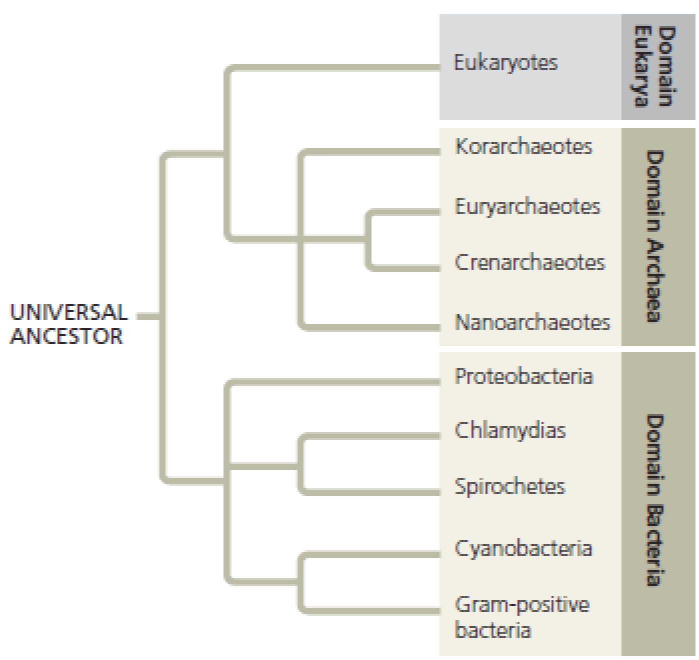
Cheat Sheet

Table 27.1 Major Nutritional Modes

Mode	Energy Source	Carbon Source	Types of Organisms
AUTOTROPH			
Photoautotroph	Light	CO_2, HCO_3^-, or related compound	Photosynthetic prokaryotes (for example, cyanobacteria); plants; certain protists (for example, algae)
Chemoautotroph	Inorganic chemicals (such as H_2S, NH_3, or Fe^{2+})	CO_2, HCO_3^-, or related compound	Unique to certain prokaryotes (for example, *Sulfolobus*)
HETEROTROPH			
Photoheterotroph	Light	Organic compounds	Unique to certain aquatic and salt-loving prokaryotes (for example, *Rhodobacter*, *Chloroflexus*)
Chemoheterotroph	Organic compounds	Organic compounds	Many prokaryotes (for example, *Clostridium*) and protists; fungi; animals; some plants

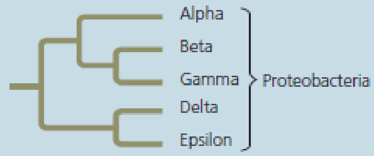


▼ **Figure 27.17**

Exploring Major Groups of Bacteria

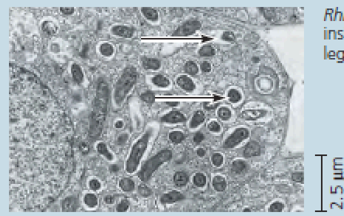
Proteobacteria

This large and diverse clade of gram-negative bacteria includes photoautotrophs, chemoautotrophs, and heterotrophs. Some proteobacteria are anaerobic, while others are aerobic. Molecular systematists currently recognize five subgroups of proteobacteria; the phylogenetic tree at right shows their relationships based on molecular data.



Subgroup: Alpha Proteobacteria

Many of the species in this subgroup are closely associated with eukaryotic hosts. For example, *Rhizobium* species live in nodules within the roots of legumes (plants of the pea/bean family), where the bacteria convert atmospheric N_2 to compounds the host plant can use to make proteins. Species in the genus *Agrobacterium* produce tumors in plants; genetic engineers use these bacteria to carry foreign DNA into the genomes of crop plants (see Figure 20.26). As explained in Chapter 25, scientists hypothesize that mitochondria evolved from aerobic alpha proteobacteria through endosymbiosis.



Rhizobium (arrows) inside a root cell of a legume (TEM)

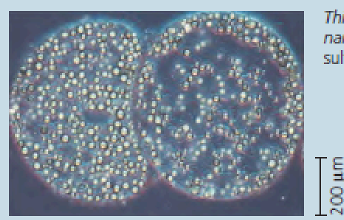
Subgroup: Beta Proteobacteria

This nutritionally diverse subgroup includes *Nitrosomonas*, a genus of soil bacteria that play an important role in nitrogen recycling by oxidizing ammonium (NH_4^+), producing nitrite (NO_2^-) as a waste product.

Nitrosomonas (colorized TEM)

Subgroup: Gamma Proteobacteria

This subgroup's autotrophic members include sulfur bacteria such as *Thiomargarita namibiensis* (see p. 557), which obtain energy by oxidizing H_2S, producing sulfur as a waste product (the small globules in the photograph at right). Some heterotrophic gamma proteobacteria are pathogens; for example, *Legionella* causes Legionnaires' disease, *Salmonella* is responsible for some cases of food poisoning, and *Vibrio cholerae* causes cholera. *Escherichia coli*, a common resident of the intestines of humans and other mammals, normally is not pathogenic.



Thiomargarita namibiensis containing sulfur wastes (LM)

Subgroup: Delta Proteobacteria

This subgroup includes the slime-secreting myxobacteria. When the soil dries out or food is scarce, the cells congregate into a fruiting body that releases resistant "myxospores." These cells found new colonies in favorable environments. Another group of delta proteobacteria, the bdellovibrios, attack other bacteria, charging at up to 100 μm/sec (comparable to a human running 240 km/hr). The attack begins when a bdellovibrio attaches to specific molecules found on the outer covering of some bacterial species. The bdellovibrio then drills into its prey by using digestive enzymes and spinning at 100 revolutions per second.

Fruiting bodies of *Chondromyces crocatus*, a myxobacterium (SEM)

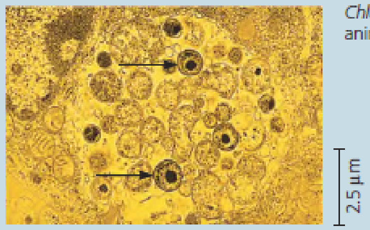
Subgroup: Epsilon Proteobacteria

Most species in this subgroup are pathogenic to humans or other animals. Epsilon proteobacteria include *Campylobacter*, which causes blood poisoning and intestinal inflammation, and *Helicobacter pylori*, which causes stomach ulcers.

Helicobacter pylori (colorized TEM)

Chlamydias

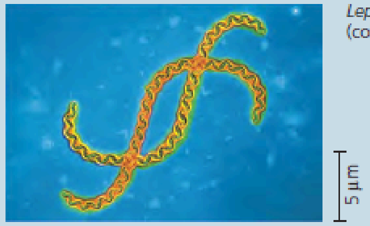
These parasites can survive only within animal cells, depending on their hosts for resources as basic as ATP. The gram-negative walls of chlamydias are unusual in that they lack peptidoglycan. One species, *Chlamydia trachomatis*, is the most common cause of blindness in the world and also causes nongonococcal urethritis, the most common sexually transmitted disease in the United States.



Chlamydia (arrows) inside an animal cell (colorized TEM)

Spirochetes

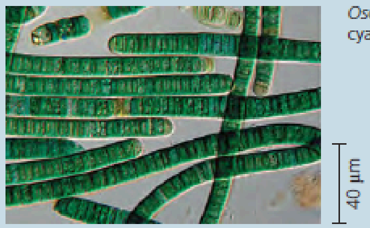
These helical heterotrophs spiral through their environment by means of rotating, internal, flagellum-like filaments. Many spirochetes are free-living, but others are notorious pathogenic parasites: *Treponema pallidum* causes syphilis, and *Borrelia burgdorferi* causes Lyme disease (see Figure 27.20).



Leptospira, a spirochete (colorized TEM)

Cyanobacteria

These photoautotrophs are the only prokaryotes with plantlike, oxygen-generating photosynthesis. (In fact, as we'll discuss in Chapter 28, chloroplasts likely evolved from an endosymbiotic cyanobacterium.) Both solitary and filamentous cyanobacteria are abundant components of freshwater and marine *phytoplankton*, the collection of photosynthetic organisms that drift near the water's surface. Some filaments have cells specialized for nitrogen fixation, the process that incorporates atmospheric N_2 into inorganic compounds that can be used in the synthesis of amino acids and other organic molecules (see Figure 27.14).



Oscillatoria, a filamentous cyanobacterium

Gram-Positive Bacteria

Gram-positive bacteria rival the proteobacteria in diversity. Species in one subgroup, the actinomycetes (from the Greek *mykes*, fungus, for which these bacteria were once mistaken), form colonies containing branched chains of cells. Two species of actinomycetes cause tuberculosis and leprosy. However, most actinomycetes are free-living species that help decompose the organic matter in soil; their secretions are partly responsible for the "earthy" odor of rich soil. Soil-dwelling species in the genus *Streptomyces* (top) are cultured by pharmaceutical companies as a source of many antibiotics, including streptomycin.

Gram-positive bacteria include many solitary species, such as *Bacillus anthracis* (see Figure 27.9), which causes anthrax, and *Clostridium botulinum*, which causes botulism. The various species of *Staphylococcus* and *Streptococcus* are also gram-positive bacteria.

Mycoplasmas (bottom) are the only bacteria known to lack cell walls. They are also the tiniest known cells, with diameters as small as 0.1 µm, only about five times as large as a ribosome. Mycoplasmas have small genomes—*Mycoplasma genitalium* has only 517 genes, for example. Many mycoplasmas are free-living soil bacteria, but others are pathogens.

Streptomyces, the source of many antibiotics (SEM)

Hundreds of mycoplasmas covering a human fibroblast cell (colorized SEM)

Chapter 27 Questions

1. **What is *Halobacterium*?**
2. **What are *Deinococcus radiodurans* and *Picrophilus oshimae*?**
3. **What is *Thiomargarita namibiensis*?**
4. **How does salt help preserve foods?**
5. **What are bacterial cell walls composed of?**
6. **What are archaean cell walls composed of?**
7. **What is the Gram stain?**
8. **What is the difference between gram-positive and gram-negative bacteria?**
9. **What is the sticky layer of polysaccharide or protein surrounding the cell wall of many prokaryotes called?**
10. **What are endospores?**
11. **What are fimbriae?**
12. **What causes gonorrhea?**
13. **What are pili?**
14. **What is taxis?**
15. **What is the difference between prokaryotic flagella and eukaryotic flagella?**
16. **What is the difference between archaeal and bacterial flagella?**
17. **What are the three main parts of a bacterial flagellum?**
18. **Where is the chromosome of prokaryotes located?**
19. **What are plasmids?**
20. **What is the difference between eukaryotic and prokaryotic ribosomes?**
21. **Under optimal conditions, how fast do prokaryotes divide?**
22. **What is the probability of a mutation occurring in an *E. coli* per cell division?**
23. **How many *E. coli* cells can be produced in a day?**
24. **How can genetic recombination occur in prokaryotes?**
25. **What is transformation?**
26. **What bacteria causes pneumonia?**
27. **What is transduction?**
28. **What is conjugation?**
29. **What is the F factor (F for fertility)?**
30. **What is the F plasmid?**
31. **What is a cell with the F factor in its chromosome called?**
32. **What is bacterial dysentery?**
33. **What are R plasmids?**
34. **What are the three prokaryotic metabolisms with respect to oxygen?**
35. **Name the four major nutritional modes, their energy sources, and which organisms use them.**
36. **What is nitrogen fixation?**
37. **What is *Anabaena* (what adaptations for nitrogen fixation)?**
38. **What are biofilms?**

39. Draw the phylogenetic tree of bacteria and archaea.
40. Name the five major groups of bacteria and describe them.
41. What are extremophiles (two types)?
42. What are methanogens?
43. What clade includes many extreme halophiles and all known methanogens? Which clade includes most thermophilic species?
44. What is TACK?
45. What are lokiarchaeotes?
46. In a symbiotic relationship, what is the larger organism called and what is the smaller called?
47. What are the three types of symbiotic relationships?
48. What are pathogens?
49. What is *Bacteroides thetaiotaomicron*?
50. What causes tuberculosis?
51. What causes Lyme disease?
52. What are exotoxins?
53. What causes cholera?
54. What causes botulism?
55. What are endotoxins?
56. What is *Salmonella*?
57. What is O157:H7?
58. What is K-12?
59. What is PHA (polyhydroxyalkanoate)?
60. What is bioremediation?

Chapter 27 Answers

1. genus of archaea with red membrane pigments (some capture light energy for ATP synthesis), among most salt tolerant organisms in earth, pumps potassium ions into cell until ionic concentration inside cell matches concentration outside
2. Prokaryote that can survive 3 million rads of radiation (3000 times the fatal dose for humans)

   Can grow at pH of 0.03 (acidic enough to dissolve metal)
3. Prokaryote that can be big as 750 μm in diameter (normal prokaryotes 0.5-5 μm)
4. Causes prokaryotes to plasmolyze
5. Peptidoglycan (polymer composed of modified sugars cross-linked by polypeptides)
6. Variety of polysaccharides and proteins, lack peptidoglycan
7. Technique to categorize bacterial species according to cell wall composition. Samples stained with crystal violet dye and iodine, rinsed with alcohol, then strained with a red dye such as safranin that enters cell and binds to DNA (structure of cell wall determines staining response)
8. Have relatively simple walls composed of thick layer of peptidoglycan, can have virulent, antibiotic-resistant strains (e.g. MRSA)

   less peptidoglycan and structurally more complex (outer membrane with lipopolysaccharides (carbs bound to lipids). Lipids of membrane are toxic, causes fever or shock. Outer membrane protects it from body's defenses, more resistant to antibiotics
9. Capsule if it is dense and well-defined, slime layer if not as well organized (glycocalyx)
10. Resistant cells developed to withstand harsh conditions. Original cell produces copy of chromosome and surrounds it with multilayered structure. Water is removed from endospore and metabolism halts, original cell lyses to release. Endospore can be rehydrated and resume metabolism when environment improves
11. hairlike appendages used by some prokaryotes stick to substrate or to one another
12. *Neisseria gonorrhoeae*, uses fimbriae to fasten itself to mucous membranes of host
13. appendages that pull two cells together prior to DNA transfer from one cell to another (aka sex pili) (longer and less numerous than fimbriae)
14. Directed movement toward or away from a stimulus
15. Prokaryotic one tenth width and typically not covered by extension of plasma membrane, differ in molecular composition and mechanism of propulsion
16. Composed of entirely different proteins although similar in size/mechanism
17. Motor, hook, filament
18. nucleoid
19. Smaller rings of independently replicating DNA molecules
20. Prokaryotic slightly smaller and differ in protein and Rna content
21. every 1-3 hours
22. 1 in 10^7

23. 2 x 10^10
24. transformation, transduction, conjugation (when from different species, called horizontal gene transfer)
25. Genotype/phenotype of prokaryotic cell altered by uptake of foreign DNA from surroundings
26. Streptococcus pneumoniae
27. Phages carry prokaryotic genes from one host cell to another
28. DNA transferred between two prokaryotic cells that are temporarily joined (in bacteria, transfer is always one-way, pilus of donor cell attaches to recipient, pulls cells together, mating bridge, a temporary structure, may form between cells for transfer of DNA or DNA may pass through hollow pilus)
29. Piece of DNA that grants the ability to form pili and donate DNA during conjugation, in *E. coli* consists of 25 genes (most for formation of pili), can be a plasmid or located in chromosome
30. Plasmid form of F factor, cells containing it called F^+ cells, function as DNA donors during conjugation. Cells lacking F factor (F^-) function as recipients
31. *Hfr* cell (high frequency of recombination), functions as donor, does not give entire gene but gene sent over and homologous parts cross over
32. Disease caused by *Shigella* bacteria, produces severe diarrhea
33. R for resistance, carry resistance genes, many have genes that encode pili
34. Obligate aerobes (must use O_2 for cellular respiration and cannot grow w/o it
    Obligate anaerobes are poisoned by O_2, some live exclusively by fermentation, some use anaerobic respiration (nitrate (NO_3^-) and sulfate (SO_3^{2-}) ions) accept electrons at ends of electron transport chains
    Facultative anaerobes use O_2 if present, can carry out fermentation/anaerobic fermentation in anaerobic environment
35. See picture
36. Used by some cyanobacteria and some methanogens (group of archaea), converts atmospheric nitrogen (N_2) to ammonia (NH_3)
37. Cyanobacteria, has genes that encode proteins for photosynthesis and nitrogen fixation, but single cell cannot carry out both because photosynthesis produces O_2 (inactivates enzymes associated with nitrogen fixation). Form filamentous chains, most cells carry out photosynthesis, a few specialized cells (heterocysts or heterocytes) carry out only nitrogen fixation (surrounded by thickened cell wall that restricts entry of O_2 produced by neighboring photosynthetic cells)
38. Surface-coating colonies where cells secrete signaling molecules that recruit nearby cells, causing colonies to grow. Cells produce polysaccharides and proteins that stick cells to substrate and one another (form capsule or slime layer), can contaminate products/medical equipment
39. See picture
40. Picture
41. archaea that live in very extreme environments
    Extreme halophiles live in highly saline environments

Extreme thermophiles thrive in very hot environments (e.g. *Sulfolobus* live in sulfur-rich volcanic springs as hot as 90ºC. strain 121 can reproduce at 121ºC, found in hydrothermal vents. Pyrococcus furiosus is extreme thermophile use as source of DNA polymerase for PCR)

42. archaea that release methane as a by-product of their metabolism. Use CO_2 to oxidize H_2, produces energy and methane waste, poisoned by O_2, useful as decomposers in sewage treatment facilities
43. Euryarchaeota, Crenarchaeota
44. A supergroup including Thaumarchaeota, Aigarchaeota, Crenarchaeota, and Korarchaeota
45. group closely related to TACK archaea, could represent sister group of eukaryotes
46. host, symbiont
47. mutualism, commensalism, parasitism
48. Parasites that cause disease
49. Synthesizes carbs, vitamins, etc. that humans need, signals from it activate human genes that build the network of intestinal blood vessels necessary to absorb nutrients, signals cause human cells to produce antimicrobial compounds that do not affect the bacteria, reduces population sizes of competing species
50. *Mycobacterium tuberculosis*
51. The spirochete *Borrelia burgdorferi*, carried by ticks
52. Proteins secreted by certain bacteria and other organisms
53. Exotoxins secreted by the proteobacterium *Vibrio cholerae*
54. Botulinum toxin, secreted by gram-positive *Clostridium botulinum*
55. Lipopolysaccharide components of the outer membrane of gram-negative bacteria, released only when bacteria die/cell walls break down
56. Endotoxin-producing bacteria, includes *Salmonella typhi*, causes typhoid fever
57. One of the most dangerous, pathogenic strains of *E. coli*
58. A harmless strain of *E. coli*
59. Polymer synthesized by bacteria to store energy, can be extracted, formed into pellets, and used to make durable, biodegradable plastics
60. Use of organisms to remove pollutants from soil, air, or water