Announcements

- Lab this week: bring textbook and photo atlas.
- Relevant reading BEFORE lab: Ch. 30

What do these things have in common?


http://i.cnn.net/cnn/SPECIALS/2001/trade.center/images/anthrax.jpg


http://www.metalunderground.com/images/gallery/Anthrax_Tour_2006_Chicago_IL/Anthrax_009.jpg


http://imagecache2.allposters.com/images/pic/ARG/20691~Beans-Peas-and-Lentils-Posters.jpg


http://www.destination360.com/north-america/us/wyoming/old-faithful.php


http://msnbcmedia4.msn.com/j/msnbc/Components/Photos/061222/061222_exxon_vmed11a.widec.jpg

Prokaryotes: Bacteria and Archaea (Ch. 28)

I. Intro – how do prokaryotes differ from eukaryotes?

II. (28.1) Why Do Biologists Study Bacteria and Archaea?
- A. Bacterial Diseases
- B. Bioremediation
- C. Extremophiles
- D. Global Change

III. (28.2) How Do Biologists Study Bacteria and Archaea?

IV. (28.3) Themes in the Diversification of Bacteria and Archaea
- A. Morphological Diversity
- B. Metabolic Diversity

KEY CONCEPTS

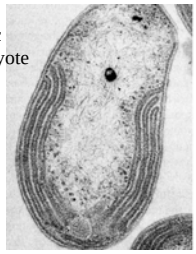
- You are only alive because of prokaryotes.
  - * But they could also kill you
- Bacteria and archaea are the best biochemists in the world
  - * very diverse biochemically

I. Prokaryotes vs. eukaryotes

Internal cellular structure

- one double stranded chromosome of DNA in the form of a ring
- smaller rings of DNA called plasmids
- specialized membranes for metabolic purposes
- no membrane-bound organelles

aerobic prokaryote

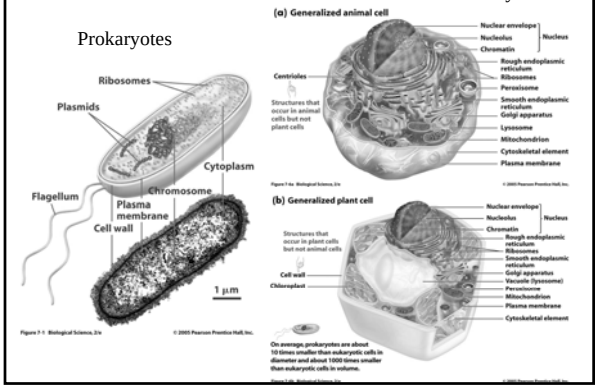


photosynthetic prokaryote

Comparison to eukaryotes

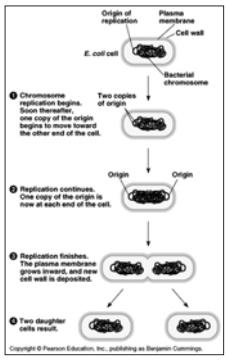
Eukaryotes

Prokaryotes



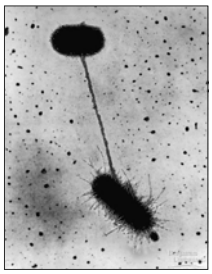
Asexual reproduction

- Binary fission
- Resistant spores



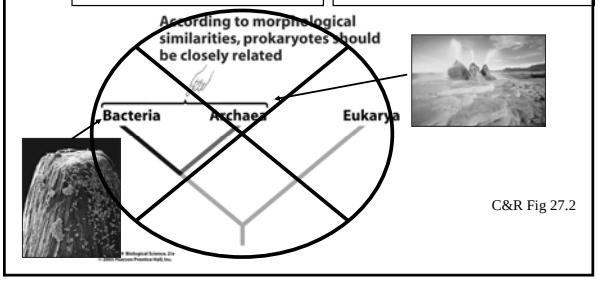
Sex in bacteria?

- No real sexual reproduction
- transformation - the uptake of genes from the surrounding environment
- conjugation - direct <u>transfer</u> of genes from prokaryote to prokaryote



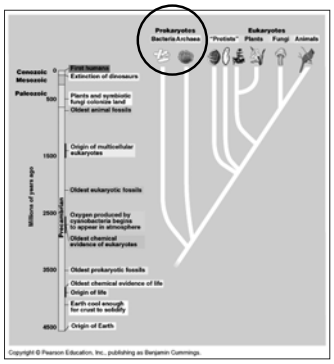
Prokaryotes vs. Eukaryotes

cells small (1-5 mm diameter) unicellular no nucleus or organelles cell wall	cells large (10-100 mm) unicellular or multicellular nucleus and organelles different cell wall when present



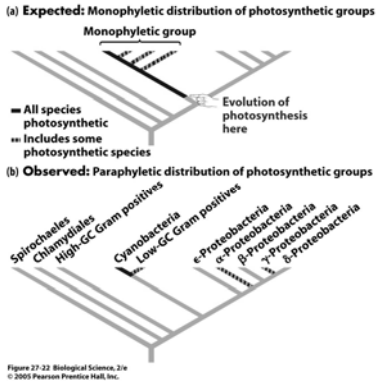
C&R Fig 27.2

Actual prokaryotic ancestry



C&R Fig 26.1

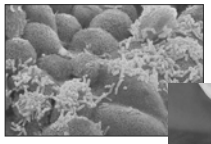
Consequences of plasmid transfer (transformation, conjugation)



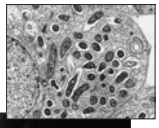
27.1 Why Do Biologists Study Bacteria and Archaea?

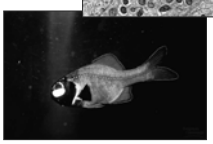
Ecological impacts of prokaryotes

decomposers - recycle nutrients from dead organisms



pathogens - cause human disease





mutualism - live closely with another organism and both benefit

a. Bacterial Diseases

TABLE 27.1 Some Diseases Caused by Bacteria

Bacterium	Lineage	Tissues Affected	Disease
Borrelia burgdorferi	Spirochaetes	Skin and nerves	Lyme disease
Chlamydia trachomatis	Planctomyces	Urogenital canal	Genital tract infection
Clostridium botulinum	Low-GC Gram positives	Gastrointestinal tract, nervous system	Food poisoning (botulism)
Clostridium tetani	Low-GC Gram positives	Wounds, nervous system	Tetanus
Haemophilus influenzae	Proteobacteria (γ group)	Ear canal, nervous system	Ear infections, meningitis
Helicobacter pylori	Proteobacteria (ε group)	Stomach	Ulcer
Mycobacterium leprae	High-GC Gram positives	Skin and nerves	Leprosy
Mycobacterium tuberculosis	High-GC Gram positives	Respiratory tract	Tuberculosis
Neisseria gonorrhoeae	Proteobacteria (β group)	Urogenital canal	Gonorrhea
Propionibacterium acnes	High-GC Gram positives	Skin	Acne
Pseudomonas aeruginosa	Proteobacteria (β group)	Urogenital canal, eyes, ear canal	Infections of eye, ear, urinary tract
Salmonella enteritidis	Proteobacteria (γ group)	Gastrointestinal tract	Food poisoning
Staphylococcus aureus	Low-GC Gram positives	Skin, urogenital canal	Acne, boils, impetigo, toxic shock syndrome
Streptococcus pneumoniae	Low-GC Gram positives	Respiratory tract	Pneumonia
Streptococcus pyogenes	Low-GC Gram positives	Respiratory tract	Strep throat, scarlet fever
Treponema pallidum	Spirochetes	Urogenital canal	Syphilis
Vibrio parahaemolyticus	Proteobacteria (γ group)	Gastrointestinal tract	Food poisoning
Yersinia pestis	Proteobacteria (γ group)	Lymph and blood	Plague

Table 27-1 Biological Science, 2/e
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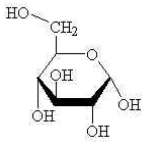
http://i.cnn.net/cnn/SPECIALS/2001/trade.center/images/anthrax.jpg

http://www.metalunderground.com/images/gallery/Anthrax_Tour_-2006_Chicago_IL)/Anthrax_009.jpg

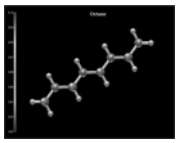
b. Bioremediation

glucose



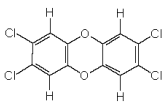
http://dl.clackamas.edu/ch106-07/images/ring.h1.jpg

octane



http://core.ecu.edu/phys/flurchickk/AtomicMolecularSystems/octaneReplacement/images/octane2.png

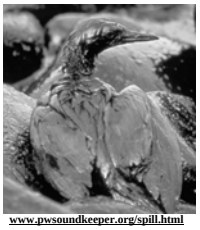
dioxin



http://mds.glc.org/carol/images/chem/2378tcdd.gif

Exxon Valdez oil spill

http://www.channel6.dk/native/Grabs%20full/AK4-078V.jpg



www.pwsoundkeeper.org/spill.html

http://msnbcmedia4.msn.com/j/msnbc/Components/Photos/061222/061222_exxon_vmed11a.widec.jpg

Issues with bioremediation

Figure 27-2 Biological Science, 2/e
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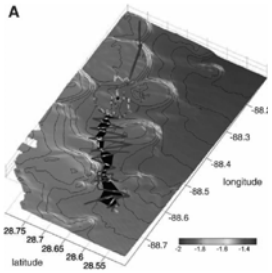
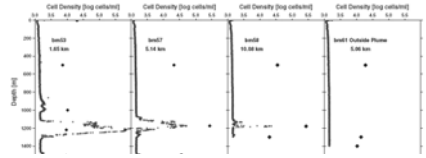
Microbial degradation of Gulf oil spill?

http://www.manausa.com/no-oil-at-cape-san-blas/



Methane concentrations in subsurface plume
(Camilli et al. 2010 Science)

Oil degrading bacteria in plume



Hazen et al. 2010 Science

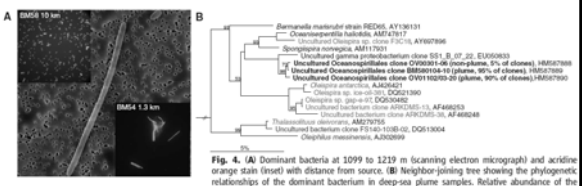


Fig. 4. (**A**) Dominant bacteria at 1099 to 1219 m (scanning electron micrograph) and acridine orange stain (inset) with distance from source. (**B**) Neighbor-joining tree showing the phylogenetic relationships of the dominant bacterium in deep-sea plume samples. Relative abundance of the dominant bacterium was 90 to 95% of plume samples and 5% of the nonplume sample (shown in parentheses). Psychrophilic, hydrocarbon-degrading bacteria, as well as uncultured organisms from low-temperature, hydrocarbon-dominated environments, are shown in blue. Organisms shown in red are either known hydrocarbon degraders or are from hydrocarbon-dominated ecosystems but are not from low-temperature environments. Bootstrap values based on 1000 replicates of ≥50% are shown at branch points. *Aquifex pyrophilus* (GenBank accession M83548) was used as the outgroup.

c. Extremophiles

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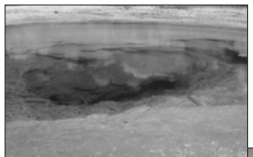
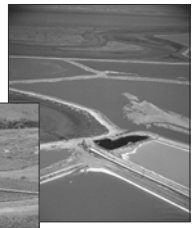
http://www.destination360.com/north-america/us/wyoming/old-faithful.php

Archaea

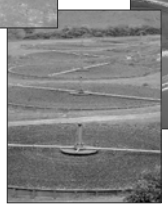
most research has focused on their ecology rather than phylogeny



extreme halophiles



extreme thermophiles



methanogens

d. Global Change
1. The Oxygen Revolution

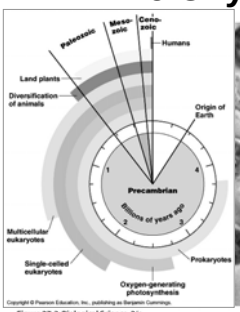


Figure 27-3 Biological Science, 2/e
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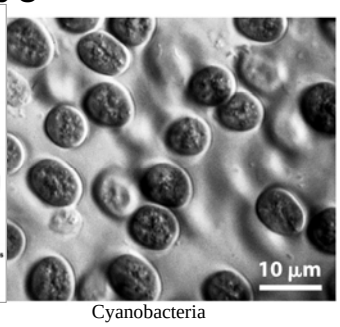
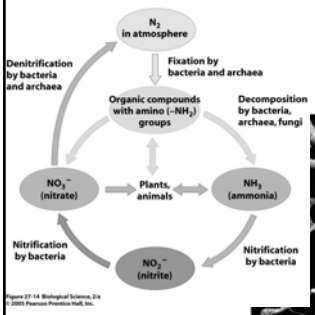
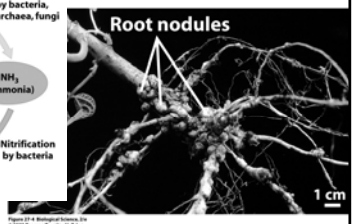


Cyanobacteria

2. The Nitrogen Cycle



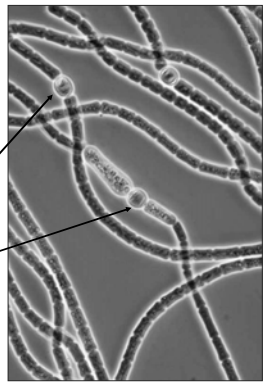


Beans, peas & lentils

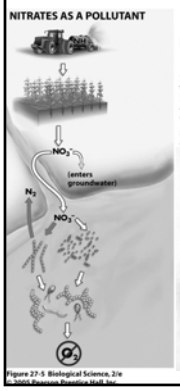

http://imagecache2.allposters.com/images/pic/ARG/20691~Beans-Peas-and-Lentils-Posters.jpg

Nitrogen fixation

- Convert atmospheric nitrogen into biological form used in proteins and nucleic acids
- *Anabaena*, a photoautotroph, can also fix nitrogen.
- **Heterocysts** – cells specialized to carry out the process



Nitrate Pollution



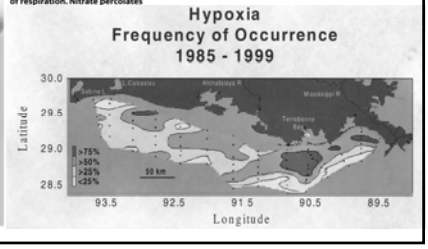


Figure 27-5 Biological Science, 2/e

III. How Do Biologists Study Bacteria and Archaea? (27.2)

1. What biases arise with using enrichment cultures to study prokaryotes?
2. How has direct sequencing changed our understanding of the evolutionary relationships among prokaryotes?
3. What is one advantage of enrichment culture over direct sequencing? Vice versa?
4. Don't worry about details of fig. 27.8.

27.3 What Themes Occur in the Diversification of Bacteria and Archaea?

Morphological Diversity

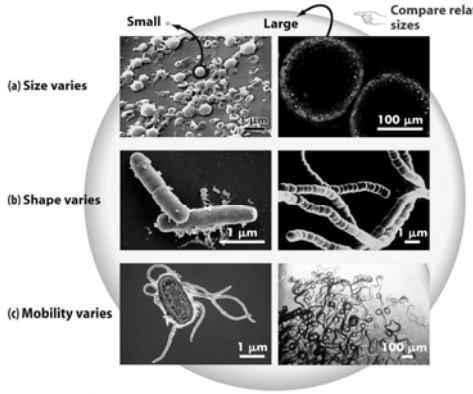


Figure 27-11 Biological Science, 2/e
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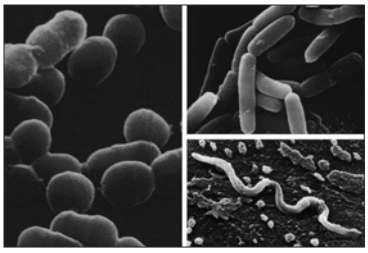
Prokaryote shape

rod-shaped (bacilli)

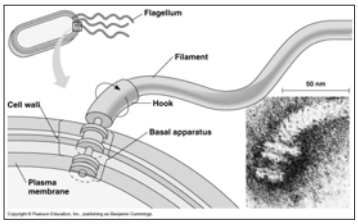
spherical (cocci)

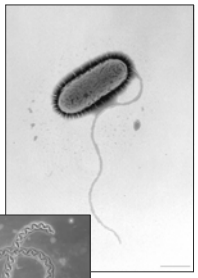


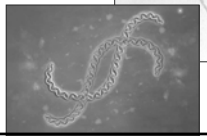
Helical (spirillum)

Movement

Animated bacterial movement towards attractant







- Flagella (bacterial)
- Chemical gliding

Gram-positive cells retain Gram stain more than Gram-negative cells do.

Gram-positive cells are purple when treated with Gram stain

Gram-negative cells are pink when treated with Gram stain

Figure 27-12c Biological Science, 2/e
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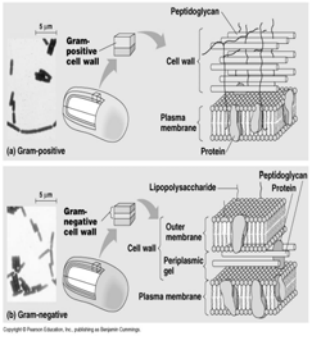
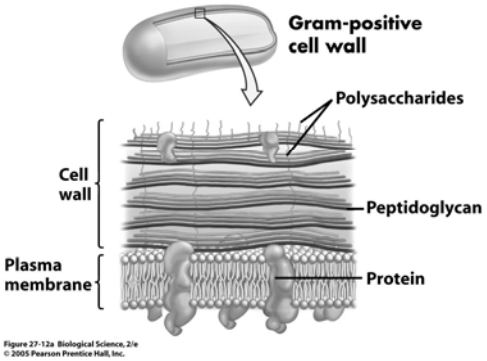
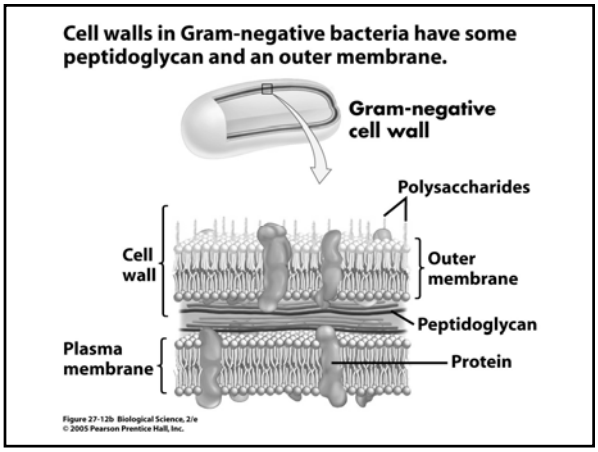
Prokaryotic cell walls



- maintain shape, protection
- complex chemically – peptidoglycan and lipids
- many antibiotics target this special chemistry

Fig 27.5





Metabolic Diversity

Aerobic/anaerobic

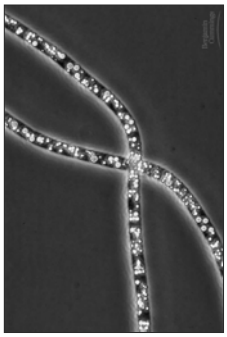
Cellular Respiration: Variation in Electron Donors and Electron Acceptors

Photosynthesis

Pathways for Fixing Carbon

Metabolism and oxygen

- obligate aerobes - oxygen required
- facultative aerobes - use oxygen when available but not required
- obligate anaerobes - poisoned by oxygen



Cellular Respiration: Variation in Electron Donors and Electron Acceptors

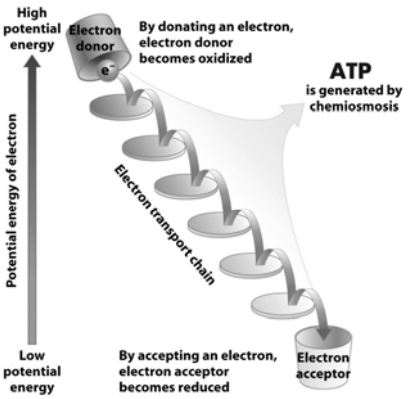


Figure 27-13 Biological Science, 2/e
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TABLE 27.4 Some Electron Donors and Acceptors Used by Bacteria and Archaea

Electron Donor	Electron Acceptor	Product	Category*
Sugars	O_2	H_2O	Organotrophs
H_2 or organic compounds	SO_4^{2-}	H_2S	Sulfate reducers
H_2	CO_2	CH_4	Methanogens
CH_4	O_2	CO_2	Methanotrophs
S or H_2S	O_2	SO_4^{2-}	Sulfur bacteria
Organic compounds	Fe^{3+}	Fe^{2+}	Iron reducers
NH_3	O_2	NO_2^-	Nitrifiers
Organic compounds	NO_3^-	N_2O, NO, or N_2	Denitrifiers (or nitrate reducers)
NO_2^-	O_2	NO_3^-	Nitrosifiers

*The name biologists use to identify species that use a particular metabolic strategy.

Table 27-4 Biological Science, 2/e
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Photosynthesis

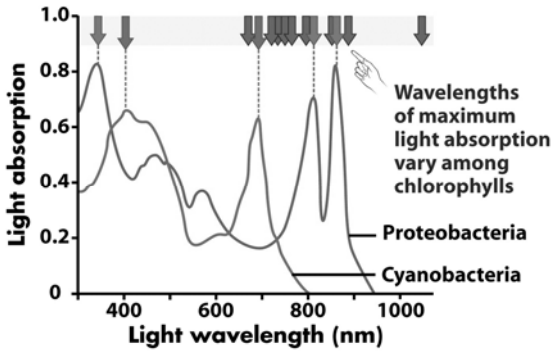

Figure 27-15 Biological Science, 2/e
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Metabolic diversity

Table 27.1 Major Nutritional Modes

Mode of Nutrition	Energy Source	Carbon Source	Types of Organisms
Autotroph			
Photo-autotroph	Light	CO_2	Photosynthetic prokaryotes, including cyanobacteria; plants; certain protists (algae)
Chemo-autotroph	Inorganic chemicals	CO_2	Certain prokaryotes (for example, *Sulfolobus*)
Heterotroph			
Photo-heterotroph	Light	Organic com-pounds	Certain prokaryotes
Chemo-heterotroph	Organic com-pounds	Organic com-pounds	Many prokaryotes and protists; fungi; animals; some parasitic plants

TABLE 27.3 Strategies for Obtaining Energy and Carbon: An Overview

Source of Energy (For ATP production)		Source of Carbon (For synthesis of organic compounds): Autotrophs	Source of Carbon (For synthesis of organic compounds): Heterotrophs
		Synthesize their own high-potential-energy organic compounds from CO_2, CH_4, or other inorganic sources.	Use organic compounds with high potential energy produced by other organisms.
	Light (phototrophs)	**Photoautotrophs** Cyanobacteria use photosynthesis to produce ATP. They fix CO_2 via the Calvin cycle.	**Photoheterotrophs** Heliobacteria use photosynthesis to produce ATP. They absorb organic molecules with high potential energy from the environment.
	Organic Molecules with High Potential Energy (organotrophs)	(no term) *Clostridium aceticum* ferments glucose to produce ATP. It uses reactions called the acetyl-CoA pathway to fix CO_2.	**Chemoorganotrophs** *E. coli* uses fermentation or respiration to produce ATP. It absorbs carbon molecules with high potential energy from the environment.
	Inorganic Molecules with High Potential Energy (lithotrophs)	**Chemolithotrophs** Nitrifying bacteria, including species of Nitrosomonas, produce ATP via respiration, using ammonia (NH_3) as an electron donor. They fix CO_2 via the Calvin cycle.	**Chemolithotrophic Heterotrophs** *Beggiatoa* produces ATP via respiration, using hydrogen sulfide (H_2S) as an electron donor. It absorbs carbon molecules with high potential energy from the environment.

Table 27-3 Biological Science, 2/e
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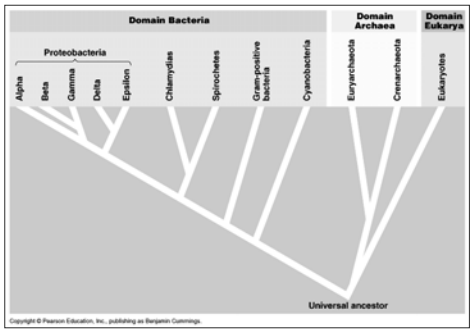
Prokaryote phylogeny



KEY CONCEPTS

- Bacteria and archaea affect your life:
  - Disease (a small percentage of prokaryotes)
  - Cleaning up pollution (bioremediation)
  - Photosynthetic bacteria: evolution of the oxygen atmosphere.
  - Bacteria and archaea cycle nutrients through both terrestrial and aquatic environments.

KEY CONCEPTS

- Bacteria and archaea are very diverse biochemically
  - small and relatively simple in their overall morphologies
  - live in a wide array of habitats
  - sophisticated chemistry: use diverse types of molecules in cellular respiration and fermentation.
  - Many species are restricted in distribution and have a limited diet.