

Part ONE PRINCIPLES OF MOLECULAR STRUCTURE AND FUNCTION

Chapter 1 INTRODUCTION TO BIOMOLECULES

Water Is the Solvent of Life
Water Contains Hydronium Ions and Hydroxyl Ions
Ionizable Groups Are Characterized by Their pK Values
The Blood pH is Tightly Regulated
Acidosis and Alkalosis Are Common in Clinical Practice
Bonds Are Formed by Reactions between Functional Groups
Isomeric Forms Are Common in Biomolecules
Properties of Biomolecules Are Determined by Their Noncovalent Interactions
Triglycerides Consist of Fatty Acids and Glycerol
Monosaccharides Are Polyalcohols with a Keto Group or an Aldehyde Group
Monosaccharides Form Ring Structures
Complex Carbohydrates Are Formed by Glycosidic Bonds
Polypeptides Are Formed from Amino Acids
Nucleic Acids Are Formed from Nucleotides
Most Biomolecules Are Polymers
Summary

Chapter 2 INTRODUCTION TO PROTEIN STRUCTURE

Amino Acids Are Zwitterions
Amino Acid Side Chains Form Many Noncovalent Interactions
Peptide Bonds and Disulfide Bonds Form the Primary Structure of Proteins
Proteins Can Fold Themselves into Many Shapes
 α -Helix and β -Pleated Sheet Are the Most Common Secondary Structures in Proteins
Globular Proteins Have a Hydrophobic Core
Proteins Lose Their Biological Activities When Their Higher-Order Structure Is Destroyed
The Solubility of Proteins Depends on pH and Salt Concentration
Proteins Absorb Ultraviolet Radiation
Proteins Can Be Separated by Their Charge or Their Molecular Weight
Abnormal Protein Aggregates Can Cause Disease
Neurodegenerative Diseases Are Caused by Protein Aggregates
Protein Misfolding Can Be Contagious
Summary

Chapter 3 OXYGEN TRANSPORTERS: HEMOGLOBIN AND MYOGLOBIN

The Heme Group Is the Oxygen-Binding Site of Hemoglobin and Myoglobin
Myoglobin Is a Tightly Packed Globular Protein
Red Blood Cells Are Specialized for Oxygen Transport
The Hemoglobins Are Tetrameric Proteins
Oxygenated and Deoxygenated Hemoglobin Have Different Quaternary Structures
Oxygen Binding to Hemoglobin Is Cooperative
2,3-Bisphosphoglycerate Is a Negative Allosteric Effector of Oxygen Binding to Hemoglobin
Fetal Hemoglobin Has a Higher Oxygen-Binding Affinity than Does Adult Hemoglobin
The Bohr Effect Facilitates Oxygen Delivery
Most Carbon Dioxide Is Transported as Bicarbonate
Summary

Chapter 4 ENZYMATIC REACTIONS

The Equilibrium Constant Describes the Equilibrium of the Reaction
The Free Energy Change Is the Driving Force for Chemical Reactions
The Standard Free Energy Change Determines the Equilibrium
Enzymes Are Both Powerful and Selective
The Substrate Must Bind to Its Enzyme before the Reaction Can Proceed
Rate Constants Are Useful for Describing Reaction Rates
Enzymes Decrease the Free Energy of Activation
Many Enzymatic Reactions Can Be Described by Michaelis-Menten Kinetics
 K_m and V_{max} Can Be Determined Graphically
Substrate Half-Life Can Be Determined for First-Order but Not Zero-Order Reactions
 K_{cat}/K_m Predicts the Enzyme Activity at Low Substrate Concentration
Allosteric Enzymes Do Not Conform to Michaelis-Menten Kinetics
Enzyme Activity Depends on Temperature and pH
Different Types of Reversible Enzyme Inhibition Can Be Distinguished Kinetically

Covalent Modification Can Inhibit Enzymes Irreversibly
Enzymes Stabilize the Transition State
Chymotrypsin Forms a Transient Covalent Bond during Catalysis
Summary

Chapter 5 COENZYMES

Enzymes Are Classified According to Their Reaction Type
Adenosine Triphosphate Has Two Energy-Rich Bonds
ATP DONATES Phosphate in Phosphorylation Reactions
ATP Hydrolysis Drives Endergonic Reactions
Cells Always Try to Maintain a High Energy Charge
Dehydrogenase Reactions Require Specialized Coenzymes
Coenzyme A Activates Organic Acids
S-Adenosyl Methionine Donates Methyl Groups
Many Enzymes Require a Metal Ion
Summary

Summary Part TWO GENETIC INFORMATION: DNA, RNA, AND PROTEIN SYNTHESIS

Chapter 6 DNA, RNA, AND PROTEIN SYNTHESIS

All Living Organisms Use DNA as Their Genetic Databank
DNA Contains Four Bases
DNA Forms a Double Helix
DNA Can Be Denatured
DNA Is Supercoiled
DNA Replication Is Semiconservative
DNA Is Synthesized by DNA Polymerases
DNA Polymerases Have Exonuclease Activities
Unwinding Proteins Present a Single-Stranded Template to the DNA Polymerases
One of the New DNA Strands Is Synthesized Discontinuously
RNA Plays Key Roles in Gene Expression
The σ Subunit Recognizes Promoters
DNA Is Faithfully Copied into RNA
Some RNAs Are Chemically Modified after Transcription
The Genetic Code Defines the Structural Relationship between mRNA and Polypeptide
Transfer RNA Is the Adapter Molecule in Protein Synthesis
Amino Acids Are Activated by an Ester Bond with the 3' Terminus of the tRNA
Many Transfer RNAs Recognize More than One Codon
Ribosomes Are the Workbenches for Protein Synthesis
The Initiation Complex Brings Together Ribosome, Messenger RNA, and Initiator tRNA
Polypeptides Grow Stepwise from the Amino Terminus to the Carboxyl Terminus
Protein Synthesis Is Energetically Expensive
Gene Expression Is Tightly Regulated
A Repressor Protein Regulates Transcription of the lac Operon in *E. coli*
Anabolic Operons Are Repressed by the End Product of the Pathway
Glucose Regulates the Transcription of Many Catabolic Operons
Transcriptional Regulation Depends on DNA-Binding Proteins
Summary

Chapter 7 THE HUMAN GENOME

Chromatin Consists of DNA and Histones
The Nucleosome Is the Structural Unit of Chromatin
Covalent Histone Modifications Regulate
DNA Replication and Transcription DNA Methylation Silences Genes
All Eukaryotic Chromosomes Have a Centromere, Telomeres, and Replication Origins
Telomerase Is Required (but Not Sufficient) for Immortality
Eukaryotic DNA Replication Requires Three DNA Polymerases
Most Human DNA Does Not Code for Proteins
Gene Families Originate by Gene Duplication
The Genome Contains Many Tandem Repeats
Some DNA Sequences Are Copies of Functional RNAs
Many Repetitive DNA Sequences Are (or Were) Mobile
L1 Elements Encode a Reverse Transcriptase
Alu Sequences Spread with the Help of L1 Reverse Transcriptase

Mobile Elements Are Dangerous
Humans Have Approximately 20,000 Genes
Transcriptional Initiation Requires General Transcription Factors
Genes Are Surrounded by Regulatory Sites
Gene Expression Is Regulated by DNA-Binding Proteins
Long Non-coding RNAs Play Roles in Gene Expression
mRNA Processing Starts during Transcription
Translational Initiation Requires Many Initiation Factors
mRNA Processing and Translation Are Often Regulated
Small RNA Molecules Inhibit Gene Expression
Mitochondria Have Their Own DNA
Human Genomes Are Very Diverse
Human Genomes Have Many Low-Frequency Copy Number Variations
Summary

Chapter 8 PROTEIN TARGETING AND PROTEOSTASIS

A Signal Sequence Directs Polypeptides to the Endoplasmic Reticulum
Glycoproteins Are Processed in the Secretory Pathway
The Endocytic Pathway Brings Proteins into the Cell
Lysosomes Are Organelles of Intracellular Digestion
Autophagy Recycles Cellular Proteins and Organelles
Poorly Folded Proteins Are Either Repaired or Destroyed
Ubiquitin Marks Proteins for Destruction
The Proteostatic System Protects Cells from Abnormal Proteins
Summary

Chapter 9 INTRODUCTION TO GENETIC DISEASES

Four Types of Genetic Disease
Mutations Occur in the Germline and in Somatic Cells
Mutations Are an Important Cause of Poor Health
Small Mutations Lead to Abnormal Proteins
Most Mutations Are Caused by Replication Errors
Mutations Can Be Induced by Radiation and Chemicals
Mismatch Repair Corrects Replication Errors
Missing Bases and Abnormal Bases Need to Be Replaced
Nucleotide Excision Repair Removes Bulky Lesions
Repair of DNA Double-Strand Breaks Is Difficult
Hemoglobin Genes Form Two Gene Clusters
Many Point Mutations in Hemoglobin Genes Are Known
Sickle Cell Disease Is Caused by a Point Mutation in the β -Chain Gene
SA Heterozygotes Are Protected from Tropical Malaria
 α -Thalassemia Is Most Often Caused by Large Deletions
Many Different Mutations Can Cause β -Thalassemia
Fetal Hemoglobin Protects from the Effects of β -Thalassemia and Sickle Cell Disease
Polygenic Diseases Have Multiple Genetic Risk Factors
Genetic Risk Factors Are Discovered in Genome-Wide Association
Summary

Chapter 10 VIRUSES

Viruses Can Replicate Only in a Host Cell
Bacteriophage T₄ Destroys Its Host Cell
DNA Viruses Substitute Their Own DNA for the Host Cell DNA
 λ Phage Can Integrate Its DNA into the Host Cell Chromosome
RNA Viruses Require an RNA-Dependent RNA Polymerase
Retroviruses Replicate Through a DNA Intermediate
Plasmids Are Small "Accessory Chromosomes" or "Symbiotic Viruses" of Bacteria
Bacteria Can Exchange Genes by Transformation and Transduction
Jumping Genes Can Change Their Position in the Genome
Summary

Chapter 11 DNA TECHNOLOGY

Restriction Endonucleases Cut Large DNA Molecules into Smaller Fragments
Large Probes Are Used to Detect Copy Number Variations
Small Probes Are Used to Detect Point Mutations

Southern Blotting Determines the Size of Restriction Fragments
DNA Can Be Amplified with the Polymerase Chain Reaction
PCR Is Used for Preimplantation Genetic Diagnosis
Allelic Heterogeneity Is the Greatest Challenge for Molecular Genetic Diagnosis
Normal Polymorphisms Are Used as Genetic Markers
Tandem Repeats Are Used for DNA Fingerprinting
DNA Microarrays Can Be Used for Genetic Screening
DNA Microarrays Are Used for the Study of Gene Expression
DNA Is Sequenced by Controlled Chain Termination
Massively Parallel Sequencing Permits Cost-Efficient Whole-Genome Genetic Diagnosis
Gene Therapy Targets Somatic Cells
Viruses Are Used as Vectors for Gene Therapy
Retroviruses Can Splice a Transgene into the Cell's Genome
Genome Editing Is Based on the Making and Healing of DNA Double Strand Breaks
Designer Nucleases Are Used for Genome Editing
Antisense Oligonucleotides Can Block the Expression of Rogue Genes
Genes Can Be Altered in Animals
Tissue-Specific Gene Expression Can Be Engineered into Animals
Human Germline Genome Editing is Technically Possible
Summary

Part THREE CELL AND TISSUE STRUCTURE

Chapter 12 BIOLOGICAL MEMBRANES

Membranes Consist of Lipid and Protein
Phosphoglycerides Are the Most Abundant Membrane Lipids
Most Sphingolipids Are Glycolipids
Cholesterol Is the Most Hydrophobic Membrane Lipid
Membrane Lipids Form a Bilayer
The Lipid Bilayer Is a Two-Dimensional Fluid
The Lipid Bilayer Is a Diffusion Barrier
Membranes Contain Integral and Peripheral Membrane Proteins
Membranes Are Asymmetrical
Membranes Are Fragile
Membrane Proteins Carry Solutes across the Lipid Bilayer
Transport against an Electrochemical Gradient Requires Metabolic Energy
Active Transport Consumes ATP
Sodium Cotransport Brings Molecules into the Cell
Summary

Chapter 13 THE CYTOSKELETON

The Erythrocyte Membrane Is Reinforced by a Spectrin Network
Keratins Give Strength to Epithelia
Actin Filaments Are Formed from Globular Subunits
Striated Muscle Contains Thick and Thin Filaments
Myosin Is a Two-Headed Molecule with ATPase Activity
Muscle Contraction Requires Calcium and ATP
The Cytoskeleton of Skeletal Muscle Is Linked to the Extracellular Matrix
Microtubules Consist of Tubulin
Eukaryotic Cilia and Flagella Contain a 9 + 2 Array of Microtubules
Cells Form Specialized Junctions with Other Cells and with the Extracellular Matrix
Summary

Chapter 14 THE EXTRACELLULAR MATRIX

Collagen Is the Most Abundant Protein in the Human Body
The Tropocollagen Molecule Forms a Long Triple Helix
Collagen Fibrils Are Staggered Arrays of Tropocollagen Molecules
Collagen Is Subject to Extensive Posttranslational Processing
Collagen Metabolism Is Altered in Aging and Disease
Many Genetic Defects of Collagen Structure and Biosynthesis Are Known
Elastic Fibers Contain Elastin and Fibrillin
The Amorphous Ground Substance Contains Hyaluronic Acid
Sulfated Glycosaminoglycans Are Covalently Bound to Core Proteins
Cartilage Contains Large Proteoglycan Aggregates

Proteoglycans Are Synthesized in the ER and Degraded in Lysosomes
Mucopolysaccharidoses Are Caused by Deficiency of Glycosaminoglycan-Degrading Enzymes
Bone Consists of Calcium Phosphates in a Collagenous Matrix
Basement Membranes Contain Type IV Collagen, Laminin, and Heparan Sulfate Proteoglycans
Fibronectin Glues Cells and Collagen Fibers Together
Summary

Part FOUR MOLECULAR PHYSIOLOGY

Chapter 15 EXTRACELLULAR MESSENGERS

Steroid Hormones Are Made from Cholesterol
Progestins Are the Biosynthetic Precursors of All Other Steroid Hormones
Thyroid Hormones Are Synthesized from Protein-Bound Tyrosine
T₄ Becomes Activated to T₃ in the Target Tissues
Both Hypothyroidism and Hyperthyroidism Are Common Disorders
Insulin Is Released Together with the C-Peptide
Proopiomelanocortin Forms Several Active Products
Angiotensin Is Formed from Circulating Angiotensinogen
Immunoassays Are Used for Determination of Hormone Levels
Catecholamines Are Synthesized from Tyrosine
Indolamines Are Synthesized from Tryptophan
Histamine Is Produced by Mast Cells and Basophils
Neurotransmitters Are Released at Synapses
Acetylcholine Is the Neurotransmitter of the Neuromuscular Junction
There Are Many Neurotransmitters
Summary

Chapter 16 INTRACELLULAR MESSENGERS

Receptor-Hormone Interactions Are Noncovalent, Reversible, and Saturable
Many Neurotransmitter Receptors Are Ion Channels
Steroid and Thyroid Hormones Bind to Transcription Factors
Seven-Transmembrane Receptors Are Coupled to G Proteins
Adenylate Cyclase Is Regulated by G Proteins
Hormones Can Both Activate and Inhibit the cAMP Cascade
Cytoplasmic Calcium Is an Important Intracellular Signal
Phospholipase C Generates Two Second Messengers
Both cAMP and Calcium Regulate Gene Transcription
Muscle Contraction and Exocytosis Are Triggered by Calcium
Atrial Natriuretic Factor Acts through a Membrane-Bound Guanylate Cyclase
Nitric Oxide Stimulates a Soluble Guanylate Cyclase
cGMP Is a Second Messenger in Retinal Rod Cells
Receptors for Insulin and Growth Factors Are Tyrosine-Specific Protein Kinases
Growth Factors and Insulin Trigger Multiple Signaling Cascades
Cytokine Receptors Use the JAK-Stat Pathway
Many Receptors Become Desensitized after Overstimulation
Summary

Chapter 17 PLASMA PROTEINS

Plasma Proteins Are Both Synthesized and Destroyed in the Liver
Albumin Prevents Edema
Albumin Binds Many Small Molecules
Some Plasma Proteins Are Specialized Carriers of Small Molecules
Deficiency of α_1 -Antitrypsin Causes Lung Emphysema
Levels of Plasma Proteins Are Affected by Many Diseases
Blood Components Are Used for Transfusions
Blood Clotting Must Be Tightly Controlled
Platelets Adhere to Exposed Subendothelial Tissue
Insoluble Fibrin Is Formed from Soluble Fibrinogen
Thrombin Is Derived from Prothrombin
Factor X Can Be Activated by the Extrinsic and Intrinsic Pathways
Negative Controls Are Necessary to Prevent Thrombosis
Plasmin Degrades the Fibrin Clot
Heparin and the Vitamin K Antagonists Are Used as Anticoagulants
Clotting Factor Deficiencies Cause Abnormal Bleeding

Tissue Damage Causes Release of Cellular Enzymes into Blood Serum Enzymes Are Used for the Diagnosis of Many Diseases
Summary

Chapter 18 DEFENSE MECHANISMS

Lipophilic Xenobiotics Are Metabolized to Water-soluble Products
Cytochrome P-450 Is Involved in Phase I Metabolism
Phase II Metabolism Makes Xenobiotics Water-Soluble for Excretion
Phase III Metabolism Excretes Xenobiotic Metabolites
Drug Metabolizing Enzymes Are Inducible
The Innate Immune System Uses Pattern Recognition Receptors
Infection Triggers Inflammation
Lymphocytes Possess Antigen Receptors
B Lymphocytes Produce Immunoglobulins
Antibodies Consist of Two Light Chains and Two Heavy Chains
Different Immunoglobulin Classes Have Different Properties
Adaptive Immune Responses Are Based on Clonal Selection
Immunoglobulin genes Are Rearranged During B-Cell Development
The T-Cell Receptor Recruits Cytosolic Tyrosine Protein Kinases
Mediators of Inflammation Are Produced from Arachidonic Acid
Prostaglandins Are Synthesized in All Tissues
Prostanoids Participate in Many Physiological Processes
Leukotrienes Are Produced by the Lipoxygenase Pathway
Antiinflammatory Drugs Inhibit the Synthesis of Eicosanoids
Summary

Chapter 19 CELLULAR GROWTH CONTROL AND CANCER

The Cell Cycle Is Controlled at Two Checkpoints
Cells Can Be Grown in Culture
Cyclins Play Key Roles in Cell Cycle Control
Retinoblastoma Protein Guards the G1 Checkpoint
Cell Proliferation Is Triggered by Mitogens
Mitogens Regulate Gene Expression
Cells Can Commit Suicide
Cancers Are Monoclonal in Origin
Cancer Is Caused by Activation of Growth-Promoting Genes and Inactivation of Growth-Inhibiting Genes
Some Retroviruses Contain an Oncogene
Retroviruses Can Cause Cancer by Inserting Themselves Next to a Cellular Proto-Oncogene
Many Oncogenes Code for Components of Mitogenic Signaling Cascades
Cancer Susceptibility Syndromes Are Caused by Inherited Mutations in Tumor Suppressor Genes
Many Tumor Suppressor Genes Are Known
Components of the Cell Cycle Machinery Are Abnormal in Most Cancers
DNA Damage Causes Either Growth Arrest or Apoptosis
Most Spontaneous Cancers Are Defective in p53 Action
The P13K/Protein Kinase B Pathway Is Activated in Many Cancers
The Products of Some Viral Oncogenes Neutralize the Products of Cellular Tumor Suppressor Genes
Tumors Become More Malignant through Darwinian Selection
Intestinal Polyps Are Benign Lesions
Intestinal Polyps Can Evolve into Colon Cancer
Summary Part

FIVE METABOLISM

Chapter 20 DIGESTIVE ENZYMES

Saliva Contains α -Amylase and Lysozyme
Protein and Fat Digestion Start in the Stomach
The Pancreas Is a Factory for Digestive Enzymes
Fat Digestion Requires Bile Salts
Some Digestive Enzymes Are Anchored to the Surface of the Microvilli
Poorly Digestible Nutrients Cause Flatulence
Many Digestive Enzymes Are Released as Inactive Precursors
Summary

Chapter 21 INTRODUCTION TO METABOLIC PATHWAYS

Alternative Substrates Can Be Oxidized in the Body
Metabolic Processes Are Compartmentalized
Free Energy Changes in Metabolic Pathways Are Additive
Most Metabolic Pathways Are Regulated
Feedback Inhibition and Feedforward Stimulation Are the Most Important Regulatory Principles
Metabolism Is Regulated to Ensure Homeostasis
Inherited Enzyme Deficiencies Cause Metabolic Diseases
Vitamin Deficiencies, Toxins, and Endocrine Disorders Can Disrupt Metabolic Pathways
Summary

Chapter 22 GLYCOLYSIS, TRICARBOXYLIC ACID CYCLE, AND OXIDATIVE PHOSPHORYLATION

Glucose Uptake into the Cells Is Regulated
Glucose Degradation Begins in the Cytoplasm and Ends in the Mitochondria
Glycolysis Begins with ATP-Dependent Phosphorylations
Most Glycolytic Intermediates Have Three Carbons
Phosphofructokinase Is the Most Important Regulated Enzyme of Glycolysis
Lactate Is Produced under Anaerobic Conditions
Pyruvate Is Decarboxylated to Acetyl-CoA in the Mitochondria
The TCA Cycle Produces Two Molecules of Carbon Dioxide for Each Acetyl Residue
Reduced Coenzymes Are the Most Important Products of the TCA Cycle
Oxidative Pathways Are Regulated by Energy Charge and [NADH]/[NAD⁺] Ratio
The TCA Cycle Provides an Important Pool of Metabolic Intermediates
Antiporters Transport Metabolites across the Inner Mitochondrial Membrane
The Respiratory Chain Channels Electrons from NADH and FADH₂ to Molecular Oxygen
The Standard Reduction Potential Is the Tendency to Donate Electrons
The Respiratory Chain Contains Flavoproteins, Iron-Sulfur Proteins, Cytochromes, Ubiquinone, and Protein-Bound Copper
The Respiratory Chain Contains Large Multiprotein Complexes
The Respiratory Chain Creates a Proton Gradient
The Proton Gradient Drives ATP Synthesis
The Efficiency of Glucose Oxidation Is Close to 40%
Oxidative Phosphorylation Is Limited by the Supply of ADP
Brown Adipose Tissue Contains an Uncoupling Protein
Mutations in Mitochondrial DNA Can Cause Disease
Summary

Chapter 23 OXYGEN DEFICIENCY AND OXYGEN TOXICITY

Ischemia Leads to Infarction
Oxidative Phosphorylation Is Inhibited by Many Poisons
Hypoxia Inducible Factor Adjusts Cell Metabolism to Hypoxia
Reactive Oxygen Derivatives Are Formed during Oxidative Metabolism
The Respiratory Chain Is a Major Source of Superoxide
Cells Have Specialized Enzymes to Destroy Reactive Oxygen Species
Free Radical Formation Is Affected by Energy Supply and Energy Consumption
Some Vitamins and Phytochemicals Can Scavenge Free Radicals
The NRF2 Transcription Factor Coordinates Defenses against Reactive Oxygen Species
Phagocytic Cells Use Reactive Oxygen Species for Intracellular Killing
Summary

Chapter 24 CARBOHYDRATE METABOLISM

An Adequate Blood Glucose Level Must Be Maintained at All Times
Gluconeogenesis Bypasses the Three Irreversible Reactions of Glycolysis
Fatty Acids Cannot Be Converted into Glucose
Glycolysis and Gluconeogenesis Are Regulated by Hormones
Glycolysis and Gluconeogenesis Are Fine Tuned by Allosteric Effectors and Hormone-Induced Enzyme Phosphorylations
Fructose-2,6-bisphosphate Switches the Liver from Gluconeogenesis to Glycolysis
Glucokinase Is Regulated by Two Regulatory Proteins
Carbohydrate Is Stored as Glycogen
Glycogen Is Synthesized from Glucose
Glycogen Is Degraded by Phosphorolytic Cleavage
Glycogen Metabolism Is Regulated by Hormones and Metabolites

Glycogen Accumulates in Several Enzyme Deficiencies
Fructose Is Channeled into Glycolysis/Gluconeogenesis
Excess Fructose Is Problematic
Excess Galactose Is Channeled into the Pathways of Glucose Metabolism
The Pentose Phosphate Pathway Supplies NADPH and Ribose-5-Phosphate
Fructose Is the Principal Sugar in Seminal Fluid
Amino Sugars and Sugar Acids Are Made from Glucose
Summary

Chapter 25 THE METABOLISM OF FATTY ACIDS AND TRIGLYCERIDES

Fatty Acids Differ in Their Chain Length and Number of Double Bonds
Chylomicrons Transport Triglycerides from the Intestine to Other Tissues
Adipose Tissue Is Specialized for the Storage of Triglycerides
Fat Metabolism in Adipose Tissue Is under Hormonal Control
Fatty Acids Are Transported into the Mitochondrion
 β -Oxidation Produces Acetyl-CoA, NADH, and FADH₂
Special Fatty Acids Require Special Reactions
The Liver Converts Excess Fatty Acids to Ketone Bodies
Fatty Acids Are Synthesized from Acetyl-CoA
Acetyl-CoA Is Shuttled into the Cytoplasm as Citrate
Fatty Acid Synthesis Is Regulated by Hormones and Metabolites
AMP-Activated Protein Kinase Adapts Metabolic Pathways to Cellular Energy Status
Most Fatty Acids Can Be Synthesized from Palmitate
Fatty Acids Regulate Gene Expression
Polyunsaturated Fatty Acids Can Be Oxidized Nonenzymatically
Summary

Chapter 26 THE METABOLISM OF MEMBRANE LIPIDS

Phosphatidic Acid Is an Intermediate in Phosphoglyceride Synthesis
Phosphoglycerides Are Remodeled Continuously
Sphingolipids Are Synthesized from Ceramide
Deficiencies of Sphingolipid-Degrading Enzymes Cause Lipid Storage Diseases
Cholesterol Is the Least Soluble Membrane Lipid
Cholesterol Is Derived from Both Endogenous Synthesis and the Diet
Cholesterol Biosynthesis Is Regulated at the Level of HMG-CoA Reductase
Bile Acids Are Synthesized from Cholesterol
Bile Acids Are Subject to Extensive Enterohepatic Circulation
Most Gallstones Consist of Cholesterol
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Chapter 27 LIPID TRANSPORT

Most Plasma Lipids Are Components of Lipoproteins
Lipoproteins Have Characteristic Lipid and Protein Compositions
Dietary Lipids Are Transported by Chylomicrons
VLDL Is a Precursor of LDL
LDL Is Removed by Receptor-Mediated Endocytosis
Cholesterol Regulates Its Own Metabolism
HDL Is Needed for Reverse Cholesterol Transport
Lipoproteins Can Initiate Atherosclerosis
Lipoproteins Respond to Diet and Lifestyle
Hyperlipoproteinemias Are Grouped into Five Phenotypes
Hyperlipidemias Are Treated with Diet and Drugs
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Chapter 28 AMINO ACID METABOLISM

Amino Acids Can Be Used for Gluconeogenesis and Ketogenesis
The Nitrogen Balance Indicates the Net Rate of Protein Synthesis
The Amino Group of Amino Acids Is Released as Ammonia
Ammonia Is Detoxified to Urea
Urea Is Synthesized in the Urea Cycle
Hyperammonemia Can Be Treated with Diet and Drugs
Some Amino Acids Are Closely Related to Common Metabolic Intermediates
Glycine, Serine, and Threonine Are Glucogenic
Proline, Arginine, Ornithine, and Histidine Are Degraded to Glutamate
Methionine and Cysteine Are Metabolically Related

Valine, Leucine, and Isoleucine Are Degraded by Transamination and Oxidative Decarboxylation
Phenylalanine and Tyrosine Are Both Glucogenic and Ketogenic
Melanin Is Synthesized from Tyrosine
Lysine and Tryptophan Have Lengthy Catabolic Pathways
The Liver Is the Most Important Organ of Amino Acid Metabolism
Glutamine Participates in Renal Acid-Base Regulation
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Chapter 29 METABOLISM OF IRON AND HEME

Iron Is Conserved Very Efficiently in the Body
Iron Uptake by Cells Is Regulated
Dietary Iron Is Absorbed in the Duodenum
Dietary Iron Absorption Is Regulated
Iron Deficiency Is the Most Common Micronutrient Deficiency Worldwide
Bone Marrow and Liver Are the Most Important Sites of
Heme Synthesis Heme Is Synthesized from Succinyl-Coenzyme A and Glycine
Porphyrias Are Caused by Deficiencies of Heme-Synthesizing Enzymes
Heme Is Degraded to Bilirubin
Bilirubin Is Conjugated and Excreted by the Liver
Elevations of Serum Bilirubin Cause Jaundice
Many Diseases Can Cause Jaundice
Summary

Chapter 30 THE METABOLISM OF PURINES AND PYRIMIDINES

Purine Synthesis Starts with Ribose-5-Phosphate
Purines Are Degraded to Uric Acid
Free Purine Bases Can Be Salvaged
Pyrimidines Are Synthesized from Carbamoyl Phosphate and Aspartate
DNA Synthesis Requires Deoxyribonucleotides
Many Antineoplastic Drugs Inhibit Nucleotide Metabolism
Uric Acid Has Limited Water Solubility
Hyperuricemia Causes Gout
Abnormalities of Purine-Metabolizing Enzymes Can Cause Gout
Gout Can Be Treated with Drugs
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Chapter 31 MICRONUTRIENTS

Riboflavin Is a Precursor of Flavin Mononucleotide and Flavin Adenine Dinucleotide
Niacin Is a Precursor of NAD and NADP
Thiamin Deficiency Causes Weakness and Amnesia
Vitamin B₆ Plays a Key Role in Amino Acid Metabolism
Pantothenic Acid Is a Building Block of Coenzyme A
Biotin Is a Coenzyme in Carboxylation Reactions
Folic Acid Deficiency Causes Megaloblastic Anemia
Vitamin B₁₂ Requires Intrinsic Factor for Its Absorption
Vitamin C Is a Water-Soluble Antioxidant
Retinol, Retinal, and Retinoic Acid Are the Active Forms of Vitamin A
Vitamin D Is a Prohormone
Vitamin E Prevents Lipid Oxidation
Many Vitamins and Phytochemicals Are Antioxidants
Vitamin K Is Required for Blood Clotting
Zinc Is a Constituent of Many Enzymes
Copper Participates in Reactions of Molecular Oxygen
Some Trace Elements Serve Very Specific Functions
Summary

Chapter 32 INTEGRATION OF METABOLISM

Insulin Is Released in Response to Elevated Glucose
Insulin Stimulates the Utilization of Nutrients
Protein Synthesis Is Coordinated by the mTOR Complex
Glucagon Maintains the Blood Glucose Level
Catecholamines Mediate the Flight-or-Fight Response
Glucocorticoids Are Released in Chronic Stress
Energy Is Expended Continuously

Stored Fat and Glycogen Are Degraded between Meals
Adipose Tissue Is the Most Important Energy Depot
The Liver Converts Dietary Carbohydrates to Glycogen and Fat after a Meal
The Liver Maintains the Blood Glucose Level during Fasting
Ketone Bodies Provide Lipid-Based Energy during Fasting
Obesity Is Common in All Affluent Countries
Appetite Control Is the Most Important Determinant of Obesity
Obesity Is Related to Insulin Resistance
Diabetes Is Caused by Insulin Deficiency or Insulin Resistance
In Diabetes, Metabolism Is Regulated as in Starvation
Diabetes Is Diagnosed with Laboratory Tests
Diabetes Leads to Late Complications
Many Drugs Are Available for Diabetes Treatment
Contracting Muscle Has Three Energy Sources
Catecholamines Coordinate Metabolism during Exercise
Physical Exercise Leads to Adaptive Changes
Ethanol Is Metabolized to Acetyl-CoA in the Liver
Liver Metabolism Is Deranged by Alcohol
Alcohol Abuse Leads to Fatty Liver and Liver Cirrhosis
Most "Diseases of Civilization" Are Caused by Aberrant Lifestyles
Aging Is the Greatest Challenge for Medical Research
AntiAging Treatments Are Being Investigated
Summary

ANSWERS TO QUESTIONS

GLOSSARY

CREDITS

EXTRA ONLINE-ONLY CASE STUDIES

The Mafia Boss
Viral Gastroenteritis
Death in Installments
A Mysterious Death
To Treat or Not to Treat?
Yellow Eyes
An Abdominal Emergency
Shortness of Breath
Itching
Abdominal Pain
Rheumatism
A Bank Manager in Trouble
Kidney Problems
Gender Blender
Man Overboard!
Spongy Bones
Blisters
The Sunburned Child
Too Much Ammonia

ANSWERS TO CASE STUDIES