97;

- elements required by, 525; evolutionary history of, 354–55; flowering. *See* Flowering plants; in food chain, 8–11; green algae as ancestors of, 326–27; herbaceous, 373; mycorrhizal fungi and, 339, 341; photosynthesis and, 14; response to day and night, 558, 559; response to environmental stimuli, 556–58; rooted, in ponds, 662–63; seed, 358, 367–75; sun and flowering, 7; tall, 355; tissue structure among, 234; tomato, 526; vascular, 361–65. *See also* Vascular plants
- Plaques, 433, 802
- Plasma, 454–55, 802; clotting and, 455–56; membrane, of neuron, 488, 489, 802
- Plasma cells, 459–60, 802
- Plasma proteins, 454–56, 802; clotting and, 455–56
- Plasmids, 216, 219, 296, 802
- Plasmodial slime molds, 759
- Plasmodium, 332, 802
- Plasmodium vivax*, 331, 760
- Plastids, 558
- Plate tectonics, 599–603, 803; defined, 601; distribution of species and, 601–3
- Platelets, 803; clotting and, 455–56; defined, 455
- Platyhelminthes, 392, 764, 803
- Platypus, 401, 774
- Pleistocene animals, 607
- Plowing, contour, 683, 684
- Pneumocystis carinii*, 313
- Pneumonia, eubacterial, 307
- Poa*, 782
- Poaceae, 782
- Polar bears: absence of, in Antarctic, 37–38; environment of, 37
- Polar bodies, 158, 160
- Polarized neuron, 489
- Polemoniaceae, 784
- Polemonium*, 784
- Polio virus, 287
- Pollen, 195
- Pollen grain, 358, 358, 359, 803
- Pollen tube, 359, 803
- Pollination, 359, 359, 803; special, in flowering plants, 370–71
- Pollution: air, control of, 705; international cooperation on problems of, 701–5; sewage, in stream, 682–83; technology to solve problems of, 705–6; thermal, 681; water, reducing, 683–84, 706
- Polychaeta, 769
- Polypeptide, 99–100, 99, 803
- Polypeptide chains, amino acids in, 100
- Polyplacophora, 769
- Polypodium glycyrrhiza*, 364
- Polysaccharides, 97, 97
- Polysiphonia*, 761
- Polytrichum*, 357, 778
- Polytrichum* moss, 361
- Ponderosa pine, 66, 367
- Ponds: cross section of, 662–63; highly eutrophic, 682; rooted plants in, 662–63; shallow alpine, 660–61
- Population bottleneck, 249
- Population density, 33; fluctuation in, 35–36
- Population growth: human, 700, 700, 701; studies of, 47–54
- Population size: abiotic and biotic factors and, 34–35; environment and, 32–33; human, uneven food distribution and, 40–41; rates determining, 31–32
- Populations, 29–59, 803; closed, 47; defined, 30; density of. *See* Population density; in ecosystems, 62–64; evolutionary mechanisms affect on, 245–46; human. *See* Human populations; individuals in, 30; open, 35; rates determining size of, 31–32; sexual selection in, 579; size of. *See* Population size; spreading of, 36
- Populus tremuloides*, 341
- Porcupine, 400, 775
- Porifera, 390, 763, 803
- Porphyra*, 761
- Porpoises, 775
- Postelia*, 761
- Postelsia*, 328
- Posterior, 388, 803
- Potassium, 746; required by plants, 524, 525
- Potassium-40, 594–95, 803
- Potato, “eyes” of, 153, 153, 517
- Prairie, 636, 636; single crop on, 694–95
- Prairie dog, 573, 574, 636, 644
- Praying mantids, 767
- Precipitation: biomes with low, 635–39; biomes with variable, 639–41
- Predacious fungi, 341
- Predator-prey relationship, 64, 803; camouflage and, 575
- Prenatal diagnosis, 178
- Pressure-flow hypothesis, 520, 520, 803
- Priapulida, 765
- Priapulid*, 765
- Primary growth, 803; of plants, 526–28
- Primate divergence, hypotheses of, 292
- Primates, 269, 774; arboreal, 609; diversity among, 609; humans as, 609–10
- Prince William Sound, Alaska, 294–95, 702
- Principle of independent assortment, 199, 803
- Principle of segregation, 196, 803
- Probability, 194, 222–24, 803
- Probelesodon*, 597
- Proboscidea, 776
- Producer, 275, 803; in communities, 67–69; defined, 8; diatom as, 327–28; in food chain, 10
- Productivity, 803; in ocean, 672; water, 669
- Progesterone, 163, 803
- Prokarya, 757
- Prokaryotae kingdom, 275, 276, 803
- Prokaryotes, 125, 296–305, 803; as biologically complex, 296–97; catalog of living, 757–58; cell structure of, 274, 296; evolution of, 280–81; fossils of, 297, 297; representative, 276; shapes of, 296; as structurally simple, 296–97; thick-walled endospore on, 297; vs. eukaryotes, 274, 274, 275
- Proline, 213
- Pronghorns, 636
- Pronuba moth, 252
- Prophase, 136, 137, 138, 803
- Prophase I, 157, 157
- Prophase II, 157
- Protease inhibitors, 315
- Protein, 96, 420, 436–37, 803; DNA and synthesis of, 212–14; foods rich in, 437; function in cells, 98–100; genetic engineering and, 216–20; plasma, 454–56; in respiration, 427
- Proteobacteria, 756
- Prothrombin, 455–56, 803
- Prothrombin activators, 455, 803
- Protista kingdom, 276, 278, 757; examples of, 278
- Protists: algae as photosynthetic, 326; autotrophic, 326–29. *See also* Autotrophic protists; catalog of living, 759–62; diseases from, 306; key to, 742–45; protozoa as animal-like, 329–34; variety among, 343–44
- Protoctista, 803
- Protons, 88, 803
- Proto-oncogenes, 183, 803
- Protoplast fusion, 555
- Protozoa, 278, 329–34
- Pseudomonas*, 758
- Pseudopods, 330
- Psilophyta, 779
- Psilotum*, 362, 363, 779
- Psuedopods, 330, 803–4
- Psuedotsuga menziesii*, 368
- Psuedotsuga taxifolia*, 234
- Psychoactive drugs, 501, 504–5, 804; abuse of, 504; sources, uses, and effects of, 750–51
- Pterophyta, 364, 779, 804
- Puberty, 804
- Puccinia*, 777
- Puffballs, 337, 777
- Pulmonary artery, 452, 453, 804
- Pulse rate, exercise and, 474–75
- Punctuated equilibria, 804; defined, 248–50; model of, 250
- Purple jelly, 763
- Pyloric valve, 419, 804
- Pyrococcus furiosus*, 299

Pyrodictium occultum, 299, 757

Pyruvate, 424, 424, 427

Pyruvate acid, 425, 428

Q

Quercus alba, 783; classification of, 279
Quetzal, 773

R

Rabbits, 775; cottontail, 775; in food chain, 8–11, 8–10

Raccoons, 267, 584

Radial symmetry, 388, 388, 804; in cnidarians, 392

Radiation: of body heat, 471–72; from Chernobyl, 703–4

Radiolarians, 330, 762

Radish seedling, root hairs on, 524

Rain, pH of, 648

Rain forest: slash-and-burn agriculture in Brazilian, 697; tropical, 634–35; diversity of, 72–73, 73

Rainbow Springs, Florida, 669, 669

Rainbow trout, 581, 668

Rain-shadow effect, 627–28, 627

Rana pipiens, 152

Ranunculaceae, 784

Ranunculus, 784

Raspberry bushes, in food chain, 9, 10

Raspberry slime mold, 324–25

Rate, 804

Rats, 775; eggs and sperm of, 155

Rattlesnake, 636, 773

Ray cells, 528, 804

Reabsorption, 468, 469, 804

Reactive chemicals, 728, 732–33

Reagent tests, 111

Receptors, 489, 804

Recessive traits, 195–96, 804

Recombinant DNA, 216, 804; bacterial plasmid technique, 219

Red algae, 328

Red blood cells, 455, 455; cancer in, 183; diffusion of water in, 133; in human blood clot, 450–51

Red fox kits, 4, 5

“Red tides,” 330

Red-eyed vireos, 633, 644

Red-footed booby, 82

Red-headed woodpecker, 633

Red-shafted flicker, 237

Reduction division, 157, 157, 804

Redwoods, giant, 353

Refined carbohydrates, 430

Reflex, 490, 491, 804; conditioned, 573, 573

Regulatory molecules, 174

Reindeer moss, 342, 342

Reindeer population, growth of, 51–52

Related ancestry, 266

Relative humidities table, 740

Renal tubule, 468, 804

Replication, DNA, 224–26, 804

Reproduction: asexual, 153–54; bryophytes and water for, 356–57; as essential for life continuity, 152–53; human. *See* Human reproductive system; mammalian embryos, 177, 179; regulated development and, 172–76; in sac fungi, 335–36; sexual, 153–54; in unicellular green algae, 327

Reproductive isolation, 235, 804

Reptiles, 771, 804; age of, 280, 280; as chordates, 398; embryo development of, 177; examples of, 399

Reptilia, 773

Resistance, 305, 804

Resources, 804; population growth and, 34

Respiration, 465–67; breathing and, 94; gas transport during, 465–67, 466. *See also* Cellular respiration

Respiratory system, as gas exchange system, 466

Retina, 175, 804

Retroviruses, 309, 311, 311, 804

Reverse transcriptase inhibitors, 315, 804

Rh factors, 464, 464, 804

Rheumatoid arthritis, 462

Rhinoceroses, 776

Rhinos, 639

Rhizobium, 304

Rhizobium meliloti, 304

Rhizoids, 362, 804

Rhizopoda, 759

Rhizopus, 335, 777; bread covered with mycelium of, 335; classification of, 279; reproduction in, 335

Rhizopus stolonifer, 335

Rhodocrobium vanielli, 302, 758

Rhodophyta, 328–29, 804

Rhodopsin, 300, 804–5

Rhodospirillum, 302

Rhodospirillum rubrum, 276

Rhombozoa, 764

Rhynia, 362, 362

Rhynia major, 362

Rib muscles, 465, 466

Ribbon worms, 764

Ribonucleic acid. *See* RNA

Ribose, 102, 805

Ribosomes, 129, 130, 805

Ribulose biphosphate (RuBP), 546

Ricksettia, 296

Riftia pachyptila, 674

Riordan, John R., 220

Ritual, 576, 805

River: as flowing water, 667; pollution in, 681

Rivularia, 758

RNA, 101, 805; in cell growth 1 phase, 135; DNA replication and transcription to, 224–46; retroviruses, 309; ribo-

somal, 298; types of, 212, 214; in viruses, 208

Robber fly, 572

Robin, 773; scientific name of, 270–71

Rock barnacles, 768

Rock doves, 584, 585

Rock layers, stratification of, 595

Rock scallop, 394

Rockweed, 676

Rocky Mountain National Park, 75

Rocky Mountain spotted fever, 296, 395

Rodentia, 775

Root cap, 527, 527, 805

Root cap cells, 527

Root hairs, 523–24, 805; on radish seedling, 524

Roots: active transport and, 524–26; fibrous, 523, 524; longitudinal section of tip, 527; role of, 523–24; structural adaptations in, 534–36; taproot, 523, 524; terminal portion of, 523

Rosa, 784

Rosaceae, 784

Rose family, 784

Rotifera, 765

Roughage, 436

Roundworms, 393, 765, 805; digestion in, 402, 403; body cavity of, 393–94; body plan of, 394; predacious fungi and, 341; reproductive system of, 410; transport of materials in, 404

rRNA, 212

Rubisco, 550, 805

Rumens, 300, 805

Rusts, 777

S

S phase, 806

Sabella, 395

Sac fungi, 335–36, 336, 777, 805; lichen fungi classified as, 341; sexual reproduction in, 336

Saccaromyces, 777

Saccharomyces cerevisiae, 48, 186, 227

Sage grouse, mating behavior of, 579, 579

Sagitta, 771

Sagittaria, 781

Sahel region, 648

Salamander: distribution in California, 256–61; marbled, 398

Salinity, in oceans, 670

Salinization, of lakes, 666, 666

Saliva, 418

Salix, 371

Salmon, secondary sexual characteristics in, 409

San Andreas fault, 601

Sand dollars, 771

Saprolegnia, 762

Sarcodines, 330, 805

Sargassum, 761

- Saturated fats, 431, 434, 805
 Savannas, 639, 640, 805
Scadoxus, 137
 Scale insects, 767
 Scallops, 769; rock, 394
 Scanning electron microscopes, 125
 Scaphopoda, 770
 Scarab beetle, 767
 Scarlet tanagers, 644
 Scavengers, 66, 639, 805
Schistosoma, 410
Schistosoma haematobium, 410
 Schleiden, Matthias, 123
 Schoolmaster snapper, 398
 Schwann, Theodor, 123
 Schwartz, Karlene V., 757
Sciurus, 775
Scorpaenopsis oxycephala, 264–65
 Scorpionfish, tasseled, 264–65
 Scorpions, 766
 Scrapie, 310
 Screwworm, 767
 Scrophulariaceae, 784
 Scrotum, 160, 805
 Scurvy, 306, 805
 Scyphozoa, 763
 Sea anemones, 763; burrowing, 392
 Sea cucumbers, 675, 771
 Sea elephants, 776
 Sea lettuce, 327
 Sea lilies, 771
 Sea lions, 776
 Sea slugs, 277, 770
 Sea stars, 676, 771; reproduction of, 153–54, 153
 Sea turtles, 676
 Sea urchins, 676, 771
 Sea walnut, 764
 Seals, 776
 Seasons, in midlatitude forest, 632–33, 632
 Seawater: animal life of, 388; elements in, 671. *See also* Oceans
Sebastes caurinus, 398
 Secondary growth, 805; of plants, 526, 528
 Secondary immunity, 461
 Secondary sexual characteristics, 805
 Secretion, 468, 469, 805
 Sedge, 781
Sedum adolphic, 356
 Seed coat, 805
 Seed plants, 358, 367–75
 Seedling: bean, 527; phototropism in, 557; pine, 32; seeds and, 537–39
 Seeds, 360, 805; bean, 360; dandelions, 36; of flowering plant, 371–72; fruits and, 383–85; germination, acid rain and, 83–85; role of, 526; seedlings and, 537–39
Sehelanthropus, 615
 Selection: behavior and, 572–80; sexual, 246, 579
 Self-pollination, 194, 195
 Semen, 166, 805
 Sensory neurons, 489, 805
 Sensory receptors, 509–11
 Sepals, 358, 805
Sequoiadendron giganteum, 353
 Serengeti Plains, 639
 Serine, 213
 Serving of food, 432
 Sessile, 388, 805
 Sessile animals, sponges as, 391
 Sewage, effect on aquatic ecosystems, 680–81
 Sex chromosome, 202, 805
 Sex hormones, 162
 Sexual reproduction, 153–54, 805; gametes and, 154; meiosis in, 156; in *Rhizopus*, 335; sperm penetrating egg in, 150
 Sexual selection, 246, 579, 805
 Sexually transmitted diseases, 312–15; from eubacteria, 312–13
 Shark, 772; whitetip reef, 398
 Sheep, 776
 Sheep's wool sponge, 763
 Shellfish, in estuaries, 678
 Short water cycle, 666
 Short-grass prairie, 636, 636, 805
 Shrews, 774
 Shrimp, 396, 769; deep-sea, 673
 Sieve cells, 519, 805
Sigillaria, 364
 Silver River, Florida, 669
 Silverfish, 766
 Simon, Julian L., 39
 Single-celled algae, 278
 Single-celled animals, transport of materials in, 404. *See also* Unicellular organisms
 Single-celled organism, reproduction of, 152
 Sirenia, 776
 Six-lined race runner, 773
 Skeletal muscle, 484, 484, 485, 804
 Skeleton: of animals, 408; chordates' internal, 397–400
 Skunk, 63, 575; as urban wildlife, 584
 Slash-and-burn agriculture, 42, 696–97, 697, 806
 Slime mold, 278, 332, 332, 334, 806; cellular, 759; plasmodial, 759; raspberry, 324–25
 Sloths, 775
 Small intestine, 419–21, 806; absorption in, 420–21; cross section of, 421
Smilodon, 608
 Smog, 72, 72
 Smooth muscle, 484, 484, 806
 Smuts, 777
 Snails, 64, 676, 770
 Snake: green, 399; as predator, 402
 Snapdragon, 784
 Sneeze, droplets from, 307
 Snow geese, 237
 Snowberry, 783
 Snowy owl, 630
 Social behavior, 576–77, 804
 Sodium (N), 88–89, 747; in atoms, 89
 Sodium chloride (NaCl), 88–89, 89
 Soil erosion, 698
 Solar energy, 627; in biomes, 629–35
Solenostemon, 784
 Somatic nervous system, 492, 494, 806
 Song sparrows, 578
 South Pole, polar bears and, 37–38
 Southern Hemisphere, tilt of, 627
 Sow bug, 396, 769
 Soybean roots, 304
 Sparrows, as urban wildlife, 584
 Speciation, 806; defined, 246; isolation and, 247–50, 247; models for rate of, 250; step in, 256–61
 Species, 73, 806; ancestral, 280–81; distribution of, 601–3; humans and conservation of, 75–76; of organisms, 235–37; simulation of competition between, 80–82
 Spectacled caiman, 399
 Sperm: fertilization of ovum by, 166; human, 150; of several organisms, 155. *See also* Human sperm; Sperm cell
 Sperm cells, 806; defined, 154; fertilization process and, 156, 156
Spermophilus lateralis, 581
Sphaerostylus, 762
Sphagnum, 362, 778
 Sphenophyta, 363, 779, 806
 Sphincter, 419, 806
 Spider web: effect of chemical substances on, 505; food chain and, 8–11
 Spiders, 395, 766; in food chain, 8–11, 9, 10; grasshopper and, 6–7, 6; nursery web, 396
 Spiderwort family, 781
 Spina bifida, 176, 806
 Spinal cord, 407, 490, 806
 Spindle apparatus, 136
 Spiny anteater, 774
 Spiny-headed worms, 765
Spirillum, 758
Spirogyra, 745
Spirostomum, 743
Spirostomum, 760
 Sponges, 763; brown volcano, 391; chemical digestion in, 403; excretion in, 405; as least complex animals, 390–92; purple vase, 391
 Spongy layer, 806; of leaf, 514
 Sporangia, 332, 332, 334, 362, 806; on fern stems, 362, 363
 Spores, 806
 Sporophyte, 357, 806; fern, 365; in land plants, 360
 Sporozoans, 331, 331, 760, 806
 Spring waters, 668–69

- Spurge family, 516
 Squid, 770; jet propulsion of, 394
 Squirrel, 775; Aberts and Kaibab, 247, 248; golden mantle ground, 581; ground, 636; as urban wildlife, 584
 Stamens, 358, 806
 Standing freshwater ecosystems: lakes, 664–66; ponds, 662–63
 Standing waters, 661. *See also* Standing freshwater ecosystems
 Stars, evidence of earth's history in, 281–82
 Stegosaurus, 596
 Stem: longitudinal section of, 527; role of, 516–20; structural adaptations of, 534–36
 Stentor, 746, 760
 Sterile, 806
 Stigeoclonium, 745
 Stigma, 358, 806
 Stimulants, 750–51, 806
 Stimulus, 407, 488, 806
 Stingray, 398, 594, 772
 Stinkbug, 767
 Stinkhorns, 777
 Stomach, 419, 806
 Stomates, 355, 356, 514, 515, 550, 806
 Stonecrop, 356
 Stored energy, 95
 Strata, 594, 806; of late Carboniferous period, 606
 Stream, 667–68; consumers in, 668; field study of, 686–89; sewage pollution in, 682–83
 Streptococcal toxic shock syndrome, 307
 Streptococcus, 758
 Streptococcus mutans, 308, 308
 Streptomyces, 758
 Stress, 501, 806; managing, 502
 Stressors, 501, 502, 807
 Striatella, 760
 Strokes, 435; blood clotting and, 456
 Stroma, 542, 807
 Stromatolites, 281, 281, 807
 Stylonychia, 746
 Subsistence agriculture, 697, 807
 Substrates, 100, 101, 102, 807
 Succession, 807; climax stage of, 642; in coniferous forest, 643; defined, 642; in lakes, 664, 664; as not orderly, 643–45
 Succulents, 516, 807
 Sucking lice, 767
 Sucrose, 12
 Sugars: carbon, 547; plants and carbon-containing, 103–4; single and double, 97, 97
 Sula dactylatrata, 82
 Sula nebulosus, 82, 579
 Sula sula, 82
 Sulfate, 648
 Sulfolobus acidocaldarius, 757
 Sulfur, 746; fossil fuels and, 699; required by plants, 525
 Sulfuric acid, 648
 Sumatra, tree ferns on, 365
 Sun: earth's orbit around, 627; flowering plants and, 7; food energy and, 12; photosynthesis and, 92–93; radiations from, 543
 Sunflower, 277, 782
 Sunflower family, 782
 “Supercrops,” 555
 “Superplants,” 555
 Surface receptors, 458–59, 807
 Surgeon General's Report on Nutrition and Health, 430
 Sustainable agriculture, 706–7, 707, 807
 Sutton, W. S., 207
 Sweet clover, *Rhizobium meliloti* nodules on, 304
 Sweet pea, 783
 Sylvilagus, 775
 Symbiosis, 64–65, 807
 Symmetry, 807; bilateral, 388, 388; radial, 388, 388, 392
 Sympathetic division, 807
 Sympathetic nervous system, 492, 494
 Symphoricarpos, 783
 Synapse, 488, 807
 Synthesis, 89, 807
 Synthesis phase, 136
 Syphilis, 312
- T**
- T cells, 458–59, 458, 807
 Taenia, 764
 Taiga, 631, 807; climatogram of, 756
 Tallgrass prairie, 636, 636, 807
 Tancredi, Laurence, 218
 Tapeworms, 393, 764
 Tapirs, 776
 Tapirus, 776
 Taproot system, 523, 524
 Tarantula, 766
 Taraxicum, 782
 Target organ, 807
 Tasseled scorpionfish, 264–65
 Taste buds, 418, 418
 Tatum, Edward L., 211
 Taxodium distichum, 780
 Taxonomic classification, 269
 Taxonomy, 266, 807
 Tayassu tajacu, 776
 Technology: human culture and, 696–700; human population and, 38–39; problems from, 699–700; solving problems with, 705–6
 Tectonics, 599–603
 Telophase, 137, 137, 807
 Telophase I, 157, 157
 Telophase II, 158, 158
 Temperature: circulation and, 412–13; measurements, 726; regulation in humans, 471–73
 10 percent rule, 68
 Tendons, 487, 807
 Termites, 766; symbiotic flagellates and, 330
 Terrestrial, 807
 Terrestrial animals, 389
 Territoriality, 578, 807
 Testes, 160, 807; hormones and, 498
 Tetanus, 307
 Tetrahymena, 743
 Thalassoma bifasciatum, 155
 Thermal pollution, 681
 Thermal receptors, hypothalamus and, 472, 472
 Thermoacidophiles, 299, 757, 807
 Thermocline, 807; defined, 665; formation of, 665
 Thiopendia, 302
 Thiospirillum, 302
 Threat display, 807
 Threonine, 213
 Thrombin, 455, 456, 807
 Thylakoids, 542, 542, 545, 807
 Thymine, 208
 Thymus, hormones and, 498
 Thyroid, 496; hormones and, 498
 Thyroid gland, 499, 807
 Thyroxine, 499, 807; control in blood of, 500
 Thysanura, 766
 Ticks, 395–96, 396, 766; Rocky Mountain spotted fever and, 296
 Tide pool community, 676
 Tiger lily, 782
 Tiger salamander, 772
 Time scale, geologic, 752
 Tissue: human muscle, 484, 484; vascular (plants), 355
 Tmesipteris, 779
 Toad: green, 772; robber fly and, 572
 Toadfish, 772
 Tobacco mosaic virus, 308
 Tolerance, 582–83, 808; to drugs, 504; environmental, 589–91; range of geranium, 582
 Toluene, 682
 Tolypothrix, 758
 Tomato, fruit development of, 372
 Tomato plants, 526
 Tongue, 418, 418
 Tooth decay, 308
 Tooth shells, 770
 Tortoises, giant, 152–53
 Toxic chemicals, 728, 730
 Toxic prey species, 575
 Toxin, 808
 Trace elements, 746–47
 Trachea, 465, 808; cells from, 122
 Tracheids, 519, 808

Tradescantia, 781
 Traits: dominant, 195–96; recessive, 195–96; X-linked, 202–4
 Trans fatty acids (trans fats), 431, 433
 Transcription, 213; RNA, 224–26
 Translation, process of, 214
 Translocation, 206, 206
 Transpiration, 515, 520–22, 808
 Tree frog, 772
 Tree pipit, 37, 37
 Tree sparrow, 773
 Trees: abiotic factors preventing growth of, 67; of Coal Age forests, 364; fire blight in, 306, 307; removal of hillside, 42; water-conducting structures in, 522. *See also specific types*
 Trematoda, 764
Treponema pallidum, 312
Triaenodor obesus, 398
 Triassic period, 605; dinosaurs in, 607
Triceratium, 760
Trichechus, 776
Trichechus manatus, 585
Trichechus manatus latirostris, 400
Trichinella, 765
Trichinella spiralis, 393
 Triglycerides, 98, 98
 Trilobites, 598; fossil, 598
 Trimester, 806
 Triphosphate group (TP), 95
 Trisomy, 204–5
 tRNA, 212
 Tropical deciduous forest, 647, 808
 Tropical deforestation, 647
 Tropical forests: cutting down, 16; destruction of, 18; potential disappearance of, 647. *See also Tropical rain forests*
 Tropical rain forests, 634–35, 806; climatogram of, 755; layering effect in, 634, 634. *See also Rain forest; Tropical forest*
 Tropisms, 556–57, 565–67, 808
 True bugs, 767
 True mosses, as bryophytes, 362
 True-breeding plants, 195, 808
 Truffles, 777
Trypanosoma gambiense, 330, 330, 760
 Tryptophan, 213
Tsuga, 272, 780
 Tsui, Lap-Chee, 220
 Tubal ligation, 165
Tubastraea coccinea, 392
 Tube worms, 674, 674
 Tuberculosis, 313
Tubifera ferreginosa, 325
 Tubifex worms, 663
 Tubules, 406
 Tubulidentata, 776
 Tulip, 782
Tulipa, 782
 Tumor, 183, 808
 Tuna, 772

Tundra; Alaskan, 629; climatogram of, 755; vegetation in, 629–31
 Tunicates, 771
 Turbellaria, 765
 Turgor pressure, 515, 520, 806; water and, 530–33
 Turkey vulture, 773
 Turner's syndrome, 205
 Turtle: box, 773; as consumers, 62–64; interactions of, 62–64, 63; scientific name of, 270–71
 Tuskshell, 770
 Twinflower, 783
 2,4,5-T, 553
 2,4-D, 553
 TYMV (turnip yellow mosaic virus), 309
 Typhoid, 307
 Tyrosine, 213

U

Ultrasound procedure, 178, 808
 Ultraviolet light, 808
Ulva, 327, 762
 Umbelliferae, 782
 Umbilical cord, 177, 808
 Umbrella grass, 781
 Underground stems, 517, 518
 Underwater farming, 675
 Unicellular, 808
 Unicellular organisms, 122. *See also* Single-celled organisms
 Uniramia, 395, 396, 808
 United States Department of Agriculture (USDA), 431
 Unsaturated fats, 431, 433, 808
 Uranium-235, 594, 808
 Uranium-238, 594
 Urban slum, 699
 Urban wildlife, 585, 808
 Urbanization, 697
 Urea, 407, 808
 Ureters, 467, 808
 Urethra, 467, 468, 808
 Urey, Harold, 282
 Uric acid, 407, 808
 Urinary bladder, 467, 808
 Urine, 467, 468, 808; glucose in, 469; materials in blood vs., 480; production of, 468, 468, 469
 Urochordata, 771
 Ursidae, 269
 Ursus arctos, 386–87
 USAF School of Aerospace Medicine (USAFSAM), 470
 Uterus, 162, 808

V

Vaccination, 461
 Vaccines, 306, 808
 Vacuole, 127, 130, 402, 403, 808

Vagina, 162, 808
 Valine, 213
 Valve, 806; heart, 453, 453, 454
Varanops, 597
 Variables, 24, 808–9
 Variation, 808; Darwin's observations of, 238–39, 240–41; defined, 237; diversity, evolution and, 234–39; hereditary, 244
 Vascular plants, adaptations of, 355
 Vascular cambium, 528
 Vascular plants, 355; club mosses as seedless, 362–64; seedless, 361–62
 Vascular tissue, 355, 808
 Vascular xylem, 519
 Vasectomy, 165
 Vegetation, tundra, 629–31
 Vegetative reproduction, 153, 808
 Veins, 452, 453, 808; of leaf, 514
 Velvet water mite, 766
 Velvet worms, 770
 Vent ecosystem, 674
 Venter, Craig, 216
 Ventral, 388, 809
 Ventricle, 453, 453, 454, 809
 Venus's girdle, 764
 Vermeij, Geerat, 366
 Vertebrae, 397, 809
 Vertebrates, 397, 772, 809; embryologic development of, 235; forelimb bones of seven, 234; nervous system, 491; structural unity in, 234
 Vesicle, 809
 Vessels, 809; in woody stems, 519–20
 Viceroy butterfly, 575, 575
 Villi, 177, 420, 421, 809
 Vinblastine, 75
 Vincristine, 75
 Virchow, Rudolph, 123
 Virulence, 305, 809
 Viruses, 6, 809; bacterial, 309; DNA in, 207; hereditary instructions of, 208; organization of matter in, 287; as pathogens, 308–11; polio, magnification of, 287; tobacco mosaic, 308; turnip yellow mosaic, 309
 Vision, human eye and, 493, 493
 Vitamin D, cholesterol and, 99
 Vitamins: foods high, 431; important to humans, 749
 Volcanic gases, 281
 Volume measurements, 726
Volvox, 744
Vorticella, 278, 744, 760
Vorticella campanula, 331
Vulpes, 268
Vulpes vulpes, 4, 5
 Vultures, 639

W

Walking sticks, 767
 Wallace, Alfred Russel, 241

Walrus, 776
Washingtonia, 272
 Washoe the chimp, 576
 Wasp, 575, 768
 Water: as compound, 14; diffusion of, 132, 132; domestic uses of, 55; for human population, 40; indirect uses of, 57; as life necessity, 54–56; light penetration into, 671; molecule of, 89; productivity of, 672; turgor pressure and, 530–33
 Water buffalo, 697
 Water bug, giant, 397
 Water cycle, in biosphere, 666, 666
 Water fern, 779
 Water fleas, 768
 Water hyacinths, 684
 Water lily, 370
 Water molds, 762
 Water mosses, 667
 Water net algae, 327
 Water plantain family, 781
 Water pollution, reducing, 683–84, 706
 Water strider, 767
 Water vapor, 281
 Watson, J. D., 208
 Wave action, 676
 Weasels, 775; in Carnivora order, 269
 Web: food. *See* Food chain; Food web; spider. *See* Spider web
 Web of life, 5–27
 Weevils, 767
 Wegener, Alfred, 599–601
Welwitschia, 780
 Western meadowlarks, 637

Western tiger swallowtail, 767
 Wetlands, 809; coastal, 678; inland, 677–78; as threatened ecosystem, 677–80
 Whales, 775; humpback, 400
 Whisk ferns, 779
 White blood cells, 455, 455
 White leghorn hens, 578
 White oak, 783
 White pine, 780
 White-tailed deer, 633
 Whitetip reef shark, 398
 Whooping cough, 307
 Whooping crane, 73, 73, 677
 Wild carrot, 782
 Wild rose, 784
 Wildebeest, 639
 Wilderness, preservation of, 705
 Wildfires, 16
 Wildlife, urban, 585
 Willamette daisies, 73, 73
 Willow, male catkin of, 371
 Withdrawal, drug, 505
 Woese, Carl, 284
 Wolves, 636, 775; in Carnivora order, 269; scientific name of, 270–71; social behavior in, 577, 577
 Woodchuck, 775
 Woodpecker, red-headed, 633
 Woody stems, 517, 517, 518–19, 518; growth rings in, 528, 529
 World as commons, 713–15
 Worms: giant tube, 674, 674; paddle-footed, 769; segmented, 769

X

Xanthomonas campestris, 306
Xenarthra, 775
 X-linked traits, 202–4, 203, 809
 Xylem, 518, 809; water transpiration and, 520–22
 Xylem cells, 519, 519, 527, 528

Y

Yeast, 777; as ascomycetes, 336; life cycle of, 186–91, 190; outcomes of mating between, 229; phenotypes of traits in, 227
 Yeast population, growth of, 47–50
 Yellow-shafted flicker, 237
Yucca glauca, 252

Z

Zea mays, 234, 542, 782. *See also* Corn
 Zebras, 192–93, 639, 776
 Zedler, Joy, 679
 Zinc, 747; required by plants, 524, 525
 Zipser, Edith, 366
 Zooplankton, 663, 668, 672, 809
Zygnema, 744
 Zygomycota, 335, 777, 809
 Zygosporangia, 335, 809
 Zygote, 156, 172–73, 809; during cleavage, 174