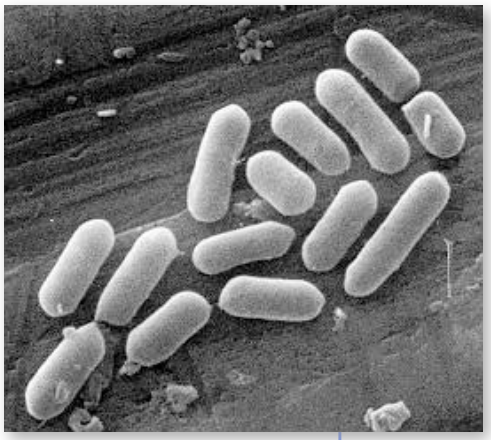
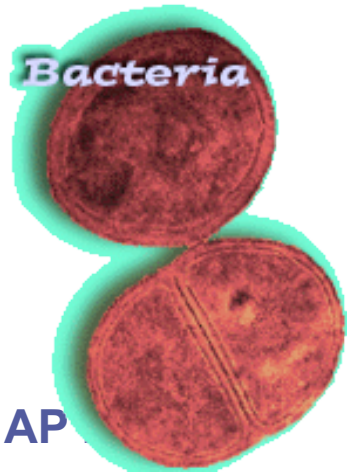
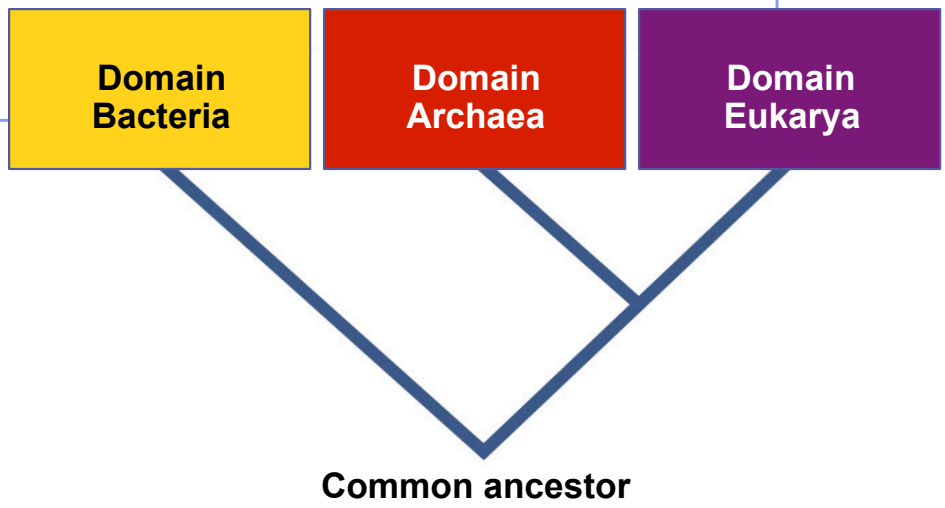
Prokaryotes



Domain Bacteria
Domain Archaebacteria





Prokaryotic Phylogeny

Prokaryotes, bacteria and archaea, were originally placed in the Kingdom Monera.

Recent molecular analysis of nucleotide sequences have shown that these two groups are distinctly different and diverge from one another very early in the history of life.

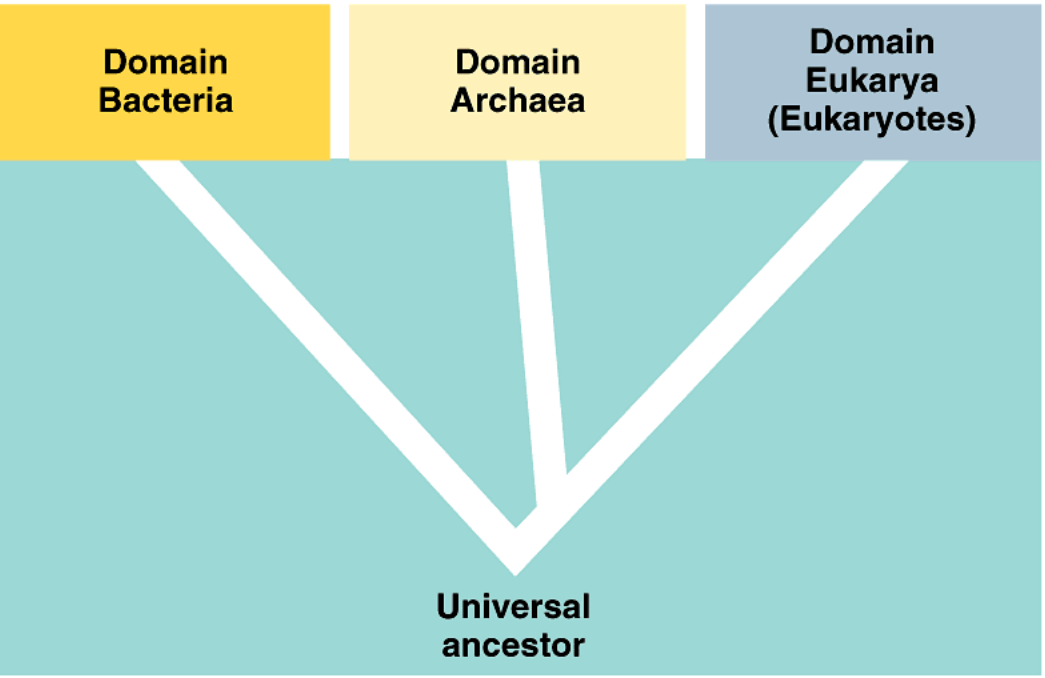
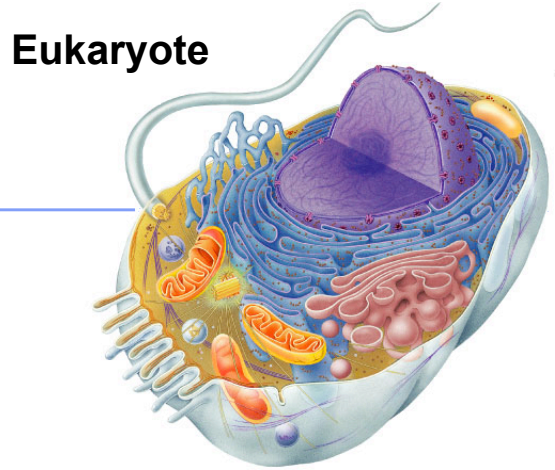


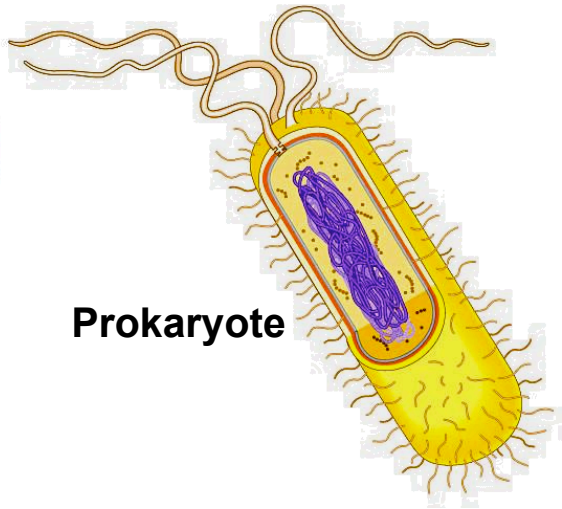
Table 27.2 A Comparison of the Three Domains of Life

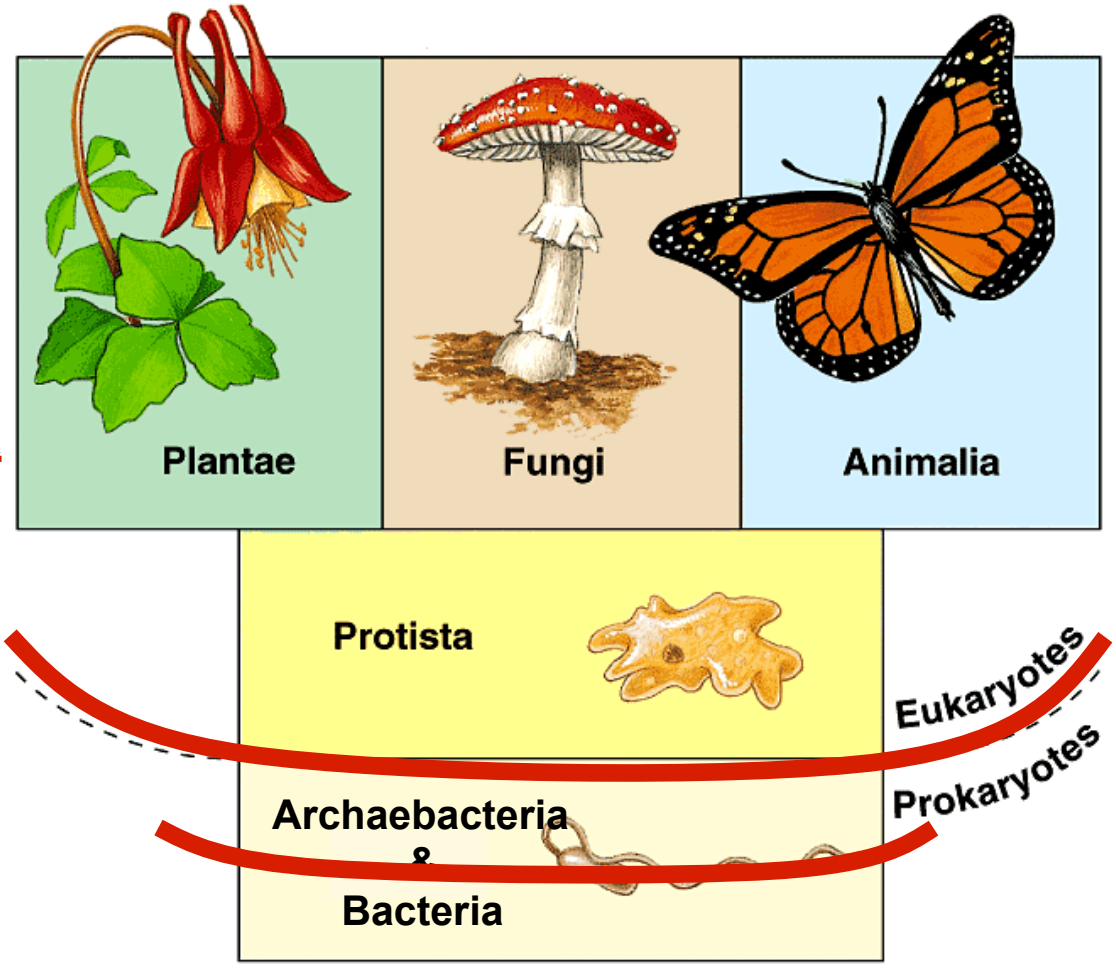
	DOMAIN		
CHARACTERISTIC	Bacteria	Archaea	Eukarya
Nuclear envelope	Absent	Absent	Present
Membrane-enclosed organelles	Absent	Absent	Present
Peptidoglycan in cell wall	Present	Absent	Absent
Membrane lipids	Unbranched hydrocarbons	Some branched hydrocarbons	Unbranched hydrocarbons
RNA polymerase	One kind	Several kinds	Several kinds
Initiator amino acid for start of protein synthesis	Formyl-methionine	Methionine	Methionine
Introns (noncoding parts of genes)	Absent	Present in some genes	Present
Response to the antibiotics streptomycin and chloramphenicol	Growth inhibited	Growth not inhibited	Growth not inhibited
Histones associated with DNA	Absent	Present	Present
Circular chromosome	Present	Present	Absent
Ability to grow at temperatures >100°C	No	Some species	No

Classification

- **Old** 5 Kingdom system
  - Monera, Protists, Plants, Fungi, Animals
- **New** 3 Domain system
  - reflects a greater understanding of evolution & molecular evidence
    - Prokaryote: Bacteria
    - Prokaryote: Archaebacteria
    - Eukaryotes
      - Protists
      - Plants
      - Fungi
      - Animals

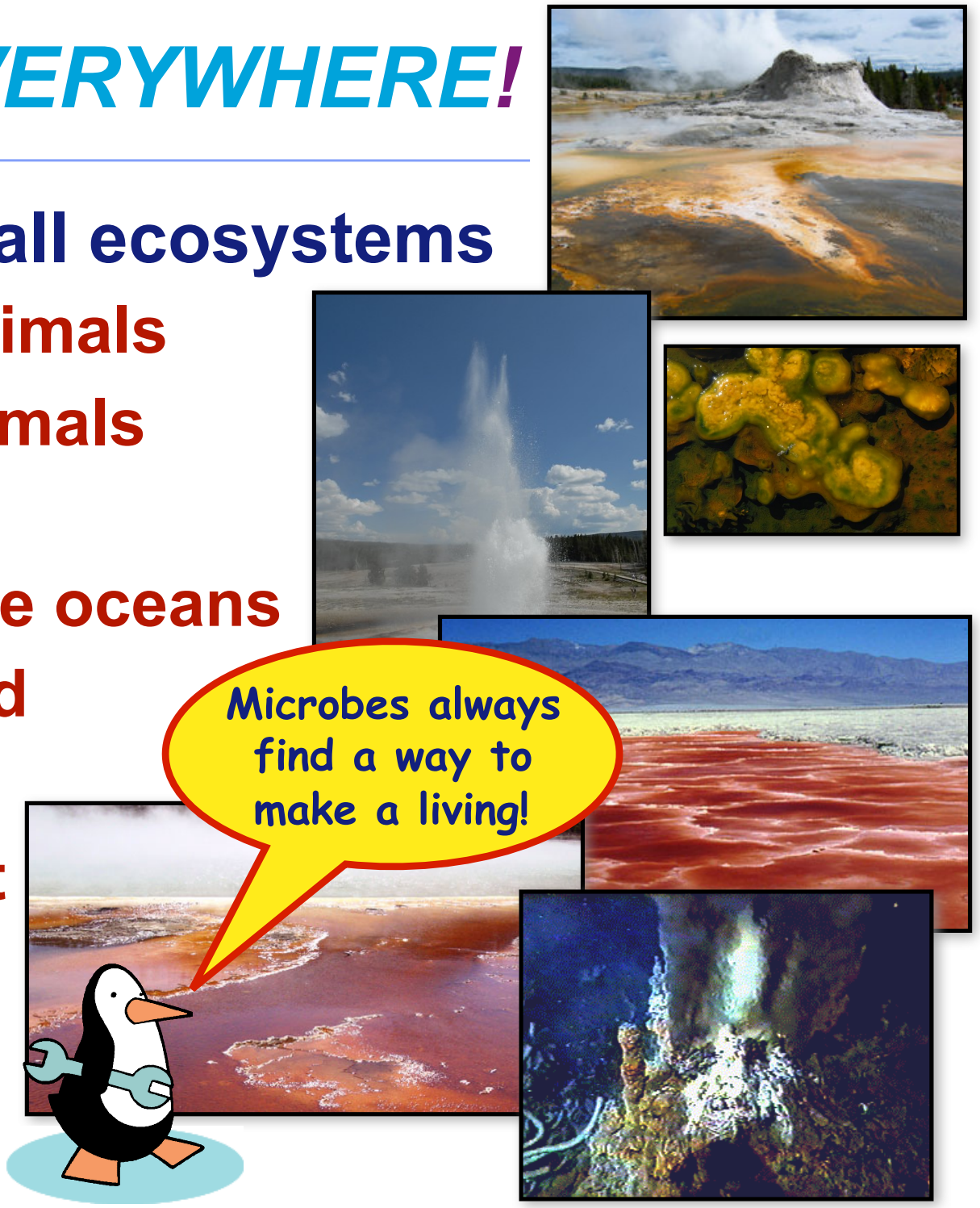






Bacteria live *EVERYWHERE!*

- Bacteria live in all ecosystems
  - on plants & animals
  - in plants & animals
  - in the soil
  - in depths of the oceans
  - in extreme cold
  - in extreme hot
  - in extreme salt
  - on the living
  - on the dead

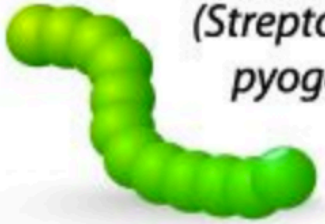


BACTERIA SHAPES

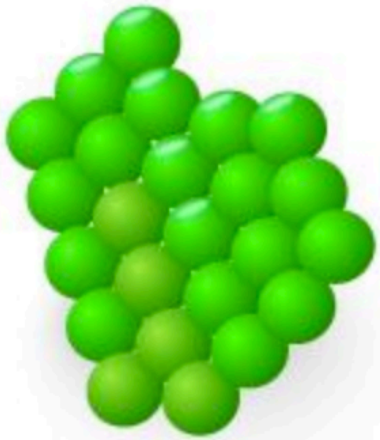
SPHERES (COCCI)

Diplococci
(Streptococcus pneumoniae)

Streptococci
(Streptococcus pyogenes)



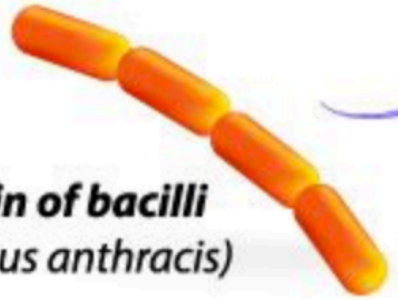
Tetrad



Staphylococci
(Staphylococcus aureus)

Sarcina
(Sarcina ventriculi)

RODS (BACILLI)



Chain of bacilli
(Bacillus anthracis)

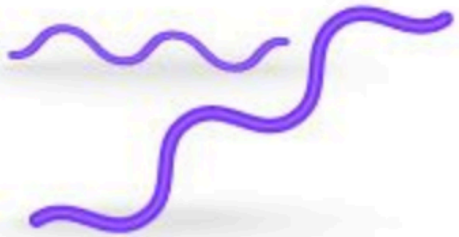
Flagellate rods
(Salmonella typhi)

Spore-former
(Clostridium botulinum)

SPIRALS

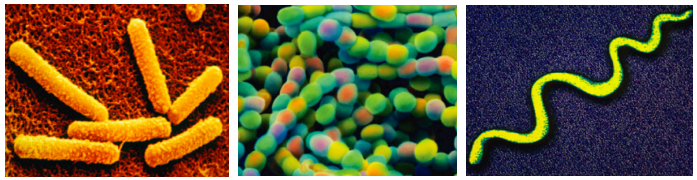
Vibrios
(Vibrio cholerae)

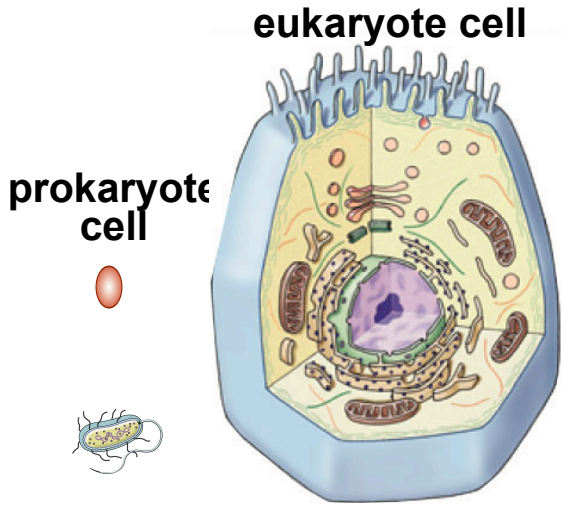
Spirilla
(Helicobacter pylori)



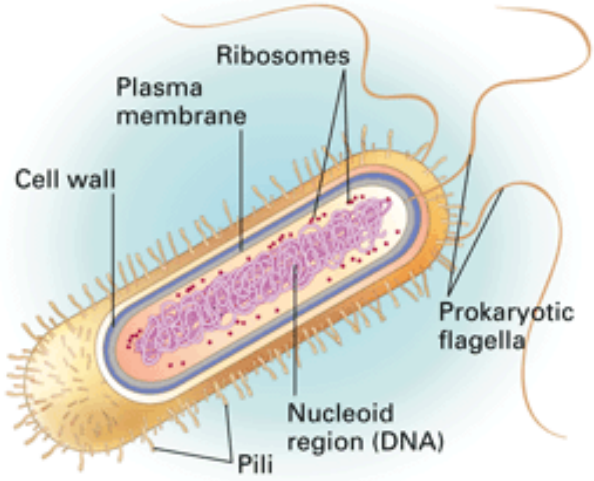
Spirochaetes
(Treponema pallidum)

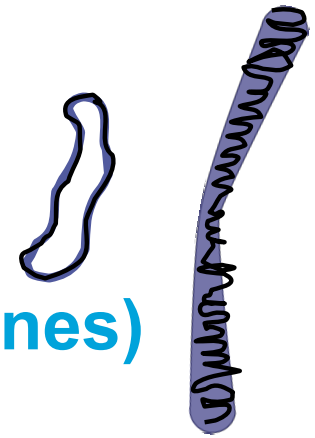
Bacterial Structure



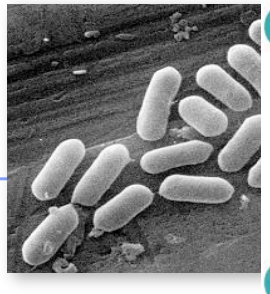


- Unicellular
  - bacilli, cocci, spirilli
- Size
  - 1/10 size of eukaryote cell
    - 1 micron (1um)
- Internal structure
  - no internal compartments
    - no membrane-bound organelles
    - only ribosomes
  - circular chromosome, naked DNA
    - not wrapped around proteins (no histones)

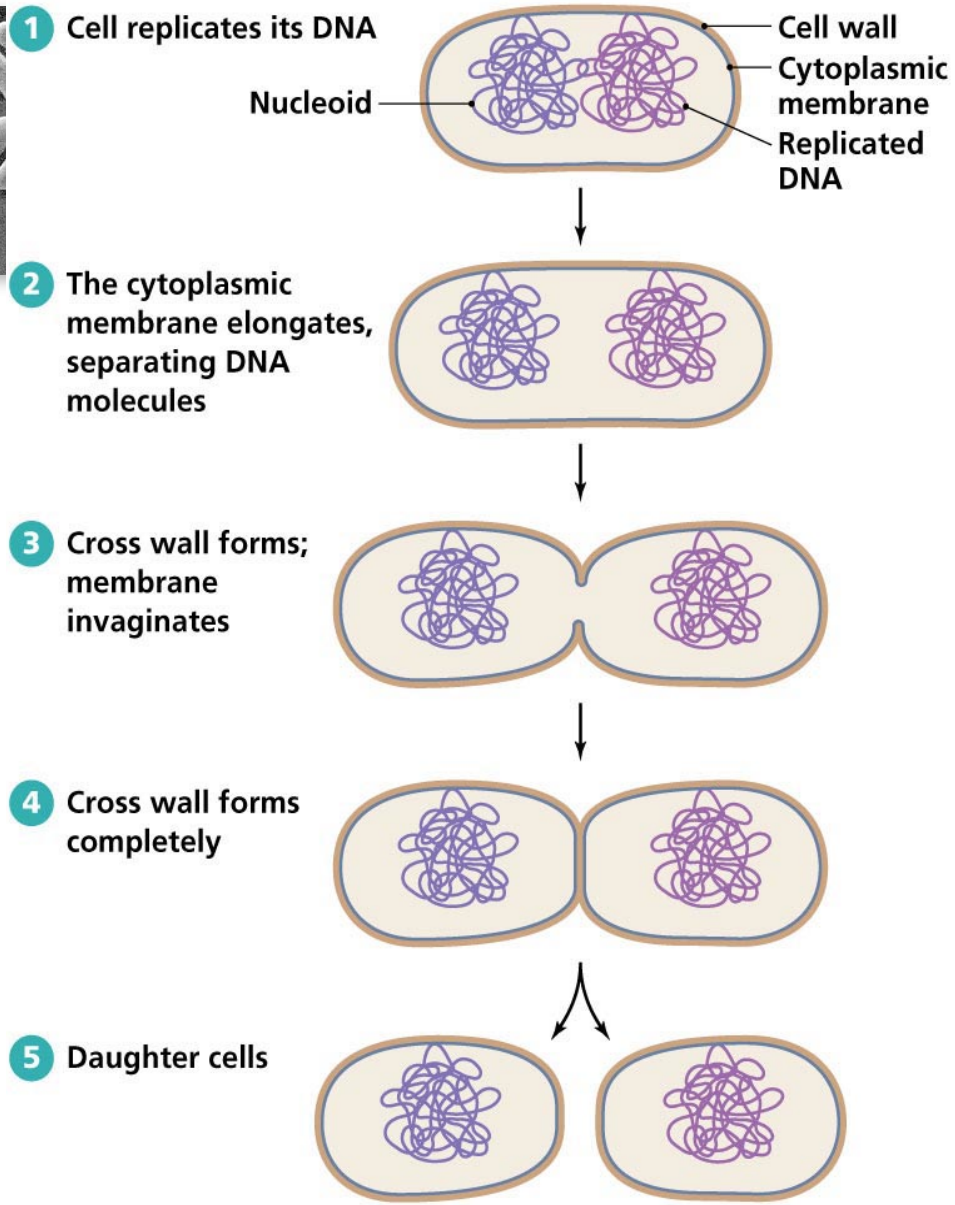


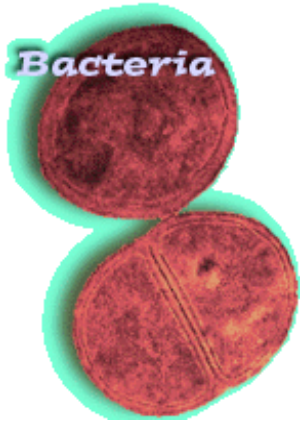


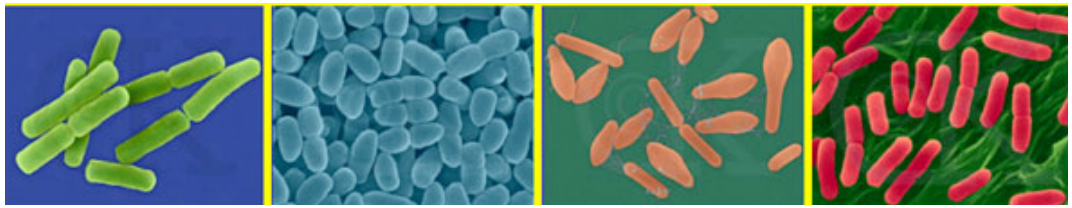
Bacteria

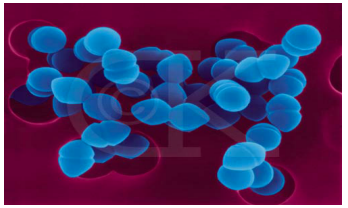


- Bacteria review
  - one-celled prokaryotes
  - Do not reproduce by mitosis
    - Divides by binary fission
  - rapid growth
    - New generation every. ~20 minutes
    - 10^8 (100 million) colony overnight!
      - dominant form of life on Earth
      - incredibly diverse



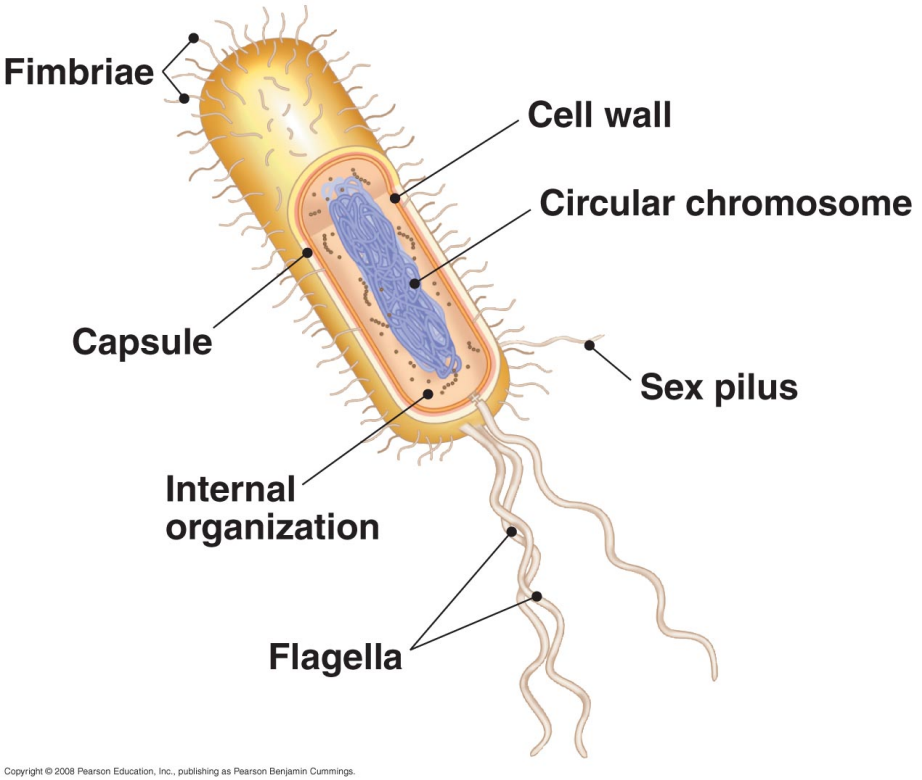


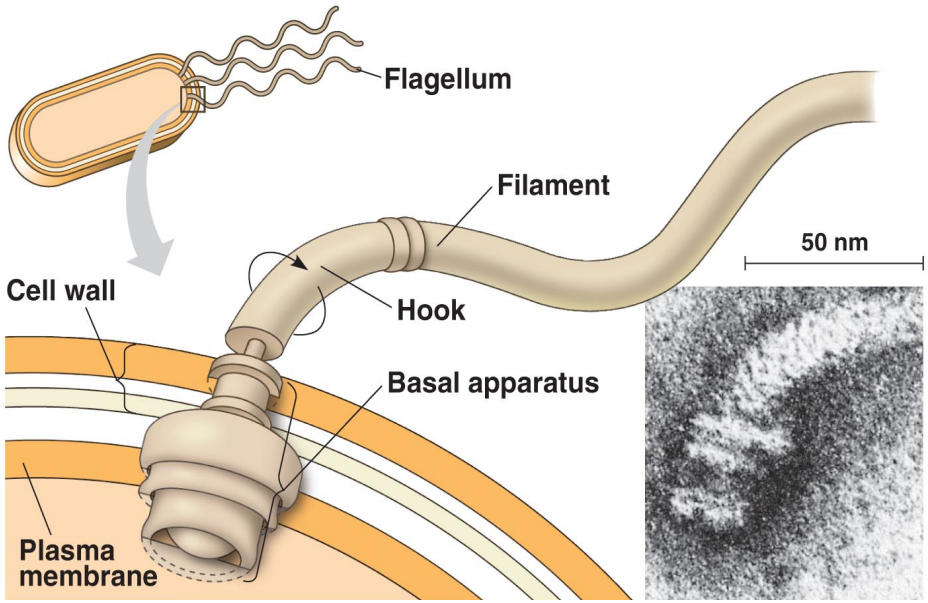




Bacterial Structure

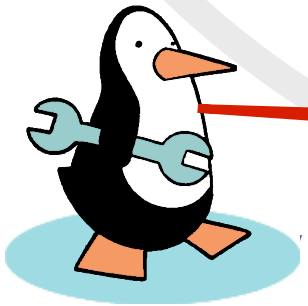
- Some prokaryotes have **fimbriae** (a.k.a. ***attachment pili***)
  - allows them to stick to their substrate or other individuals in a colony
- **Sex pili** are longer than fimbriae and allow prokaryotes to exchange DNA
- The most common method of locomotion in bacteria is the **flagellum** allowing for **taxis**.
  - The ability of mobile cells move in a desired direction away from stimuli
    - PHOTOTAXIS, CHEMOTAXIS, MAGNETOTAXIS

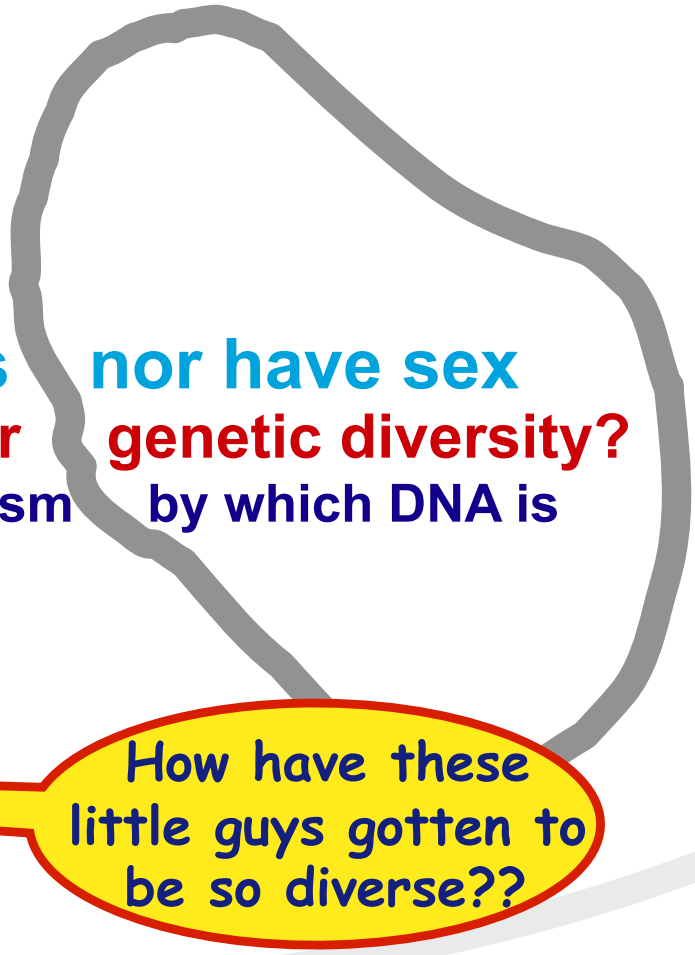




Bacterial genome

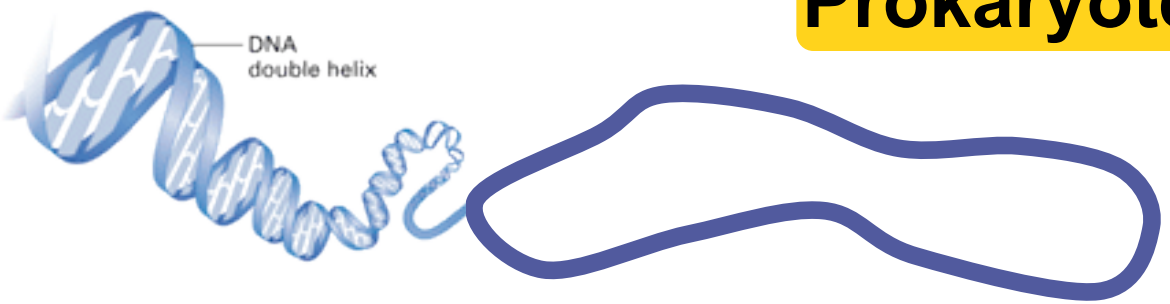
- Single circular chromosome
  - Haploid (1n)
  - No introns or exons
  - Naked DNA
    - no histone proteins
  - ~4 million base pairs
    - ~4300 genes
    - 1/1000 DNA in eukaryote
  - Bacteria do not form gametes nor have sex
    - How then do they increase their genetic diversity?
      - Genetic transfer is the mechanism by which DNA is transferred from a donor to a recipient.
        1. Mutations
        2. Transformation
        3. Conjugation
        4. Transduction





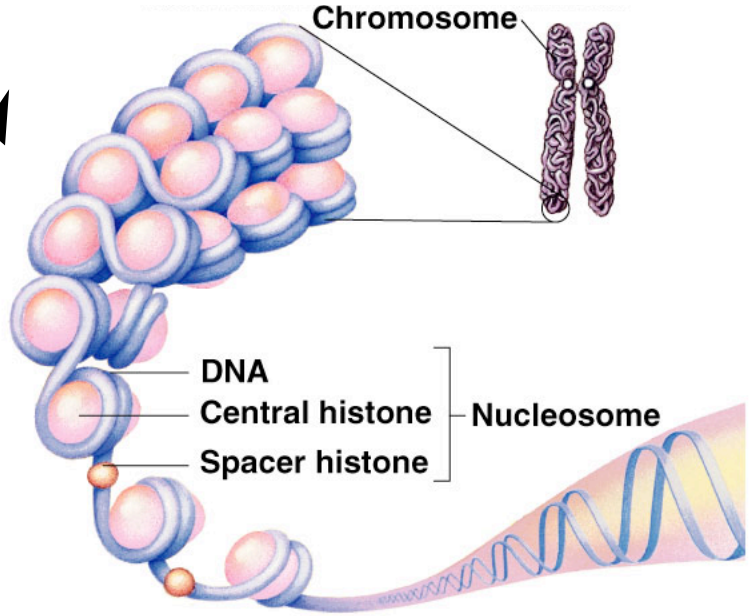
Prokaryote vs. Eukaryote Chromosome

Prokaryote



double helix

Eukaryote



Variations in Cell Interior Exist in Bateria

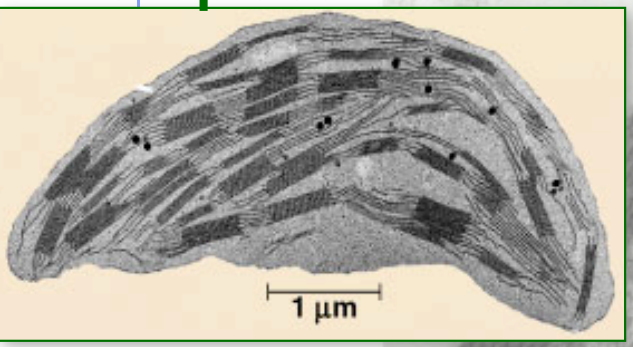
mitochondria

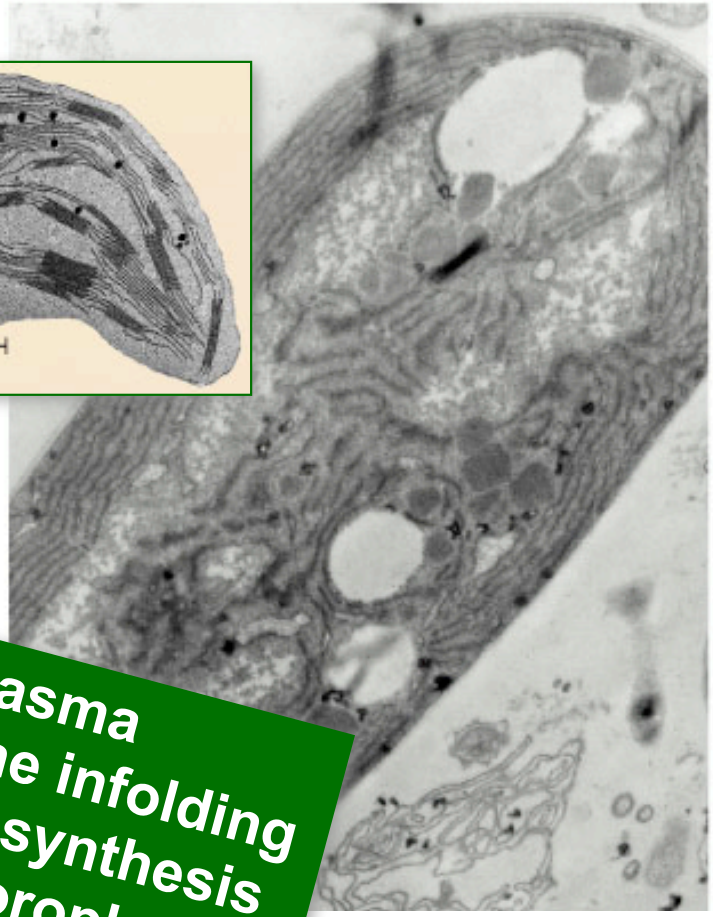
cyanobacterium

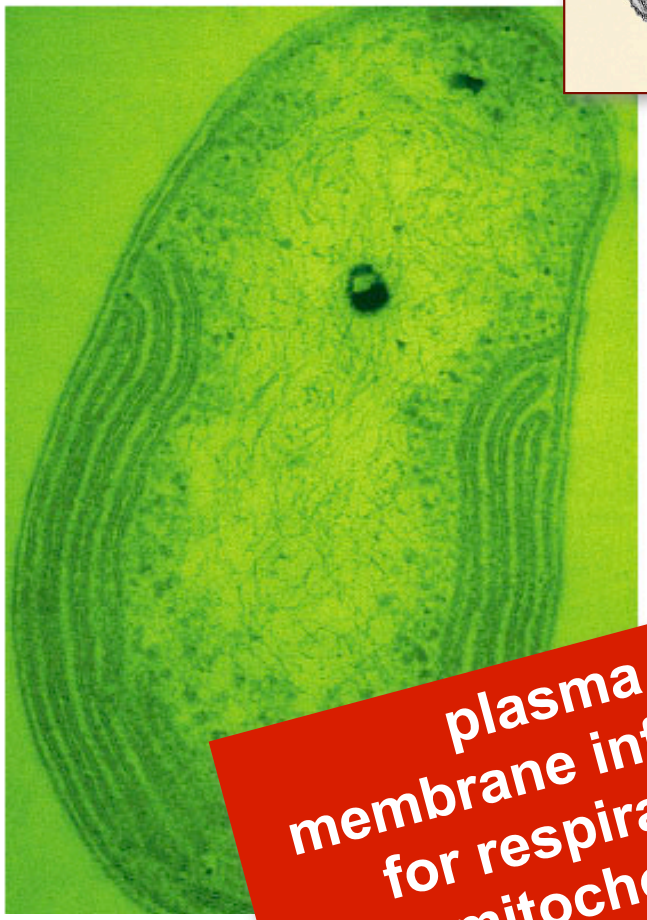
(photosythetic) bacterium

aerobic bacterium

chloroplast





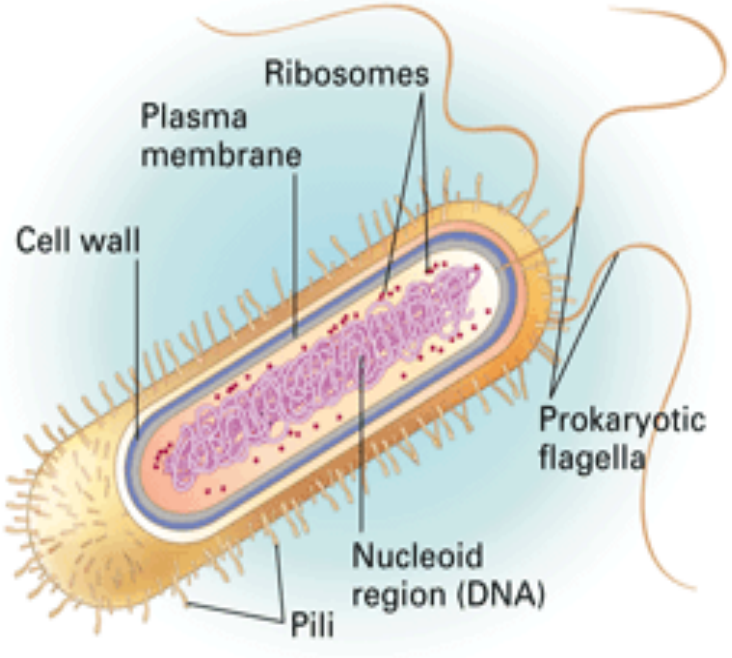


plasma membrane infolding for photosynthesis like a chloroplast's **thylakoids**

plasma membrane infolding for respiration like a mitochondrion's **cristae**

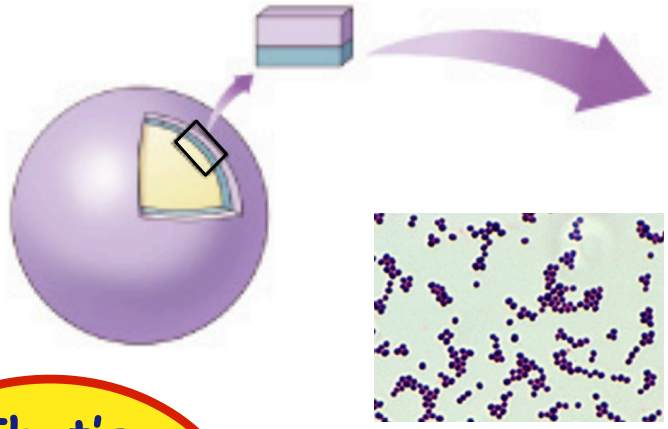
Cell-Surface Structures

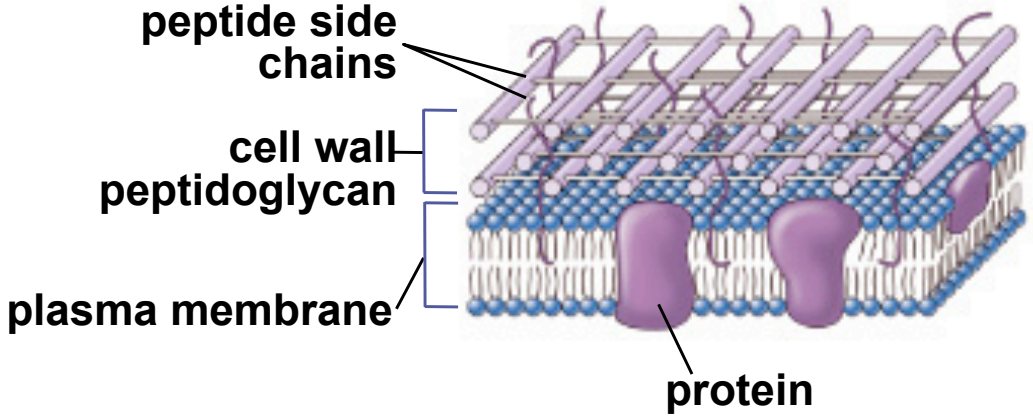
- An important feature of nearly all prokaryotic cells is their cell wall, which maintains cell shape, provides physical protection, and prevents the cell from bursting in a hypotonic environment
  - Eukaryote cell walls are made of cellulose or chitin
  - Bacterial cell walls contain peptidoglycan, a network of sugar polymers cross-link polypeptides
    - Many antibiotics target peptidoglycan bacterial cell walls while bacterial ribosome
  - A polysaccharide or protein layer called a capsule covers many prokaryotes



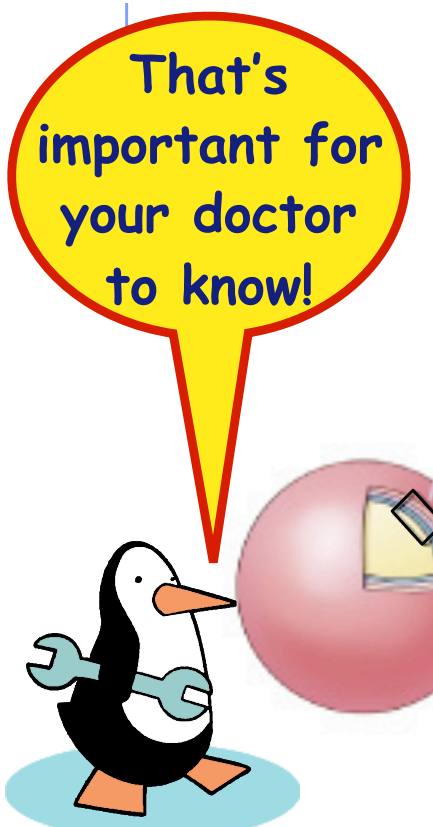
Eubacterial Cell Wall Structure

Gram-positive bacteria

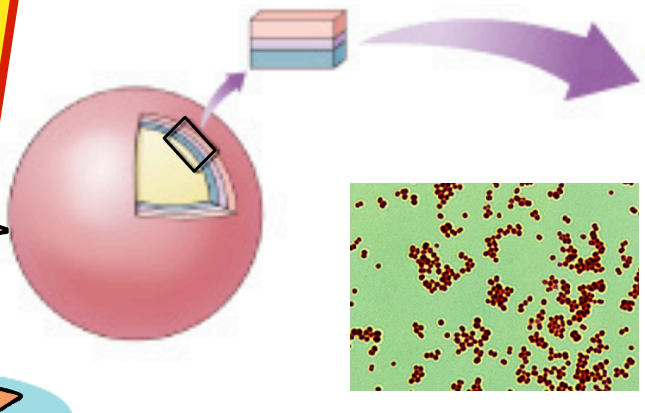


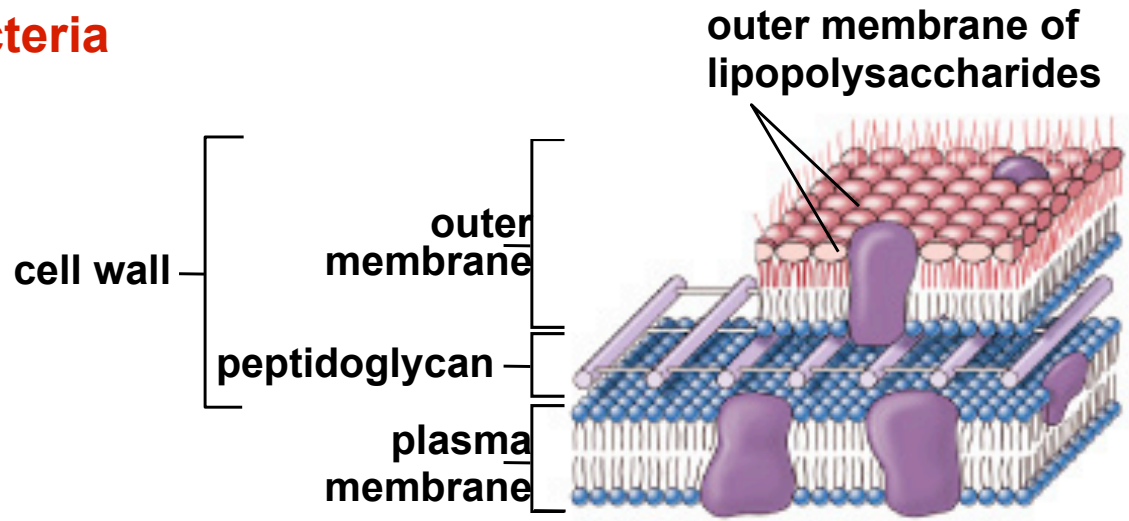


peptidoglycan = polysaccharides + amino acid chains
lipopolysaccharides = lipids + polysaccharides



Gram-negative bacteria





peptidoglycan = polysaccharides + amino acid chains
lipopolysaccharides = lipids + polysaccharides

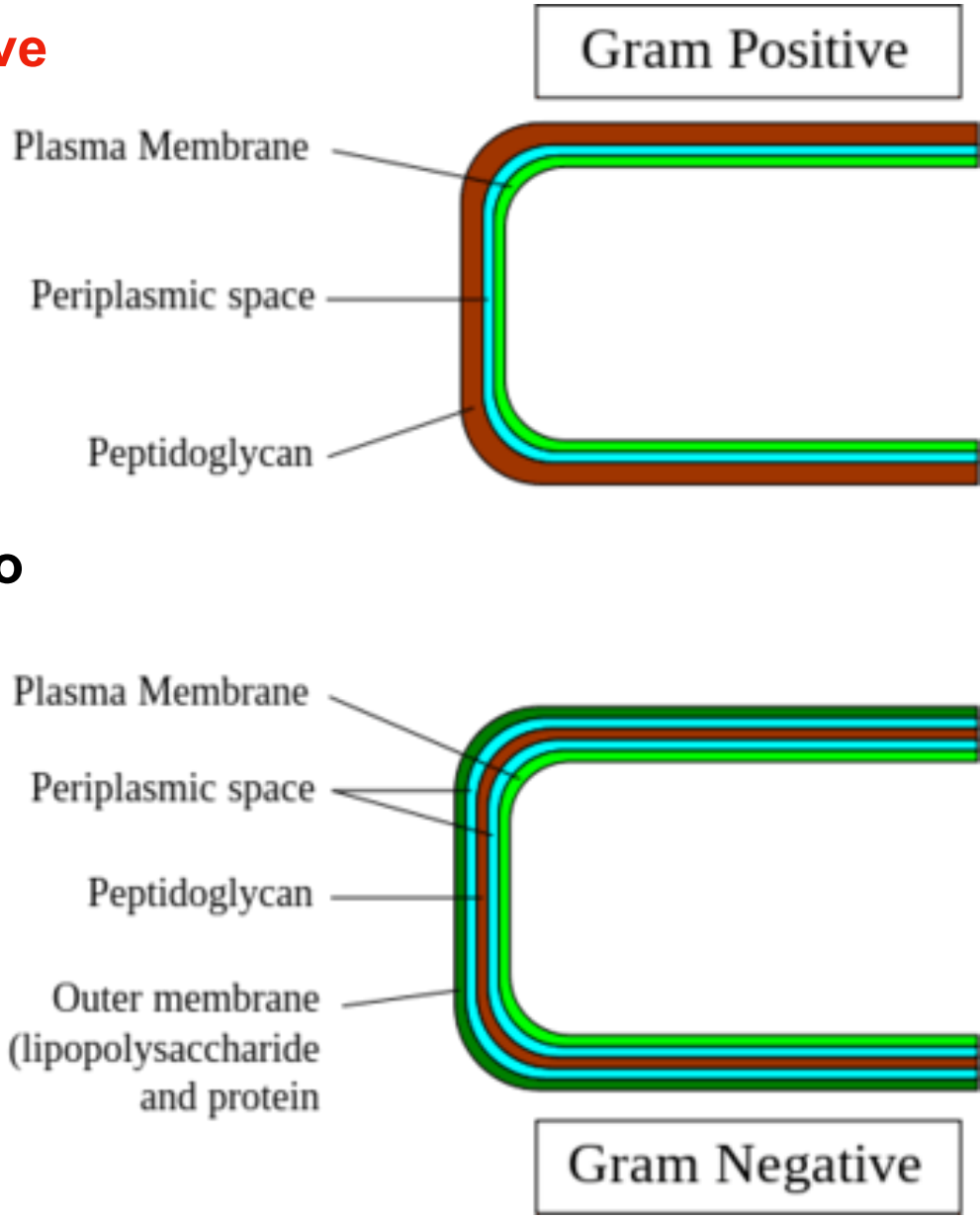
Eubacterial Cell Wall Structure

Both gram-positive and gram-negative bacteria can be pathogenic

Six gram-positive genera of bacteria are known to cause disease in humans: Streptococcus, Staphylococcus, Corynebacterium, Listeria, Bacillus and Clostridium.

Many gram-negative bacteria are also pathogenic e.g., Pseudomonas aeruginosa, Neisseria gonorrhoeae, Chlamydia trachomatis, and Yersinia pestis.

Gram-negative bacteria are also more resistant to antibiotics and their outer membrane comprises a complex lipopolysaccharide (LPS) whose lipid portion acts as an endotoxin.



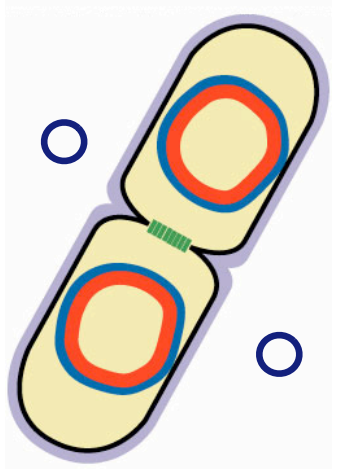
Transformation

- **Many bacteria are opportunists**
  - pick up small pieces of naked foreign DNA wherever it may be hanging out
    - have surface transport proteins that are specialized for the uptake of naked DNA
      - While *E. coli* lacks this specialized mechanism, it can be induced to take up small pieces of DNA if cultured in a medium with a relatively high concentration of calcium ions.
        - In biotechnology, this technique has been used to foreign DNA into *E. coli*.
  - import bits of chromosomes from other bacteria
  - incorporate the DNA bits into their own chromosome
    - express new genes
      - Process of internalizing foreign DNA= TRANSFORMATION
        - The genetically transformed cell is called a recombinant cell because it has a different genetic makeup than the donor and the recipient
        - Give rise to genetic diversity in the population = diversity in the population.
    - form of 'recombination'

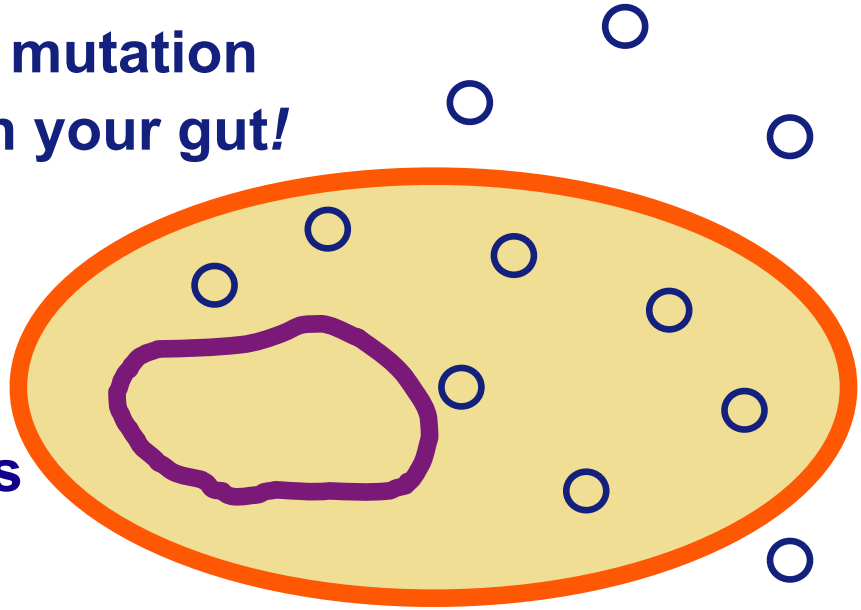
Remember Griffith?

mix heat-killed pathogenic & non-pathogenic *bacteria*

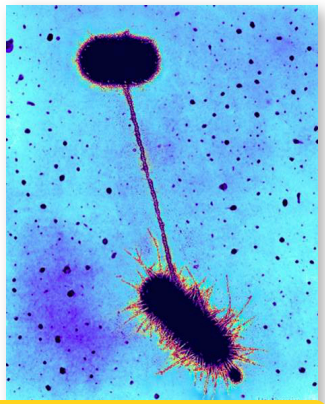
Generating Genetic variation in bacteria



- **Mutations**
  - bacteria can reproduce every 20 minutes
    - binary fission
  - error rate in copying DNA is higher in prokaryotes than eukaryotes *(prokaryotic DNA polymerase lacks proofreading ability that)*
    - 1 in every 200 bacteria has a mutation
    - you have billions of *E. coli* in your gut*!*
      - *lots of mutation potential!*



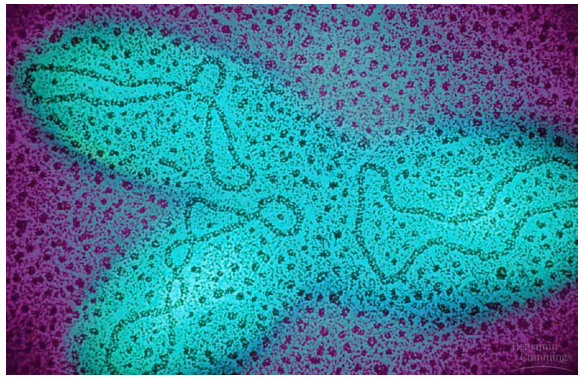
- **Genetic recombination**
  - bacteria share genes
    - plasmids contain extra genes
      - small supplemental circles of DNA
    - <u>conjugation</u> = the process by which bacteria can share a copy of their plasmid or genes with neighboring bacteria
      - direct transfer of DNA "horizontally"

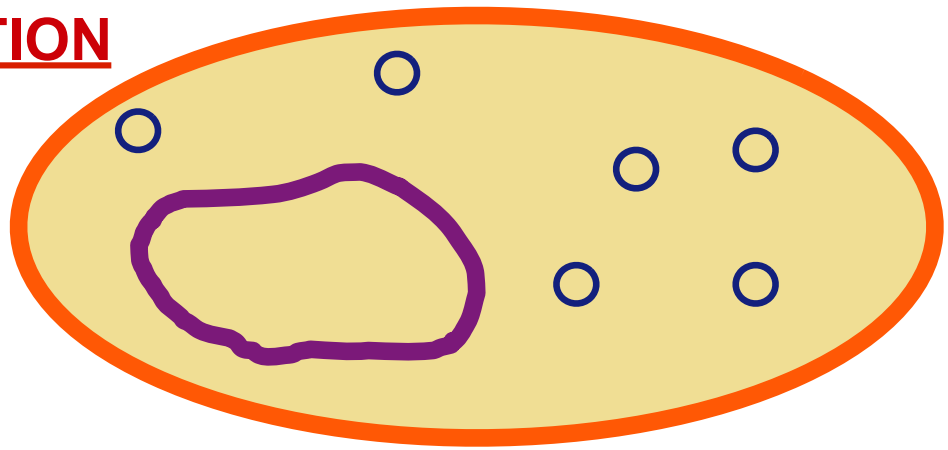


conjugation

Extrachromosomal DNA exists inside prokaryotes

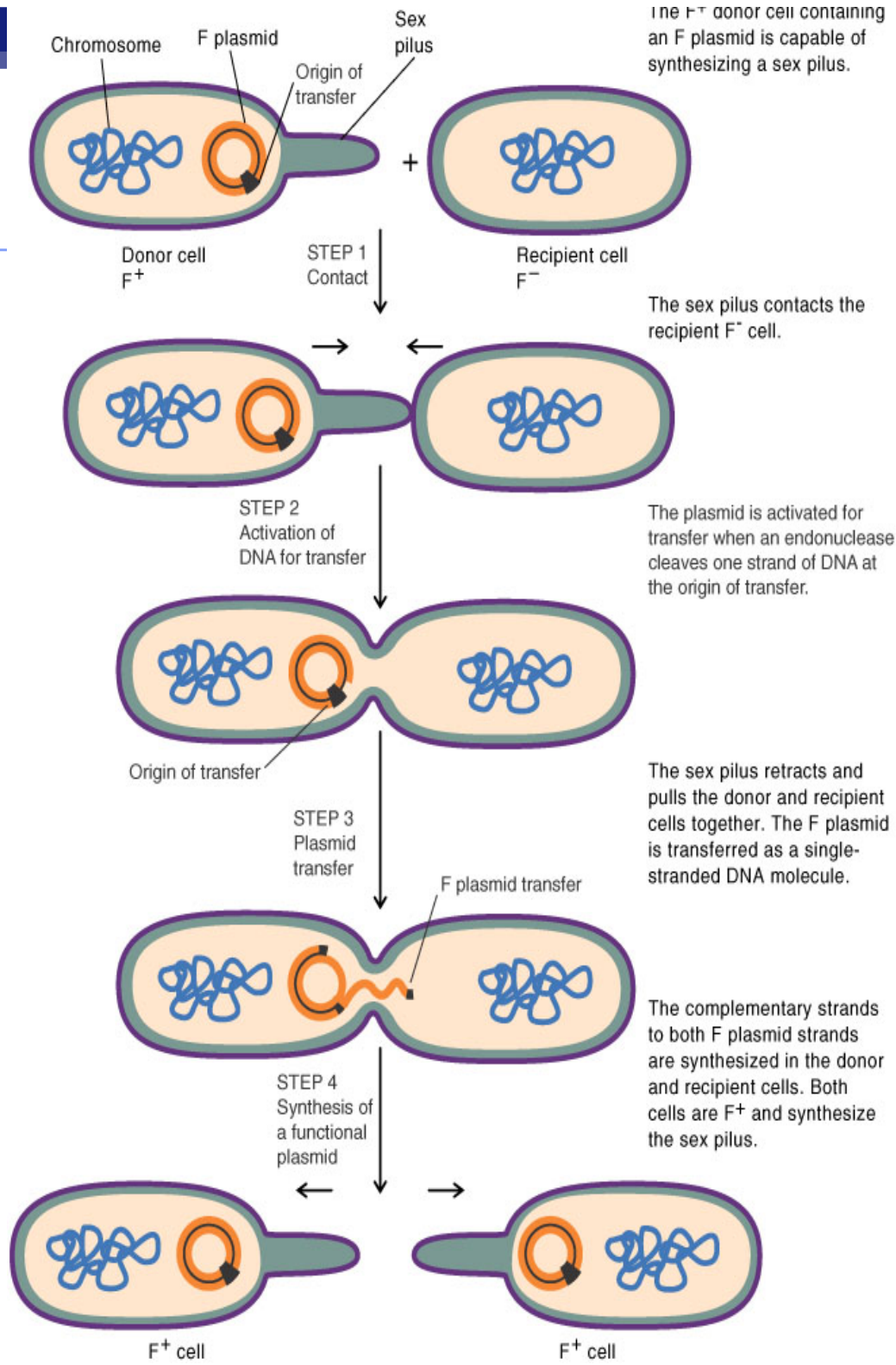
- **Plasmids**
  - Small supplemental circles of DNA
    - 5000 - 20,000 base pairs
    - self-replicating
      - Replicate separately from chromosome
  - carry extra genes
    - 2-30 genes
      - Often also genes for antibiotic resistance
  - Plasmids can be exchanged between bacteria
    - bacterial "sex" = CONJUGATION
    - can lead to rapid evolution!!!
  - can be imported from environment





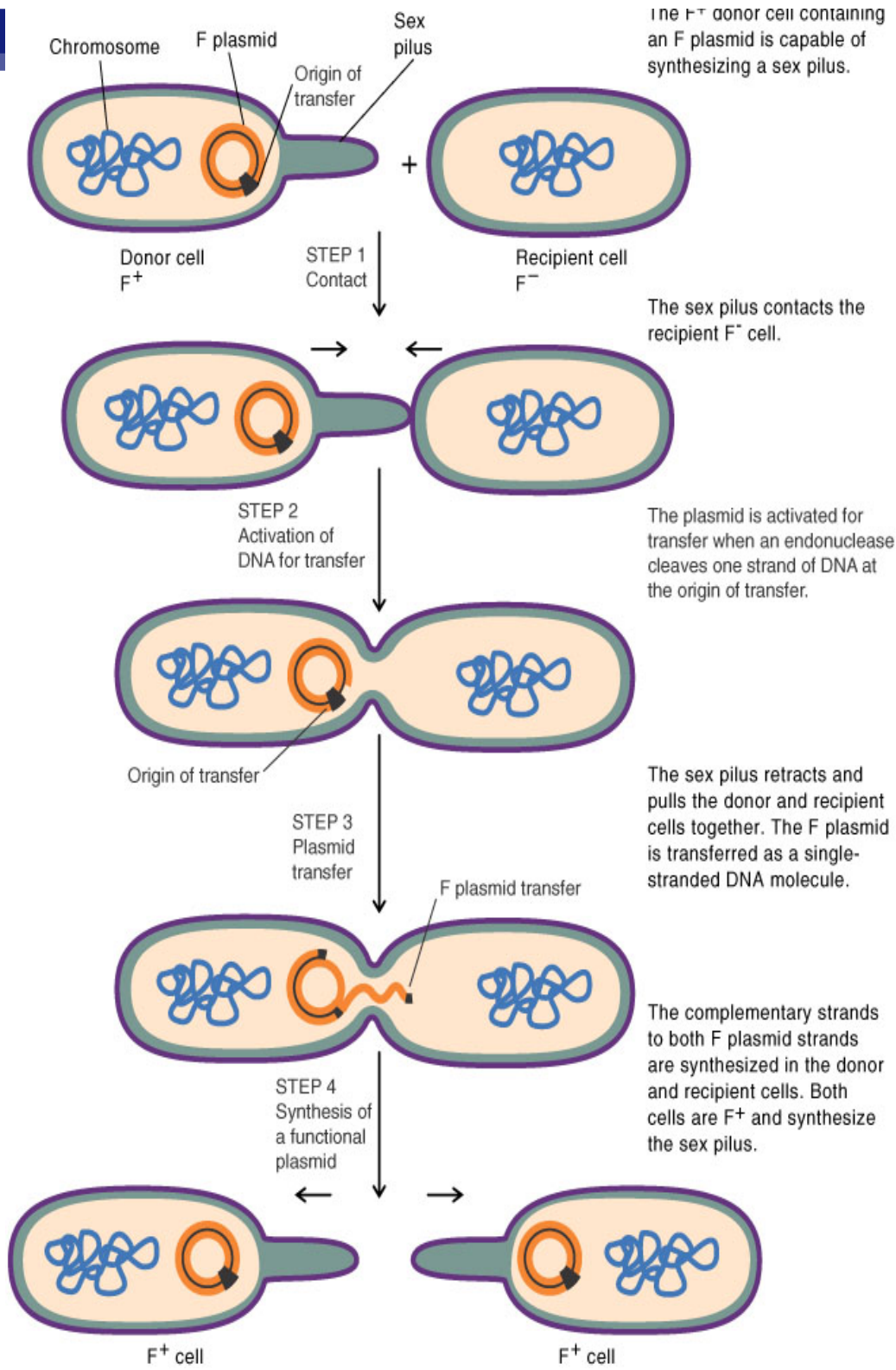
Conjugation

- **A special plasmid is needed for conjugation**
  - **The F plasmid (fertility plasmid) facilitates conjugation.**
    - **This can give a bacterium new genes that may help it survive in a changing environment.**
  - **Some plasmids can integrate reversibly into the bacterial chromosome.**
    - **An integrated plasmid is called an episome.**
      - **Bacteria that have a F plasmid are referred to as as F+ or male.**
      - **Those that do not have an F plasmid are F- of female.**



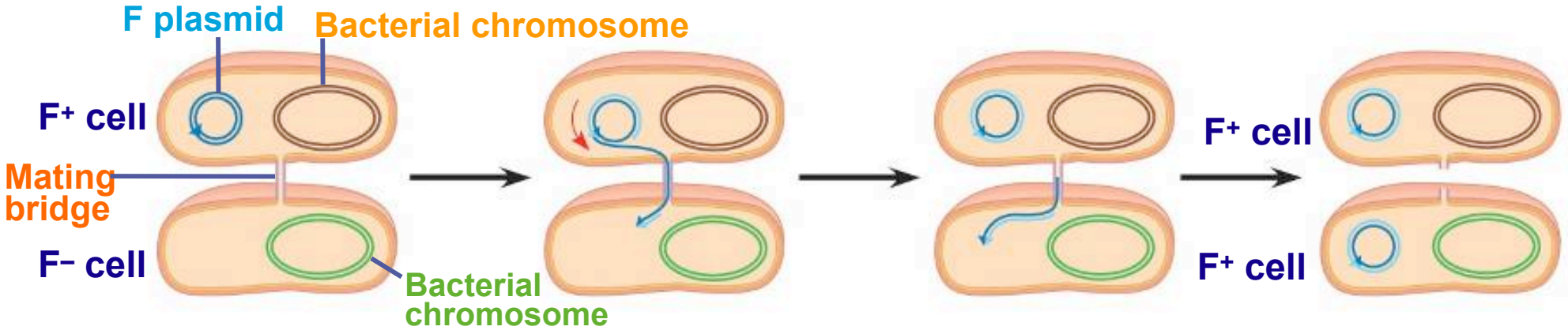
Conjugation

- The F plasmid consists of 25 genes that mostly code for production of sex pili.
  - A conjugation event occurs when the male cell extends his sex pili and one attaches to the "female" (F- bacteria)
    - This attached pilus is a temporary cytoplasmic bridge through which a replicating F plasmid is transferred from the male to the female.
      - When transfer is complete, the result is two "male" cells.

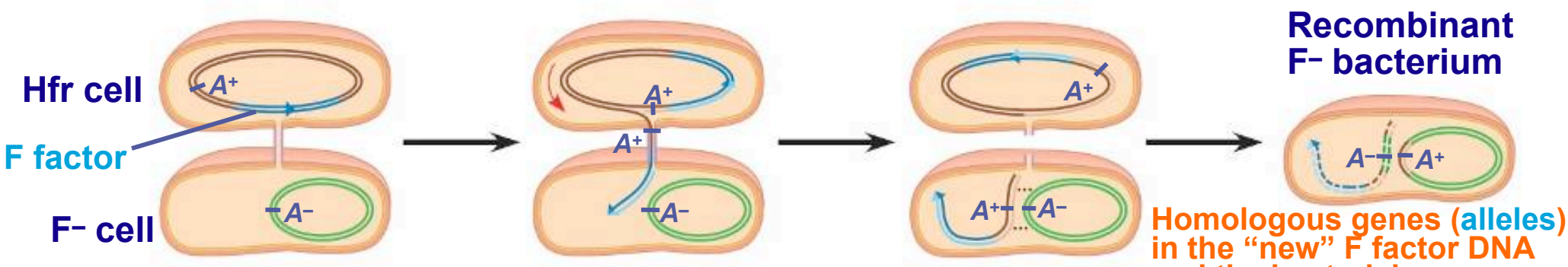


Conjugation

- **The F plasmid can behave as an episome.**
  - When the F+ plasmid is integrated within the bacterial chromosome, the cell is called an Hfr cell (high frequency of recombination cell).
    - Hfr cell still behaves as a F+ cell, transferring F genes to a F-cell, but now some of the bacterial chromosome is moves along with the episome to the new bacterial cell



(a) Conjugation and transfer of an F plasmid



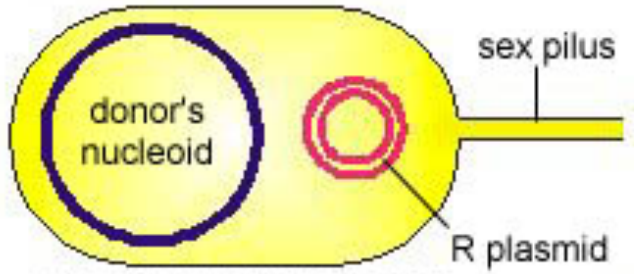
(b) Conjugation and transfer of part of an Hfr bacterial chromosome

Homologous genes (alleles) in the "new" F factor DNA and the bacteria's chromosome are swapped

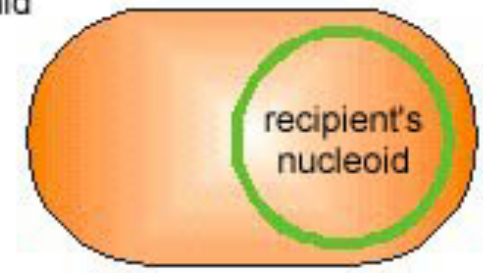
R Plasmids and Antibiotic Resistance

- R plasmids carry genes for antibiotic resistance
  - Antibiotics select for bacteria with genes that are resistant to the antibiotics
    - Antibiotic resistant strains of bacteria are becoming more common

The bacterium with an R-plasmid is multiple antibiotic resistant and can produce a sex pilus (serve as a genetic donor).



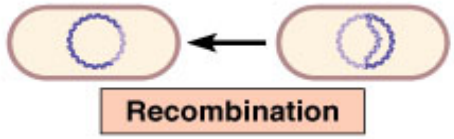
Bacterium with R plasmid: multiple antibiotic resistant and male (donor).



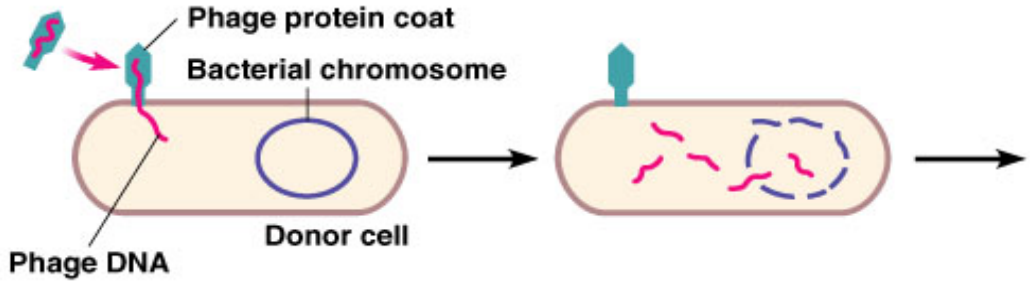
Bacterium without R plasmid: antibiotic sensitive and female (recipient).

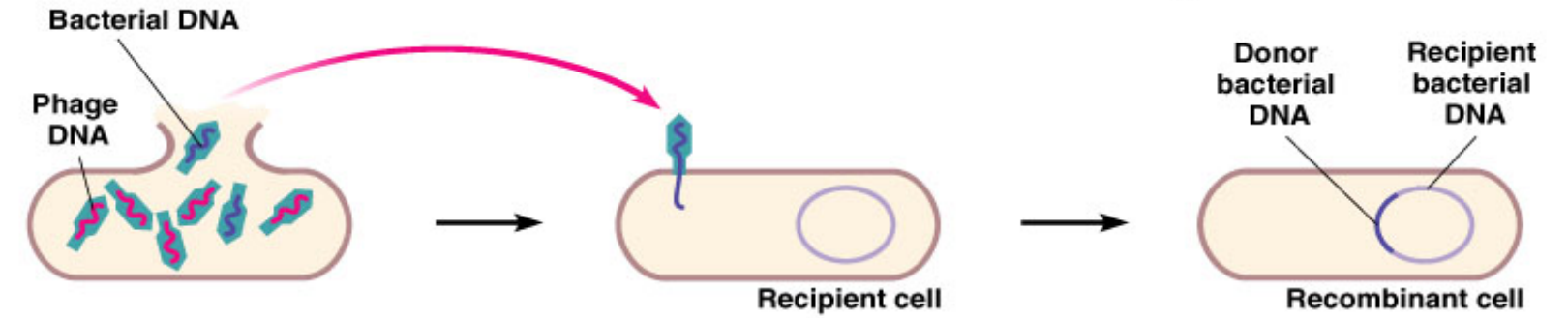
Mutations are a big source of genetic diversity

- But together with transformation, conjugation, and finally transduction, genetic information gets shared.
  - **Transduction** - when viruses inadvertently carry genetic information from one bacterial cell to another

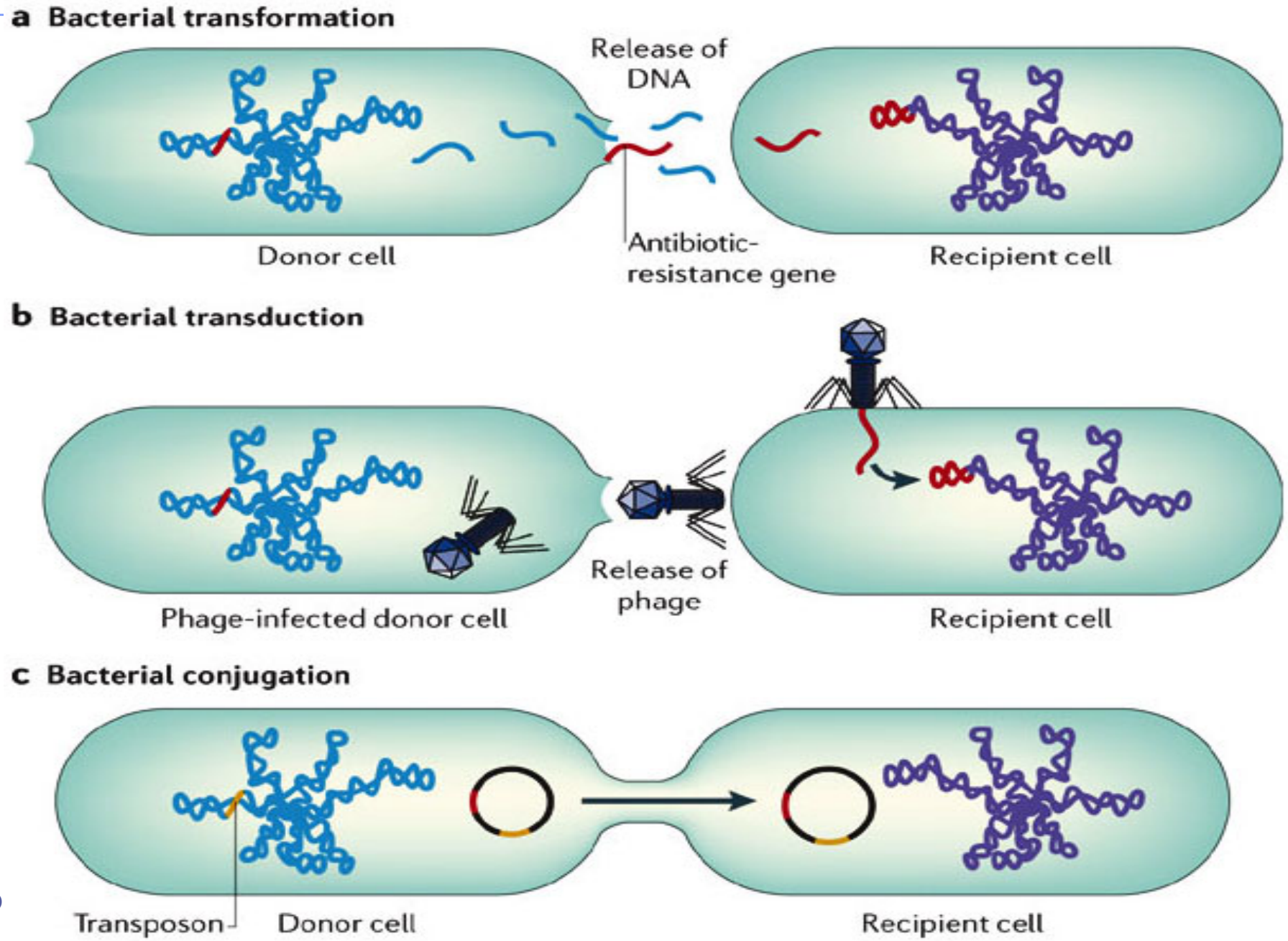


Bacteriophages or Phages (bacterial viruses) are obligatory intracellular parasites and must invade a host cell in order to reproduce.



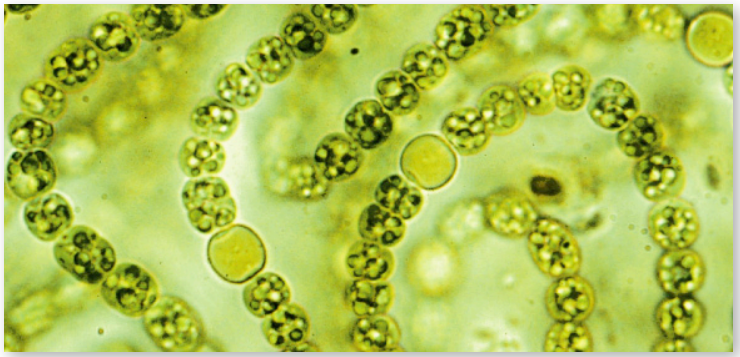


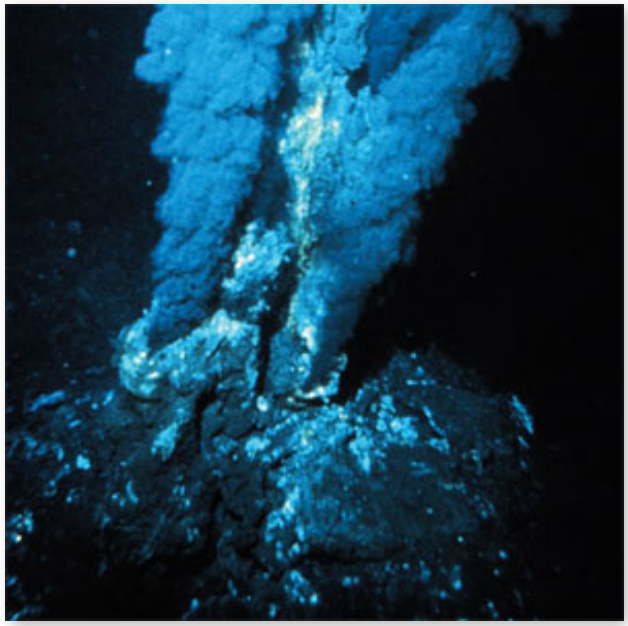
Bacteria make recombinant DNA = increase their genetic diversity

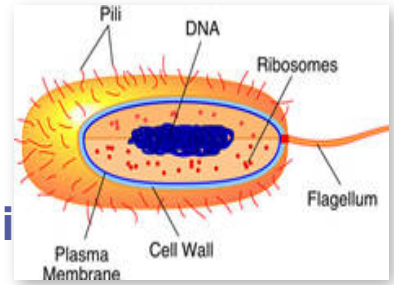


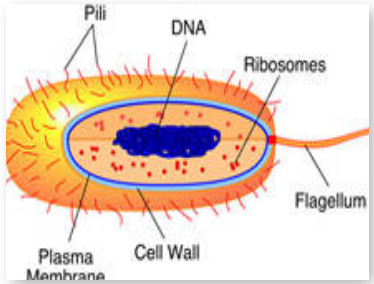
Prokaryotic metabolism

- **How do bacteria acquire their energy & nutrients?**
  - Where does it get C from for making organic compounds….
    - Auto = C from CO_2
    - Hetero = C from organic compounds
  - Where is energy harvested from
    - Photo = energy from sunlight
    - Chemo = energy from chemical bonds
- photoautotrophs
  - photosynthetic bacteria
- chemoautotrophs
  - oxidize inorganic compounds
    - nitrogen, sulfur, hydrogen…
- chemoheterotrophs
  - live on plant & animal matter
  - decomposers & pathogens









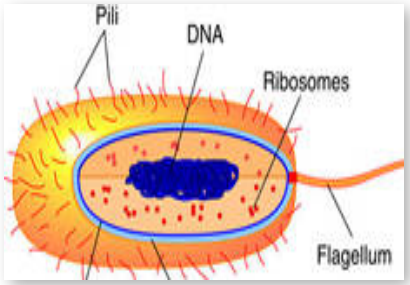


Table 27.1 Major Nutritional Modes

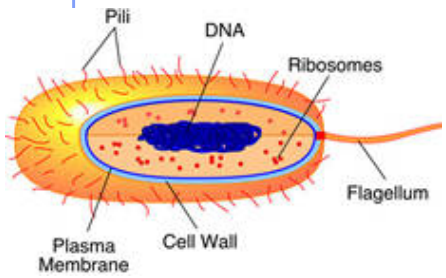
Mode of Nutrition	Energy Source	Carbon Source	Types of Organisms
Autotroph			
Photoautotroph	Light	CO_2	Photosynthetic prokaryotes, including cyanobacteria; plants; certain protists (algae)
Chemoautotroph	Inorganic chemicals	CO_2	Certain prokaryotes (for example, *Sulfolobus*)
Heterotroph			
Photoheterotroph	Light	Organic compounds	Certain prokaryotes
Chemoheterotroph	Organic compounds	Organic compounds	Many prokaryotes and protists; fungi; animals; some parasitic plants

The Role of Oxygen in Metabolism

- **Prokaryotic metabolism varies with respect to O_2:**

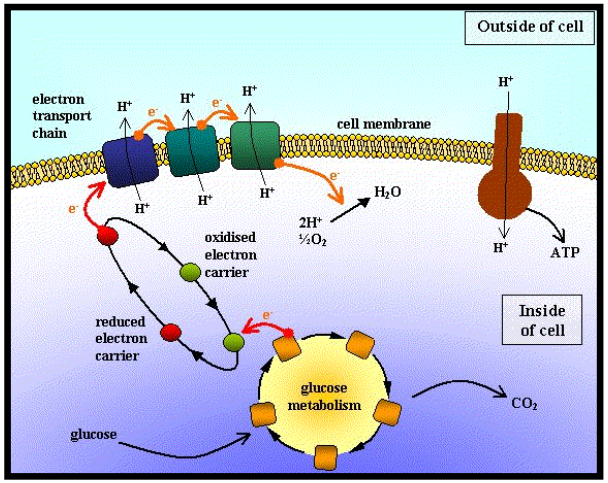
Obligate aerobes require O_2 for cellular respiration

- Use their plasma membrane instead of mitochondria for their Electron Transport Chain, pumping H+ out of the cell and allowing diffusing back into the cell to make ATP



In prokaryotes the enzymes and intermediates of the Krebs cycle are distributed throughout the cytoplasm.

The pyruvate-dehydrogenase complex (catalyzes the conversion of pyruvate to acetyl CoA) and electron transport system are associated with the plasma membrane.



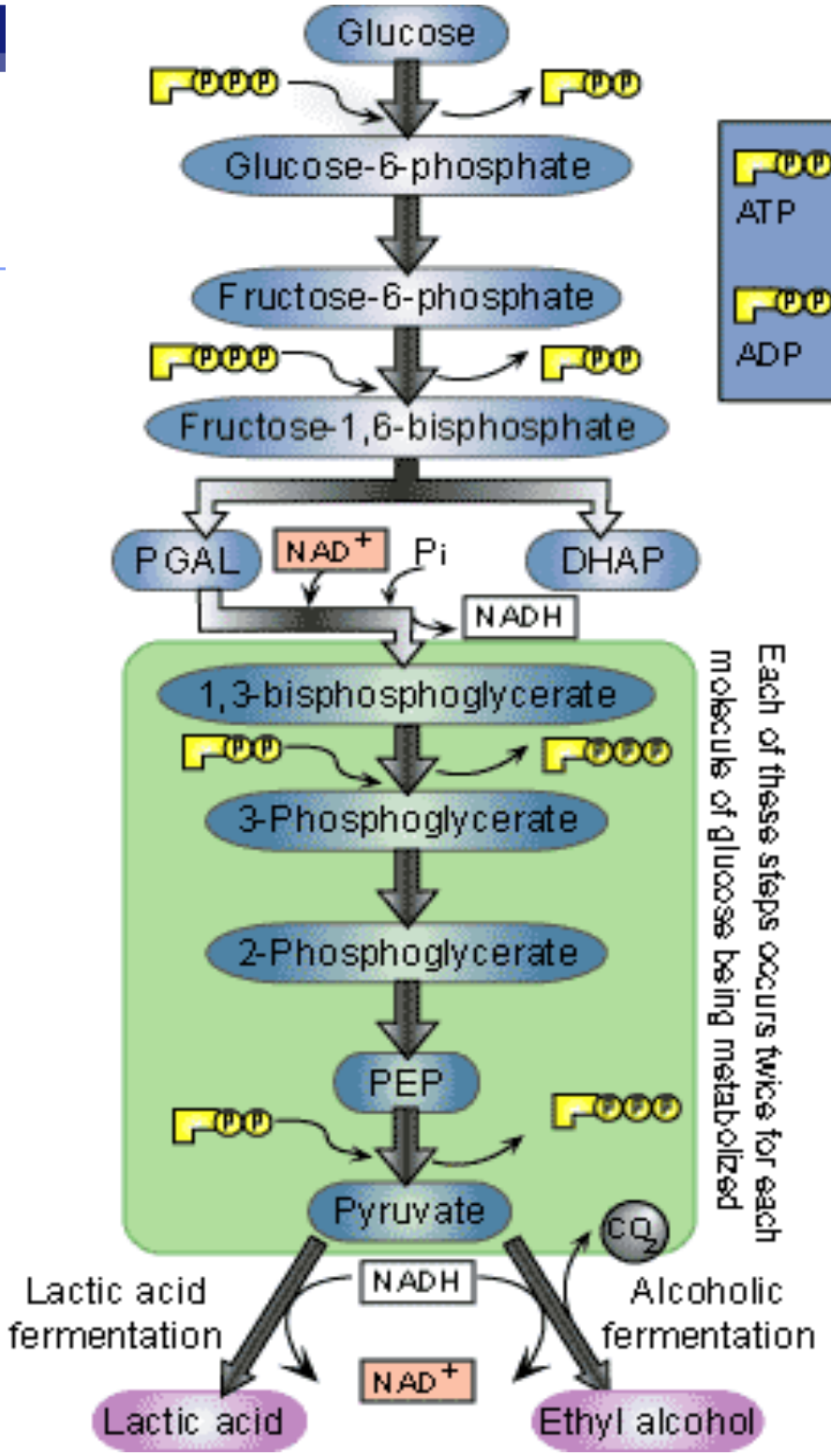
Some bacteria do not use organic molecules as the source of electrons.

These bacteria can strip electrons directly from inorganic substances (such as H_2S, H_2, or Fe^{++})

Aerobic species of prokaryotes use O_2 as the final acceptor of electrons.

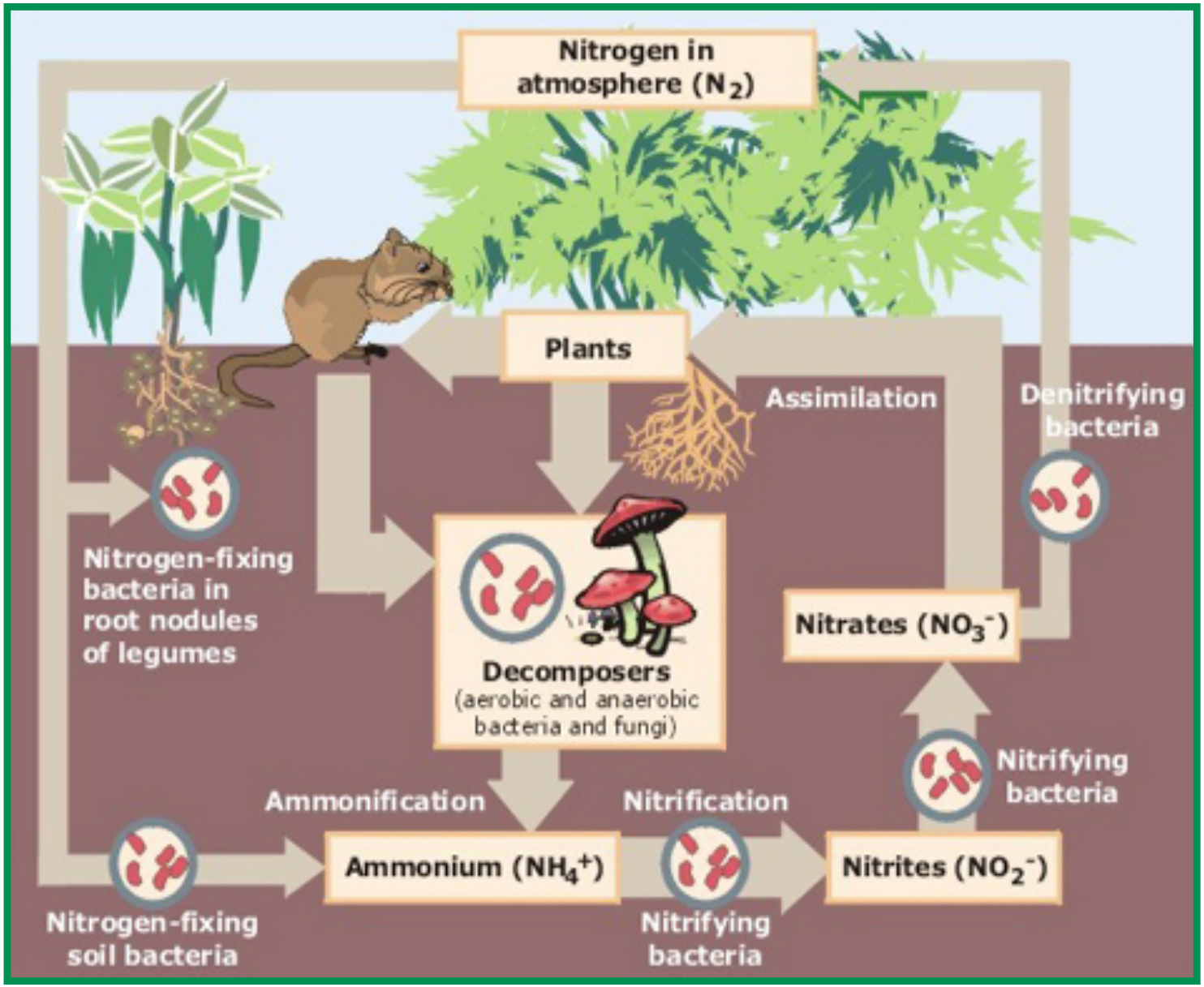
The Role of Oxygen in Metabolism

- **Prokaryotic metabolism varies with respect to O_2:**
  1. **<u>Obligate anaerobes</u> are poisoned by O_2 and use fermentation or anaerobic respiration**
  2. **<u>Facultative anaerobes</u> can survive with or without O_2**



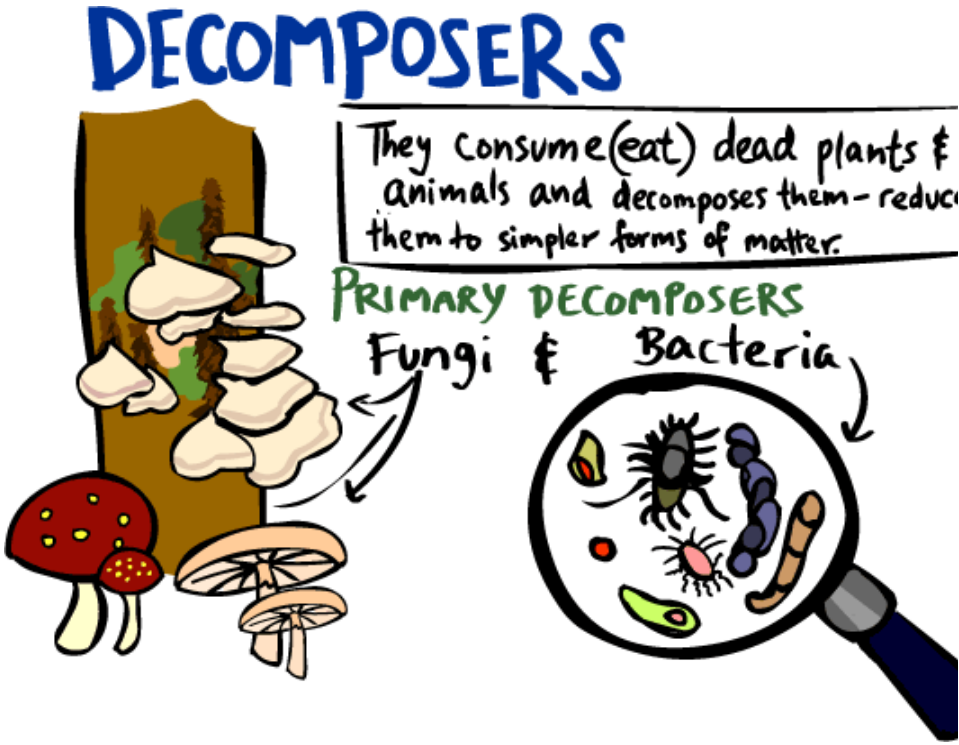
Nitrogen Metabolism & the Nitrogen Cycle

- **Prokaryotes can metabolize nitrogen in a variety of ways**
- **In nitrogen fixation, some chemoheterotrophic prokaryotes convert atmospheric nitrogen (N_2) to ammonia (NH_3)**
  - **Other prokaryotes then convert NH_3 NO_2- and NO_3-, the chief way plants get their nitrogen!!!**



Chemical Cycling

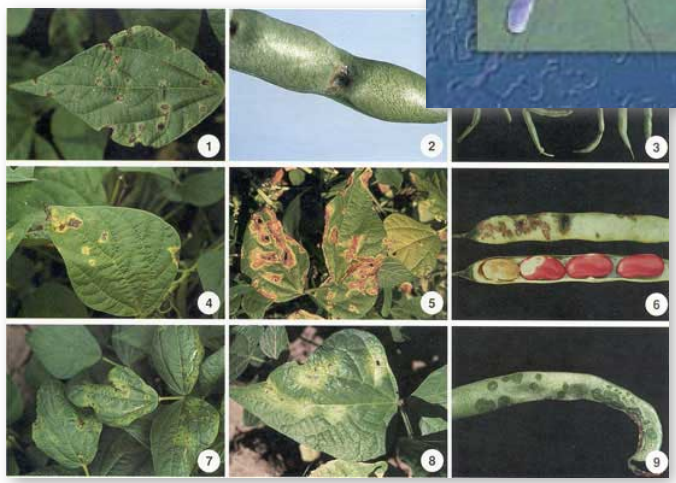
- **Prokaryotes play a major role in the recycling of chemical elements between the living and nonliving components of ecosystems**
  - **Chemoheterotrophic prokaryotes function as decomposers, breaking down corpses, dead vegetation, and waste products**

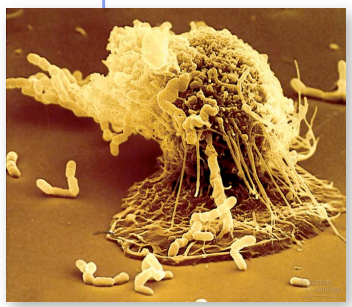


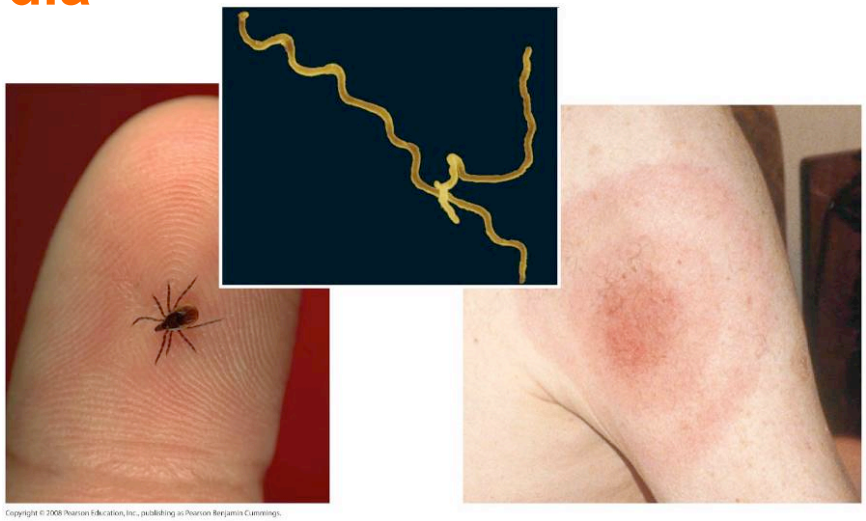
    - ✦ **These bacteria convert organic molecules back into organic ions in the soil - the minerals photosynthetic organisms like plants will later absorb to make their organic molecules out of, which are then passed through the ecosystem when consumers consume producers.**

Bacteria as pathogens

- Disease-causing microbes
  - plant diseases
    - wilts, fruit rot, blights
  - animal diseases
    - tooth decay, ulcers
    - anthrax, botulism
    - plague, leprosy, “flesh-eating” disease
    - STDs: gonorrhea, chlamydia
    - typhoid, cholera
    - TB, pneumonia
    - lyme disease







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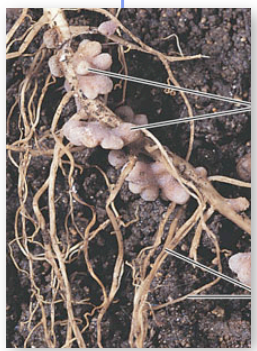
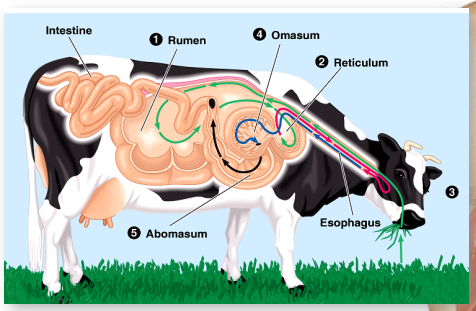
Bacteria also include beneficial & necessary organisms

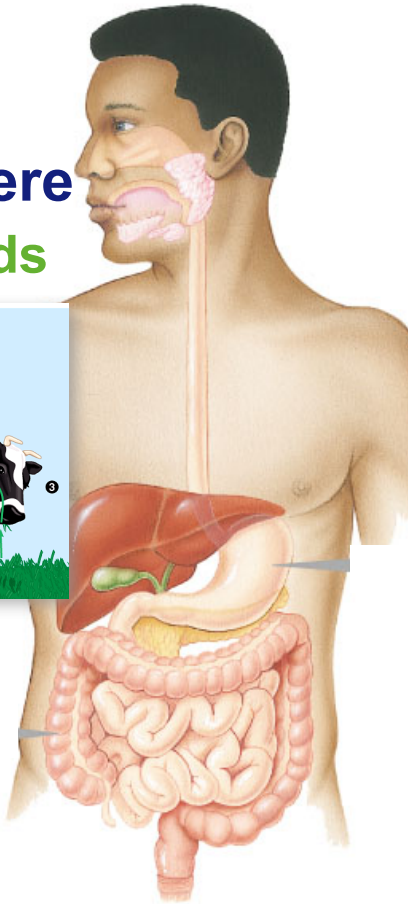
- **Life on Earth is dependent on bacteria**
- **Prokaryotes are so important to the biosphere that if they were to disappear the prospects for any other life surviving would be dim**
  - **decomposers**
    - recycling of nutrients from dead to living



  - **nitrogen fixation**
    - ONLY organisms that can fix N from atmosphere
      - needed for synthesis of proteins & nucleic acids
      - Live in plant root nodules
  - **help in digestion (E. coli)**
    - digest cellulose for herbivores
      - Can make cellulase enzyme
    - produce vitamins K & B_{12} for humans



  - **produce foods & medicines**
    - from yogurt to insulin



Got any Questions?? Ask da' Boss!

illustration: Don Smith

2007-2008