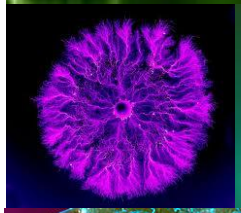
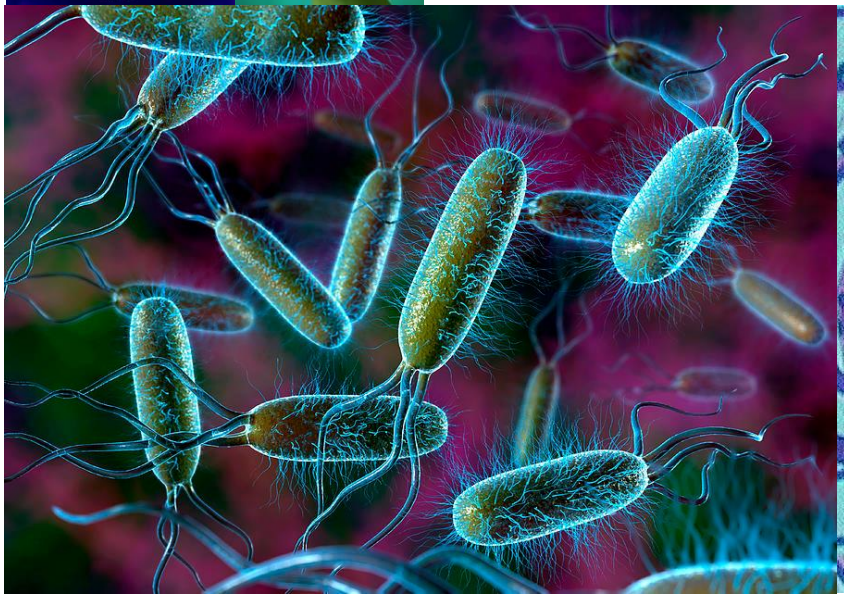
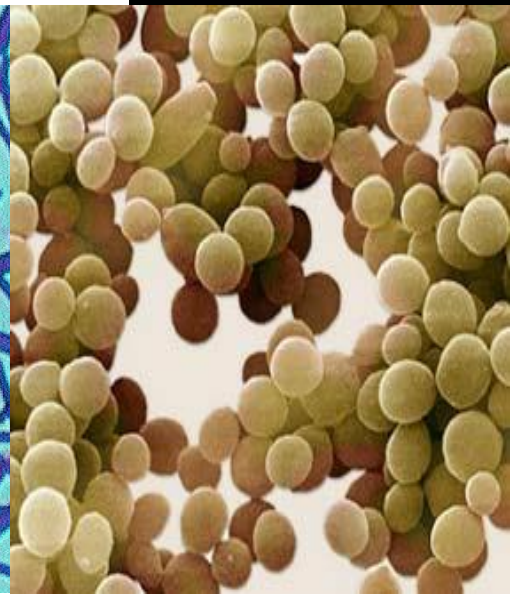


BACTERIA





What are bacteria?

Bacteria **(sin. *bacterium*) is the oldest and most abundant living organism on earth.**

- **There are approximately 5×10^{30} bacteria on Earth.**
- **Most bacteria are harmless, but a few are pathogens.**
- **A gram of soil typically contains about 40 million bacterial cells.**
- **A milliliter of fresh water has about a million bacterial cells in it.**

Most bacteria have not been characterized yet…

General Characteristics

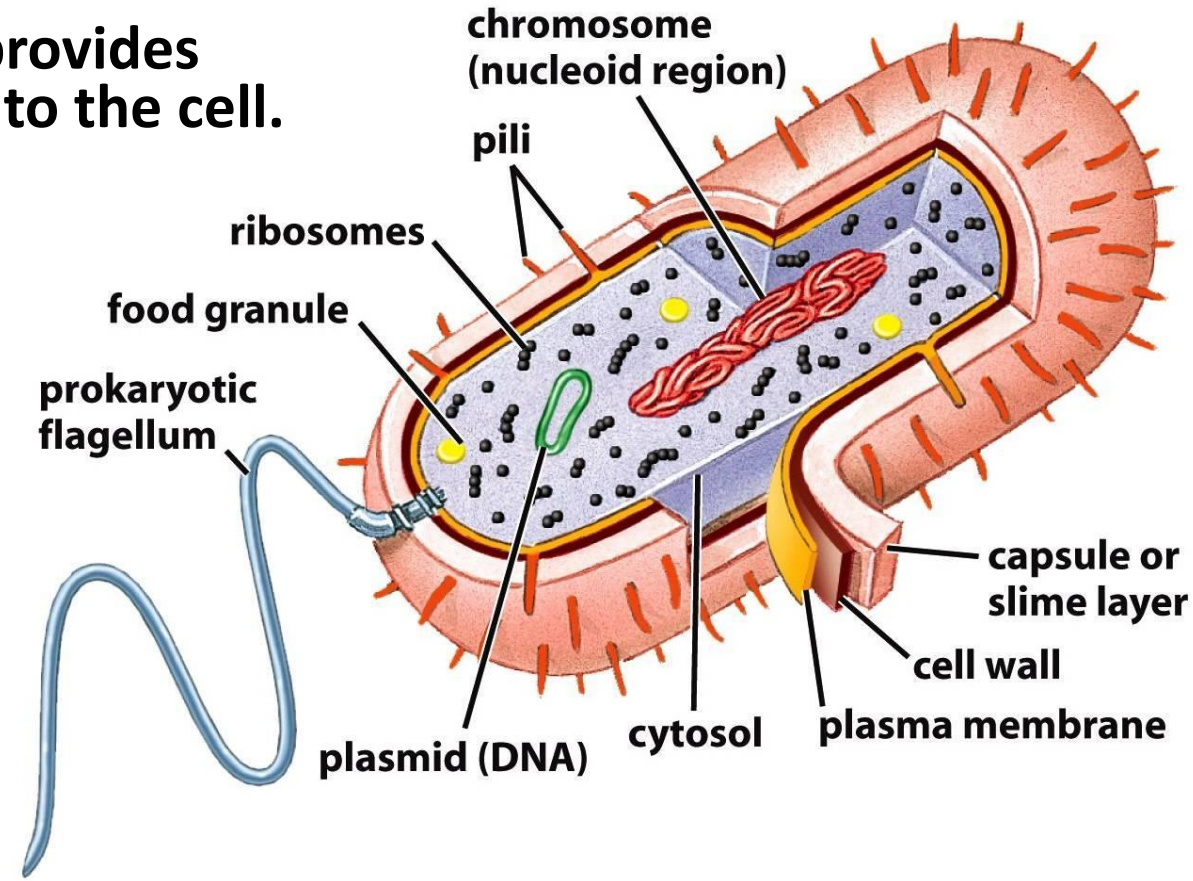
Bacteria can be found everywhere: in air, water, land, and living organisms including people.

1. **All are unicellular (one-celled structural level).**
2. **All are prokaryotic (lack nucleus).**
3. **All have cell walls (no cellulose in cell walls).**
4. **Exceptional diversity in size, shape, and metabolism.**
5. **Can live in both aerobic (with O_2) and anaerobic (without O_2) environments.**
6. **Bacteria reproduce (make more of themselves).**
7. **Bacteria need food.**

Billions *on* and *inside* your body right now!

Typical Structure

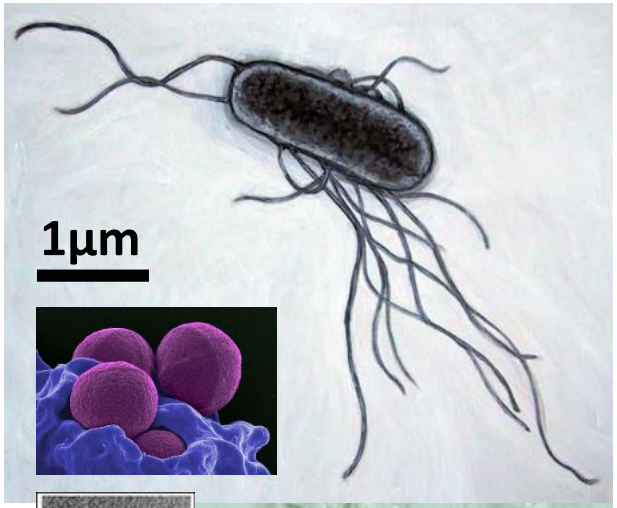
- Bacterial <u>cell wall</u> provides structural integrity to the cell.
- <u>Plasmids</u> are small independent "extra" pieces of DNA, often coding for non-essential advantageous traits (can be easily *lost*, *gained* and *transferred* between bacterial cells).

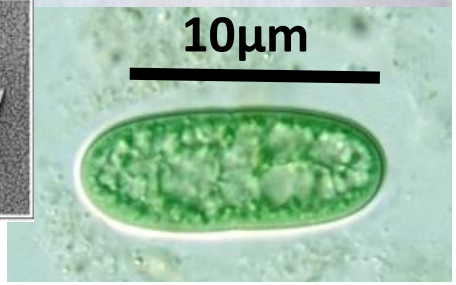


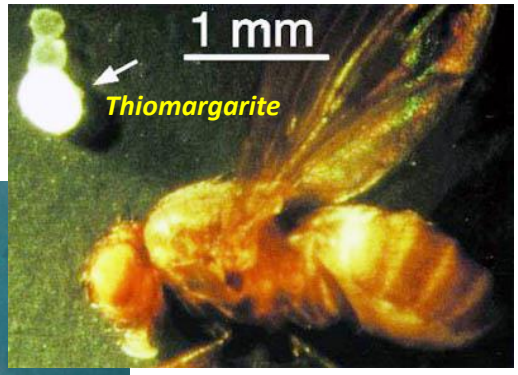
- <u>Pili</u> are *protein tubes* that extend out from the outer membrane; used for attachment to surfaces and movement.
- <u>Flagella</u> are whip-like *filament structures* protruding from the bacterial cell wall; responsible for movement.

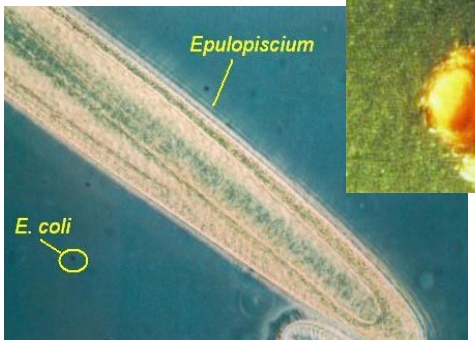
Bacteria Size

- **Average ~1 micrometer: an average-size rod bacterium (ex. *Escherichia coli* found in your intestine) is about 2-3 µm long and 0.5-1µm across; the spherical cells of *Staphylococcus aureus* are up to 1 µm in diameter.**
- **Smallest ~0.1 micrometer: *Mycoplasma pneumonia* are just ~0.1-0.25 µm across.**
- **Large ~10 micrometers: *cyanobacterium Synechococcus* averages 6 µm by 12 µm.**
- **Giant (more than half a millimeter!) bacteria can be visible with the unaided eye: *Thiomargarite namibiensis* averages 750 µm in diameter; the rod-shaped *Epulopsicium fishelsoni* is 80 µm in diameter by 600 µm in length.**

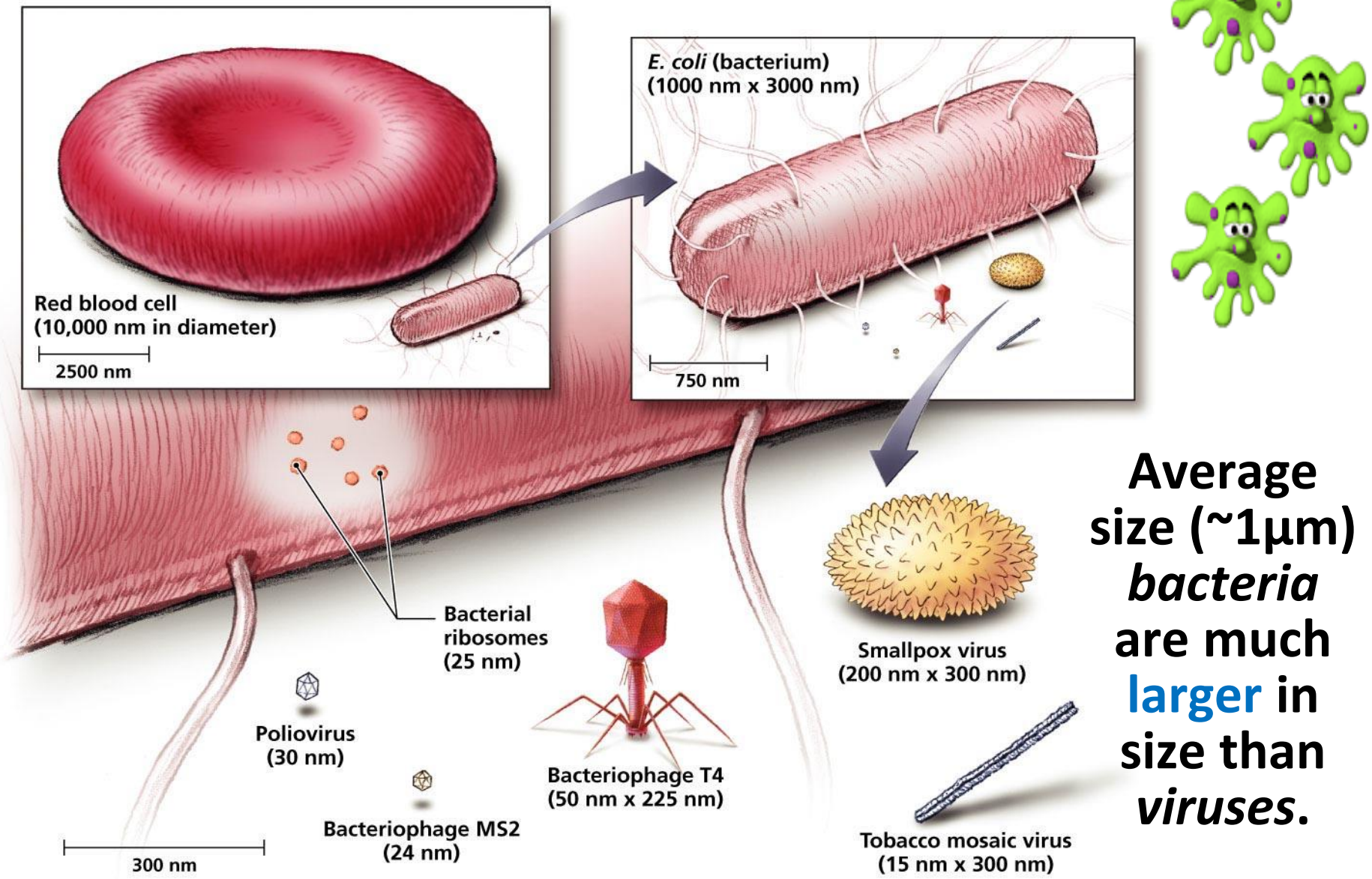








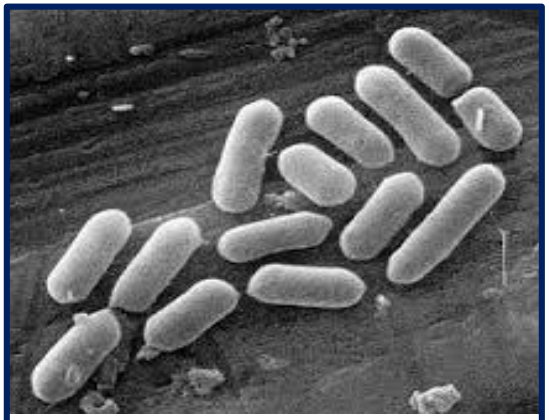
Scale Sense



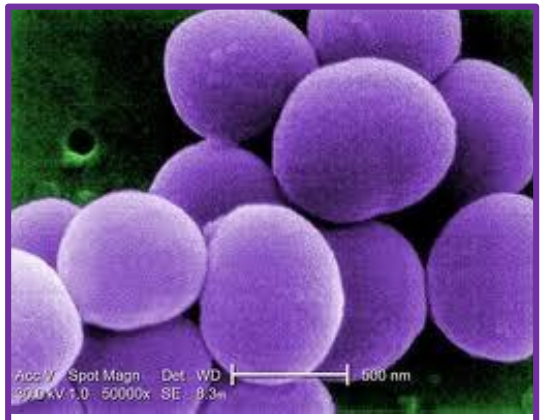
Average size (~1µm) *bacteria* are much larger in size than *viruses*.

Bacteria Shapes

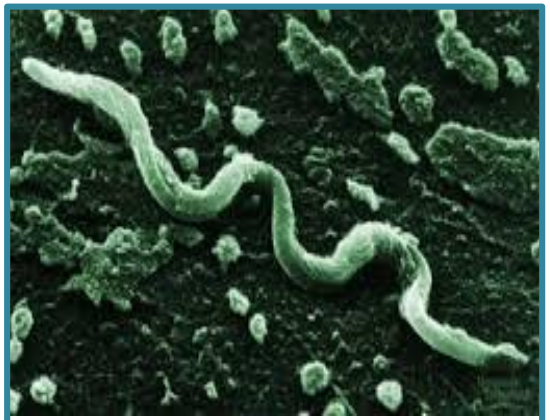
- **Three basic shapes:**



Bacilli
(buh-sill-eye)
rod shaped



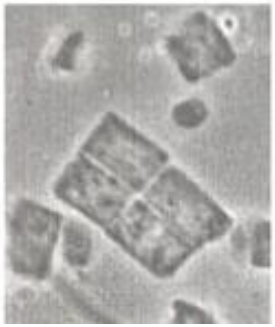
Cocci
(cox-eye)
round shaped

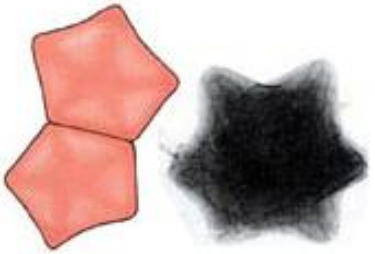


Curve shaped
(vibrio, spirilla, spirochete)

- **Some unusual shapes:**

square

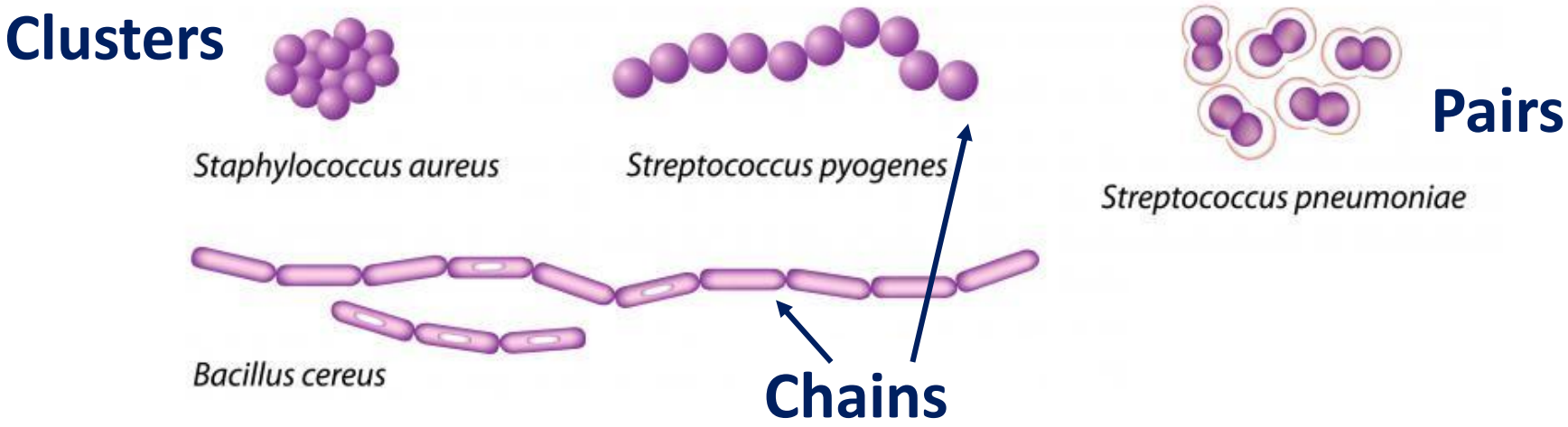




star-shaped

Do bacteria get together?

Many bacterial species exist simply as single cells, others associate in characteristic patterns:

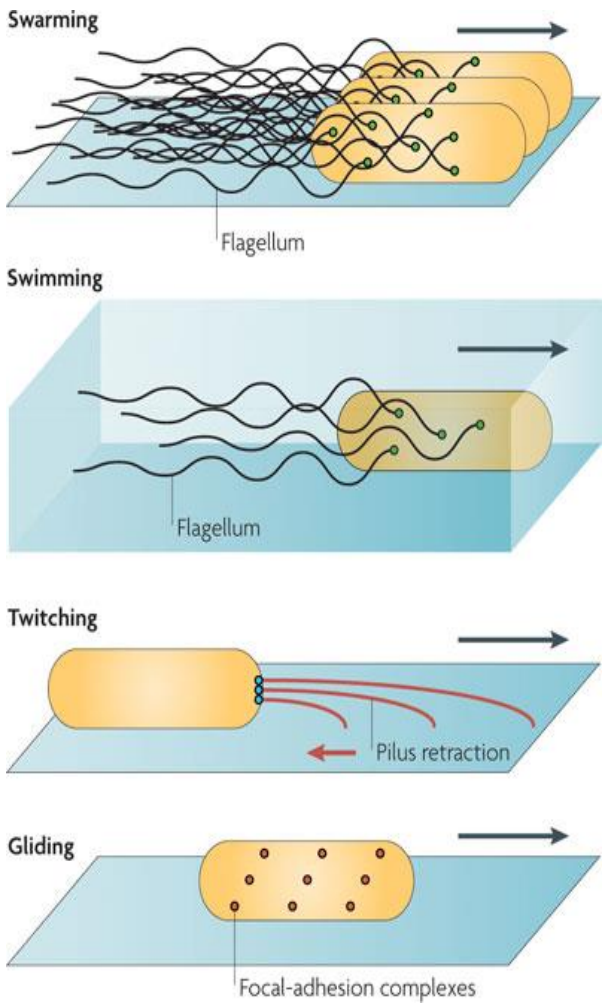


Many bacteria can form aggregated structures called biofilms:

- **Organisms in biofilms often display substantially different properties from the same organism in the individual state.**
- **Biofilms can communicate information about population size and metabolic state.**

Can bacteria move?

Many bacteria can move using a variety of mechanisms:

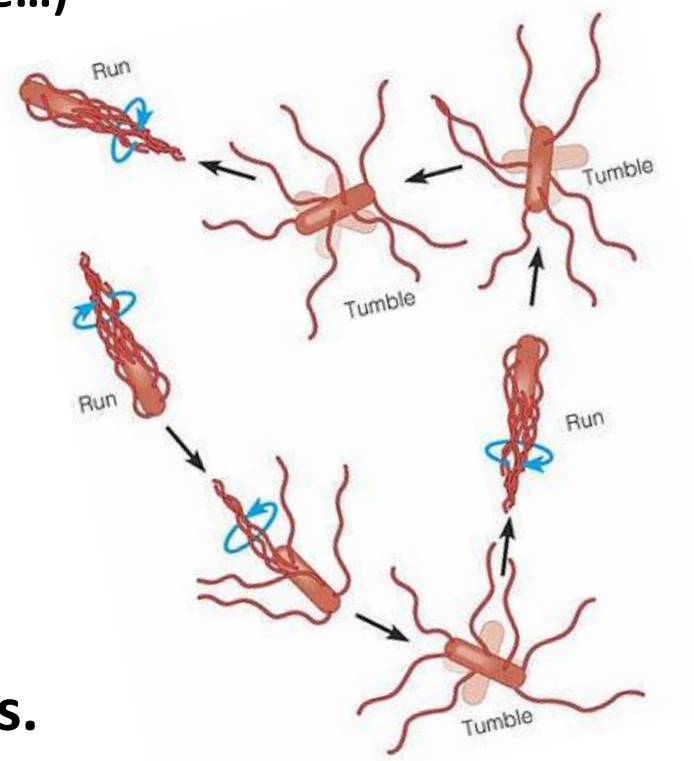


- *Flagella* are used for swimming through fluids as well as for "run and tumble".

  (swimming bacteria frequently move near 10 body lengths per second and a few as fast as 100; this makes them at least as fast as fish, on a relative scale…)

- Changes of *buoyancy* allow vertical motion.

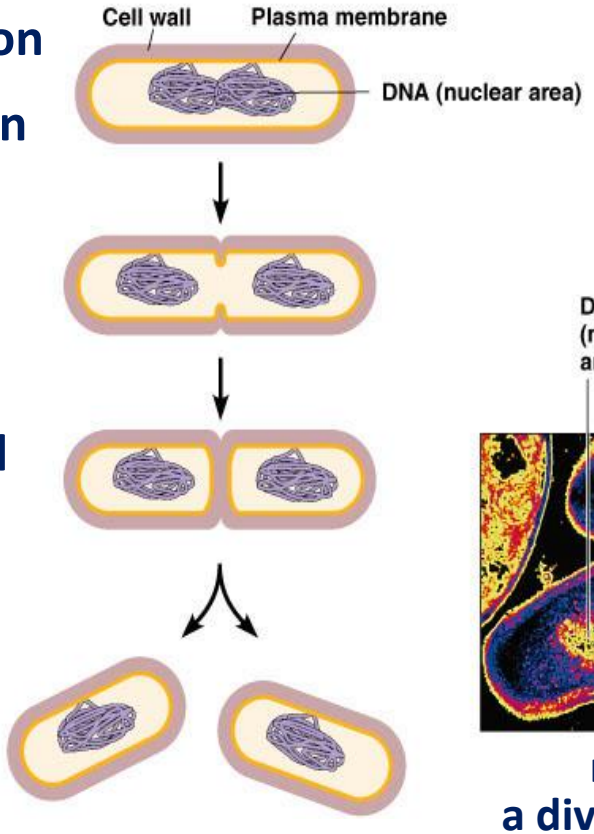
- Gliding and twitching (using *pili*) move bacteria across surfaces.



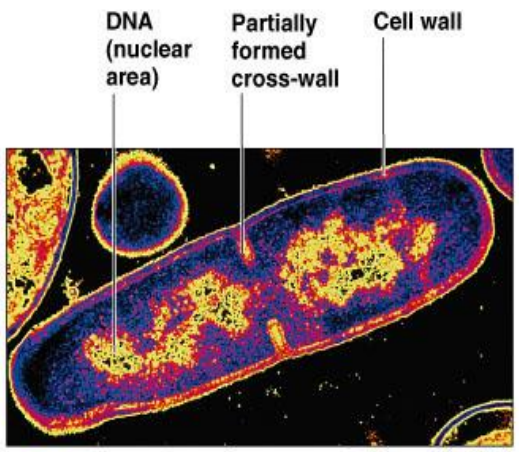
Reproduction

Bacteria grow to a fixed size and then reproduce through binary fission: bacterial cell divides in half, producing two genetically identical *clone* daughter cells.

1. Cell elongation and DNA replication
2. DNA separation
3. Cross-wall formation
4. Daughter cells separation

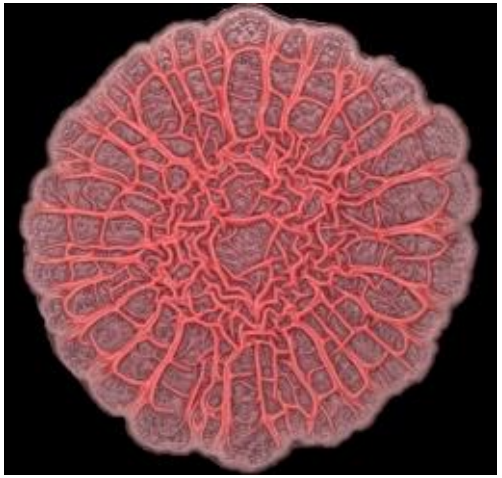


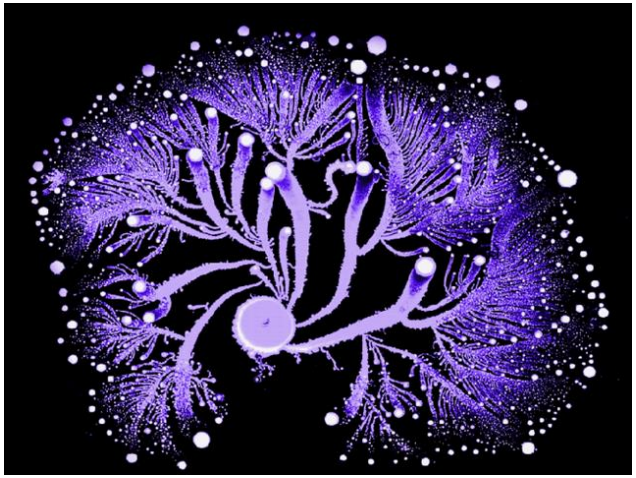
Under optimal conditions, bacteria can grow and divide extremely rapidly: bacterial populations can double as quickly as every 9.8 minutes.



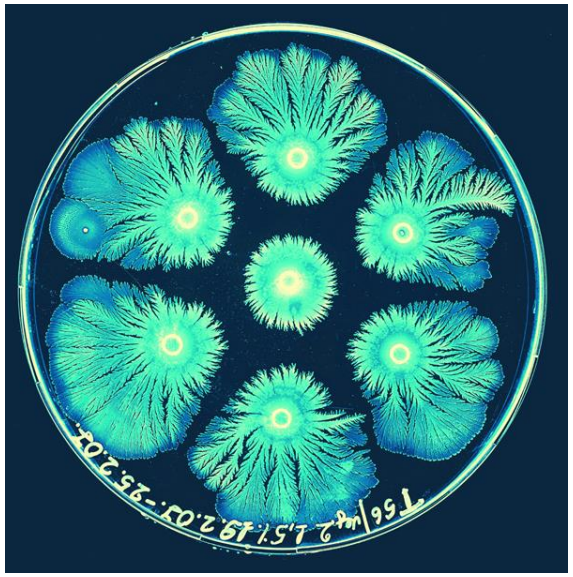
micrograph of a dividing bacterial cell

Bacterial Colonies





<u>In the laboratory</u>, bacteria are usually grown using solid (*agar plates*) or liquid nutritious media.



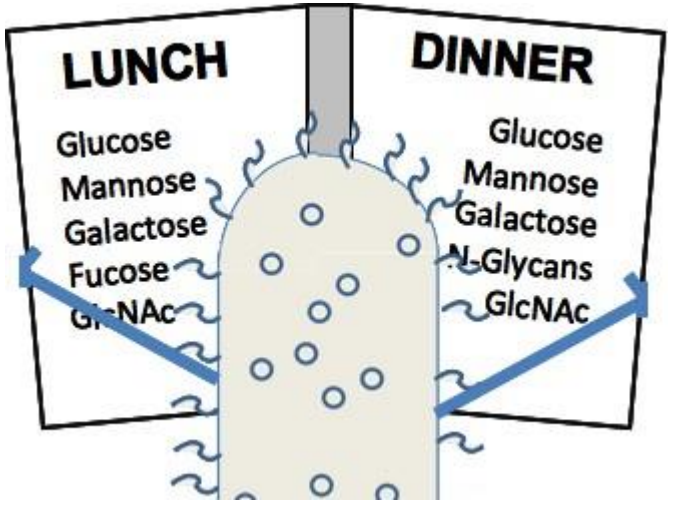
What do bacteria eat?

Autotrophic bacteria **create their own food**:

- Some make food from sunlight by **photosynthesis** - involves the use of *sunlight*, *carbon dioxide* and *water* to create energy and building materials.
- Other manufacture food through **chemosynthesis** - the process of using *water*, *carbon dioxide* and *other inorganic chemicals* like ammonia, sulfur, phosphorus, nitrogen, and metallic elements, to synthesize organic components.

Heterotrophic bacteria must **consume organic compounds**:

- They eat **other organisms** and absorb **dead organic material** from its surroundings.
- Some of these *parasitic* bacteria feed by **killing their hosts**, while others **coexist with or even help** their hosts.



Unusual Foods

Nuclear Waste

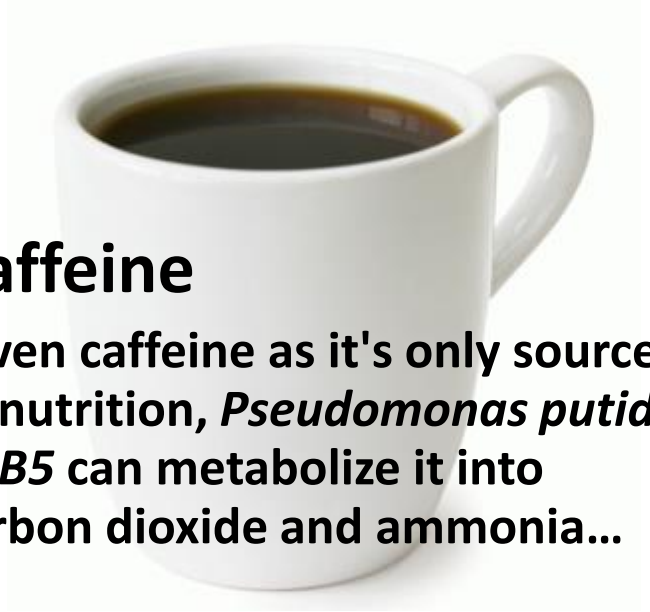
Geobacter sulfurreducens changes the isotopic form of uranium to a stable solid form, which is easier to recover in clean up efforts...

Crude Oil

Several types of bacteria naturally consume oil (*Alcanivorax* naturally appeared and consumed oil plumes generated from the 2010 Deepwater Horizon spill), but an engineered form of *Pseudomonas putida* is capable of doing it in a very efficient manner!

The Titanic

Two miles below the ocean surface, bacteria deemed *Halomonas Titanicae* are consuming the steel of the RMS Titanic as a fuel source (the only material the bacteria stay away from on the ship are brass items: brass contains copper, which quickly kills most bacteria).



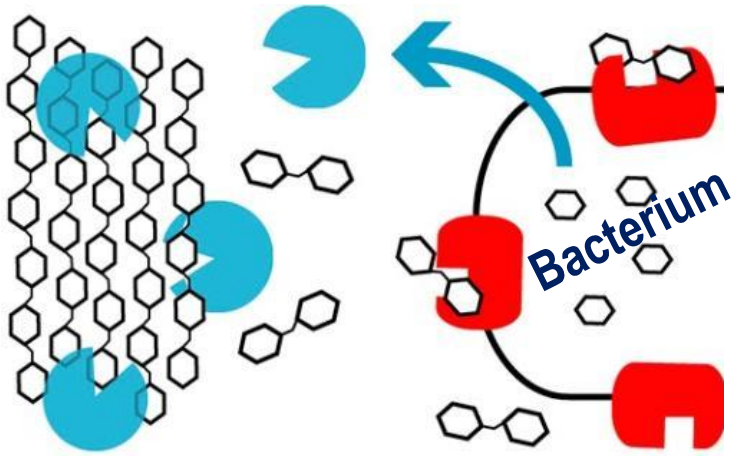
Caffeine

Given caffeine as it's only source of nutrition, *Pseudomonas putida CBB5* can metabolize it into carbon dioxide and ammonia…

How do bacteria digest food?

Bacteria employ <u>extra-cellular digestion</u>.

- **Make proteins called enzymes inside the cell.**
- **Enzymes travel through the cell wall into the surrounding medium, catch the food and break it down into tiny subunits (most bacteria need *oxygen* to do it).**
- **Resulting simple compounds are taken into the bacteria cell.**

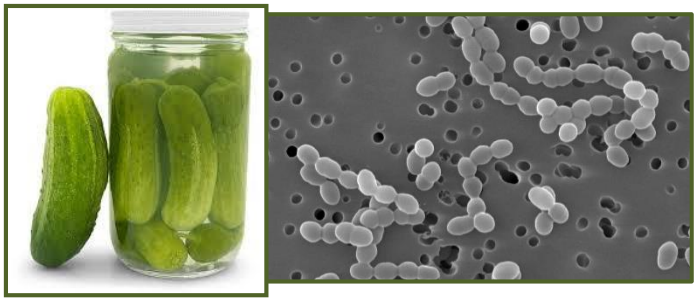


- **Each <u>specific food</u> requires a <u>specific enzyme</u>:**
  - **Some bacteria produce many kinds of enzymes and can eat many kinds of foods.**
  - **Other bacteria have few enzymes and are able to digest very few kinds of food (however they can still live off a given food by growing where other bacteria have already broken the food down).**

Beneficial Bacteria

The <u>vast majority</u> of bacteria are harmless or beneficial.

- **Lactobacillus**: makes cheese, yogurt, helps initial digestion in your mouth and produces vitamins in your intestine.



- **Leuconostoc**: makes pickles and sauerkraut as well as sour cream.

- **Pediococcus**: makes pepperoni, salami, summer sausage.
- **Actinomycetes**: produce antibiotics such as streptomycin and nocardicin and are very useful in breaking down compost (the "earthy" smell of soil).

Pathogenic Bacteria

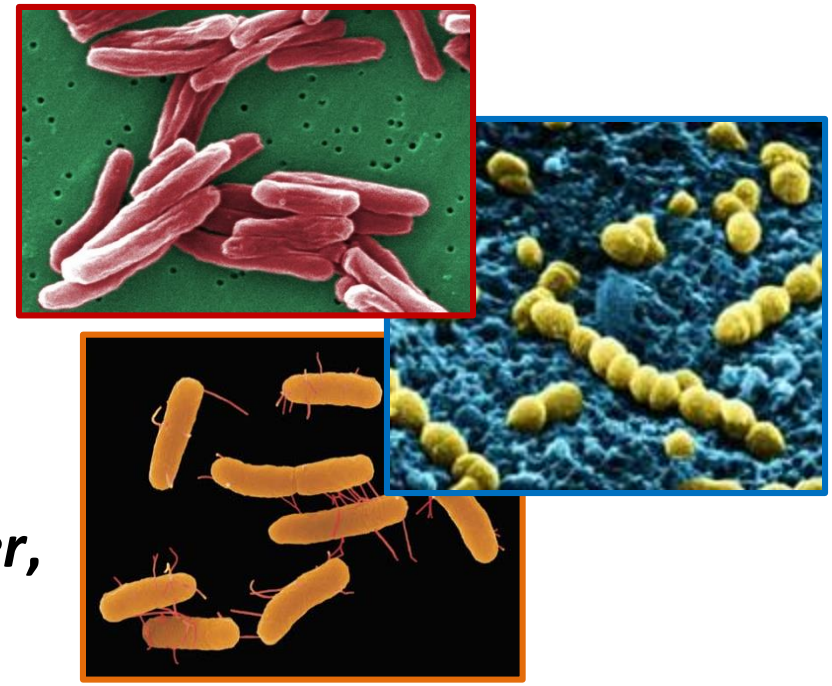
Pathogenic bacteria that can cause infectious diseases are much better studied than many of the free-living species.

- **How do they make us sick:**
  - **Iron competition.**
  - **Direct damage to host cells.**
  - **Production of toxins - poisonous substances that work by destroying particular parts of the host cell or by inhibiting certain metabolic functions (*release of toxins* after death of bacterial cells often cause *symptom worsening* immediately after beginning the course of antibiotics…).**

- **Conditionally pathogenic bacteria are only pathogenic under certain conditions, such as a wound that allows for entry into the blood stream, or a decrease in immune function.**

Globally Important Diseases
caused by bacterial infections

- **Tuberculosis** (***Mycobacterium tuberculosis***) **kills about 2 million people a year.**
- **Pneumonia can be caused by *Streptococcus* and *Pseudomonas*.**
- **Foodborne illnesses can be caused by *Shigella*, *Campylobacter*, and *Salmonella*.**



- **Other: tetanus, typhoid fever, diphtheria, syphilis, borelliosis and leprosy.**
- **Common pathogenic bacteria: pathogenic E. coli, Listeria, Salmonella, Helicobacter pylori, Clostridium, Staphylococcus, Streptococcus.**