Contents

Preface ix



1

What Is Science?

Objects and Properties 2 Quantifying Properties 4 Measurement Systems 4 Standard Units for the Metric System 5 Length 6 Mass 6 Time 6 Metric Prefixes 6 Understandings from Measurements 7 Data 7 Ratios and Generalizations 8 The Density Ratio 8 Symbols and Equations 10 The Nature of Science 12 The Scientific Method 12 Explanations and Investigations 13 Scientific Laws 14 Models and Theories 15 Science, Nonscience, and Pseudoscience 15 From Experimentation to Application 17 Science and Nonscience 17 Pseudoscience 18 Limitations of Science 19 People Behind the Science: Florence Bascom 20



Motion 25

Outline 25 Describing Motion 26 Measuring Motion 27 Speed 27 Velocity 28 Acceleration 29 Forces 30 Horizontal Motion on Land 32 A Closer Look: A Bicycle Racer's Edge 34 Falling Objects 34 Compound Motion 36 Vertical Projectiles 36 Horizontal Projectiles 36 Three Laws of Motion 37 Newton's First Law of Motion 38 Newton's Second Law of Motion 39 Weight and Mass 41 Newton's Third Law of Motion 42 Momentum 43 Conservation of Momentum 43 Impulse 44 Forces and Circular Motion 45 Newton's Law of Gravitation 46 People Behind the Science: Isaac Newton 48 Earth Satellites 49 A Closer Look: Gravity Problems 50 Weightlessness 50



Energy 55

Outline 55 Work 56 Units of Work 57 Power 58 Motion, Position, and Energy 59 Potential Energy 59 Kinetic Energy 60 Energy Flow 62 Energy Forms 62 Energy Conversion 63 Energy Conservation 65 Energy Transfer 65 Energy Sources Today 66 Petroleum 66 Coal 67 Moving Water 67 Nuclear 67 People Behind the Science: James Prescott Joule 68 Conserving Energy 68 Energy Tomorrow 69 Solar Technologies 69 Geothermal Energy 70 Hydrogen 71



Heat and Temperature 75

Outline 75 The Kinetic Molecular Theory 76 Molecules 77 Molecules Interact 77 Phases of Matter 77 Molecules Move 78 Temperature 79 Thermometers 79 Thermometer Scales 80 Heat 82 Heat as Energy Transfer 83 Measures of Heat 83 Specific Heat 84 Heat Flow 86 A Closer Look: Passive Solar Design 88 Energy, Heat, and Molecular Theory 88 Phase Change 89 Evaporation and Condensation 92 Relative Humidity 93 Thermodynamics 94 The First Law of Thermodynamics 95 The Second Law of Thermodynamics 95 The Second Law and Natural Processes 96 People Behind the Science: Count Rumford

(Benjamin Thompson) 98



Wave Motions and Sound 103

Outline 103

Forces and Elastic Materials 104 Forces and Vibrations 104 Describing Vibrations 105 Waves 106 Kinds of Waves 107 Waves in Air 107 Hearing Waves in Air 108 Describing Waves 110 **A Closer Look**: *Hearing Problems 111* Sound Waves 111

iii

tiL12192_fm_i_xvi.indd iii

۲

Velocity of Sound in Air 111 Refraction and Reflection 112 Interference 114 Energy and Sound 115 Loudness 115 Resonance 116 Sources of Sounds 117 Vibrating Strings 118 People Behind the Science: Johann Christian Doppler 119 Sounds from Moving Sources 119



Electricity 125

Outline 125 Electric Charge 126 Measuring Electric Charge 128 Measuring Electric Force 128 Electric Current 129 Resistance 130 A Closer Look: Hydrogen and Fuel Cells 131 AC and DC 132 The Electric Circuit 132 People Behind the Science: Benjamin Franklin 133 Electric Power and Work 134 A Closer Look: Household Circuits and SafeTv 136 Magnetism 137 Moving Charges and Magnetic Fields 140 Magnetic Fields Interact 141 A Moving Magnet Produces an Electric Field 142 A Closer Look: Solar Cells 147



Light 152

Outline 152 Sources of Light 153 Properties of Light 156 Light Interacts with Matter 156 Reflection 157 Refraction 158 A Closer Look: Optics 161 Dispersion and Color 163 Evidence for Waves 164 Interference 164 Polarization 165 A Closer Look: *The Rainbow 166* Evidence for Particles 168 Photoelectric Effect 169 Quantization of Energy 169 The Present Theory 170 A Closer Look: *The Compact Disc (CD) 171* Relativity 172 Special Relativity 172 General Relativity 173 Relativity Theory Applied 173 People Behind the Science: James Clerk Maxwell 173



Atoms and Periodic Properties 178

Outline 178 Atomic Structure Discovered 179 Discovery of the Electron 180 The Nucleus 181 The Bohr Model 183 The Quantum Concept 183 Atomic Spectra 183 Bohr's theory 184 Quantum Mechanics 185 The Periodic Table 187 A Closer Look: The Rare Earths 190 Metals, Nonmetals, and Semiconductors 190 People Behind the Science: Dmitri Ivanovich Mendeleyev 192



Chemical Reactions 196

Outline 196 Compounds 197 Elements 199 Chemical Change 199 Valence Electrons and Ions 201 Chemical Bonds 202 Ionic Bonds 203 Covalent Bonds 204 A Closer Look: Name That Compound 207 Composition of Compounds 208 Chemical Equations 209 A Closer Look: How To Write A Chemical Formula 210 A Closer Look: On Balancing Equations 212 Types of Chemical Reactions 213 Combination Reactions 214 Decomposition Reactions 214 Replacement Reactions 215 Ion Exchange Reactions 215 People Behind the Science: Linus Carl Pauling 217



Water and Solutions 222 Outline 222 Household Water 223 Properties of Water 224 Structure of the Water Molecule 225 The Dissolving Process 226 A Closer Look: Decompression Sickness 227 Solubility 227 Properties of Water Solutions 228 Electrolytes 228 Boiling Point 229 Freezing Point 230 Acids, Bases, and Salts 230 Properties of Acids and Bases 231 Explaining Acid-Base Properties 232 Strong and Weak Acids and Bases 233 The pH Scale 233 Properties of Salts 234 Hard and Soft Water 235 A Closer Look: Acid Rain 236 People Behind the Science: Johannes Nicolaus Brönsted 237



Nuclear Reactions 240

Outline 240 Natural Radioactivity 241 Nuclear Equations 242 The Nature of the Nucleus 243 Types of Radioactive Decay 245 Radioactive Decay Series 246 A Closer Look: How Is Half-Life Determined? 248 Measurement of Radiation 248 Measurement Methods 249

iv Contents





Radiation Units 249 Radiation Exposure 250 Nuclear Energy 250 Nuclear Fission 251 Nuclear Power Plants 252 Nuclear Fusion 255 A Closer Look: Three Mile Island and Chernobyl 256 A Closer Look: Nuclear Waste 258 People Behind the Science: Marie Curie 259



The Universe 263

Outline 263 The Night Sky 263 Origin of Stars 265 Brightness of Stars 266 Star Temperature 267 Star Types 267 The Life of a Star 269 Galaxies 272 The Milky Way Galaxy 272 Other Galaxies 273 The Life of a Galaxy 274 A Closer Look: Extraterrestrials? 275 A Closer Look: Redshift and Hubble's Law 276 A Closer Look: Dark Matter 277 People Behind the Science: Jocelyn (Susan) Bell Burnell 280



The Solar System 283

Outline 283 Planets, Moons, and Other Bodies 284 Mercury 285 Venus 287 Earth's Moon 288 Mars 290 Jupiter 292 A Closer Look: Planets and Astrology 293 Saturn 295 Uranus and Neptune 297 Small Bodies of the Solar System 298 Comets 298 Asteroids 299 Meteors and Meteorites 300 Origin of the Solar System 301 Stage A 302 Stage B 302 Stage C 302 People Behind the Science: Percival Lowell 303



Earth in Space 306 Outline 306 Shape and Size of Earth 307 A Closer Look: The Celestial Sphere 309 Motions of Earth 309 Revolution 310 Rotation 311 Precession 312 Place and Time 313 Identifying Place 313 Measuring Time 314 The Earth-Moon System 319 Phases of the Moon 320 Eclipses of the Sun and Moon 321 Tides 322 People Behind the Science: Carl Edward Sagan 323



Earth 327

Outline 327 Earth Materials 328 Minerals 328 Rocks 331 A Closer Look: Asbestos 332 The Rock Cycle 335 Earth's Interior 335 The Crust 336 The Mantle 336 The Core 337 A More Detailed Structure 338 Plate Tectonics 338 Evidence from Earth's Magnetic Field 339 Evidence from the Ocean 339 Lithosphere Plates and Boundaries 341 Present-Day Understandings 343 A Closer Look: Seismic Tomography 344

A Closer Look: Measuring Plate Movement 345 People Behind the Science: Frederick John Vine 346



Earth's Surface 349

Outline 349 Interpreting Earth's Surface 350 Processes That Build Up the Surface 351 Stress and Strain 351 Folding 352 Faulting 354 Earthquakes 355 Origin of Mountains 358 A Closer Look: Volcanoes Change the World 359 Processes That Tear Down the Surface 361 Weathering 361 Erosion 364 People Behind the Science: James Hutton 369



Earth's Weather 373

Outline 373 The Atmosphere 374 Composition of the Atmosphere 375 Atmospheric Pressure 376 Warming the Atmosphere 377 Structure of the Atmosphere 377 A Closer Look: Hole In the Ozone Layer? 378 The Winds 379 Local Wind Patterns 379 A Closer Look: The Wind Chill Factor 380 Global Wind Patterns 381 Water and the Atmosphere 383 Evaporation and Condensation 383 Fog and Clouds 386 Precipitation 389 Weather Producers 389 Air Masses 390 Weather Fronts 391 Waves and Cyclones 393 Major Storms 394 Weather Forecasting 398 Climate 399 Major Climate Groups 399

Contents

v

۲

A Closer Look: El Niño and La Niña 402 Regional Climatic Influence 403 People Behind the Science: Vilhelm Firman Koren Bjerknes 404 Climate Change 404 Causes of Global Climate Change 405 Global Warming 407



Earth's Waters 412

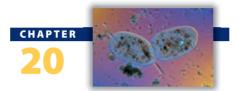
Outline 412 Water on Earth 413 Freshwater 414 Surface Water 415 Groundwater 416 Freshwater as a Resource 417 A Closer Look: Wastewater Treatment 419 Seawater 420 Oceans and Seas 421 The Nature of Seawater 421 Movement of Seawater 423 A Closer Look: Roque Waves 426 The Ocean Floor 428 A Closer Look: Key Forecasting Tool for the Chesapeake Bay 429 **People Behind the Science:** Rachel Louise Carson 430



Organic and Biochemistry 433

۲

Outline 433 Part I: The Nature of Organic Compounds 434 Organic Chemistry 435 Hydrocarbons 435 People Behind the Science: James Watson, Francis Crick, and Maurice Wilkins 436 Hydrocarbons with Double or Triple Bonds 438 Hydrocarbons That Form Rings 438 Petroleum 439 Hydrocarbon Derivatives 441 Functional Groups Generate Variety 441 Synthetic Polymers 446 A Closer Look: Nonpersistent and Persistent Organic Pollutants 448 Part II: Organic Compounds of Life 449 Organisms and Their Macromolecules 449 Carbohydrates 449 A Closer Look: So You Don't Eat Meat! How to Stay Healthy 451 Proteins 451 A Closer Look: What Enzymes Are and How They Work 454 Nucleic Acids 454 Lipids 456 A Closer Look: Omega Fatty Acids and Your Diet 459 A Closer Look: Fat and Your Diet 460



The Nature of Living Things 464

Outline 464 Part I: The Characteristics of Life 465 What Makes Something Alive? 465 The Cell Theory 468 People Behind the Science: Matthias Jakob Schleiden and Theodor Schwann 470 Cell Membranes 470 Getting Through Membranes 472 Diffusion 472 Osmosis 473 Controlled Methods of Transporting Molecules 476 Organelles Composed of Membranes 478 Nonmembranous Organelles 481 Nuclear Components 482 Major Cell Types 482 The Prokaryotic Cell Structure 482 A Closer Look: Antibiotics and Cell Structural Differences 483 The Eukaryotic Cell Structure 483 Part II: Energy Transformations in Cells 484 Respiration and Photosynthesis 484 The Energy Transfer Molecules of Living Things-ATP 484 Aerobic Cellular Respiration 485 Photosynthesis 486 The Importance of Cell Division 488 Part III: Cellular Reproduction 488 A Closer Look: Stem Cells 489 The Cell Cycle 489 The Stages of Mitosis 491 Prophase 491

Metaphase 492 Anaphase 492 Telophase 492



The Origin and Evolution of Life 495

Outline 495

Part I: How Did Life Originate? 496 Early Attempts to Understand the Origin of Life 497 Current Thinking About the Origin of Life 498 Extraterrestrial or Earth Origin? 498 Meeting Metabolic Needs 499 Summary of Ideas About the Origin of Life 500 Major Events in the Early Evolution of Living Things 500 Reproduction and the Origin of Genetic Material 501 The Development of an Oxidizing Atmosphere 501 The Establishment of Three Major Domains of Life 501 The Endosymbiotic Theory and the Origin of Eukaryotic Cells 502 A Summary of the Early Evolution of Life 502 Part II: The Process of Evolution 504 The Development of Evolutionary Thought 504 Evolution and Natural Selection 505 Defining Evolution 505 The Role of the Environment In Evolution 505 Natural Selection Leads To Evolution 505 A Closer Look: The Voyage of HMS Beagle, 1831-1836 506 Genetic Diversity is Important for Natural Selection 507 Genetic Diversity Resulting from Mutation 507 Genetic Diversity Resulting from Sexual Reproduction 508 Processes That Drive Natural Selection 508 Differential Survival 508 Differential Reproductive Rates 509 Differential Mate Selection 509 Acquired Characteristics Do Not Influence Natural Selection 510 The Hardy-Weinberg Concept 511

vi Contents

A Closer Look: The Development of New Viral Diseases 512 A Closer Look: Human-Designed Organisms 514 Accumulating Evidence of Evolution 514 A Closer Look: Other Mechanisms That Cause Evolution 515 People Behind the Science: Ernst Mayr 516 Part III: Speciation 516 Species: A Working Definition 516 How New Species Originate 518 The Role of Geographic Isolation in Speciation 518 The Role of Natural Selection in Speciation 519 Reproductive Isolation 519 Speciation Without Isolation 519 The Tentative Nature of the Evolutionary History of Organisms 520



The History of Life on Earth 524

Outline 524 Part I: The Geologic History of Earth 525 Geologic Time 525 Early Attempts at Earth Dating 525 Modern Techniques for Determining the Age of Earth 526 Interpreting the Geologic Record 527 Geologic Time and the Fossil Record 529 Early Ideas About Fossils 529 Types of Fossils 530 A Closer Look: What Is Carbon-14 Dating? 532 Using Fossils to Determine the Order of Geologic Events 533 The Geologic Time Scale 533 Paleontology, Archaeology, and Human Evolution 538 A Closer Look: Neandertals Were Probably a Different Species 539 The Australopiths 539 Ardipithecus 539 The Genus Homo 540 The Origin of Homo Sapiens 541 Part II: Kinds of Organisms 541 The Classification of Organisms 541 The Problem with Common Names 541 Taxonomy 542 Phylogeny 544 A Brief Survey of Biodiversity 546

A Closer Look: Cladistics—A Tool for Taxonomy and Phylogeny 548 Domains Bacteria and Archaea 548 Domain Eucarya 549

A Closer Look: The World's Oldest and Largest Living Organisms 552

People Behind the Science: Lynn (Alexander) Margulis 554 Acellular Infectious Particles 554

Viruses 555 Viroids: Infectious Rna 556

Prions: Infectious Proteins 556

CHAPTER 23

Ecology and Environment 560

Outline 560 A Definition of Environment 561 The Organization of Ecological Systems 562 People Behind the Science: Eugene Odum 563 Energy Flow in Ecosystems 565 Community Interactions 565 Types of Terrestrial Communities 567 Temperate Deciduous Forest 568 Temperate Grassland or Prairie 568 Savanna 568 Desert 568 Boreal Coniferous Forest 569 Mediterranean Shrublands (Chaparral) 569 Temperate Rainforest 569 Tundra 570 Tropical Rainforest 570 Tropical Dry Forest 570 Types of Aquatic Communities 570 Marine Communities 571 Freshwater Communities 571 Estuaries 572 A Closer Look: The Importance of Habitat Size 573 Individual Species Requirements: Habitat and Niche 573 Habitat 573 Niche 573 A Closer Look: Zebra Mussels: Invaders from Europe 575 Kinds of Organism Interactions 575 Predation 575 Parasitism 575 Commensalism 577 Mutualism 577 Competition 578

Competition and Natural Selection 579 The Cycling of Materials in Ecosystems 579 The Carbon Cycle 579 The Nitrogen Cycle 579 A Closer Look: Carbon Dioxide and Global Warming 581 The Phosphorus Cycle 583 Nutrient Cycles and Geologic Time 583 Bioaccumulation and Biomagnification 584 Population Characteristics 586 Genetic Differences 586 Age Structure 586 Sex Ratio 587 Population Density 587 The Population Growth Curve 588 Population-Size Limitations 589 Limiting Factors to Human Population Growth 589 Human Population Growth and the Global Ecosystem 592



Human Biology: Materials Exchange and Control Mechanisms 596

Outline 596 Homeostasis 597 Exchanging Materials: Basic Principles 597 Transporting Materials: The Circulatory System 598 The Nature of Blood 598 The Heart 600 Arteries, Veins, and Capillaries 601 Skin: The Body's Container 602 Primary Functions of the Skin 603 The Structure of the Skin 603 Other Features of the Skin 604 Exchanging Gases: The Respiratory System 605 Structure and Function of Lungs 605 The Mechanism of Breathing 605 A Closer Look: Cigarette Smoking and Your Health 606 Homeostasis and Breathing 606 Obtaining Nutrients: The Digestive System 607 Processing Food 607 People Behind the Science: William Beaumont 608 Nutrient Uptake 609 Nutrition 610 Kinds of Nutrients 610

Contents vii

CONFIRMING PAGES

Guidelines for Obtaining Adequate Nutrients 611 A Closer Look: The Dynamic Skeleton 614 Eating Disorders 616 A Closer Look: Nutrition During Pregnancy and Lactation 618 Waste Disposal: The Excretory System 618 Control Mechanisms 619 The Structure of the Nervous System 619 The Nature of the Nerve Impulse 620 Activities at the Synapse 621 Endocrine System Function 622 Sensory Input 623 Chemical Detection 623 Light Detection 624 Sound Detection 624 Touch 626 Output Mechanisms 626 Muscles 626 A Closer Look: Which Type of Exercise Do You Do? 627 Glands 627 Growth Responses 627



Human Biology: Reproduction 631

Outline 631

Sexual Reproduction 632
The Mechanics of Meiosis 634
Human Sexuality from Different Points of View 635
A Closer Look: Speculation on the Evolution of Human Sexual Behavior 636
Chromosomal Determination of Sex and Early Development 637
Chromosomal Abnormalities and Sex 637
A Closer Look: Karyotyping and Down Syndrome 638
A Closer Look: Cryptorchidism—Hidden Testes 640
Fetal Development and Sex 640

Sexual Maturation of Young Adults 642

The Maturation of Females 642 The Maturation of Males 642 Spermatogenesis 643 Oogenesis 645 Hormonal Control of Female Sexual Cycles 647 Hormonal Control of Fertility 647 Fertilization, Pregnancy, and Birth 648 Twins 649 People Behind the Science: Robert Geoffrey Edwards and Patrick Christopher Steptoe 651 Birth 653 Contraception 653 Chemical Methods 653 Hormonal Control Methods 653 A Closer Look: Sexually Transmitted Diseases 655 Timing Method 656 Barrier Methods 656 Surgical Methods 656 Termination of Pregnancy-Abortion 657 Changes in Sexual Function With Age 657 Hormone Therapy 658 Impotence 658



Mendelian and Molecular Genetics 661

Outline 661 Part I: Mendelian Genetics Updated 662 Genetics, Meiosis, and Cells 662 Single-Gene Inheritance Patterns 663 A Closer Look: Cystic Fibrosis—What Is the Probability? 664 A Simple Model of Inheritance—Dominant and Recessive Alleles 664 Mendel's Laws of Heredity 665 People Behind the Science: Gregor Johann Mendel 666 Steps in Solving Heredity Problems: Single-Factor Crosses 666 A Closer Look: Muscular Dystrophy and Genetics 667

More Complex Models of Inheritance 668 X-Linked Genes 668

Codominance 668 Incomplete Dominance 668 Multiple Alleles 669 A Closer Look: Blame That Trait on Your Mother! 669 Polygenic Inheritance 670 Pleiotropy 670 Environmental Influences on Gene Expression 672 Epigenetics and Gene Expression 673 Part II: The Molecular Basis of Genetics 674 The Central Dogma 674 The Structure of DNA and RNA 674 DNA Replication 675 DNA Transcription 678 A Closer Look: Basic Steps of Translation 679 Translation or Protein Synthesis 680 Alterations of DNA 681 Using DNA to Our Advantage 683 Genetic Modification of Organisms 683 A Closer Look: Stem Cells 685 Strategy Two: Sequencing 686 APPENDIX A Mathematical Review 692 Working with Equations 692 Significant Figures 694 Conversion of Units 695 Scientific Notation 696 APPENDIX B Solubilities Chart 698 APPENDIX C Relative Humidity Table 699 APPENDIX D Solutions for Second Example Exercises 700 APPENDIX E Solutions for Group A Parallel Exercises 704 APPENDIX F Problem Solving 721 Glossary 722 Credits 741 Index 743 INSIDE FRONT COVER Conversion Factors Metric Prefixes

Physical Constants

INSIDE BACK COVER Table of Atomic Weights Periodic Table of the Elements