

Characterizing & Classifying Prokaryotes

Abbreviated Ch. 11 Material
CCV
Microbiology

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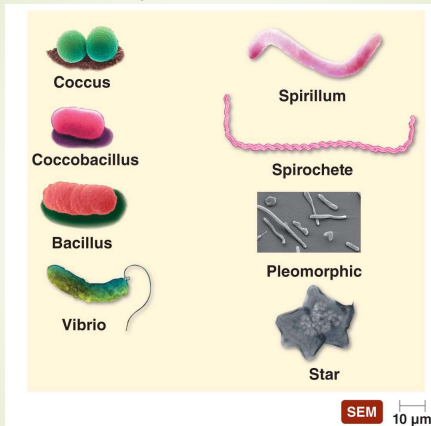
General Characteristics of Prokaryotic Organisms

Prokaryotes

- Most numerous and diverse group of cellular microbes
- Thrive in various habitats
- Only a few are capable of colonizing humans and causing disease

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Figure 11.1 Typical prokaryotic morphologies.



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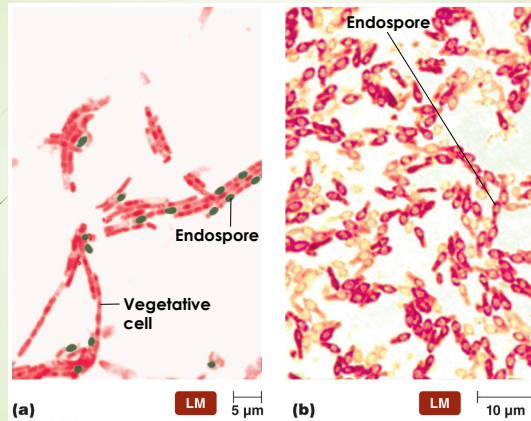
General Characteristics of Prokaryotic Organisms

Endospores

- Produced by Gram-positive bacteria *Bacillus* and *Clostridium*
- Each vegetative cell transforms into one endospore
- Each endospore germinates to form one vegetative cell
- Defensive strategy against unfavorable conditions
- Endospores are often difficult to kill
 - Concern to food processors, health care professionals, and government

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Figure 11.2 Locations of endospores.



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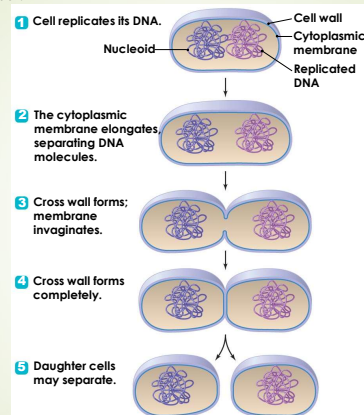
General Characteristics of Prokaryotic Organisms

Reproduction of Prokaryotic Cells

- All reproduce asexually
- Several different methods
 - Binary fission (most common)
 - Snapping division
 - Reproductive spores
 - Budding
 - Viviparity

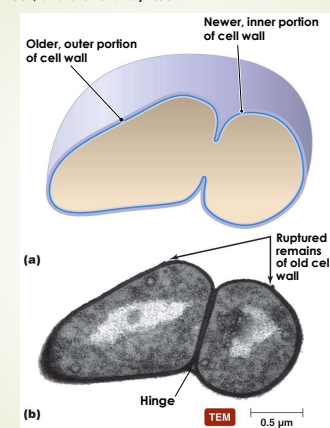
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Figure 11.3 Binary fission.



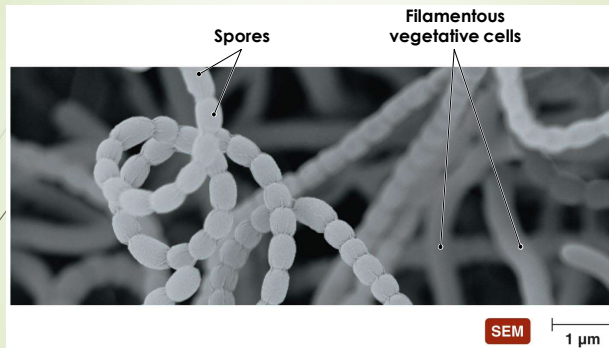
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Figure 11.4 Snapping division, a variation of binary fission.



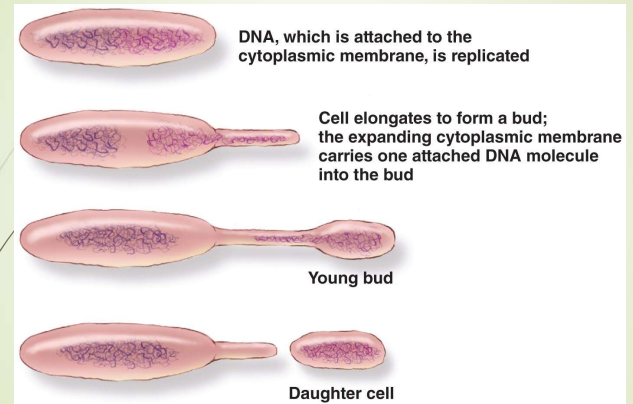
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Figure 11.5 Spores of actinomycetes.



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Figure 11.6 Budding.



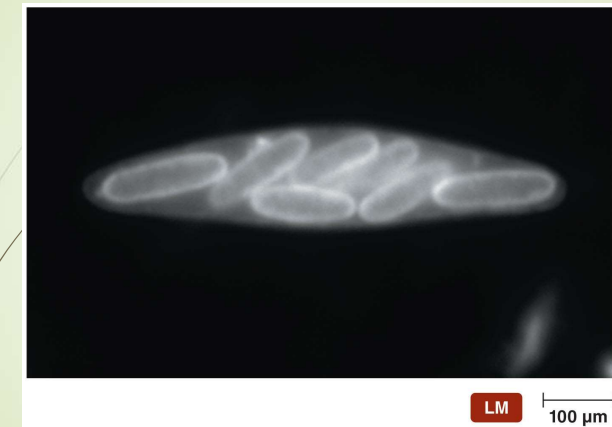
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General Characteristics of Prokaryotic Organisms

Reproduction of Prokaryotic Cells

- *Epulopiscium* and its relatives have unique method of reproduction
- Live offspring emerge from the body of the dead mother cell (viviparity)
- First noted case of viviparous behavior in prokaryotic world

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Figure 11.7 Viviparity in *Epulopiscium*.

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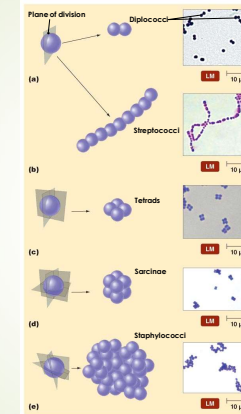
General Characteristics of Prokaryotic Organisms

■ Arrangements of Prokaryotic Cells

- Result from two aspects of division during binary fission
 - Planes in which cells divide
 - Separation of daughter cells

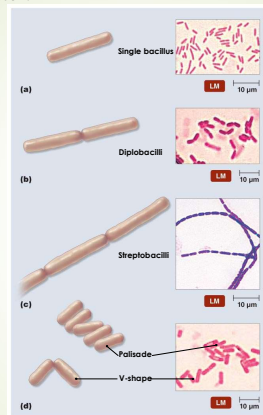
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Figure 11.8 Arrangements of cocci.



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Figure 11.9 Arrangements of bacilli.



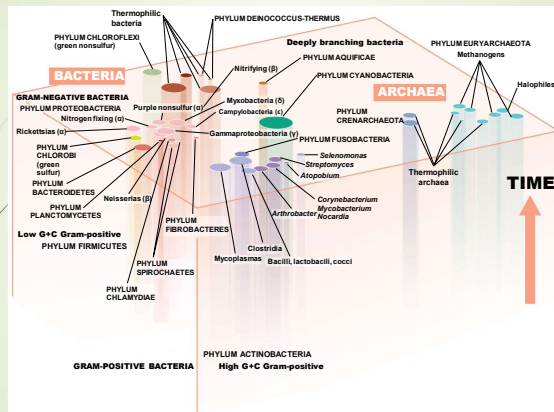
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Modern Prokaryotic Classification

- Currently based on genetic relatedness of rRNA sequences
- Three domains
 - Archaea
 - Bacteria
 - Eukarya
- *Bergey's Manual of Systematic Bacteriology* provides prokaryotic classification scheme

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Figure 11.10 Prokaryotic taxonomy.



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Survey of Archaea

- Common features
 - Lack true peptidoglycan
 - Cell membrane lipids have branched hydrocarbon chains
 - AUG codon codes for methionine
- Two phyla: Crenarchaeota, Euryarchaeota
- Reproduce by binary fission, budding, or fragmentation
- Are cocci, bacilli, spirals, or pleomorphic
- Not known to cause disease

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Survey of Archaea

- **Extremophiles**
 - Require extreme conditions to survive
 - Temperature, pH, and/or salinity
 - Prominent members are thermophiles and halophiles
- **Thermophiles**
 - DNA, RNA, cytoplasmic membranes, and proteins do not function properly below 45°C
 - **Hyperthermophiles**—require temperatures over 80°C
- **Halophiles**—inhabit extremely saline habitats
 - Depend on greater than 9% NaCl to maintain integrity of cell walls
 - Many contain red or orange pigments
 - May protect from sunlight

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Survey of Archaea

- **Methanogens**
 - Largest group of archaea
 - Convert carbon dioxide, hydrogen gas, and organic acids to methane gas
 - Convert organic wastes in pond, lake, and ocean sediments to methane
 - Some live in colons of animals
 - One of primary sources of environmental methane
 - Produced ~10 trillion tons of methane buried on ocean floor
 - Digest sludge during sewage treatment

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Survey of Bacteria

Deeply Branching and Phototrophic Bacteria

- Deeply branching bacteria
 - Scientists believe these organisms are similar to earliest bacteria
- Autotrophic
- Live in habitats similar to those thought to exist on early Earth

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Survey of Bacteria

Deeply Branching and Phototrophic Bacteria

- Phototrophic bacteria
 - Phototrophs that contain photosynthetic lamellae
 - Autotrophic
 - Divided into five groups based on pigments and source of electrons for photosynthesis
 - Blue-green bacteria (cyanobacteria)
 - Green sulfur bacteria
 - Green nonsulfur bacteria
 - Purple sulfur bacteria
 - Purple nonsulfur bacteria

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TABLE 11.1 Characteristics of the Major Groups of Phototrophic Bacteria

	Phylum				
	Cyanobacteria	Chlorobi	Chloroflexi	Proteobacteria	Proteobacteria
Class	Cyanobacteria	Chlorobia	Chloroflexi	Gammaaproteobacteria	Alphaproteobacteria and one genus in betaproteobacteria
Common name(s)	Blue-green bacteria ("blue-green algae")	Green sulfur bacteria	Green nonsulfur bacteria	Purple sulfur bacteria	Purple nonsulfur bacteria
Major photosynthetic pigments	Chlorophyll a	Bacteriochlorophyll a plus c, d, or e	Bacteriochlorophylls a and c	Bacteriochlorophyll a or b	Bacteriochlorophyll a or b
Types of photosynthesis	Oxygenic	Anoxygenic	Anoxygenic	Anoxygenic	Anoxygenic
Electron donor in photosynthesis	H ₂ O	H ₂ , H ₂ S, or S	Organic compounds	H ₂ , H ₂ S, or S	Organic compounds
Sulfur deposition	None	Outside of cell	None	Inside of cell	None
Nitrogen fixation	Some species	None	None	None	None
Motility	Nonmotile or gliding	Nonmotile	Gliding	Motile with polar or peritrichous flagella	Nonmotile or motile with polar flagella

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Survey of Bacteria

Low G + C Gram-Positive Bacteria

- Gram + bacteria sub-classification
- G + C content below 50%
- Refers to % of base pairs in the genome that are guanine-cytosine pairings
- Have similar 16S rRNA sequences
- Classified in phylum Firmicutes
 - Rod-shaped, obligate anaerobes
 - Ex. *Clostridia*, *Mycoplasma*, *Listeria*, *Lactobacillus*, *Streptococcus*, *Staphylococcus*, *Bacillus*, *Enterococcus*

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Survey of Bacteria

High G + C Gram-Positive Bacteria

- Gram + bacteria sub-classification
- Frequency of G + C pairs in the genome is greater than 50%
- Key examples: *Corynebacterium* (Diphtheria), *Mycobacterium* (TB and leprosy) and Actinocycetes: *Actinomyces*, *Nocardia* and *Streptomyces*

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TABLE 11.2 Characteristics of Selected Gram-Positive Bacteria

Phylum/Class	G + C Percentage	Representative Genera	Special Characteristics	Diseases
Firmicutes				
Clostridia	Low (less than 50%)	Clostridium	Obligate anaerobic rods; endospore formers	Tetanus Botulism Gangrene Severe diarrhea Dental caries
		Epulopiscium Selenomonas	Giant rods Part of oral biofilm on human teeth; stain like Gram-negative bacteria (pink)	
		Mycoplasmata	Lack cell walls; pleomorphic; smallest free-living cells; stain like Gram-negative bacteria (pink)	Pneumonia Urinary tract infections
Bacilli	Low (less than 50%)	Bacillus	Facultative anaerobic rods; endospore formers	Anthrax
		Listeria	Contaminates dairy products	Listeriosis
		Lactobacillus Streptococcus	Produce yogurt, buttermilk, pickles, sauerkraut Cocci in chains	Rare blood infections Strep throat, scarlet fever, and others
		Staphylococcus	Cocci in clusters	Bacteremia, food poisoning, and others
Actinobacteria				
Actinobacteria	High (greater than 50%)	Corynebacterium	Snapping division; metachromatic granules in cytoplasm	Diphtheria
		Mycobacterium	Waxy cell walls (mycolic acid)	Tuberculosis and leprosy
		Actinomyces	Filaments	Actinomycosis
		Nocardia	Filaments; degrade pollutants	Lesions
		Streptomyces	Produce antibiotics	Rare sinus infections

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Survey of Bacteria

Gram-Negative Proteobacteria

- Largest and most diverse group of bacteria
- Different shapes, reproductive strategies, & nutritional types
- Share: common 16S rRNA nucleotide sequences
- Five classes of proteobacteria, distinguished by minor differences in rRNA sequences
 - Alphaproteobacteria
 - Betaproteobacteria
 - Gammaproteobacteria
 - Deltaproteobacteria
 - Epsilonproteobacteria

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TABLE 11.3 Representative Glycolytic Facultative Anaerobes of the Class Gammaproteobacteria

Family	Special Characteristics	Representative Genera	Typical Human Diseases
Enterobacteriaceae	Straight rods; oxidase negative; peritrichous flagella or nonmotile	<i>Escherichia</i>	Gastroenteritis
		<i>Enterobacter</i>	(Rarely pathogenic)
		<i>Serratia</i>	(Rarely pathogenic)
		<i>Salmonella</i>	Enteritis
		<i>Proteus</i>	Urinary tract infection
		<i>Shigella</i>	Shigellosis
		<i>Yersinia</i> <i>Klebsiella</i>	Plague Pneumonia
Vibrionaceae	Vibrios; oxidase positive; polar flagella	<i>Vibrio</i>	Cholera
Pasteurellaceae	Cocci or straight rods; oxidase positive; nonmotile	<i>Haemophilus</i>	Meningitis in children, middle ear infections, pneumonia

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TABLE 11.4 Characteristics of Selected Gram-Negative Bacteria

Phylum/Class	Representative Members	Special Characteristics	Diseases
Proteobacteria			
Alphaproteobacteria	<i>Azospirillum</i>	Nitrogen fixer	
	<i>Rhizobium</i>	Nitrogen fixer	
	<i>Nitrobacter</i>	Nitrifying bacterium	
	Purple nonsulfur bacteria	Anoxygenic phototrophs	
	<i>Rickettsia</i>	Intracellular pathogen	Typhus and Rocky Mountain spotted fever
	<i>Brucella</i>	Coccobacillus	Brucellosis
	<i>Acetobacter</i> , <i>Gluconobacter</i>	Synthesize acetic acid	
	<i>Caulobacter</i>	Prosthecae bacterium	
	<i>Agrobacterium</i>	Causes galls in plants; vector for gene transfer in plants	
Betaproteobacteria	<i>Nitrosomonas</i>	Nitrifying bacterium	
	<i>Neisseria</i>	Diplococcus	Gonorrhea and meningitis
	<i>Bordetella</i>		Pertussis
	<i>Burkholderia</i>		Lung infection of cystic fibrosis patients
	<i>Thiobacillus</i>	Colorless sulfur bacterium	
	<i>Zoogloea</i>	Used in sewage treatment	
	<i>Sphaerotilus</i>	Blocks sewage treatment pipes	

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TABLE 11.4 Characteristics of Selected Gram-Negative Bacteria (Continued)

Phylum/Class	Representative Members	Special Characteristics	Diseases	
Proteobacteria				
Gammaproteobacteria	Purple sulfur bacteria			
	Legionella	Intracellular pathogen	Legionnaires' disease	
	Coxiella	Intracellular pathogen	Q fever	
	Methylococcus	Oxidizes methane		
	(Families: Enterobacteriaceae Vibrionaceae Pasteurellaceae)	Glycolytic facultative anaerobes: Escherichia, Enterobacter, Serratia, Salmonella, Proteus, Shigella, Yersinia, Klebsiella, Vibrio, Haemophilus	Facultative anaerobes that catabolize carbohydrates via glycolysis and the pentose phosphate pathway	See Table 11.3 on p. 342
	Pseudomonas	Aerobe that catabolizes carbohydrates via Either-Doudoroff and pentose phosphate pathways		Urinary tract infections, external otitis
	Azotobacter	Nitrogen fixers not associated with plant roots		
	Azomonas			
	Desulfovibrio	Sulfate reducer		
	Bdellovibrio	Pathogen of Gram-negative bacteria		
Deltaproteobacteria	Myxobacteria	Reproduces by forming differentiated fruiting bodies		

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TABLE 11.4 Characteristics of Selected Gram-Negative Bacteria (Continued)

Phylum/Class	Representative Members	Special Characteristics	Diseases
Proteobacteria			
Epsilonproteobacteria	<i>Campylobacter</i>	Curved rod	Gastroenteritis
	<i>Helicobacter</i>	Spiral	Gastric ulcers
Chlamydiae			
Chlamydiae	<i>Chlamydia</i>	Intracellular pathogen; lacks peptidoglycan	Neonatal blindness and lymphogranuloma venereum
Spirochaetes			
Spirochaetes	<i>Treponema</i>	Motile by axial filaments	Syphilis
	<i>Borrelia</i>	Motile by axial filaments	Lyme disease
Bacteroidetes			
"Bacteroidia" ^a	<i>Bacteroides</i>	Anaerobe that lives in animal colons	Abdominal infections
"Sphingobacteria"	<i>Cytophaga</i>	Digests complex polysaccharides	

^aThe names of taxa in quotations are not officially recognized.

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