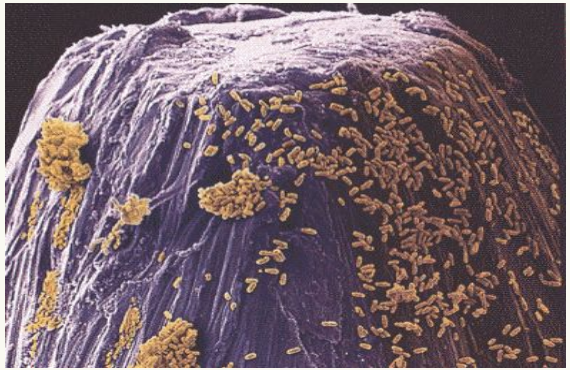
2.1 The Prokaryotes: Eubacteria and Archaea

(P. 46 - 53)

Introduction: Prokaryotes

- **Smallest** organisms on Earth (most are 1-2 µm long)
- Lack organelles and a nucleus but all have a cell wall
- Live in **every imaginable habitat**: ice, boiling hot springs, water, soil, etc.
- **Not very diverse** (only 10 000 species isolated to date - account for 1% of total number of species)
- Classification is based on **internal biochemistry and DNA**.



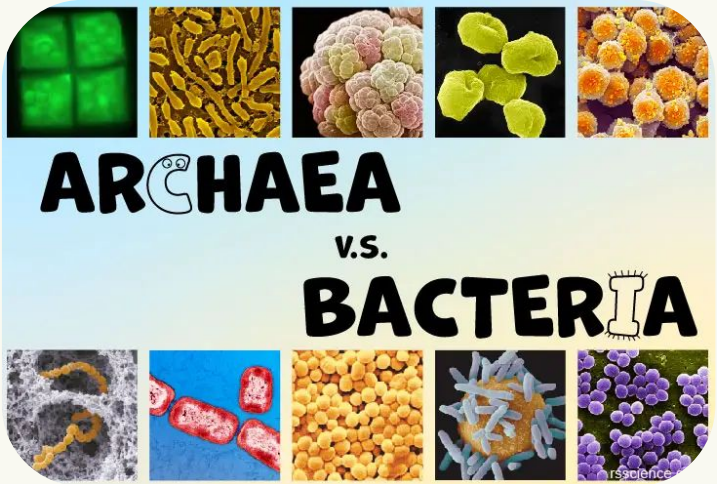
Introduction: Prokaryotes

- **Two** major groups

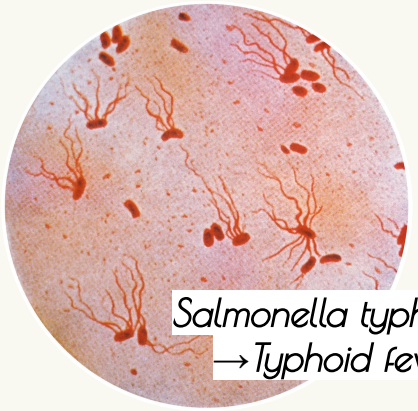
    1. **Eubacteria**
    (sometimes just called bacteria)

    2. **Archaea**
    (historically called Archaebacteria)

- These two groups are **very different** genetically

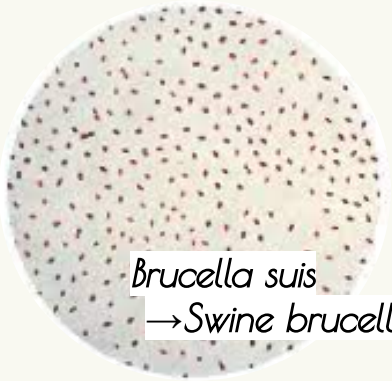


Harmful Prokaryotes



Salmonella typhi
→*Typhoid fever*

Streptococcus pyogenes
→*Strep throat*



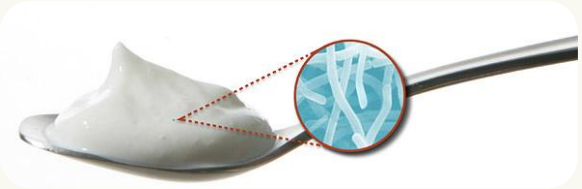
Brucella suis
→*Swine brucellosis*

- Pathogenic to humans
  - Diseases caused by prokaryotes include
    - tuberculosis
    - strep throat
    - cholera
    - typhoid fever

- Pathogenic to livestock and crops
  - Can threaten our food supply

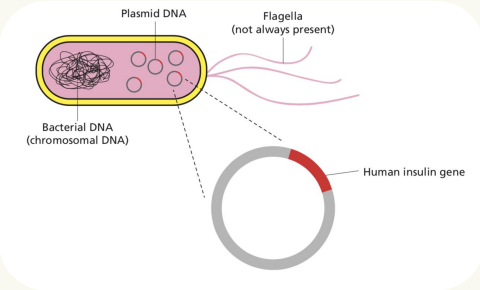
Helpful Prokaryotes

- Support production of bread, cheese, yogurt, beer, chocolate, etc.

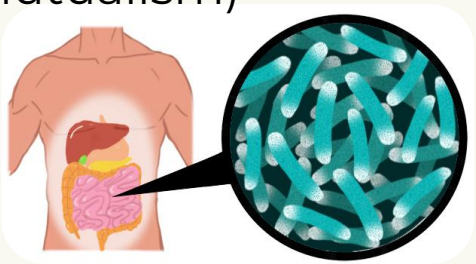


- Some produce antibiotics as a way to kill competitors. We have learned to use them.

- Some have been engineered to produce other compounds such as insulin and growth hormone

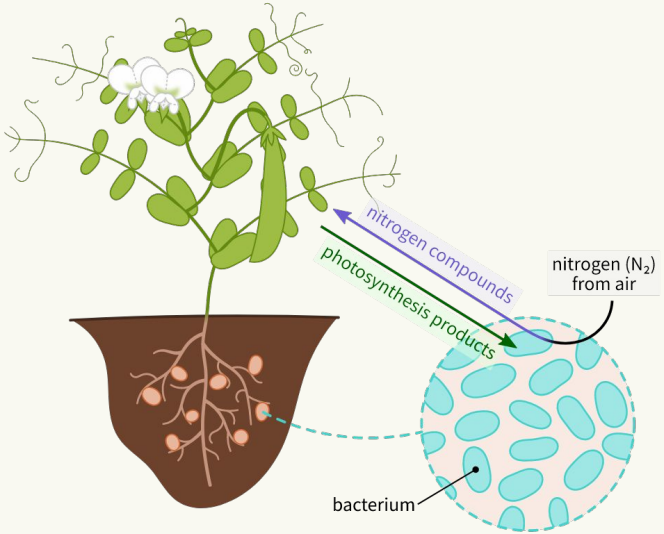


- Bacteria residing in the large intestine produce vitamin K and B12 (mutualism)

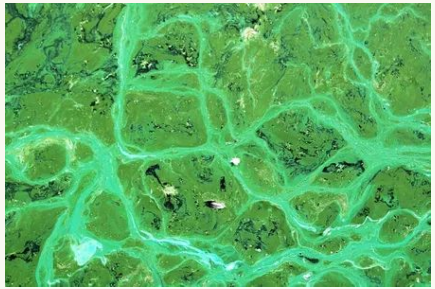


Helpful Prokaryotes

- Important role in ecosystems as decomposers, producer
- Fix or convert atmospheric nitrogen to useable form for plants
- Photosynthetic bacteria in marine ecosystems are major producers of atmospheric oxygen

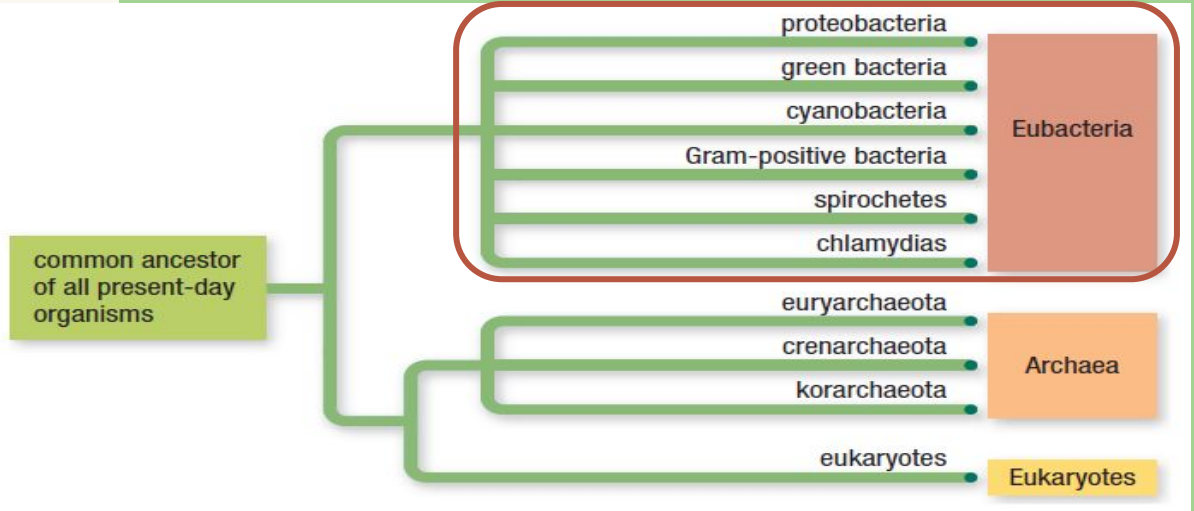


Cyanobacteria are photosynthetic



Domain Eubacteria

Shown here are six of the major groups of bacteria. They are extremely diverse.



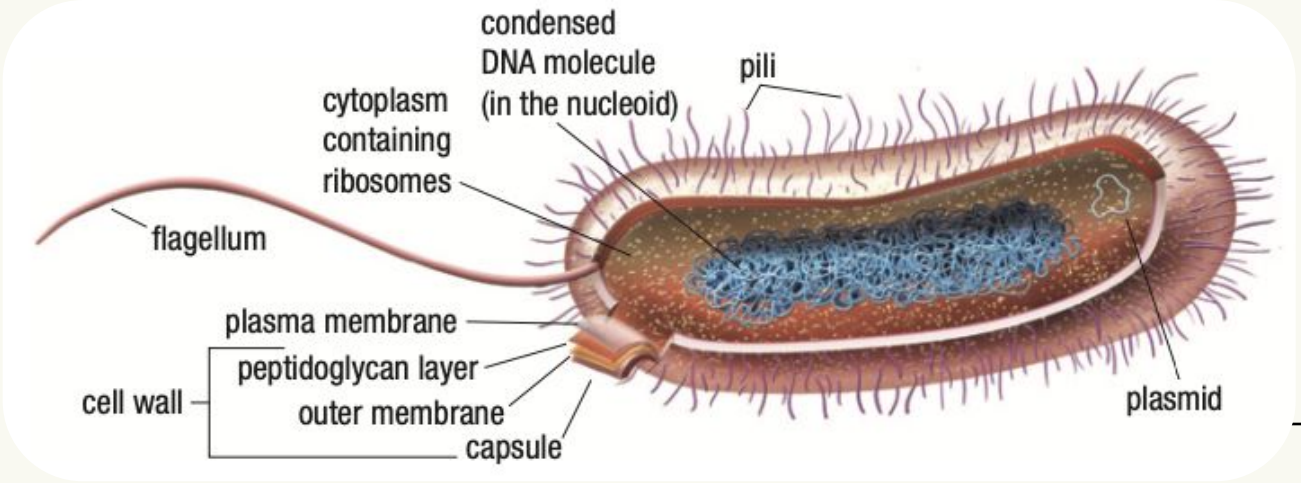
Key Features of the Six Major Groups of Bacteria

Table 1 Key Features of the Six Major Groups of Bacteria

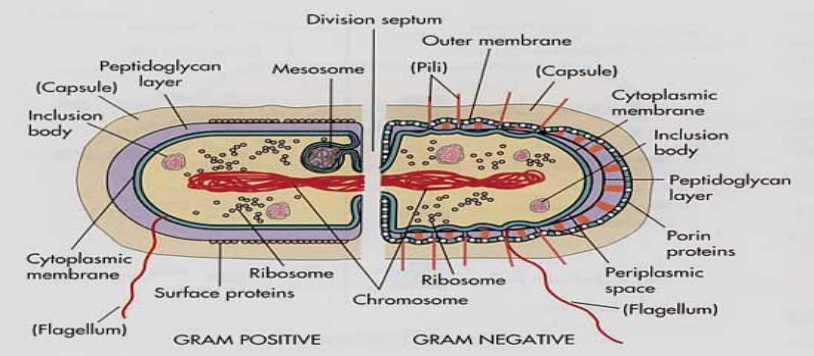
Group	Key features
proteobacteria (purple bacteria)	• Some are photosynthetic but use a form of photosynthesis that differs from that of plants. • Ancient forms of these bacteria were the likely ancestors of eukaryotic mitochondria. • Some are nitrogen fixing. • They are responsible for many diseases, including bubonic plague, gonorrhea, dysentery, and some ulcers.
green bacteria	• They use a form of photosynthesis that differs from that of plants. • They are usually found in salt-water environments or hot springs.
cyanobacteria (blue-green algae)	• They use a form of photosynthesis similar to plants and other eukaryotes. • Ancient forms of these bacteria were the likely ancestors of eukaryotic chloroplasts. • They play major roles as producers and nitrogen fixers in aquatic ecosystems. • They form symbiotic relationships with fungi.
Gram-positive bacteria	• They cause many diseases, including anthrax, strep throat, bacterial pneumonia, and meningitis. • They are used in food production (for example, lactobacillus is used in yogurt and probiotic products). • Some have lost their cell wall. • One type—mycoplasmas—are the smallest known cells (0.1 µm to 0.2 µm).
spirochetes	• Their spiral-shaped flagellum is embedded in their cytoplasm. • They move with a corkscrew motion. • They cause syphilis. • Symbiotic spirochetes in termite intestines digest wood fibre.
chlamydias	• All are parasites that live within other cells. • They cause chlamydia, one of the most common sexually transmitted infections. • They cause trachoma, the leading cause of blindness in humans.

Structure of Bacteria

- **DNA** loose in cytoplasm (no nucleus)
- **ribosomes** are also scattered in the cytoplasm
- many have one or more **plasmids**.
    - **Plasmid:** A small loop of DNA that carries genes that often provide an advantage to the cell (e.g. antibiotic resistance)



Structure of bacteria (cont.)



- move using **flagella**: whip-like hairs
- have **pili** - stiff proteins that help cells attach to one another

- **Peptidoglycan** - protective coating ONLY on bacteria
  - makes up its cell wall.
  - used to:
    1. identify different types of bacteria
    2. kill bacteria

- some **bacteria** have an **outer capsule** that provides protection
  - reduces water loss
  - resists high temp
  - resists antibiotics and viruses

Bacterial Morphology

- **Shape:**
  - coccus (spheres)
  - bacillus (rods)
  - spirillum (spiral) is less common.

- **Aggregation of cells:**
  - single cells,
  - pairs (diplo),
  - chains (strepto),
  - clusters (staphylo).

- Thus we have types such as **diplococcus** (pair of spheres) and **streptobacillus** (chain of rods).

Metabolic Diversity of Bacteria

Autotroph vs. Heterotroph

- **Autotrophs:** make their own food from inorganic chemicals (ie. carbon dioxide, minerals, etc.)
- **Heterotrophs:** get nutrients from carbon containing organic chemicals found in living or dead organisms

Most bacteria get energy from **sunlight** or **organic chemicals** (e.g. fat, sugar), but many can also get energy from **inorganic chemicals** in the environment (e.g. H, S, Fe)

Relationship to Oxygen

Many bacteria evolved under **anaerobic** (no oxygen) conditions.

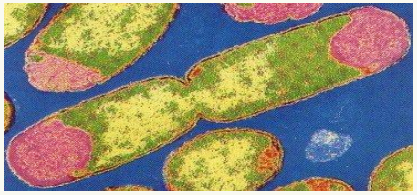
Classification:

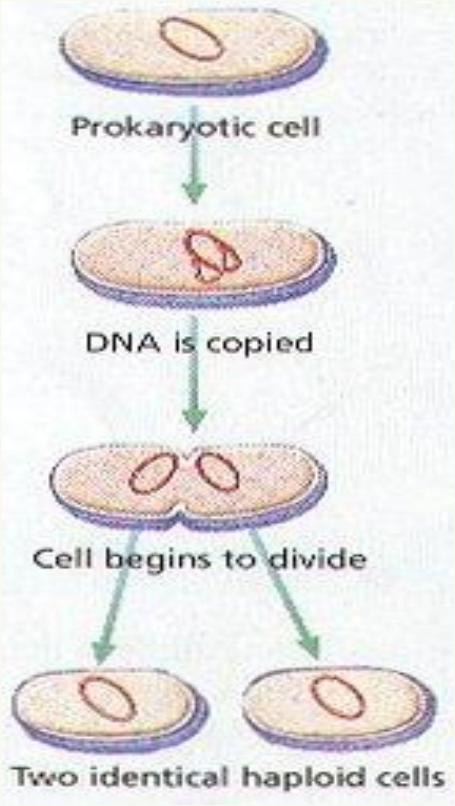
1. **Obligate aerobes:** need oxygen to survive

2. **Obligate anaerobes:** killed by oxygen. Found in intestinal tracts of animals, deep in the ocean, landfills, deep sediments in the soil

3. **Facultative anaerobes:** use oxygen when it is present (i.e. aerobic respiration), but live anaerobically (through fermentation) when oxygen is absent. Most life-threatening pathogens are these type.

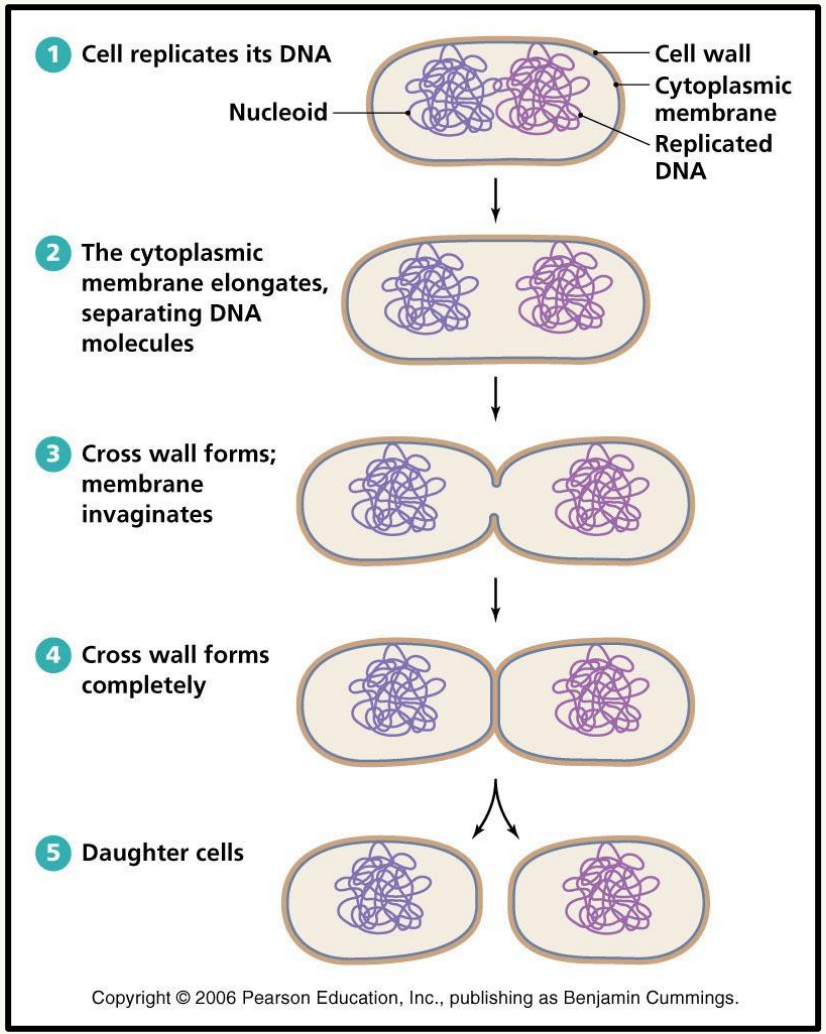
Bacterial Reproduction



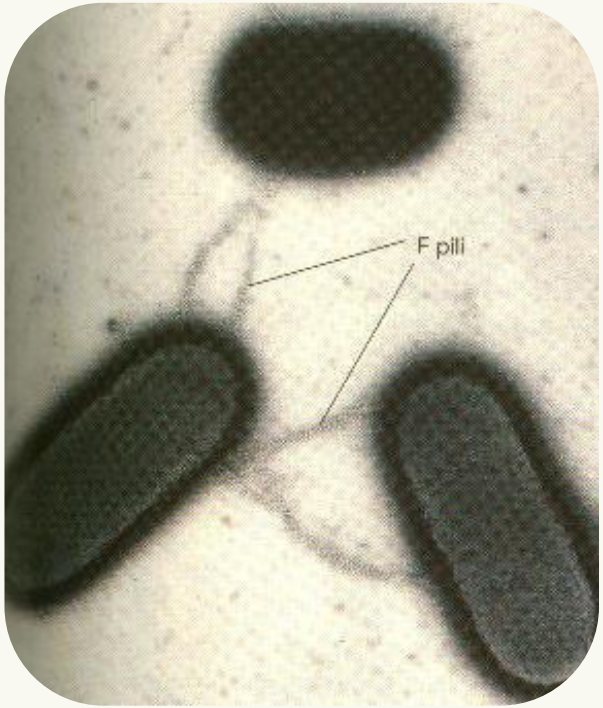


- Reproduce **asexually** by **binary fission**.
- DNA is replicated, parent cell splits into two daughter cells.
- Each daughter cell receives an exact copy of the genetic material – both the chromosome and plasmids.
- Replicate quickly therefore many mutations occur. These mutations lead to genetic diversity.

Bacterial Reproduction (binary fission)

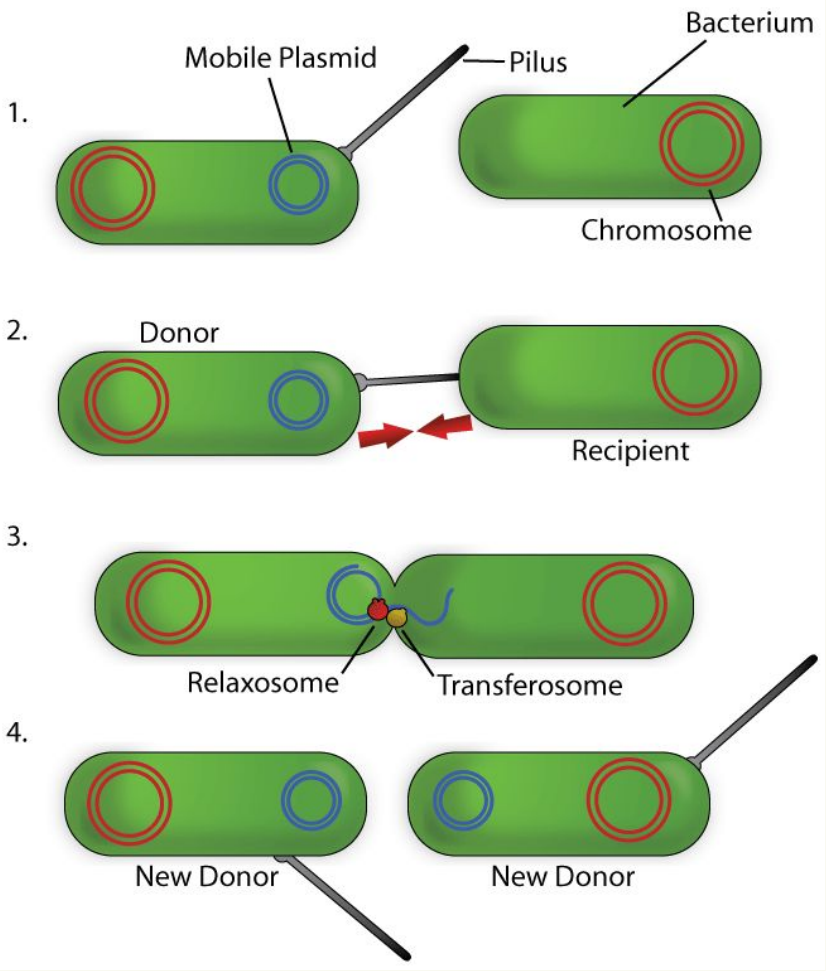


Bacterial Reproduction (conjugation)

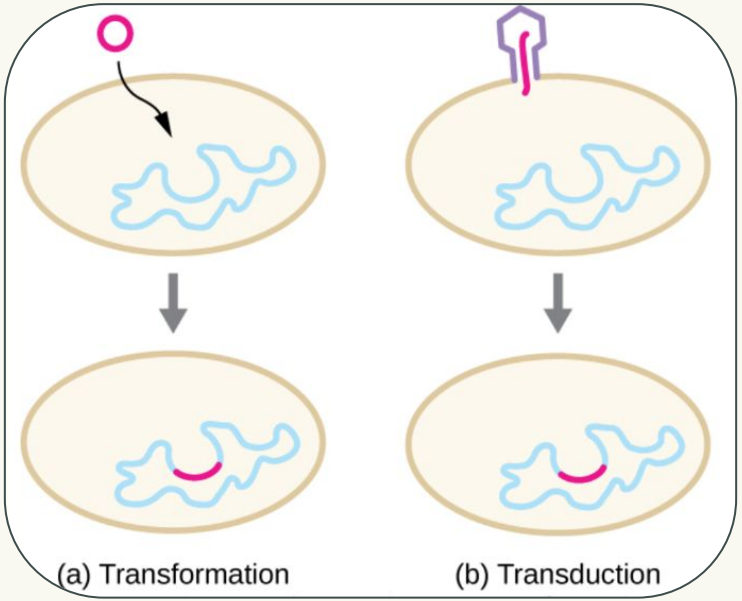


- Considered a form of sexual reproduction (2 cells exchange genetic information)
- One bacterial cell passes a copy of a **plasmid** to a nearby bacterial cell through a **hollow pilus**
- If the new DNA came from a **different species** this is called **horizontal gene transfer.**

Bacterial Reproduction (conjugation)



Other Ways Bacteria Can Increase their Genetic Diversity...

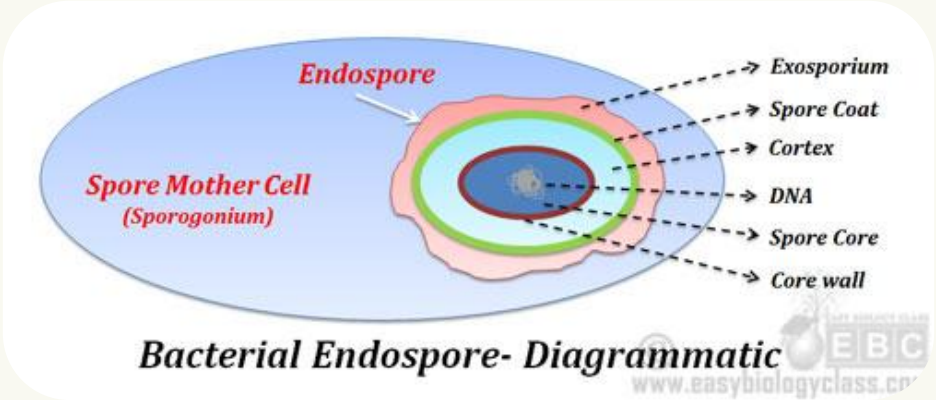


a) Transformation:
- Bacterial cells can take in pieces of DNA from the <u>environment</u>

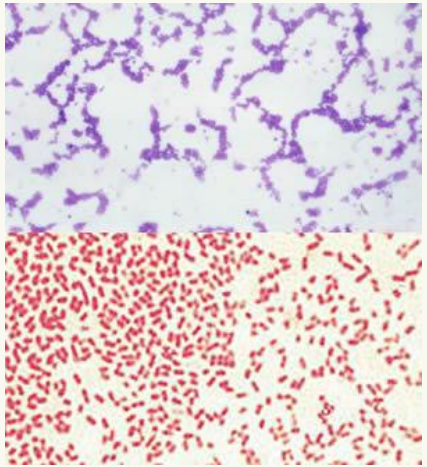
b) Transduction:
- Bacteria can also gain genetic diversity by being infected with a <u>virus</u>.

Endospores

- Some bacteria can form dormant structures (endospores) that surround their DNA when conditions are unfavourable.
  - They can survive for thousands of years in this form.



Testing Bacteria Types: Gram Staining



Gram Positive bacteria are *purple when stained:*

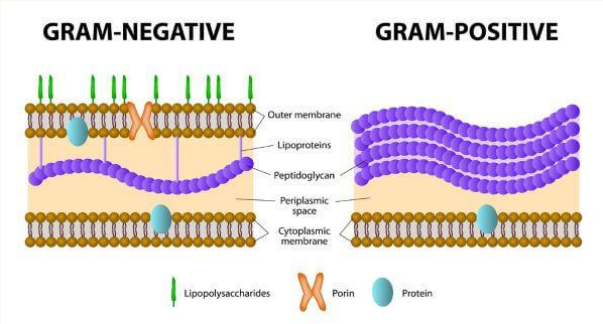
cell wall:

- lack outer membrane
- thick layers of peptidoglycan which pick up staining.

Gram Negative bacteria pink when stained:

cell wall:

- has outer membrane
- small layer of peptidoglycan.

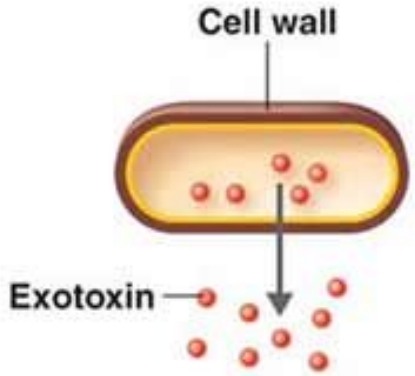


Bacteria and Human Disease

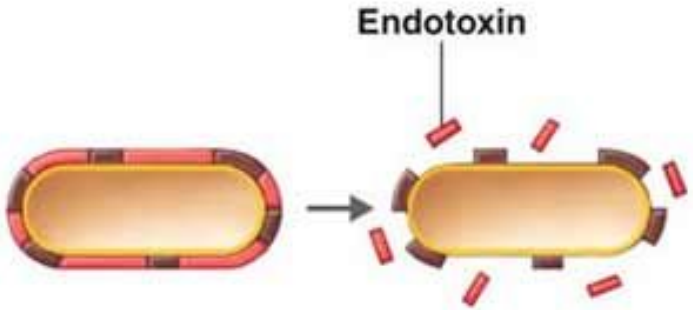
- Harmful bacteria cause disease by releasing poisons
  - ENDOTOXINS are produced by gram **-**
  - EXOTOXINS are produced by gram **+**
- These toxins cause fatigue, body aches, and weakness.

Disease	Bacterial Species (gram +/-)
Cholera	*Vibrio cholerae*(-)
Diphtheria	*Corynebacterium diphtheriae* (+)
Lyme disease	*Borrelia burgdorferi* (-)
Pertussis	*Bordetella pertussis* (-)
Rocky Mountain spotted fever	*Rickettsia rickettsii* (-)
Scarlet fever	*Streptococcus pyogenes* (+)
tetanus	*Clostridium tetani* (+)

Differences Between Exotoxins and Endotoxins



(a) Exotoxins are proteins produced inside pathogenic bacteria, most commonly gram-positive bacteria, as part of their growth and metabolism. The exotoxins are then secreted or released into the surrounding medium following lysis.



(b) Endotoxins are the lipid portions of lipopolysaccharides (LPSs) that are part of the outer membrane of the cell wall of gram-negative bacteria (lipid A; see Figure 4.13c). The endotoxins are liberated when the bacteria die and the cell wall breaks apart.

Treatment for bacterial diseases

- ANTIBIOTICS - combat bacteria by interfering with the PEPTIDOGLYCAN in their cell wall.

Antibiotic Resistance

Because antibiotics have been overused, bacteria have evolved and are more resistant to dying.

- *This is why you should always finish the full course of an antibiotic prescription – even if you are feeling better.*

Antibiotic Resistance

- Antibiotics kill the **most susceptible bacteria first.**
- The **resistant bacteria survive** because they have a PLASMID or mutation that provides resistance to the antibiotic.
- These resistant bacteria will **remain and reproduce** creating a line of bacteria that are no longer affected by the antibiotic.

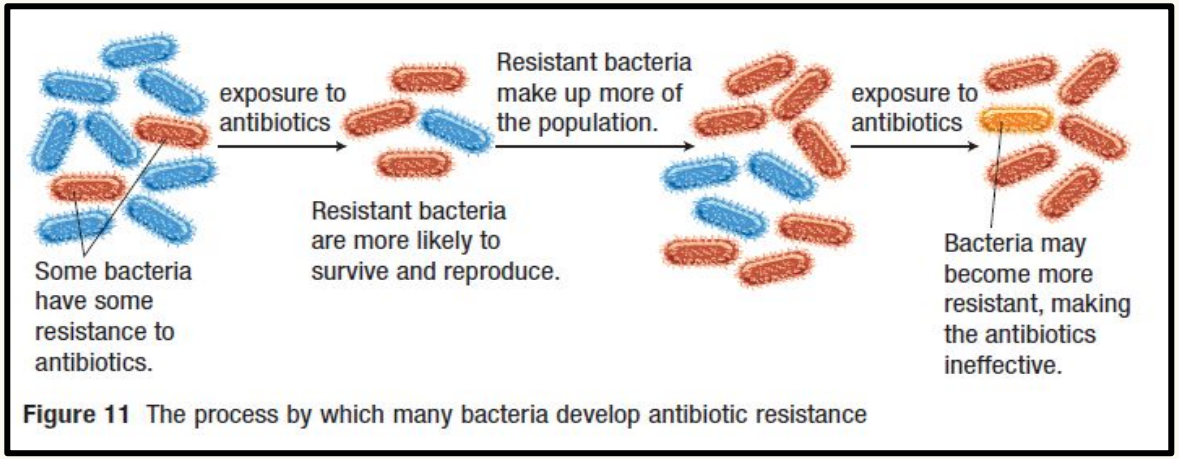
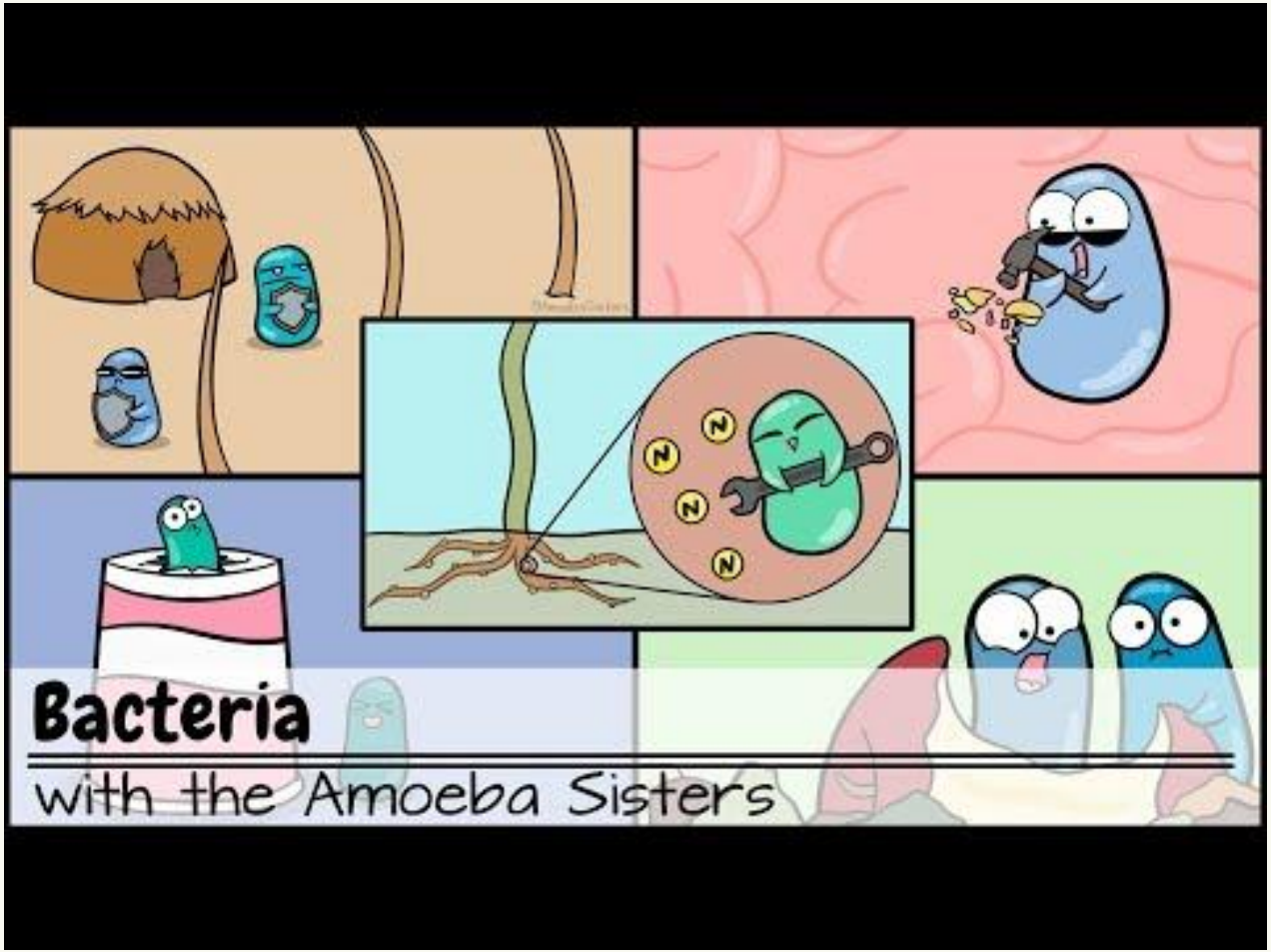


Figure 11 The process by which many bacteria develop antibiotic resistance

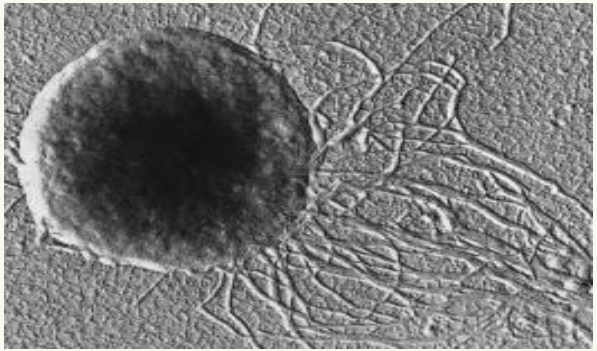

Bacteria
with the Amoeba Sisters

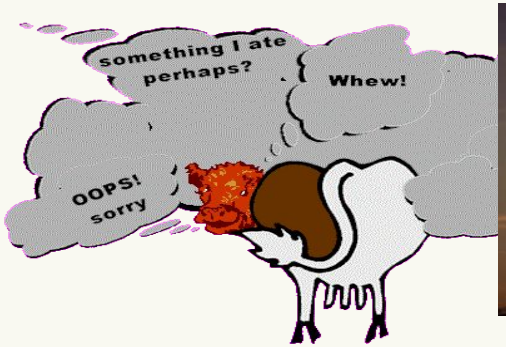
The Kingdom Archaea

- Sometimes called “**Archaebacteria**” (historical)
  → Archaea are very different from bacteria
- Cell walls **do not** contain peptidoglycan
- Inhabit **extreme** environments
- There are **NO pathogenic Archaea** that we know of

Types of Archaea: Methanogens

- convert hydrogen and carbon dioxide into methane for energy
- obligate anaerobes
- digest cellulose in cow and termite guts. Each cow belches 50 liters of methane a day (a major greenhouse gas)
- Also in swamps, wetlands, and garbage dumps





Types of Archaea: Halophiles

- Salt-loving

- Grow in very salty conditions (e.g. Dead Sea, and foods preserved by salting)
- Mostly aerobic
- Get energy from organic food molecules
  - some use light as a secondary energy source

Great Salt Lake, Utah

Types of Archaea: Thermophiles

- Heat-loving
- Live at very high temperatures:
  - e.g. ocean hydrothermal vents and hot springs
- Optimal conditions for growth between 70°C - 85°C

hydrothermal vent

Types of Archaea: Psychrophiles

- Cold-loving
- Found mostly in Antarctic and Arctic oceans
- Optimal temperature range is -10°C to -20°C