

Contents

PART ONE Fundamentals of Microbiology

1 The Microbial World and You 27

Microbes in Our Lives 28

Naming and Classifying Microorganisms 28

Nomenclature • Types of Microorganisms • Classification of Microorganisms

A Brief History of Microbiology 32

The First Observations • The Debate over Spontaneous Generation • The Golden Age of Microbiology • The Birth of Modern Chemotherapy: Dreams of a “Magic Bullet” • Modern Developments in Microbiology

Microbes and Human Welfare 39

Recycling Vital Elements • Sewage Treatment: Using Microbes to Recycle Water • Bioremediation: Using Microbes to Clean Up Pollutants • Insect Pest Control by Microorganisms • Modern Biotechnology and Recombinant DNA Technology

Microbes and Human Disease 41

Normal Microbiota • Biofilms • Infectious Diseases • Emerging Infectious Diseases

Study Outline • Study Questions 46

2 Chemical Principles 50

The Structure of Atoms 51

Chemical Elements • Electronic Configurations

How Atoms Form Molecules: Chemical Bonds 53

Ionic Bonds • Covalent Bonds • Hydrogen Bonds • Molecular Weight and Moles

Chemical Reactions 56

Energy in Chemical Reactions • Synthesis Reactions • Decomposition Reactions • Exchange Reactions • The Reversibility of Chemical Reactions

IMPORTANT BIOLOGICAL MOLECULES 57

Inorganic Compounds 58

Water • Acids, Bases, and Salts • Acid–Base Balance: The Concept of pH

Organic Compounds 60

Structure and Chemistry • Carbohydrates • Lipids • Proteins • Nucleic Acids • Adenosine Triphosphate (ATP)

Study Outline • Study Questions 73

3 Observing Microorganisms Through a Microscope 77

Units of Measurement 78

Microscopy: The Instruments 78

Light Microscopy • Two-Photon Microscopy • Scanning Acoustic Microscopy • Electron Microscopy • Scanned-Probe Microscopy

Preparation of Specimens for Light Microscopy 88

Preparing Smears for Staining • Simple Stains • Differential Stains • Special Stains

Study Outline • Study Questions 95

4 Functional Anatomy of Prokaryotic and Eukaryotic Cells 98

Comparing Prokaryotic and Eukaryotic Cells: An Overview 99

THE PROKARYOTIC CELL 99

The Size, Shape, and Arrangement of Bacterial Cells 99

Structures External to the Cell Wall 101

Glycocalyx • Flagella • Axial Filaments • Fimbriae and Pili

The Cell Wall 106

Composition and Characteristics • Cell Walls and the Gram Stain Mechanism • Atypical Cell Walls • Damage to the Cell Wall

Structures Internal to the Cell Wall 111

The Plasma (Cytoplasmic) Membrane • The Movement of Materials across Membranes • Cytoplasm • The Nucleoid • Ribosomes • Inclusions • Endospores

THE EUKARYOTIC CELL 120

Flagella and Cilia 122

The Cell Wall and Glycocalyx 122

The Plasma (Cytoplasmic) Membrane 123

Cytoplasm 124

Ribosomes 124

Organelles 124

The Nucleus • Endoplasmic Reticulum • Golgi Complex • Lysosomes • Vacuoles • Mitochondria • Chloroplasts • Peroxisomes • Centrosome

The Evolution of Eukaryotes 128

Study Outline • Study Questions 129

5 Microbial Metabolism 133

Catabolic and Anabolic Reactions 136

Enzymes 137

- Collision Theory • Enzymes and Chemical Reactions
- Enzyme Specificity and Efficiency • Naming Enzymes
- Enzyme Components • Factors Influencing Enzymatic Activity • Feedback Inhibition • Ribozymes

Energy Production 143

- Oxidation-Reduction Reactions • The Generation of ATP
- Metabolic Pathways of Energy Production

Carbohydrate Catabolism 145

- Glycolysis • Additional Pathways to Glycolysis • Cellular Respiration • Fermentation

Lipid and Protein Catabolism 157

Biochemical Tests and Bacterial Identification 157

Photosynthesis 159

- The Light-Dependent Reactions: Photophosphorylation
- The Light-Independent Reactions: The Calvin-Benson Cycle

A Summary of Energy Production Mechanisms 161

Metabolic Diversity among Organisms 162

- Photoautotrophs • Photoheterotrophs • Chemoautotrophs
- Chemoheterotrophs

Metabolic Pathways of Energy Use 166

- Polysaccharide Biosynthesis • Lipid Biosynthesis • Amino Acid and Protein Biosynthesis • Purine and Pyrimidine Biosynthesis

The Integration of Metabolism 168

Study Outline • Study Questions 170

6 Microbial Growth 175

The Requirements for Growth 176

- Physical Requirements • Chemical Requirements

Biofilms 182

Culture Media 183

- Chemically Defined Media • Complex Media • Anaerobic Growth Media and Methods • Special Culture Techniques • Selective and Differential Media • Enrichment Culture

Obtaining Pure Cultures 188

Preserving Bacterial Cultures 189

The Growth of Bacterial Cultures 189

- Bacterial Division • Generation Time • Logarithmic Representation of Bacterial Populations • Phases of Growth
- Direct Measurement of Microbial Growth • Estimating Bacterial Numbers by Indirect Methods

Study Outline • Study Questions 198

7 The Control of Microbial Growth 202

The Terminology of Microbial Control 203

The Rate of Microbial Death 204

Actions of Microbial Control Agents 204

- Alteration of Membrane Permeability • Damage to Proteins and Nucleic Acids

Physical Methods of Microbial Control 206

- Heat • Filtration • Low Temperatures • High Pressure
- Desiccation • Osmotic Pressure • Radiation

Chemical Methods of Microbial Control 211

- Principles of Effective Disinfection • Evaluating a Disinfectant
- Types of Disinfectants

Microbial Characteristics and Microbial Control 220

Study Outline • Study Questions 223

8 Microbial Genetics 227

Structure and Function of the Genetic Material 230

- Genotype and Phenotype • DNA and Chromosomes • The Flow of Genetic Information • DNA Replication • RNA and Protein Synthesis

The Regulation of Bacterial Gene Expression 240

- Pre-transcriptional Control • Post-transcriptional Control

Changes in the Genetic Material 244

- Mutation • Types of Mutations • Mutagens • The Frequency of Mutation • Identifying Mutants • Identifying Chemical Carcinogens

Genetic Transfer and Recombination 251

- Transformation in Bacteria • Conjugation in Bacteria
- Transduction in Bacteria • Plasmids and Transposons

Genes and Evolution 259

Study Outline • Study Questions 260

9 Biotechnology and DNA Technology 264

Introduction to Biotechnology 265

- Recombinant DNA Technology • An Overview of Recombinant DNA Procedures

Tools of Biotechnology 267

- Selection • Mutation • Restriction Enzymes • Vectors
- Polymerase Chain Reaction

Techniques of Genetic Modification 270

- Inserting Foreign DNA into Cells • Obtaining DNA • Selecting a Clone • Making a Gene Product

Applications of DNA Technology 276

- Therapeutic Applications • Genome Projects • Scientific Applications • Agricultural Applications

Safety Issues and the Ethics of Using DNA Technology 284
 Study Outline • Study Questions 286

PART TWO A Survey of the Microbial World

10 Classification of Microorganisms 290

The Study of Phylogenetic Relationships 291
 The Three Domains • A Phylogenetic Tree

Classification of Organisms 295

- Scientific Nomenclature • The Taxonomic Hierarchy
- Classification of Prokaryotes • Classification of Eukaryotes
- Classification of Viruses

Methods of Classifying and Identifying Microorganisms 298

- Morphological Characteristics • Differential Staining
- Biochemical Tests • Serology • Phage Typing • Fatty Acid Profiles • Flow Cytometry • DNA Base Composition • DNA Fingerprinting • Nucleic Acid Amplification Tests (NAATs)
- Nucleic Acid Hybridization • Putting Classification Methods Together

Study Outline • Study Questions 312

11 The Prokaryotes: Domains Bacteria and Archaea 316

The Prokaryotic Groups 317

DOMAIN BACTERIA 318

Gram-Negative Bacteria 318

- Proteobacteria • The Nonproteobacteria Gram-Negative Bacteria

The Gram-Positive Bacteria 334

- Firmicutes (Low G + C Gram-Positive Bacteria)
- Actinobacteria (High G + C Gram-Positive Bacteria)

DOMAIN ARCHAEA 340

Diversity within the Archaea 340

MICROBIAL DIVERSITY 341

Discoveries Illustrating the Range of Diversity 341

Study Outline • Study Questions 342

12 The Eukaryotes: Fungi, Algae, Protozoa, and Helminths 345

Fungi 346

- Characteristics of Fungi • Medically Important Fungi • Fungal Diseases • Economic Effects of Fungi

Lichens 357

Algae 358

- Characteristics of Algae • Selected Phyla of Algae • Roles of Algae in Nature

Protozoa 363

- Characteristics of Protozoa • Medically Important Protozoa

Slime Molds 368

Helminths 369

- Characteristics of Helminths • Platyhelminths • Nematodes

Arthropods as Vectors 377

Study Outline • Study Questions 379

13 Viruses, Viroids, and Prions 384

General Characteristics of Viruses 385

- Host Range • Viral Size

Viral Structure 386

- Nucleic Acid • Capsid and Envelope • General Morphology

Taxonomy of Viruses 388

Isolation, Cultivation, and Identification of Viruses 389

- Growing Bacteriophages in the Laboratory • Growing Animal Viruses in the Laboratory • Viral Identification

Viral Multiplication 395

- Multiplication of Bacteriophages • Multiplication of Animal Viruses

Viruses and Cancer 406

- The Transformation of Normal Cells into Tumor Cells • DNA Oncogenic Viruses • RNA Oncogenic Viruses • Viruses to Treat Cancer

Latent Viral Infections 408

Persistent Viral Infections 408

Prions 409

Plant Viruses and Viroids 409

Study Outline • Study Questions 411

PART THREE Interaction between Microbe and Host

14 Principles of Disease and Epidemiology 415

Pathology, Infection, and Disease 416

Normal Microbiota 416

- Relationships between the Normal Microbiota and the Host
- Opportunistic Microorganisms • Cooperation among Microorganisms

The Etiology of Infectious Diseases 420

- Koch's Postulates • Exceptions to Koch's Postulates

Classifying Infectious Diseases 421

Occurrence of a Disease • Severity or Duration of a Disease
• Extent of Host Involvement

Patterns of Disease 423

Predisposing Factors • Development of Disease

The Spread of Infection 424

Reservoirs of Infection • Transmission of Disease

Healthcare-Associated Infections 428

Microorganisms in the Hospital • Compromised Host
• Chain of Transmission • Control of Healthcare-Associated
Infections

Emerging Infectious Diseases 431**Epidemiology 433**

Descriptive Epidemiology • Analytical Epidemiology
• Experimental Epidemiology • Case Reporting • The Centers
for Disease Control and Prevention (CDC)

Study Outline • Study Questions 438

15 Microbial Mechanisms of Pathogenicity 443

How Microorganisms Enter a Host 444

Portals of Entry • The Preferred Portal of Entry • Numbers
of Invading Microbes • Adherence

How Bacterial Pathogens Penetrate Host Defenses 447

Capsules • Cell Wall Components • Enzymes • Antigenic
Variation • Penetration into the Host Cell Cytoskeleton

How Bacterial Pathogens Damage Host Cells 450

Using the Host's Nutrients: Siderophores • Direct Damage
• Production of Toxins • Plasmids, Lysogeny, and Pathogenicity

Pathogenic Properties of Viruses 456

Viral Mechanisms for Evading Host Defenses • Cytopathic
Effects of Viruses

Pathogenic Properties of Fungi, Protozoa, Helminths, and Algae 458

Fungi • Protozoa • Helminths • Algae

Portals of Exit 459**Study Outline • Study Questions 461**

16 Innate Immunity: Nonspecific Defenses of the Host 465

The Concept of Immunity 468**FIRST LINE OF DEFENSE: SKIN AND MUCOUS MEMBRANES 468****Physical Factors 468****Chemical Factors 470****Normal Microbiota and Innate Immunity 471****SECOND LINE OF DEFENSE 472****Formed Elements in Blood 472****The Lymphatic System 474****Phagocytes 475**

Actions of Phagocytic Cells • The Mechanism of Phagocytosis
• Microbial Evasion of Phagocytosis

Inflammation 478

Vasodilation and Increased Permeability of Blood Vessels
• Phagocyte Migration and Phagocytosis • Tissue Repair

Fever 481**Antimicrobial Substances 482**

The Complement System • Interferons • Iron-Binding Proteins
• Antimicrobial Peptides

Study Outline • Study Questions 490

17 Adaptive Immunity: Specific Defenses of the Host 494

The Adaptive Immune System 495**Dual Nature of the Adaptive Immune System 495**

Overview of Humoral Immunity • Overview of Cellular
Immunity

Cytokines: Chemical Messengers of Immune Cells 496**Antigens and Antibodies 497**

Antigens • Antibodies

Humoral Immunity Response Process 501

Clonal Selection of Antibody-Producing Cells • The Diversity
of Antibodies

Antigen–Antibody Binding and Its Results 503**Cellular Immunity Response Process 505**

Antigen-Presenting Cells (APCs) • Classes of T Cells

Extracellular Killing by the Immune System 510**Antibody-Dependent Cell-Mediated Cytotoxicity 510****Immunological Memory 511****Types of Adaptive Immunity 512****Study Outline • Study Questions 515**

18 Practical Applications of Immunology 518

Vaccines 519

Principles and Effects of Vaccination • Types of Vaccines
and Their Characteristics • The Development of New Vaccines
• Vaccination Technologies • Adjuvants • Safety of Vaccines

Diagnostic Immunology 526

Immunologic-Based Diagnostic Tests • Monoclonal Antibodies
• Precipitation Reactions • Agglutination Reactions
• Neutralization Reactions • Complement-Fixation Reactions

- Fluorescent-Antibody Techniques • Enzyme-Linked Immunosorbent Assay (ELISA) • Western Blotting (Immunoblotting) • The Future of Diagnostic and Therapeutic Immunology

Study Outline • Study Questions 538

19 Disorders Associated with the Immune System 541

Hypersensitivity 542

- Allergies and the Microbiome • Type I (Anaphylactic) Reactions • Preventing Anaphylactic Reactions • Type II (Cytotoxic) Reactions • Type III (Immune Complex) Reactions • Type IV (Delayed Cell-Mediated) Reactions

Autoimmune Diseases 552

- Cytotoxic Autoimmune Reactions • Immune Complex Autoimmune Reactions • Cell-Mediated Autoimmune Reactions

Reactions Related to the Human Leukocyte Antigen (HLA) Complex 554

- Reactions to Transplantation • Immunosuppression

The Immune System and Cancer 558

- Immunotherapy for Cancer

Immunodeficiencies 559

- Congenital Immunodeficiencies • Acquired Immunodeficiencies

Acquired Immunodeficiency Syndrome (AIDS) 560

- The Origin of AIDS • HIV Infection • Diagnostic Methods • HIV Transmission • AIDS Worldwide • Preventing and Treating AIDS • The AIDS Epidemic and the Importance of Scientific Research

Study Outline • Study Questions 570

20 Antimicrobial Drugs 574

The History of Chemotherapy 575

- Antibiotic Use and Discovery Today

Spectrum of Antimicrobial Activity 576

The Action of Antimicrobial Drugs 577

- Inhibiting Cell Wall Synthesis • Inhibiting Protein Synthesis • Injuring the Plasma Membrane • Inhibiting Nucleic Acid Synthesis • Inhibiting the Synthesis of Essential Metabolites

Common Antimicrobial Drugs 580

- Antibacterial Antibiotics: Inhibitors of Cell Wall Synthesis • Antimycobacterial Antibiotics • Inhibitors of Protein Synthesis • Injury to the Plasma Membrane • Nucleic Acid Synthesis Inhibitors • Competitive Inhibition of Essential Metabolites • Antifungal Drugs • Antiviral Drugs • Antiprotozoan and Anthelmintic Drugs

Tests to Guide Chemotherapy 593

- The Diffusion Methods • Broth Dilution Tests

Resistance to Antimicrobial Drugs 595

- Mechanisms of Resistance • Antibiotic Misuse • Cost and Prevention of Resistance

Antibiotic Safety 600

Effects of Combinations of Drugs 600

Future of Chemotherapeutic Agents 600

Study Outline • Study Questions 602

PART FOUR Microorganisms and Human Disease

21 Microbial Diseases of the Skin and Eyes 605

Structure and Function of the Skin 606

- Mucous Membranes

Normal Microbiota of the Skin 606

Microbial Diseases of the Skin 607

- Bacterial Diseases of the Skin • Viral Diseases of the Skin • Fungal Diseases of the Skin and Nails • Parasitic Infestation of the Skin

Microbial Diseases of the Eye 625

- Inflammation of the Eye Membranes: Conjunctivitis • Bacterial Diseases of the Eye • Other Infectious Diseases of the Eye

Study Outline • Study Questions 629

22 Microbial Diseases of the Nervous System 633

Structure and Function of the Nervous System 634

Bacterial Diseases of the Nervous System 635

- Bacterial Meningitis • Tetanus • Botulism • Leprosy

Viral Diseases of the Nervous System 644

- Poliomyelitis • Rabies • Arboviral Encephalitis

Fungal Disease of the Nervous System 652

- Cryptococcus neoformans* Meningitis (Cryptococcosis)

Protozoan Diseases of the Nervous System 653

- African Trypanosomiasis • Amebic Meningoencephalitis

Nervous System Diseases Caused by Prions 656

- Bovine Spongiform Encephalopathy and Variant Creutzfeldt-Jakob Disease

Disease Caused by Unidentified Agents 658

- Chronic Fatigue Syndrome

Study Outline • Study Questions 659

23 Microbial Diseases of the Cardiovascular and Lymphatic Systems 663

Structure and Function of the Cardiovascular and Lymphatic Systems 664

Bacterial Diseases of the Cardiovascular and Lymphatic Systems 665

- Sepsis and Septic Shock • Bacterial Infections of the Heart
- Rheumatic Fever • Tularemia • Brucellosis (Undulant Fever)
- Anthrax • Gangrene • Systemic Diseases Caused by Bites and Scratches • Vector-Transmitted Diseases

Viral Diseases of the Cardiovascular and Lymphatic Systems 681

- Burkitt's Lymphoma • Infectious Mononucleosis • Other Diseases and Epstein-Barr Virus • Cytomegalovirus Infections
- Chikungunya Fever • Classic Viral Hemorrhagic Fevers
- Emerging Viral Hemorrhagic Fevers

Protozoan Diseases of the Cardiovascular and Lymphatic Systems 687

- Chagas' Disease (American Trypanosomiasis) • Toxoplasmosis
- Malaria • Leishmaniasis • Babesiosis

Helminthic Disease of the Cardiovascular and Lymphatic Systems 694

- Schistosomiasis

Disease of Unknown Etiology 696

- Kawasaki Syndrome

Study Outline • Study Questions 697

24 Microbial Diseases of the Respiratory System 701

Structure and Function of the Respiratory System 702

Normal Microbiota of the Respiratory System 703

MICROBIAL DISEASES OF THE UPPER RESPIRATORY SYSTEM 703

Bacterial Diseases of the Upper Respiratory System 704

- Streptococcal Pharyngitis (Strep Throat) • Scarlet Fever
- Diphtheria • Otitis Media

Viral Disease of the Upper Respiratory System 706

- The Common Cold

MICROBIAL DISEASES OF THE LOWER RESPIRATORY SYSTEM 707

Bacterial Diseases of the Lower Respiratory System 707

- Pertussis (Whooping Cough) • Tuberculosis • Bacterial Pneumonias • Melioidosis

Viral Diseases of the Lower Respiratory System 720

- Viral Pneumonia • Respiratory Syncytial Virus (RSV)
- Influenza (Flu)

Fungal Diseases of the Lower Respiratory System 724

- Histoplasmosis • Coccidioidomycosis • *Pneumocystis* Pneumonia
- Blastomycosis (North American Blastomycosis) • Other Fungi Involved in Respiratory Disease

Study Outline • Study Questions 729

25 Microbial Diseases of the Digestive System 733

Structure and Function of the Digestive System 734

Normal Microbiota of the Digestive System 734

Bacterial Diseases of the Mouth 735

- Dental Caries (Tooth Decay) • Periodontal Disease

Bacterial Diseases of the Lower Digestive System 738

- Staphylococcal Food Poisoning (Staphylococcal Enterotoxigenesis)
- Shigellosis (Bacillary Dysentery) • Salmonellosis (*Salmonella* Gastroenteritis) • Typhoid Fever • Cholera • Noncholera Vibrios • *Escherichia coli* Gastroenteritis • *Campylobacter* Gastroenteritis • *Helicobacter* Peptic Ulcer Disease • *Yersinia* Gastroenteritis • *Clostridium perfringens* Gastroenteritis
- *Clostridium difficile*-Associated Diarrhea • *Bacillus cereus* Gastroenteritis

Viral Diseases of the Digestive System 750

- Mumps • Hepatitis • Viral Gastroenteritis

Fungal Diseases of the Digestive System 758

Protozoan Diseases of the Digestive System 759

- Giardiasis • Cryptosporidiosis • *Cyclospora* Diarrheal Infection
- Amebic Dysentery (Amebiasis)

Helminthic Diseases of the Digestive System 761

- Tapeworms • Hydatid Disease • Nematodes

Study Outline • Study Questions 767

26 Microbial Diseases of the Urinary and Reproductive Systems 772

Structure and Function of the Urinary System 773

Structure and Function of the Reproductive Systems 773

Normal Microbiota of the Urinary and Reproductive Systems 774

DISEASES OF THE URINARY SYSTEM 775

Bacterial Diseases of the Urinary System 775

- Cystitis • Pyelonephritis • Leptospirosis

DISEASES OF THE REPRODUCTIVE SYSTEMS 777

Bacterial Diseases of the Reproductive Systems 777

Gonorrhea • Nongonococcal Urethritis (NGU) • Pelvic Inflammatory Disease (PID) • Syphilis • Lymphogranuloma Venereum (LGV) • Chancroid (Soft Chancre) • Bacterial Vaginosis

Viral Diseases of the Reproductive Systems 788

Genital Herpes • Genital Warts • AIDS

Fungal Disease of the Reproductive Systems 790

Candidiasis

Protozoan Disease of the Reproductive Systems 791

Trichomoniasis • The TORCH Panel of Tests

Study Outline • Study Questions 793**PART FIVE Environmental and Applied Microbiology****27 Environmental Microbiology 797****Microbial Diversity and Habitats 798**

Symbiosis

Soil Microbiology and Biogeochemical Cycles 798

The Carbon Cycle • The Nitrogen Cycle • The Sulfur Cycle
• Life without Sunshine • The Phosphorus Cycle
• The Degradation of Synthetic Chemicals in Soil and Water

Aquatic Microbiology and Sewage Treatment 806

Aquatic Microorganisms • The Role of Microorganisms in Water Quality • Water Treatment • Sewage (Wastewater) Treatment

Study Outline • Study Questions 816**28 Applied and Industrial Microbiology 820****Food Microbiology 821**

Foods and Disease • Industrial Food Canning • Aseptic Packaging • Radiation and Industrial Food Preservation
• High-Pressure Food Preservation • The Role of Microorganisms in Food Production

Industrial Microbiology 827

Fermentation Technology • Industrial Products • Alternative Energy Sources Using Microorganisms • Biofuels
• Industrial Microbiology and the Future

Study Outline • Study Questions 834**Answers to Knowledge and Comprehension Questions 837****Appendix A Metabolic Pathways 853****Appendix B Exponents, Exponential Notation, Logarithms, and Generation Time 855****Appendix C Methods for Taking Clinical Samples 857****Appendix D Pronunciation of Scientific Names 859****Appendix E Word Roots Used in Microbiology 861****Appendix F Classification of Prokaryotes According to *Bergey's Manual* 865****Credits 867****Glossary 871****Index 889****CLINICAL FOCUS**

Human Tuberculosis—Dallas, Texas 165

Infection Following Anesthesia Injection 219

Tracking West Nile Virus 241

Norovirus—Who Is Responsible for the Outbreak? 285

The Most Frequent Cause of Recreational Waterborne

Diarrhea 373

Influenza: Crossing the Species Barrier 390

Healthcare-Associated Infections 437

A World Health Problem 524

A Delayed Rash 523

Antibiotics in Animal Feed Linked to Human Disease 599

Infections in the Gym 614