

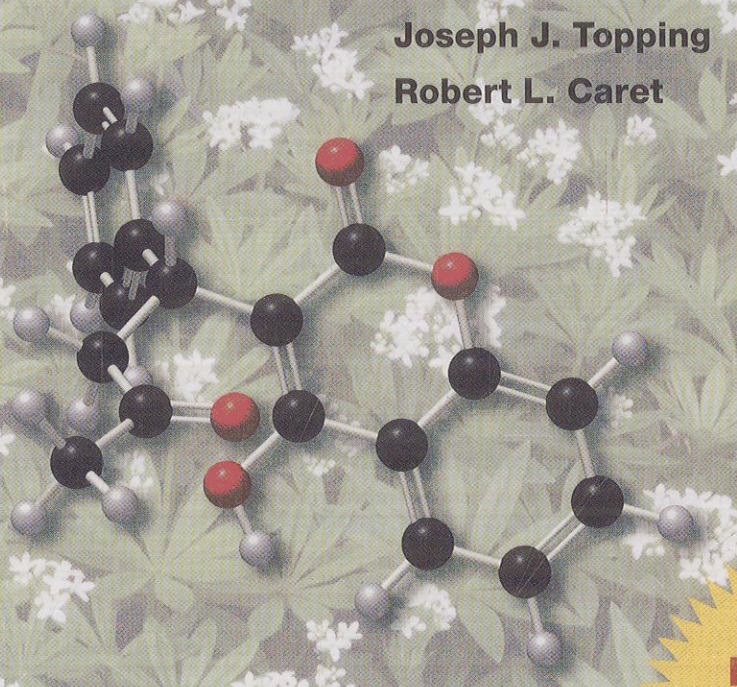
Seventh Edition

# General, Organic, *and* Biochemistry

Katherine J. Denniston

Joseph J. Topping

Robert L. Caret



**This  
International  
Student Edition  
is for use  
outside  
the U.S.**

McGraw-Hill International Edition



# Contents

Perspectives xiii

Preface xv

## GENERAL CHEMISTRY

### 1 Chemistry: Methods and Measurement 1

#### 1.1 The Discovery Process 2

Chemistry 2

Major Areas of Chemistry 2

**A Medical Perspective:** Curiosity, Science, and Medicine 3

The Scientific Method 4

Models in Chemistry 4

**A Human Perspective:** The Scientific Method 5

#### 1.2 Matter and Properties 6

Data and Results 6

States of Matter 7

Matter and Physical Properties 7

Matter and Chemical Properties 8

Intensive and Extensive Properties 9

Classification of Matter 10

#### 1.3 Significant Figures and Scientific Notation 11

Significant Figures 11

Recognition of Significant Figures 12

Scientific Notation 13

Error, Accuracy, Precision, and Uncertainty 14

Significant Figures in Calculation of Results 15

Exact (Counted) and Inexact Numbers 17

Rounding Off Numbers 17

#### 1.4 Units and Unit Conversion 18

English and Metric Units 18

Unit Conversion: English and Metric Systems 19

Conversion of Units Within the Same System 19

Conversion of Units from One System to Another 21

#### 1.5 Experimental Quantities 23

Mass 23

Length 24

Volume 24

Time 25

Temperature 25

Energy 27

Concentration 27

**A Human Perspective:** Food Calories 28

Density and Specific Gravity 29

**A Medical Perspective:** Assessing Obesity: The Body-Mass Index 31

**A Human Perspective:** Quick and Useful Analysis 33

Summary 33

Key Terms 34

Questions and Problems 35

Critical Thinking Problems 37

### 2 The Structure of the Atom and the Periodic Table 39

#### 2.1 Composition of the Atom 40

Electrons, Protons, and Neutrons 40

Isotopes 42

**Chemistry at the Crime**

**Scene:** Microbial Forensics 44

#### 2.2 Development of Atomic Theory 45

Dalton's Theory 46

Evidence for Subatomic Particles: Electrons, Protons, and Neutrons 46

Evidence for the Nucleus 46

#### 2.3 Light, Atomic Structure, and the Bohr Atom 47

Light and Atomic Structure 47

**Green Chemistry:** Electromagnetic Radiation and Its Effects on Our Everyday Lives 49

The Bohr Atom 50

**A Human Perspective:** Atomic Spectra and the Fourth of July 51

Modern Atomic Theory 52

#### 2.4 The Periodic Law and the Periodic Table 53

Numbering Groups in the Periodic Table 54

Periods and Groups 55

Metals and Nonmetals 55

**A Medical Perspective:** Copper Deficiency and Wilson's Disease 56

Atomic Number and Atomic Mass 56

#### 2.5 Electron Arrangement and the Periodic Table 57

The Quantum Mechanical Atom 58

Principal Energy Levels, Sublevels, and Orbitals 58

Electron Configurations 60

Guidelines for Writing Electron Configurations 60

Electron Configurations and the Periodic Table 64

#### 2.6 Valence Electrons and the Octet Rule 65

Valence Electrons 65

The Octet Rule 66

Shorthand Electron Configurations 66

Ions 67

Ion Formation and the Octet Rule 67

**A Medical Perspective:** Dietary Calcium 69

## 2.7 Trends in the Periodic Table 70

Atomic Size 70

Ion Size 70

Ionization Energy 71

Electron Affinity 72

Summary 73

Key Terms 74

Questions and Problems 74

Critical Thinking Problems 77

## 3 Structure and Properties of Ionic and Covalent Compounds 79

### 3.1 Chemical Bonding 80

Lewis Symbols 80

Principal Types of Chemical Bonds:

Ionic and Covalent 80

**A Medical Perspective:** Unwanted  
Crystal Formation 83

Polar Covalent Bonding and Electronegativity 84

### 3.2 Naming Compounds and Writing Formulas of Compounds 86

Ionic Compounds 86

Covalent Compounds 91

### 3.3 Properties of Ionic and Covalent Compounds 93

Physical State 93

Melting and Boiling Points 93

**A Medical Perspective:** Rebuilding Our Teeth 94

Structure of Compounds in the Solid State 94

Solutions of Ionic and Covalent Compounds 94

### 3.4 Drawing Lewis Structures of Molecules and Polyatomic Ions 95

Lewis Structures of Molecules 95

**A Medical Perspective:** Blood Pressure and the Sodium  
Ion/Potassium Ion Ratio 96

Lewis Structures of Polyatomic Ions 98

Lewis Structure, Stability, Multiple Bonds, and Bond  
Energies 101

Isomers 102

Lewis Structures and Resonance 103

Lewis Structures and Exceptions to the Octet Rule 105

Lewis Structures and Molecular Geometry; VSEPR  
Theory 106

Periodic Structural Relationships 108

Lewis Structures and Polarity 111

### 3.5 Properties Based on Electronic Structure and Molecular Geometry 113

Solubility 113

Boiling Points of Liquids and Melting Points of Solids 114

Summary 115

Key Terms 116

Questions and Problems 117

Critical Thinking Problems 119

## 4 Calculations and the Chemical Equation 121

### 4.1 The Mole Concept and Atoms 122

The Mole and Avogadro's  
Number 122

Calculating Atoms, Moles, and  
Mass 124

### 4.2 The Chemical Formula, Formula Mass, and Molar Mass 127

The Chemical Formula 127

Formula Mass and Molar Mass 128

### 4.3 The Chemical Equation and the Information It Conveys 131

A Recipe for Chemical Change 131

Features of a Chemical Equation 131

The Experimental Basis of a Chemical Equation 132

Strategies for Writing Chemical Equations 132

### 4.4 Chemical Equations Represent Chemical Change 134

Balancing Chemical Equations 134

Classifying Chemical Reactions 139

Writing Precipitation Reactions as Net Ionic Equations 141

### 4.5 Calculations Using the Chemical Equation 143

General Principles 143

Use of Conversion Factors 144

**A Human Perspective:** The Chemistry of Automobile  
Air Bags 146

**A Medical Perspective:** Carbon Monoxide Poisoning:  
A Case of Combining Ratios 149

Theoretical and Percent Yield 151

**A Medical Perspective:** Pharmaceutical Chemistry:  
The Practical Significance of Percent Yield 152

Summary 154

Key Terms 155

Questions and Problems 155

Critical Thinking Problems 157

## 5 States of Matter: Gases, Liquids, and Solids 159

### 5.1 The Gaseous State 160

Ideal Gas Concept 160

Measurement of Gases 161

Kinetic Molecular Theory of  
Gases 162

Properties of Gases and the Kinetic Molecular Theory 162

**A Human Perspective:** The Demise of the Hindenburg 162

Boyle's Law 163

Charles's Law 165

Combined Gas Law 167

Avogadro's Law 168

Molar Volume of a Gas 169

- Gas Densities 169  
 The Ideal Gas Law 170  
 Dalton's Law of Partial Pressures 172  
**Green Chemistry: The Greenhouse Effect and Global Climate Change** 173  
 Ideal Gases Versus Real Gases 174
- 5.2 The Liquid State 174**  
 Compressibility 174  
 Viscosity 174  
**A Medical Perspective: Blood Gases and Respiration** 175  
 Surface Tension 175  
 Vapor Pressure of a Liquid 176  
 van der Waals Forces 177  
**Chemistry at the Crime Scene: Explosives at the Airport** 177  
 Hydrogen Bonding 178
- 5.3 The Solid State 179**  
 Properties of Solids 179  
 Types of Crystalline Solids 180  
 Sublimation of Solids 181  
 Summary 182  
 Key Terms 182  
 Questions and Problems 182  
 Critical Thinking Problems 184
- 6 Solutions 185**
- 6.1 Properties of Solutions 186**  
 General Properties of Liquid Solutions 187  
 Solutions and Colloids 187  
 Degree of Solubility 188  
 Solubility and Equilibrium 189  
 Solubility of Gases: Henry's Law 189  
**A Human Perspective: Scuba Diving: Nitrogen and the Bends** 190
- 6.2 Concentration Based on Percent by Mass 191**  
 Mass/Volume Percent 191  
 Mass/Mass Percent 192  
 Parts Per Thousand (ppt) and Parts Per Million (ppm) 193
- 6.3 Concentration Based on Moles 194**  
 Molarity 195  
 Dilution 196
- 6.4 Concentration-Dependent Solution Properties 198**  
 Vapor Pressure Lowering 198  
 Freezing Point Depression and Boiling Point Elevation 199  
 Calculating Freezing Points and Boiling Points of Aqueous Solutions 200  
 Osmotic Pressure, Osmosis, and Osmolarity 202  
**A Medical Perspective: Oral Rehydration Therapy** 205
- 6.5 Aqueous Solutions 206**  
 Water as a Solvent 206  
**A Human Perspective: An Extraordinary Molecule** 207  
 Electrolytes in Solution 208  
 Biological Effects of Electrolytes in Solution 210  
**A Medical Perspective: Hemodialysis** 211  
 Summary 212  
 Key Terms 213  
 Questions and Problems 213  
 Critical Thinking Problems 215
- 7 Energy, Rate, and Equilibrium 217**
- 7.1 Thermodynamics 218**  
 The Chemical Reaction and Energy 218  
 The First Law of Thermodynamics 219  
**Green Chemistry: Twenty-first Century Energy** 221  
 The Second Law of Thermodynamics 222  
 Free Energy 224  
**A Medical Perspective: Hot and Cold Packs** 225
- 7.2 Experimental Determination of Energy Change in Reactions 226**
- 7.3 Kinetics 229**  
 Chemical Kinetics 229  
 Activation Energy and the Activated Complex 230  
 Factors That Affect Reaction Rate 231  
 Mathematical Representation of Reaction Rate 233  
**A Human Perspective: Too Fast or Too Slow?** 236
- 7.4 Equilibrium 237**  
 Rate and Reversibility of Reactions 237  
 Physical Equilibrium 237  
 Chemical Equilibrium 238  
 The Generalized Equilibrium Constant Expression for a Chemical Reaction 238  
 Using Equilibrium Constants 242  
 LeChatelier's Principle 243  
**A Human Perspective: Light-Sensitive Glasses** 246  
 Summary 246  
 Key Terms 247  
 Questions and Problems 247  
 Critical Thinking Problems 249
- 8 Acids and Bases and Oxidation-Reduction 251**
- 8.1 Acids and Bases 252**  
 Arrhenius Theory of Acids and Bases 252  
 Brønsted-Lowry Theory of Acids and Bases 253  
 Acid-Base Properties of Water 253  
 Acid and Base Strength 253  
 Conjugate Acids and Bases 254  
 The Dissociation of Water 257

- 8.2 pH: A Measurement Scale for Acids and Bases 258**  
 A Definition of pH 258  
 Measuring pH 258  
 Calculating pH 259  
 The Importance of pH and pH Control 263  
**A Medical Perspective:** Drug Delivery 263
- 8.3 Reactions Between Acids and Bases 264**  
 Neutralization 264  
 Polyprotic Substances 266  
**Green Chemistry:** Acid Rain 267
- 8.4 Acid-Base Buffers 268**  
 The Buffer Process 268  
 Addition of Base or Acid to a Buffer Solution 269  
 Preparation of a Buffer Solution 270  
 The Henderson-Hasselbalch Equation 273  
**A Medical Perspective:** Control of Blood pH 273
- 8.5 Oxidation-Reduction Processes 274**  
 Oxidation and Reduction 274  
**A Medical Perspective:** Oxidizing Agents for Chemical Control of Microbes 275  
 Applications of Oxidation and Reduction 276  
 Biological Processes 277  
 Voltaic Cells 278  
**A Medical Perspective:** Electrochemical Reactions in the Statue of Liberty and in Dental Fillings 280  
 Electrolysis 280  
 Summary 281  
 Key Terms 282  
 Questions and Problems 282  
 Critical Thinking Problems 284

## 9 The Nucleus, Radioactivity, and Nuclear Medicine 285

- 9.1 Natural Radioactivity 286**  
 Alpha Particles 287  
 Beta Particles and Positrons 287  
 Gamma Rays 288  
 Properties of Alpha, Beta, Positron, and Gamma Radiation 288  
**A Human Perspective:** Origin of the Elements 289
- 9.2 Writing a Balanced Nuclear Equation 289**  
 Alpha Decay 289  
 Beta Decay 290  
 Positron Emission 290  
 Gamma Production 290  
 Predicting Products of Nuclear Decay 291
- 9.3 Properties of Radioisotopes 292**  
 Nuclear Structure and Stability 292  
 Half-Life 292  
**A Human Perspective:** An Extraordinary Woman in Science 295  
 Radiocarbon Dating 295

- 9.4 Nuclear Power 296**  
 Energy Production 296  
 Nuclear Fission 296  
**Green Chemistry:** Nuclear Waste Disposal 298  
 Nuclear Fusion 298  
 Breeder Reactors 298
- 9.5 Medical Applications of Radioactivity 299**  
 Cancer Therapy Using Radiation 299  
 Nuclear Medicine 299  
 Making Isotopes for Medical Applications 300  
**A Medical Perspective:** Magnetic Resonance Imaging 302
- 9.6 Biological Effects of Radiation 303**  
 Radiation Exposure and Safety 303
- 9.7 Measurement of Radiation 305**  
 Nuclear Imaging 305  
 Computer Imaging 305  
 The Geiger Counter 305  
 Film Badges 306  
 Units of Radiation Measurement 306  
**Green Chemistry:** Radon and Indoor Air Pollution 307  
 Summary 307  
 Key Terms 308  
 Questions and Problems 309  
 Critical Thinking Problems 310

## ORGANIC CHEMISTRY

- 10 An Introduction to Organic Chemistry: The Saturated Hydrocarbons 311**
- 10.1 The Chemistry of Carbon 312**  
 Important Differences Between Organic and Inorganic Compounds 313  
 Families of Organic Compounds 314  
**Green Chemistry:** Frozen Methane: Treasure or Threat? 315
- 10.2 Alkanes 317**  
 Structure and Physical Properties 317  
 Alkyl Groups 321  
**Chemistry at the Crime Scene:** Arson and Alkanes 323  
 Nomenclature 323  
**Green Chemistry:** Oil-Eating Microbes 325  
 Constitutional or Structural Isomers 328
- 10.3 Cycloalkanes 330**  
*cis-trans* Isomerism in Cycloalkanes 331
- 10.4 Conformations of Alkanes and Cycloalkanes 334**  
 Alkanes 334  
 Cycloalkanes 334  
**Green Chemistry:** The Petroleum Industry and Gasoline Production 335

## 10.5 Reactions of Alkanes and Cycloalkanes 336

Combustion 336

Halogenation 337

**A Medical Perspective:** Polyhalogenated Hydrocarbons  
Used as Anesthetics 339

Summary of Reactions 340

Summary 340

Key Terms 340

Questions and Problems 341

Critical Thinking Problems 345

## 11 The Unsaturated Hydrocarbons: Alkenes, Alkynes, and Aromatics 347

### 11.1 Alkenes and Alkynes: Structure and Physical Properties 348

### 11.2 Alkenes and Alkynes: Nomenclature 350

**A Medical Perspective:** Killer Alkynes in Nature 354

### 11.3 Geometric Isomers: A Consequence of Unsaturation 356

### 11.4 Alkenes in Nature 361

### 11.5 Reactions Involving Alkenes and Alkynes 361

Hydrogenation: Addition of  $H_2$  363

Halogenation: Addition of  $X_2$  365

Hydration: Addition of  $H_2O$  367

Hydrohalogenation: Addition of  $HX$  370

Addition Polymers of Alkenes 372

**A Human Perspective:** Life Without Polymers? 373

**Green Chemistry:** Plastic Recycling 374

### 11.6 Aromatic Hydrocarbons 374

Structure and Properties 376

Nomenclature 376

Polynuclear Aromatic Hydrocarbons 379

Reactions Involving Benzene 380

### 11.7 Heterocyclic Aromatic Compounds 381

Summary of Reactions 382

Summary 383

Key Terms 383

Questions and Problems 383

Critical Thinking Problems 387

## 12 Alcohols, Phenols, Thiols, and Ethers 389

### 12.1 Alcohols: Structure and Physical Properties 391

### 12.2 Alcohols: Nomenclature 392

I.U.P.A.C. Names 392

Common Names 393

### 12.3 Medically Important Alcohols 394

**A Medical Perspective:** Fetal Alcohol Syndrome 395

### 12.4 Classification of Alcohols 396

### 12.5 Reactions Involving Alcohols 397

Preparation of Alcohols 397

Dehydration of Alcohols 400

**Chemistry at the Crime Scene:** Fingerprinting 401

Oxidation Reactions 402

### 12.6 Oxidation and Reduction in Living Systems 405

**Chemistry at the Crime Scene:** Drinking and Driving 407

### 12.7 Phenols 407

### 12.8 Ethers 408

### 12.9 Thiols 411

**Kitchen Chemistry:** The Magic of Garlic 413

Summary of Reactions 415

Summary 416

Key Terms 416

Questions and Problems 416

Critical Thinking Problems 420

## 13 Aldehydes and Ketones 421

### 13.1 Structure and Physical Properties 423

### 13.2 I.U.P.A.C. Nomenclature and Common Names 425

Naming Aldehydes 425

Naming Ketones 427

### 13.3 Important Aldehydes and Ketones 430

### 13.4 Reactions Involving Aldehydes and Ketones 432

Preparation of Aldehydes and Ketones 432

Oxidation Reactions 432

**A Medical Perspective:** Formaldehyde and Methanol Poisoning 433

**A Human Perspective:** Alcohol Abuse and Antabuse 436

Reduction Reactions 436

**A Medical Perspective:** That Golden Tan Without the Fear of Skin Cancer 438

Addition Reactions 439

Keto-Enol Tautomers 442

Aldol Condensation 443

Summary of Reactions 444

Summary 445

Key Terms 446

Questions and Problems 446

Critical Thinking Problems 449

## 14 Carboxylic Acids and Carboxylic Acid Derivatives 451

### 14.1 Carboxylic Acids 453

Structure and Physical Properties 453  
Nomenclature 454

#### Chemistry at the Crime

**Scene:** Carboxylic Acids and the Body Farm 458

**Green Chemistry:** Garbage Bags from Potato Peels? 460

Some Important Carboxylic Acids 460  
Reactions Involving Carboxylic Acids 463

### 14.2 Esters 466

Structure and Physical Properties 466  
Nomenclature 466  
Reactions Involving Esters 468

**A Human Perspective:** The Chemistry of Flavor and Fragrance 470

### 14.3 Acid Chlorides and Acid Anhydrides 476

Acid Chlorides 476  
Acid Anhydrides 479

### 14.4 Nature's High-Energy Compounds: Phosphoesters and Thioesters 482

**A Human Perspective:** Carboxylic Acid Derivatives of Special Interest 484

Summary of Reactions 485  
Summary 486  
Key Terms 486  
Questions and Problems 486  
Critical Thinking Problems 491

## 15 Amines and Amides 493

### 15.1 Amines 495

Structure and Physical Properties 495  
Nomenclature 498  
Medically Important Amines 501  
Reactions Involving Amines 502

#### Chemistry at the Crime Scene:

Methamphetamine 505  
Quaternary Ammonium Salts 507

### 15.2 Heterocyclic Amines 507

### 15.3 Amides 509

Structure and Physical Properties 510  
Nomenclature 510  
Medically Important Amides 512

**A Medical Perspective:** Semisynthetic Penicillins 513  
Reactions Involving Amides 513

### 15.4 A Preview of Amino Acids, Proteins, and Protein Synthesis 516

### 15.5 Neurotransmitters 517

Catecholamines 517  
Serotonin 517

**A Medical Perspective:** Opiate Biosynthesis and the Mutant Poppy 518

Histamine 519  
 $\gamma$ -Aminobutyric Acid and Glycine 520  
Acetylcholine 520  
Nitric Oxide and Glutamate 521

Summary of Reactions 522

Summary 522

Key Terms 523

Questions and Problems 523

Critical Thinking Problems 526

## BIOCHEMISTRY

## 16 Carbohydrates 529

### 16.1 Types of Carbohydrates 530

### 16.2 Monosaccharides 532

**A Medical Perspective:** Tooth Decay and Simple Sugars 533

### 16.3 Stereoisomers and Stereochemistry 534

Stereoisomers 534  
Rotation of Plane-Polarized Light 535  
The Relationship Between Molecular Structure and Optical Activity 536  
Fischer Projection Formulas 536  
Racemic Mixtures 538  
Diastereomers 538  
Meso Compounds 539  
The D- and L- System of Nomenclature 540

### 16.4 Biologically Important Monosaccharides 541

Glucose 541  
Fructose 545  
Galactose 546  
Ribose and Deoxyribose, Five-Carbon Sugars 547  
Reducing Sugars 547

### 16.5 Biologically Important Disaccharides 549

Maltose 550  
Lactose 550

**Chemistry at the Crime Scene:** Blood Group

Antigens 551  
Sucrose 552

### 16.6 Polysaccharides 553

Starch 553  
Glycogen 553  
Cellulose 554

**A Medical Perspective:** Monosaccharide Derivatives and Heteropolysaccharides of Medical Interest 555

Summary 556

Key Terms 557

Questions and Problems 557

Critical Thinking Problems 559

## 17 Lipids and Their Functions in Biochemical Systems 561

### 17.1 Biological Functions of Lipids 562

**A Medical Perspective:**  
Lifesaving Lipids 563

### 17.2 Fatty Acids 564

Structure and Properties 564  
Chemical Reactions of Fatty Acids 567  
Eicosanoids: Prostaglandins, Leukotrienes, and  
Thromboxanes 570  
Omega-3 Fatty Acids 572

### 17.3 Glycerides 574

Neutral Glycerides 574  
Phosphoglycerides 575

**Chemistry at the Crime Scene:** Adipocere and  
Mummies of Soap 577

### 17.4 Nonglyceride Lipids 578

Sphingolipids 578  
Steroids 580

**A Medical Perspective:** Disorders of Sphingolipid  
Metabolism 581

**A Medical Perspective:** Steroids and the Treatment of  
Heart Disease 582

Waxes 584

### 17.5 Complex Lipids 585

### 17.6 The Structure of Biological Membranes 588

Fluid Mosaic Structure of Biological Membranes 588

**A Medical Perspective:** Liposome Delivery  
Systems 590

Summary 592

Key Terms 593

Questions and Problems 593

Critical Thinking Problems 594

## 18 Protein Structure and Function 595

### 18.1 Protein Building Blocks:

#### The $\alpha$ -Amino Acids 596

Structure of Amino Acids 596  
Stereoisomers of Amino Acids 597

**A Medical Perspective:** Proteins in  
the Blood 598

Classes of Amino Acids 598

### 18.2 The Peptide Bond 601

**A Human Perspective:** The Opium Poppy and Peptides  
in the Brain 602

### 18.3 The Primary Structure of Proteins 605

### 18.4 The Secondary Structure of Proteins 605

$\alpha$ -Helix 606  
 $\beta$ -Pleated Sheet 607

### 18.5 The Tertiary Structure of Proteins 608

**A Medical Perspective:** Collagen, Cosmetic Procedures,  
and Clinical Applications 610

### 18.6 The Quaternary Structure of Proteins 610

### 18.7 An Overview of Protein Structure and Function 612

### 18.8 Myoglobin and Hemoglobin 613

Myoglobin and Oxygen Storage 613  
Hemoglobin and Oxygen Transport 613  
Oxygen Transport from Mother to Fetus 614  
Sickle Cell Anemia 615

### 18.9 Denaturation of Proteins 615

Temperature 616

pH 616

**A Medical Perspective:** Immunoglobulins: Proteins That  
Defend the Body 618

Organic Solvents 618

Detergents 618

Heavy Metals 618

Mechanical Stress 619

### 18.10 Dietary Protein and Protein Digestion 619

Summary 621

Key Terms 622

Questions and Problems 622

Critical Thinking Problems 624

## 19 Enzymes 625

### 19.1 Nomenclature and Classification 626

Classification of Enzymes 626

Nomenclature of Enzymes 630

### 19.2 The Effect of Enzymes on the Activation Energy of a Reaction 631

### 19.3 The Effect of Substrate Concentration on Enzyme-Catalyzed Reactions 632

### 19.4 The Enzyme-Substrate Complex 633

### 19.5 Specificity of the Enzyme-Substrate Complex 634

### 19.6 The Transition State and Product Formation 635

**A Medical Perspective:** HIV Protease Inhibitors and  
Pharmaceutical Drug Design 637

### 19.7 Cofactors and Coenzymes 637

### 19.8 Environmental Effects 641

Effect of pH 641

Effect of Temperature 641

**A Medical Perspective:**  $\alpha_1$ -Antitrypsin and Familial  
Emphysema 642

### 19.9 Regulation of Enzyme Activity 643

Allosteric Enzymes 643

Feedback Inhibition 644



- Proenzymes 645
- Protein Modification 646
- 19.10 Inhibition of Enzyme Activity 646**
  - Irreversible Inhibitors 646
  - Reversible, Competitive Inhibitors 647
  - Chemistry at the Crime Scene:** Enzymes, Nerve Agents, and Poisoning 648
  - Reversible, Noncompetitive Inhibitors 649
- 19.11 Proteolytic Enzymes 650**
  - A Medical Perspective:** Enzymes and Acute Myocardial Infarction 651
- 19.12 Uses of Enzymes in Medicine 652**
  - Summary 653
  - Key Terms 654
  - Questions and Problems 655
  - Critical Thinking Problems 657
- 20 Introduction to Molecular Genetics 659**
  - 20.1 The Structure of the Nucleotide 660**
    - Nucleotide Structure 661
  - 20.2 The Structure of DNA and RNA 663**
    - DNA Structure: The Double Helix 663
    - Chromosomes 665
    - A Medical Perspective:** Molecular Genetics and Detection of Human Genetic Disorders 667
    - RNA Structure 667
  - 20.3 DNA Replication 668**
    - Bacterial DNA Replication 668
    - Eukaryotic DNA Replication 671
  - 20.4 Information Flow in Biological Systems 672**
    - Classes of RNA Molecules 672
    - Transcription 673
    - Post-transcriptional Processing of RNA 674
  - 20.5 The Genetic Code 676**
  - 20.6 Protein Synthesis 678**
    - The Role of Transfer RNA 678
    - The Process of Translation 679
  - 20.7 Mutation, Ultraviolet Light, and DNA Repair 682**
    - The Nature of Mutations 682
    - The Results of Mutations 683
    - A Medical Perspective:** The Ames Test for Carcinogens 684
    - Mutagens and Carcinogens 685
    - Ultraviolet Light Damage and DNA Repair 685
    - Consequences of Defects in DNA Repair 685
  - 20.8 Recombinant DNA 685**
    - Tools Used in the Study of DNA 685
    - Genetic Engineering 687
  - 20.9 Polymerase Chain Reaction 691**
  - 20.10 The Human Genome Project 691**
    - Chemistry at the Crime Scene:** DNA Fingerprinting 692
    - Genetic Strategies for Genome Analysis 692
    - DNA Sequencing 693
    - A Medical Perspective:** A Genetic Approach to Familial Emphysema 694
    - Summary 695
    - Key Terms 696
    - Questions and Problems 697
    - Critical Thinking Problems 698
  - 21 Carbohydrate Metabolism 701**
    - 21.1 ATP: The Cellular Energy Currency 702**
    - 21.2 Overview of Catabolic Processes 705**
      - Stage I: Hydrolysis of Dietary Macromolecules into Small Subunits 706
      - Stage II: Conversion of Monomers into a Form That Can Be Completely Oxidized 708
      - Stage III: The Complete Oxidation of Nutrients and the Production of ATP 708
    - 21.3 Glycolysis 708**
      - An Overview 708
      - Reactions of Glycolysis 710
      - A Medical Perspective:** Genetic Disorders of Glycolysis 712
      - Regulation of Glycolysis 715
      - A Human Perspective:** Fermentations: The Good, the Bad, and the Ugly 716
    - 21.4 Fermentations 716**
      - Lactate Fermentation 716
      - Alcohol Fermentation 718
    - 21.5 The Pentose Phosphate Pathway 719**
    - 21.6 Gluconeogenesis: The Synthesis of Glucose 719**
    - 21.7 Glycogen Synthesis and Degradation 722**
      - The Structure of Glycogen 722
      - Glycogenolysis: Glycogen Degradation 722
      - Glycogenesis: Glycogen Synthesis 724
      - A Medical Perspective:** Diagnosing Diabetes 727
      - Compatibility of Glycogenesis and Glycogenolysis 729
      - A Human Perspective:** Glycogen Storage Diseases 730
      - Summary 730
      - Key Terms 731
      - Questions and Problems 731
      - Critical Thinking Problems 733

## **22 Aerobic Respiration and Energy Production 735**

### **22.1 The Mitochondria 736**

Structure and Function 736

Origin of the Mitochondria 737

**A Human Perspective:** Exercise and Energy Metabolism 738

### **22.2 Conversion of Pyruvate to Acetyl CoA 738**

### **22.3 An Overview of Aerobic Respiration 741**

### **22.4 The Citric Acid Cycle (The Krebs Cycle) 742**

Reactions of the Citric Acid Cycle 742

### **22.5 Control of the Citric Acid Cycle 745**

### **22.6 Oxidative Phosphorylation 747**

Electron Transport Systems and the Hydrogen Ion Gradient 747

**A Human Perspective:** Brown Fat: The Fat That Makes You Thin? 748

ATP Synthase and the Production of ATP 750

Summary of the Energy Yield 750

### **22.7 The Degradation of Amino Acids 751**

Removal of  $\alpha$ -Amino Groups: Transamination 752

Removal of  $\alpha$ -Amino Groups: Oxidative Deamination 753

The Fate of Amino Acid Carbon Skeletons 755

### **22.8 The Urea Cycle 755**

Reactions of the Urea Cycle 755

**A Medical Perspective:** Pyruvate Carboxylase Deficiency 758

### **22.9 Overview of Anabolism: The Citric Acid Cycle as a Source of Biosynthetic Intermediates 759**

Summary 761

Key Terms 761

Questions and Problems 762

Critical Thinking Problems 763

## **23 Fatty Acid Metabolism 765**

### **23.1 Lipid Metabolism in Animals 766**

Digestion and Absorption of Dietary Triglycerides 766

Lipid Storage 767

**A Medical Perspective:** Obesity: A Genetic Disorder? 769

### **23.2 Fatty Acid Degradation 770**

An Overview of Fatty Acid Degradation 770

The Reactions of  $\beta$ -Oxidation 771

**A Human Perspective:** Losing Those Unwanted Pounds of Adipose Tissue 774

### **23.3 Ketone Bodies 777**

Ketosis 777

Ketogenesis 777

### **23.4 Fatty Acid Synthesis 779**

A Comparison of Fatty Acid Synthesis and Degradation 779

### **23.5 The Regulation of Lipid and Carbohydrate Metabolism 781**

The Liver 781

Adipose Tissue 781

**A Medical Perspective:** Diabetes Mellitus and Ketone Bodies 782

Muscle Tissue 783

The Brain 784

### **23.6 The Effects of Insulin and Glucagon on Cellular Metabolism 784**

Summary 786

Key Terms 786

Questions and Problems 786

Critical Thinking Problems 788

Glossary G-1

Answers to Odd-Numbered Problems AP-1

Credits C-1

Index I-1