

Prescott's Microbiology

Joanne M. Willey
HOFSTRA UNIVERSITY

Linda M. SherwoodMONTANA STATE UNIVERSITY

Christopher J. Woolverton
KENT STATE UNIVERSITY



Part	One	e Introduction to Microbiology		3.7	Many Bacteria Have External Structures Used for Attachment and Motility	68
(1		Evolution of Microorganisms and obiology Micro Focus:	1	3.8 3.9	Bacteria Move in Response to Environmental Conditions Bacterial Endospores Are a Survival Strategy	71 75
	1.1	Over 4,000 Potential Planets Discovered Members of the Microbial World	$\frac{1}{1}$ $\binom{4}{4}$	Δrch	naeal Cell Structure	80
	1.2	Microbes Have Evolved and Diversified for Billions of Years	4	Arci	Micro Focus: Cows and Buffaloes and Sheep,	
	1.3	Microbiology Advanced as New Tools for Studying Microbes Were Developed	11	4.1	Oh My! Archaea Are Diverse but Share Some	80
	1.4	Microbiology Encompasses Many Subdisciplines	17	4.2	Common Features Six Major Types of Archaeal Cell	80
(2	Micr	roscopy	22	4.3	Envelopes Have Been Identified Archaeal Cytoplasm Is Similar to	82
•		Micro Focus: Anthrax Bioterrorism Attack 2001	22	4.4	Bacterial Cytoplasm Many Archaea Have External Structures	85
	2.1 2.2	Lenses Create Images by Bending Light There Are Several Types of Light	22		Used for Attachment and Motility Microbial Diversity & Ecology 4.1	86
		Microscopes	23		What's in a Name?	87
	2.3	Staining Specimens Helps to Visualize and Identify Microbes	32	4.5	Comparison of <i>Bacteria</i> and <i>Archaea</i>	88
	2.4	Electron Microscopes Use Beams of Electrons to Create Highly Magnified	(5	Euk	aryotic Cell Structure	90
		Images	34		Micro Focus: Red Means Dead	90
	2.5	Scanning Probe Microscopy Can Visualize Molecules and Atoms	39	5.1 5.2	Eukaryotic Cells Are Diverse but Share Some Common Features Eukaryotic Cell Envelopes	90 92
(3	Bact	terial Cell Structure	42	5.3	The Eukaryotic Cytoplasm Contains	
•	3.1	Micro Focus: Hooking Up Use of the Term "Prokaryote" Is	42	5.4	a Complex Cytoskeleton and Many Membranous Organelles Several Cytoplasmic Membranous	93
	3.2	Controversial Bacteria Are Diverse but Share Some	42	0.1	Organelles Function in the Secretory and Endocytic Pathways	95
	3.3	Common Features Bacterial Plasma Membranes Control	43	5.5	The Nucleus and Ribosomes Are Involved in Genetic Control of the Cell	98
	3.4	What Enters and Leaves the Cell There Are Two Main Types of	47	5.6		
		Bacterial Cell Walls Microbial Diversity & Ecology 3.1	53		Conservation	100
		Gram Positive and Gram Negative or Monoderms and Diderms?	54		Microbial Diversity & Ecology 5.1 There Was an Old Woman Who Swallowed a Fly	103
	3.5	The Cell Envelope Often Includes Layers Outside the Cell Wall	61	5.7	Many Eukaryotic Microbes Have External Structures Used for Motility	104
	3.6	The Bacterial Cytoplasm Is More		5.8	•	

6	Viru	ses and Other Acellular Infectious Agents	109		8.2	The Pattern of Microbial Death Mirrors	
•		Micro Focus:				the Pattern of Microbial Growth	174
		Mustard, Catsup, and Viruses?	109		8.3	Mechanical Removal Methods Rely	
	6.1	Viruses Are Acellular	109			on Barriers	175
	0.1				8.4	Physical Control Methods Alter	
		Microbial Diversity & Ecology 6.1 Host-Independent Growth of an Archaeal Virus	110			Microorganisms to Make Them	
		,	110			Nonviable	177
	6.2	Virion Structure Is Defined by Capsid			8.5	Microorganisms Are Controlled with	
		Symmetry and Presence or Absence of	414			Chemical Agents	180
	~ ~	an Envelope	111		8.6	Antimicrobial Agents Must Be Evaluated	
	6.3	Viral Life Cycles Have Five Steps	116			for Effectiveness	184
	6.4	There Are Several Types of Viral Infections	122 125		8.7	Microorganisms Can Be Controlled by	
	6.5	Cultivation and Enumeration of Viruses	125			Biological Methods	185
	6.6	Viroids and Satellites: Nucleic	127				400
	67	Acid-Based Subviral Agents	127	(9	Antı	microbial Chemotherapy	188
	6.7	Prions Are Composed Only of Protein	123			Micro Focus:	
		AND				A Teaspoon of Sugar Helps the Bacteria	
Par	t Twe	o Microbial Nutrition, Growth,				Go Down	188
		and Control			9.1	Antimicrobial Chemotherapy Evolved	
· ·		and Control				from Antisepsis Efforts	188
(7	Micr	obial Growth	132		9.2	Antimicrobial Drugs Need to Be Selectively	
•		Micro Focus: Metal or Plastic?	132			Toxic over a Range of Effectiveness	189
	7.1	Most Bacteria and Archaea Reproduce	132		9.3	Antimicrobial Activity Can Be Measured	
	7.1	by Binary Fission	132			by Specific Tests	192
	7.2	Bacterial Cell Cycles Can Be Divided	102		9.4	Antibacterial Drugs	194
	7.2	into Three Phases	133		9.5	Antifungal Drugs	200
	7.3	Some Archaeal Cell Cycles Resemble	.00		9.6	Antiviral Drugs	200
		the Eukaryotic Cell Cycle	140		9.7	Antiprotozoan Drugs	204
	7.4	Environmental Factors Affect Microbial			9.8	Several Factors Influence Antimicrobial	
		Growth	141			Drug Effectiveness	205
	7.5	Microbial Growth in Natural Environments	150				
	7.6	Laboratory Culture of Cellular Microbes					
		Requires Media and Conditions That				AND SECULATION OF THE PROPERTY	
		Mimic the Normal Habitat of a Microbe	154	Part	inr	ee Microbial Metabolism	
	7.7	Growth Curves Consist of Five Phases	161	(10	Intro	oduction to Metabolism	208
	7.8	Microbial Population Size Can Be		(10	111111		
		Measured Directly or Indirectly	164		40.4	Micro Focus: Flushed Away	208
	7.9	Chemostats and Turbidostats Are Used			10.1	Metabolism: Important Principles	200
		for Continuous Culture of Microorganisms	168		10.3	and Concepts	209
					10.2	ATP: The Major Energy Currency	24
8		trol of Microorganisms in the			10.0	of Cells	21
*	Envi	ronment	172		10.3	Redox Reactions: Reactions of Central	242
		Micro Focus:			10.4	Importance in Metabolism	213
		Bacterial Kamikazes Seek Out and			10.4	Electron Transport Chains: Sets of	244
		Destroy Pathogens	172		10 E	Sequential Redox Reactions	214
	8.1	Microbial Growth and Replication			10.5	Biochemical Pathways: Sets of Linked Chemical Reactions	217
		Pathways: Targets for Control	172			Chemical Reactions	21/

		Enzymes and Ribozymes Speed Up Cellular Chemical Reactions Metabolism Must Be Regulated	217	Part	Fou	r Microbial Molecular Biology and Genetics	
		to Maintain Homeostasis and	222	(13 E	3act	erial Genome Replication and Expression	284
		Prevent Waste	222			Micro Focus: Making Code	284
(11	Cata	bolism: Energy Release and		1	31	Experiments Using Bacteria and Viruses	
/		servation	227			Demonstrated that DNA is the Genetic	
	Cons					Material	285
		Micro Focus: The Richest Hill On Earth	227	1	3.2	Nucleic Acid and Protein Structure	286
	11.1	Metabolic Diversity and Nutritional	227			DNA Replication in Bacteria	291
	44.0	Types	227			Bacterial Genes Consist of Coding	
	11.2	There Are Three Chemoorganotrophic	220	•		Regions and Other Sequences Important	
	44.0	Fueling Processes	229			for Gene Function	298
	11.3	Aerobic Respiration Can Be Divided	232	1	13.5	Transcription in Bacteria	301
	44 4	into Three Steps	232			The Genetic Code Consists of	
	11.4	Glucose to Pyruvate: The First Step Pyruvate to Carbon Dioxide (Step 2) Is	232			Three-Letter "Words"	305
	11.5			1	13.7	Translation in Bacteria	308
		Accomplished by the Tricarboxylic Acid Cycle	236	1	13.8	Protein Maturation and Secretion	315
	11 6	Electron Transport and Oxidative	230	The state of the s			
	11.0	Phosphorylation (Step 3) Generate		(14	Regu	lation of Bacterial Cellular Processes	321
		the Most ATP	236			Micro Focus: Letting Go	321
	11.7	Anaerobic Respiration Uses the Same	250	1	14.1	Bacteria Use Many Regulatory Options	322
	11.7	Three Steps as Aerobic Respiration	244			Regulation of Transcription Initiation	
	11.8	Fermentation Does Not Involve an				Saves Considerable Energy and Materials	322
		Electron Transport Chain	245	•	14.3	Attenuation and Riboswitches Can	
	11.9	Catabolism of Organic Molecules				Stop Transcription Prematurely	329
		Other Than Glucose	248	•	14.4	Riboswitches and Small RNAs Can	
	11.10	Chemolithotrophy: "Eating Rocks"	250			Control Translation	332
		Phototrophy	253	•	14.5	Bacteria Combine Several Regulatory	
*						Mechanisms to Control Complex	
(12	Ana	bolism: The Use of Energy in				Cellular Processes	334
•	Bios	ynthesis	262				
		Micro Focus: An Author's Life Saved	262			aryotic and Archaeal Genome	
	12.1	Principles Governing Biosynthesis	262	•	Repl	ication and Expression	349
		Precursor Metabolites: Starting				Micro Focus:	
		Molecules for Biosynthesis	264			Plastics: Brought to You by Microbes	349
	12.3	CO ₂ Fixation: Reduction and Assimilation		•	15.1	Why Consider Eukaryotic and Archaeal	
		of CO ₂ Carbon	264			Genetics Together?	350
	12.4	Synthesis of Carbohydrates	267		15.2	DNA Replication: Similar Overall, but	
		Synthesis of Amino Acids Consumes				with Different Replisome Proteins	350
		Many Precursor Metabolites	270	,	15.3	Transcription	354
	12.6	Synthesis of Purines, Pyrimidines, and			15.4	Translation and Protein Maturation and	
		Nucleotides	276			Localization	358
	12.7	Lipid Synthesis	278		15.5	Regulation of Cellular Processes	364

(16	Mec	hanisms of Genetic Variation	369		18.4	Bioinformatics: What Does the	
*		Micro Focus: Manure Happens	369			Sequence Mean?	428
	16.1	Mutations: Heritable Changes in			18.5	Functional Genomics Links Genes to	
		a Genome	370			Phenotype	43′
	16.2	Detection and Isolation of Mutants	375		18.6	Systems Biology: Making and Testing	
		DNA Repair Maintains Genome Stability	377			Complex Predictions	437
		Microbes Use Mechanisms Other than	0,,		18.7	Comparative Genomics	438
	10.4	Mutation to Create Genetic Variability	380				
	16 5	Transposable Elements Move Genes	500			The state of the s	
	10.5	Within and Between DNA Molecules	382	Part	t Fiv	e The Diversity of the Microbial World	ł
	16.6	Bacterial Conjugation Requires	302				
	10.0	Cell-Cell Contact	384	(19		obial Taxonomy and the Evolution	
	16.7	Bacterial Transformation Is the Uptake	J07		of D	iversity	443
	10.7	of Free DNA from the Environment	389			Micro Focus:	
	16 0	Transduction Is Virus-Mediated	303			Scientists Query: "Is the Microbial	
	10.0	DNA Transfer	391			Universe Expanding?"	443
	4C O		391		19.1	Microbial Taxonomy Is Based on the	
	10.9	Evolution in Action: The Development	204			Evolution of Multiple Traits	444
- PF		of Antibiotic Resistance in Bacteria	394		19 2	Taxonomic Ranks Provide an	
(17	Reco	ombinant DNA Technology	400		13.2	Organizational Framework	445
e .		Micro Focus:			19 3	Microbial Taxonomy and Phylogeny	
					10.0	Are Largely Based on Molecular	
		Archeological Digs Reveal Source	400			Characterization	446
		of Ancient Pathogen	400		19 4	Phylogenetic Trees Illustrate	
	17.1	Key Discoveries Led to the Development			13.4	Evolutionary Relationships	452
		of Recombinant DNA Technology	401		10 5	Evolutionary Processes and the Concept	752
		Techniques & Applications 17.1			19.5	of a Microbial Species Inspire Debate	455
		Streptavidin-Biotin Binding and Biotechnology	405		10.6	Bergey's Manual of Systematic Bacteriology	460
	17.2	Polymerase Chain Reaction Amplifies			15.0	Bergey's Maridal of Systematic Bacteriology	700
		Targeted DNA	406	(20	Arch	naea	464
	17.3	Cloning Vectors Are Needed to Create		*:		Micro Focus:	
		Recombinant DNA	408			Methanogenic Archaea Fuel Domestic	
	17.4	Introducing Recombinant DNA into				Energy Debate	464
		Host Cells	411		201	Overview of Archaea	465
		Techniques & Applications 17.2					400
		How to Build a Microorganism	412		20.2	Phylum <i>Crenarchaeota</i> : Metabolically	47 ⁻
	17 E	_			20.0	Diverse Thermophiles	47
	17.5	Genomic Libraries: Cloning Genomes	440		20.3	Phylum <i>Thaumarchaeota</i> : Mesophilic	47
	47.C	in Pieces	413		20.4	Ammonia Oxidizers	474
	17.6	Expressing Foreign Genes in Host Cells	414		20.4	Phylum <i>Euryarchaeota</i> : Methanogens,	47
(18	Micr	obial Genomics	419			Haloarchaea, and Others	474
1		Micro Focus:		(21	Deir	nococci, Mollicutes, and	
						proteobacterial Gram-Negative Bacteria	483
		"Synthetic Life": Oxymoron or the	440			Micro Focus:	
		Future?	419				
	18.1		419			Cyanobacteria Stimulate Broad Appeal for Biofuel Production	401
		Genome Sequencing	424				483
	18.3	Metagenomics Provides Access to			21.1	Aquificae and Thermotogae Are Ancient	
		Uncultured Microbes	427			Bacterial Lineages	484

	21.2	Deinococcus-Thermus Includes		(24	Acti	nobacteria: The High $G+C$ Gram-Positive	
		Radiation-Resistant Bacteria	484	*	Bact	eria	552
	21.3	Class Mollicutes, Phylum Tenericutes:				Micro Focus:	
		Bacteria That Lack Cell Walls	485			Antibiotic Production: Is it Actually	
	21.4	Photosynthetic Bacteria Are Diverse	488			Bacterial Chit-Chat?	552
	21.5	Phylum <i>Planctomycetes</i> : Bacteria with			241	Class Actinobacteria	554
		Intracellular Compartments	495	E.Y	27.1	Old33 Actinobacteria	557
	21.6	Phylum <i>Chlamydiae</i> : Obligate		(25	Prot	ists	563
		Intracellular Parasites	497	*		Micro Focus:	
	21.7	Phylum Verrucomicrobia Includes				Sustainable Farming Practiced	
		Human Symbionts and Methylotrophs	497			by Amoebae	563
	21.8	Phylum <i>Spirochaetes</i> : Bacteria with			251	Protist Diversity Reflects Broad Phylogeny	564
		a Corkscrew Morphology	499			Supergroup <i>Excavata</i> : Primitive Eukaryotes	566
	21.9	Phylum Bacteroidetes Includes				Supergroup Amoebozoa Includes	500
		Important Gut Microbiota	501		20.0	Protists with Pseudopodia	568
					25.4	Supergroup SAR: Protists of Great	500
22	Prote	eobacteria	504		25.4	Importance	570
٠,		Micro Focus:			25.5	Supergroup Archaeplastida Includes	3,0
		Bison and Brucellosis Spark Controversy	504		25.5	"Green Algae"	579
	22.1	Class Alphaproteobacteria Includes				•	3,3
		Many Oligotrophs	505	(26	Fung	gi (Eumycota)	583
	22.2	Class Betaproteobacteria Includes		*		Micro Focus:	
		Chemoheterotrophs and				Fungi May Be Key to Quelling Malaria	583
		Chemolithotrophs	515		261	Fungal Biology Reflects Vast Diversity	585
		Microbial Diversity & Ecology 22.1				Chytridiomycota Produce Motile Spores	588
		Acid Mine Drainage	519			Zygomycota: Fungi with Coenocytic	000
	22.3	Class Gammaproteobacteria Is the				Hyphae	588
	22.5	Largest Bacterial Class	519		26.4	Glomeromycota Are Mycorrhizal Symbionts	589
			313			Ascomycota Includes Yeasts and Molds	590
		Microbial Diversity & Ecology 22.2 Bacterial Bioluminescence	527			Basidiomycota Includes Mushrooms	
			527			and Plant Pathogens	592
	22.4	Class Deltaproteobacteria Includes				Disease 26.1	
		Chemoheterotrophic Anaerobes				White-Nose Syndrome Is Decimating	
		and Predators	529			North American Bat Populations	593
	22.5	Class Epsilonproteobacteria Ranges			26.7	Microsporidia Are Intracellular Parasites	595
		from Pathogens to Deep-Sea Bacteria	535				
(22	Eirm	icutes: The Low G + C Gram-Positive		(27	Viru	ses	597
123	Bact	icutes: The Low G + C Gram-Positive	539			Micro Focus:	
	Daci		559			Deadly New Virus Strikes European	
		Micro Focus:				Farm Animals	597
		Invasive Strep Strikes Young, Old,			27.1	Virus Phylogeny Is Difficult to Establish	597
		and Famous	539			Double-Stranded DNA Viruses Infect	
	23.1	Class Clostridia: Anaerobic				All Cell Types	599
		Endospore-Forming Bacteria	540			Microbial Diversity & Ecology 27.1	
	23.2	Class Negativicutes: Gram-Positive				What Is a Virus?	609
		Bacteria with Outer Membranes	544		27.3	Single-Stranded DNA Viruses Use	
	23.3	Class Bacilli: Aerobic Endospore-				a Double-Stranded Intermediate in	
		Forming Bacteria	544			Their Life Cycles	610
						•	•

	27.4	Double-Stranded RNA Viruses: RNA-		<u> </u>	009
		Dependent RNA Polymerase Replicates		31.3 Microbe-Plant Interactions Can Be	
		the Genome and Synthesizes mRNA	611	, 5 ,	671
	27.5	Plus-Strand RNA Viruses: Genomes	640	31.4 The Subsurface Biosphere Is Vast	683
	27.6	That Can Be Translated upon Entry Minus-Strand RNA Viruses: RNA-Dependent	613	32 Microbial Interactions 6	85
		RNA Polymerase Is Part of the Virion	616	Micro Focus:	
	27.7	Retroviruses: Plus-Strand Viruses That Use Reverse Transcriptase in Their		Embrace Your Gut Flora, for You Know Not What They Do	85
		Life Cycles	618	32.1 Many Types of Microbial Interactions	,00
	27.8	Reverse Transcribing DNA Viruses	619	* **	586
				Microbial Diversity & Ecology 32.1 Wolbachia pipientis: The World's Most	
Dari	Siv	Ecology and Symbiosis			687
		•			598
(28		eochemical Cycling and Global Climate		Microbial Diversity & Ecology 32.2	
•	Chai	_	623	•	700
		Micro Focus:		32.3 Normal Microbiota of the Human Body	
		Global Climate Change; Global	622	Adapt to the Human Condition 7	700
	004	Infectious Disease Change?	623		
	28.1	Biogeochemical Cycling Sustains Life on Earth	624	- 10 () () () () () () () () () (
	28.2	Global Climate Change: Biogeochemical	024	Part Seven Pathogenicity and Host Response	
	20.2	Cycling Out of Balance	633	33 Innate Host Resistance 7	707
(29	Meti	hods in Microbial Ecology	637	•	707
•		Micro Focus:		33.1 Immunity Arises from Innate Resistance	
		Scientists Search for Intraterrestrial		•	707
		Life—and Find It	637		708
	29.1	Microbial Biology Relies on Cultures	638	33.3 Innate Resistance Relies on Chemical	712
		Genetic Methods Are Used to Assess		Mediators 33.4 Cells, Tissues, and Organs Work	/ 12
		Microbial Diversity	641		717
	29.3	Assessment of Microbial Community		33.5 Phagocytosis: Destroying Invaders and	, .,
		Activity Relies on Biochemistry and		- · · · · · · · · · · · · · · · · · · ·	726
		Genetics	645	33.6 Inflammation Unites All the Components	
30	Micr	oorganisms in Marine and Freshwater		of Immunity	731
*		systems	650	6	
		Micro Focus:			736
		Ocean Death Coming Soon to a Coast			736
		Near you	650	34.1 Adaptive Immunity Relies on Recognition	-
		Water Is the Largest Microbial Habitat	651	•	736
		Microorganisms in Marine Ecosystems	652	34.2 Molecules That Elicit Immunity Are Called Antigens 7	738
	30.3	Microorganisms in Freshwater Ecosystems	661	34.3 Adaptive Immunity Can Be Earned or	- 50
31	Micro	oorganisms in Terrestrial Ecosystems	667	·	739
*		Micro Focus: A Short History of Rust	667	34.4 Recognition of Foreignness Is Critical for	
	31.1	Soils Are an Important Microbial Habitat	667	a Strong Defense	740

	34.5 T Cells Oversee and Participate in Immune Functions	743	37.2	Epidemiology Is Rooted in Well-Tested Methods	808
	34.6 B Cells Make Antibodies and Do a Whole Lot More	747		Historical Highlights 37.3 A Modern Epidemic Exposed	809
	34.7 Antibodies Are Proteins That Bind to Specific 3-D Molecules34.8 Antibody Binding Dooms the Target	749 757	37.3	Infectious Disease Is Revealed Through Patterns Within a Population	812
	Techniques & Applications 34.1 Monoclonal Antibody Therapy	757		Historical Highlights 37.4 "Typhoid Mary"	814
	34.9 Not Responding Is Also Part of Immunity	760		Infectious Diseases and Pathogens Are Emerging and Reemerging	815
-	34.10 Sometimes the Immune System Doesn't Work the Way It Should	760		Health-Care Facilities Harbor Infectious Agents	816
(35	Pathogenicity and Infection	770 770	37.6	Coordinated Efforts Are Required to Prevent and Control Epidemics	818
	Micro Focus: Sneaky Little Buggers 35.1 Pathogenicity Drives Infectious Disease 35.2 Virulence Defines a Pathogen's Success	770 770 773		Historical Highlights 37.5 The First Immunizations	820
	35.3 Exposure and Transmission Can Lead to Infectious Disease	782	37.7	Bioterrorism Readiness Is an Integral Component of Public Health Microbiology	822
	Historical Highlights 35.1 The First Indications of Person-to-Person Spread of an Infectious Disease	783		Historical Highlights 37.6 1346—The First Recorded Biological Warfare Attack	823
		(38	3 Hum	an Diseases Caused by Viruses	
	(一般の一般の一般の一般の一般の一般の一般の一般の一般の一般の一般の一般の一般の一	\ .			027
Part	t Eight Microbial Diseases, Detection, and Their Control	•		Prions Micro Focus:	827
	and Their Control	L :	and	Prions Micro Focus: Honest It Was the Mosquito!	827 827
	and Their Control Clinical Microbiology and Immunology Micro Focus: Seeing the Next Frontier 36.1 The Clinical Microbiology Laboratory	786 786	38.1 38.2	Micro Focus: HonestIt Was the Mosquito! Viruses Can Be Transmitted by Airborne Routes Arthropods Can Transmit Viral Diseases	
	and Their Control Clinical Microbiology and Immunology Micro Focus: Seeing the Next Frontier	786	38.1 38.2 38.3	Micro Focus: HonestIt Was the Mosquito! Viruses Can Be Transmitted by Airborne Routes Arthropods Can Transmit Viral Diseases Direct Contact Diseases Can Be Caused by Viruses Food and Water Are Vehicles for	827 828 836 837
	and Their Control Clinical Microbiology and Immunology Micro Focus: Seeing the Next Frontier 36.1 The Clinical Microbiology Laboratory Is the Front Line for Infectious Disease Detection 36.2 Biosafety Practices Protect Lab Workers 36.3 Identification of Microorganisms from Specimens	786 786	38.1 38.2 38.3	Micro Focus: Honest It Was the Mosquito! Viruses Can Be Transmitted by Airborne Routes Arthropods Can Transmit Viral Diseases Direct Contact Diseases Can Be Caused by Viruses	827 828 836
	and Their Control Clinical Microbiology and Immunology Micro Focus: Seeing the Next Frontier 36.1 The Clinical Microbiology Laboratory Is the Front Line for Infectious Disease Detection 36.2 Biosafety Practices Protect Lab Workers 36.3 Identification of Microorganisms from	786 786 786 787	38.1 38.2 38.3 38.4	Micro Focus: Honest It Was the Mosquito! Viruses Can Be Transmitted by Airborne Routes Arthropods Can Transmit Viral Diseases Direct Contact Diseases Can Be Caused by Viruses Food and Water Are Vehicles for Viral Diseases Historical Highlights 38.1	828 836 837 851
	and Their Control Clinical Microbiology and Immunology Micro Focus: Seeing the Next Frontier 36.1 The Clinical Microbiology Laboratory Is the Front Line for Infectious Disease Detection 36.2 Biosafety Practices Protect Lab Workers 36.3 Identification of Microorganisms from Specimens 36.4 Immune Responses Can Be Measured or Exploited to Detect Infections Epidemiology and Public Health Microbiology	786 786 786 787 790 797 806	38.1 38.2 38.3 38.4	Micro Focus: HonestIt Was the Mosquito! Viruses Can Be Transmitted by Airborne Routes Arthropods Can Transmit Viral Diseases Direct Contact Diseases Can Be Caused by Viruses Food and Water Are Vehicles for Viral Diseases Historical Highlights 38.1 A Brief History of Polio Zoonotic Diseases Arise from	827 828 836 837 851 853
(36	and Their Control Clinical Microbiology and Immunology Micro Focus: Seeing the Next Frontier 36.1 The Clinical Microbiology Laboratory Is the Front Line for Infectious Disease Detection 36.2 Biosafety Practices Protect Lab Workers 36.3 Identification of Microorganisms from Specimens 36.4 Immune Responses Can Be Measured or Exploited to Detect Infections Epidemiology and Public Health Microbiology Micro Focus: Practice What You Preach 37.1 Epidemiology Is an Evidence-Based	786 786 786 787 790 797 806 806	38.1 38.2 38.3 38.4 38.5 38.6	Micro Focus: Honest It Was the Mosquito! Viruses Can Be Transmitted by Airborne Routes Arthropods Can Transmit Viral Diseases Direct Contact Diseases Can Be Caused by Viruses Food and Water Are Vehicles for Viral Diseases Historical Highlights 38.1 A Brief History of Polio Zoonotic Diseases Arise from Human-Animal Interactions Prion Proteins Transmit Disease an Diseases Caused by Bacteria	828 836 837 851 853
(36	and Their Control Clinical Microbiology and Immunology Micro Focus: Seeing the Next Frontier 36.1 The Clinical Microbiology Laboratory Is the Front Line for Infectious Disease Detection 36.2 Biosafety Practices Protect Lab Workers 36.3 Identification of Microorganisms from Specimens 36.4 Immune Responses Can Be Measured or Exploited to Detect Infections Epidemiology and Public Health Microbiology Micro Focus: Practice What You Preach 37.1 Epidemiology Is an Evidence-Based Science Historical Highlights 37.1	786 786 786 787 790 797 806	38.1 38.2 38.3 38.4 38.5 38.6 Hum	Micro Focus: Honest It Was the Mosquito! Viruses Can Be Transmitted by Airborne Routes Arthropods Can Transmit Viral Diseases Direct Contact Diseases Can Be Caused by Viruses Food and Water Are Vehicles for Viral Diseases Historical Highlights 38.1 A Brief History of Polio Zoonotic Diseases Arise from Human-Animal Interactions Prion Proteins Transmit Disease an Diseases Caused by Bacteria Micro Focus: "This Little Piggie Stayed Home"	828 836 837 851 853 854 856
(36	and Their Control Clinical Microbiology and Immunology Micro Focus: Seeing the Next Frontier 36.1 The Clinical Microbiology Laboratory Is the Front Line for Infectious Disease Detection 36.2 Biosafety Practices Protect Lab Workers 36.3 Identification of Microorganisms from Specimens 36.4 Immune Responses Can Be Measured or Exploited to Detect Infections Epidemiology and Public Health Microbiology Micro Focus: Practice What You Preach 37.1 Epidemiology Is an Evidence-Based Science	786 786 786 787 790 797 806 806	38.1 38.2 38.3 38.4 38.5 38.6 Hum	Micro Focus: Honest It Was the Mosquito! Viruses Can Be Transmitted by Airborne Routes Arthropods Can Transmit Viral Diseases Direct Contact Diseases Can Be Caused by Viruses Food and Water Are Vehicles for Viral Diseases Historical Highlights 38.1 A Brief History of Polio Zoonotic Diseases Arise from Human-Animal Interactions Prion Proteins Transmit Disease an Diseases Caused by Bacteria Micro Focus:	828 836 837 851 853 854 856 859

	39.3	Direct Contact Diseases Can Be Caused by Bacteria	872	41.4 Detection of Food-Borne Pathogens Requires Government-Industry Cooperation 9	36
		Disease 39.1 A Brief History of Syphilis	879	41.5 Microbiology of Fermented Foods: Beer,	937
		Disease 39.2 Biofilms	880	Techniques & Applications 41.1	938
	39.4	Food and Water Are Vehicles for Bacterial Diseases	885)44
		Techniques & Applications 39.3 Clostridial Toxins as Therapeutic Agents: Benefits of Nature's Most Toxic Proteins	889	Micro Focus:	947 947
		Zoonotic Diseases Arise from Human-Animal Interactions	894	42.1 Microbes Are the Source of Many Products of Industrial Importance 9	948
	39.6	Opportunistic Diseases Can Be Caused by Bacteria	897	42.3 Growing Microbes in Industrial Settings	95
(40		nan Diseases Caused by Fungi Protists	902	42.4 Production Strains Are Developed to Maximize Output of Industrially	
	40.1	Micro Focus: Death by—Mushroom? Relatively Few Fungi and Protists Are Human Pathogens	902 902	42.5 Agricultural Biotechnology Relies on a Plant Pathogen 9	953 959
	40.2	Fungi and Protists Can Be Transmitted by Airborne Routes	904		959 9 64
		Disease 40.1 A Brief History of Malaria	907	Micro Focus:	
		Arthropods Can Transmit Fungal and Protozoal Disease	907		964
		Direct Contact Diseases Can Be Caused by Fungi and Protists	914	43.1 Purification and Sanitary Analysis Ensure Safe Drinking Water 43.2 Wastewater Treatment Maintains	964
		Food and Water Are Vehicles of Fungal and Protozoal Diseases	917		968
	40.6	Opportunistic Diseases Can Be Caused by Fungi and Protists	921		975
Part	Nin	e Applied Microbiology			976
(41	Micr	obiology of Food Micro Focus:	927	Appendix 1 A Review of the Chemistry of Biological Molecules A-1	
		The Art, Science, and Genetics of Brewing Beer	927	Appendix 2 Common Metabolic Pathways A-9	
	41.1	Microbial Growth Can Cause Food Spoilage	928	Appendix 3 Microorganism Pronunciation Guide A-1	7
	41.2	Various Methods Are Used to Control Food Spoilage	930	Glossary G-1 Credits C-1	
	41.3	Food-Borne Disease Outbreaks	933	Index I-1	

41.4 Detection of Food-Borne Pathogens