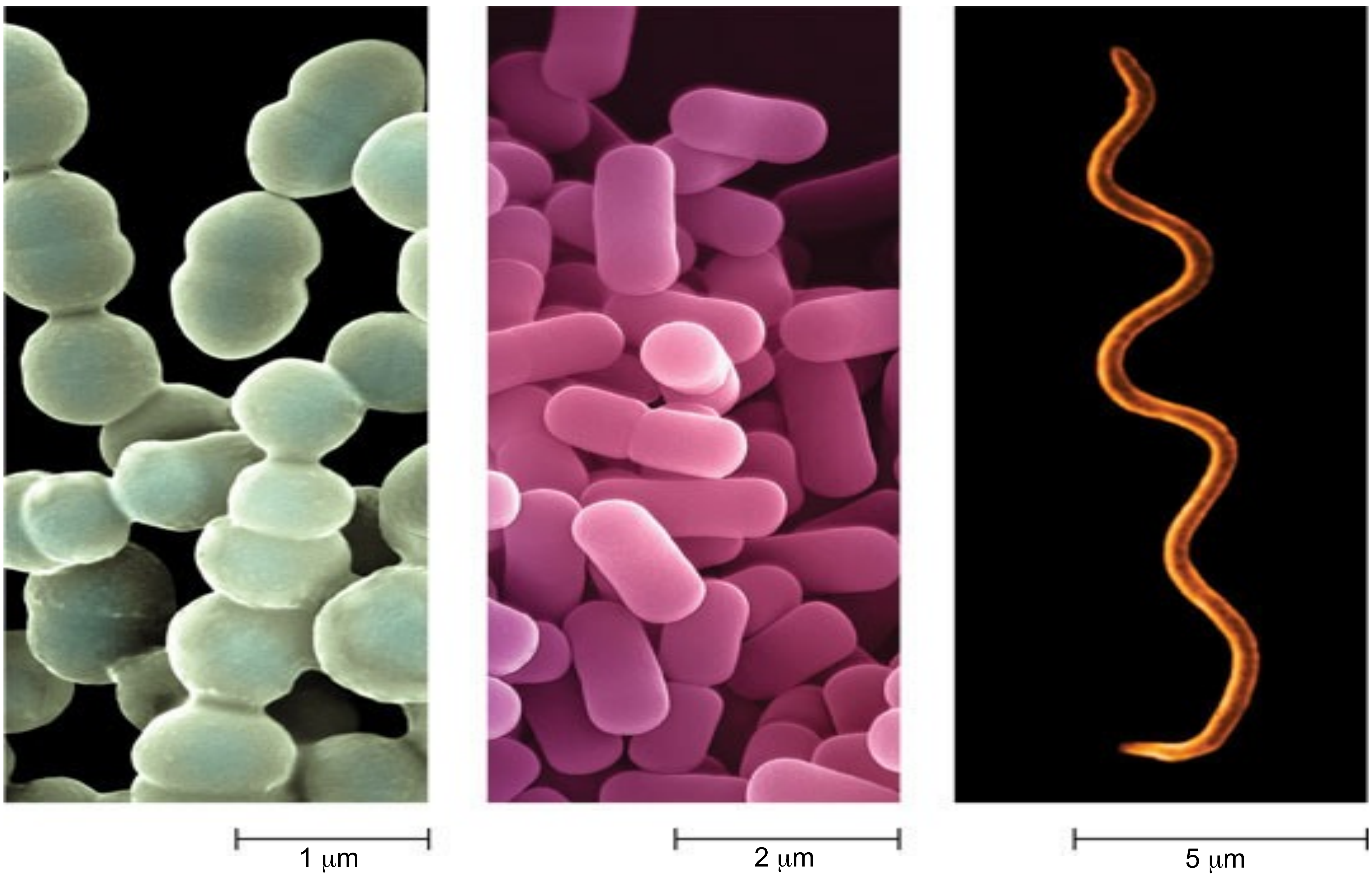
Structure & Function of Bacteria

Bacteria

- **The oldest organisms**
  - *at least 3.5 billion years old*
- **The most abundant organism**
  - *more bacteria in a handful soil than all humans that have ever lived*
- **Incredible diversity**
- **Microscopic**
  - *about the size of eukaryotic organelles like nuclei and mitochondria*
  - *some form colonies*
- **Found virtually everywhere**
  - *environments that are very hot, ice cold, acidic, salty, high pressures, no oxygen, in the dark, etc*

Bacterial Structure

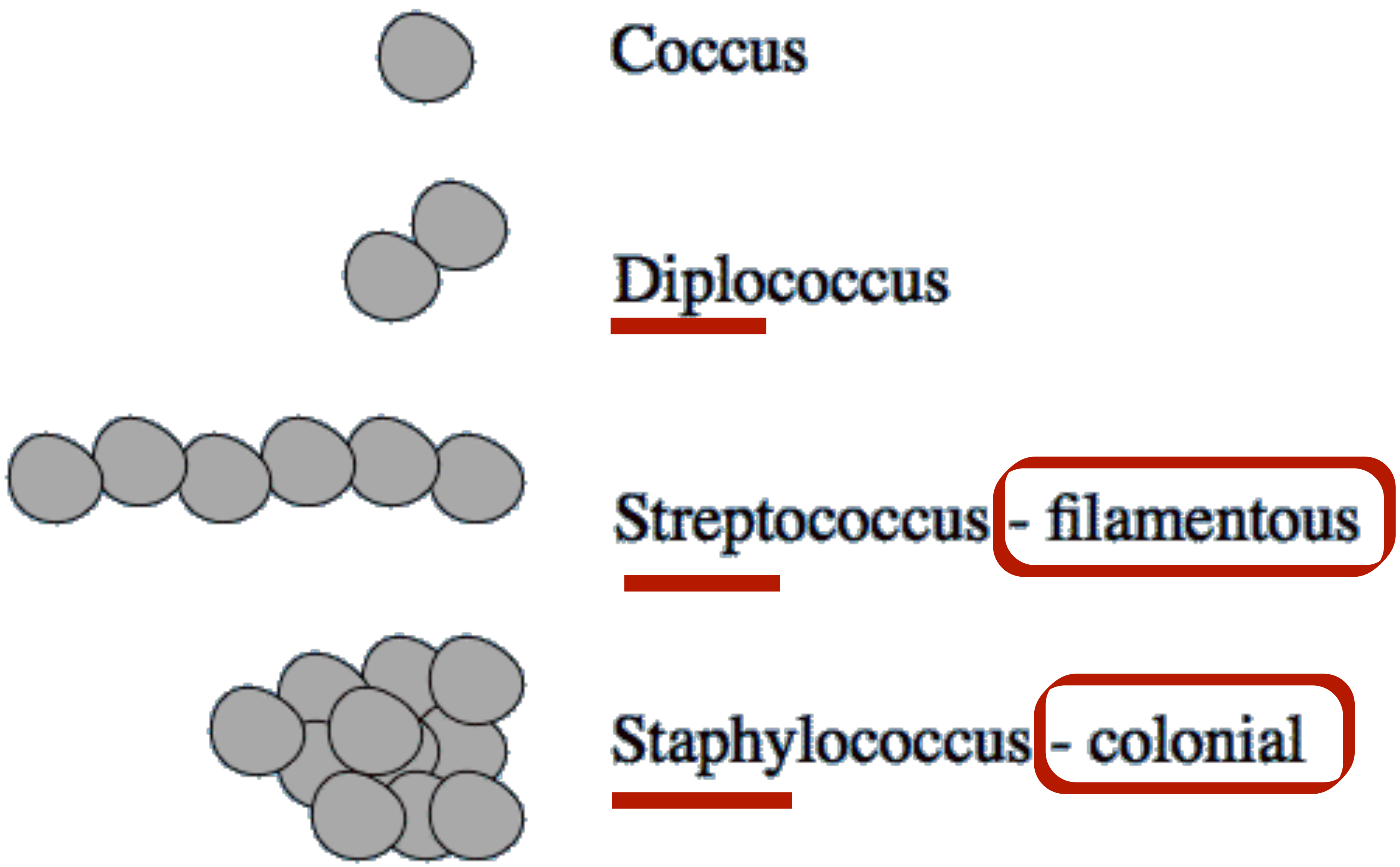
- Bacteria are found in three main shapes.



(a) Spherical (cocci) **(b) Rod-shaped (bacilli)** **(c) Spiral**

- Some bacteria remain connected after cell division.

Cell Associations



How would name this bacteria?

Answer- streptobaccilus

How do bacteria maintain a separation from its environment?

- Like all cells, bacteria possess a **plasma membrane**
- Like others, they possess a **cell wall**
    - *although there cell is unique*
- And some bacteria have further unique protective structures

Bacterial Barriers

- The first and most fundamental barrier is the **plasma membrane** itself.
- The key protective barrier for bacteria is however their **cell walls**.
    - Recall that the cell wall keeps the bacterial cell from bursting when introduced into a hypoosmotic environment.
    - The cell walls protect them from a variety of biotic threats
- Many bacteria have a sticky or slime layer around the cell wall called a **capsule** that provides an additional layer of protection.

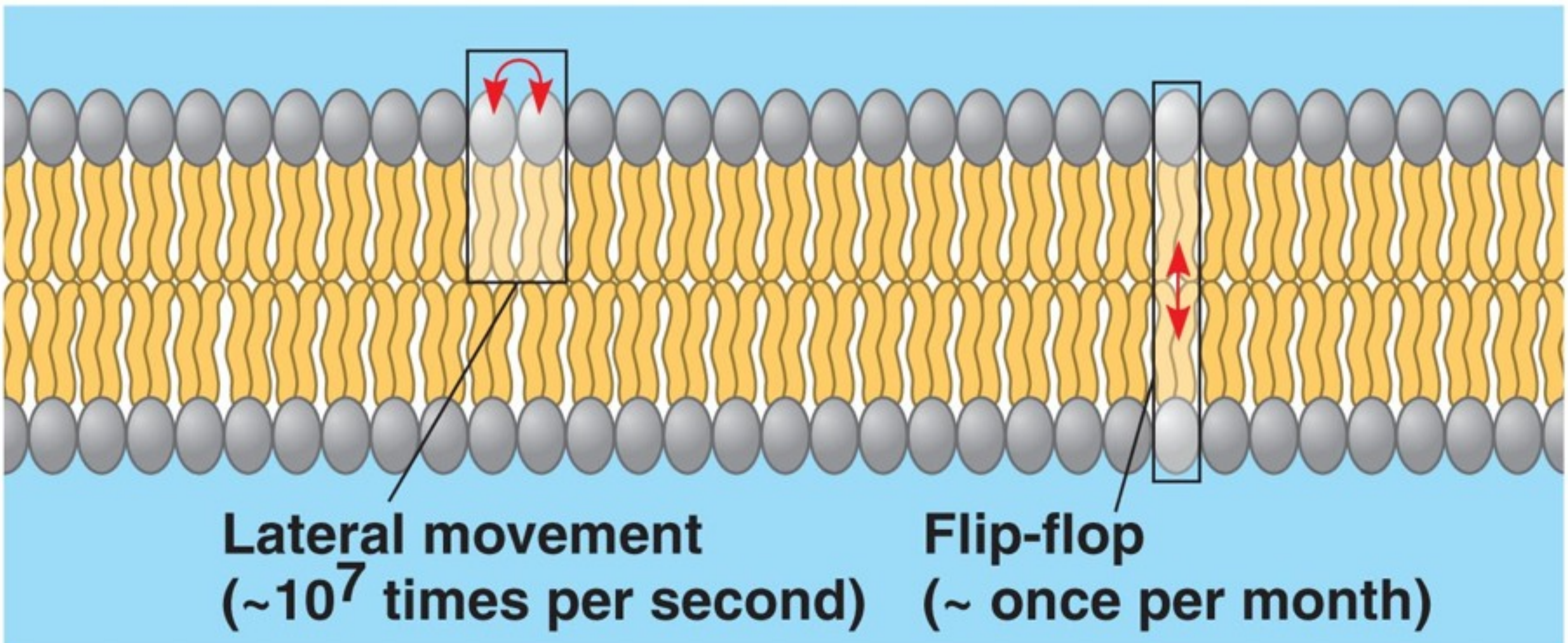
Bacterial Barriers- Plasma Membranes

CELLULAR MEMBRANES ARE FLUID MOSAICS OF LIPIDS AND PROTEINS

- The foundation of the membrane is the phospholipid.
- Phospholipids are **amphipathic** meaning that have a hydrophilic region and a hydrophobic region.
  - They will inherently form membranes when they come together.
- The remainder of the membrane is littered with proteins and sugars.
  - Many of the proteins are themselves amphipathic

Bacterial Barriers-Fluid

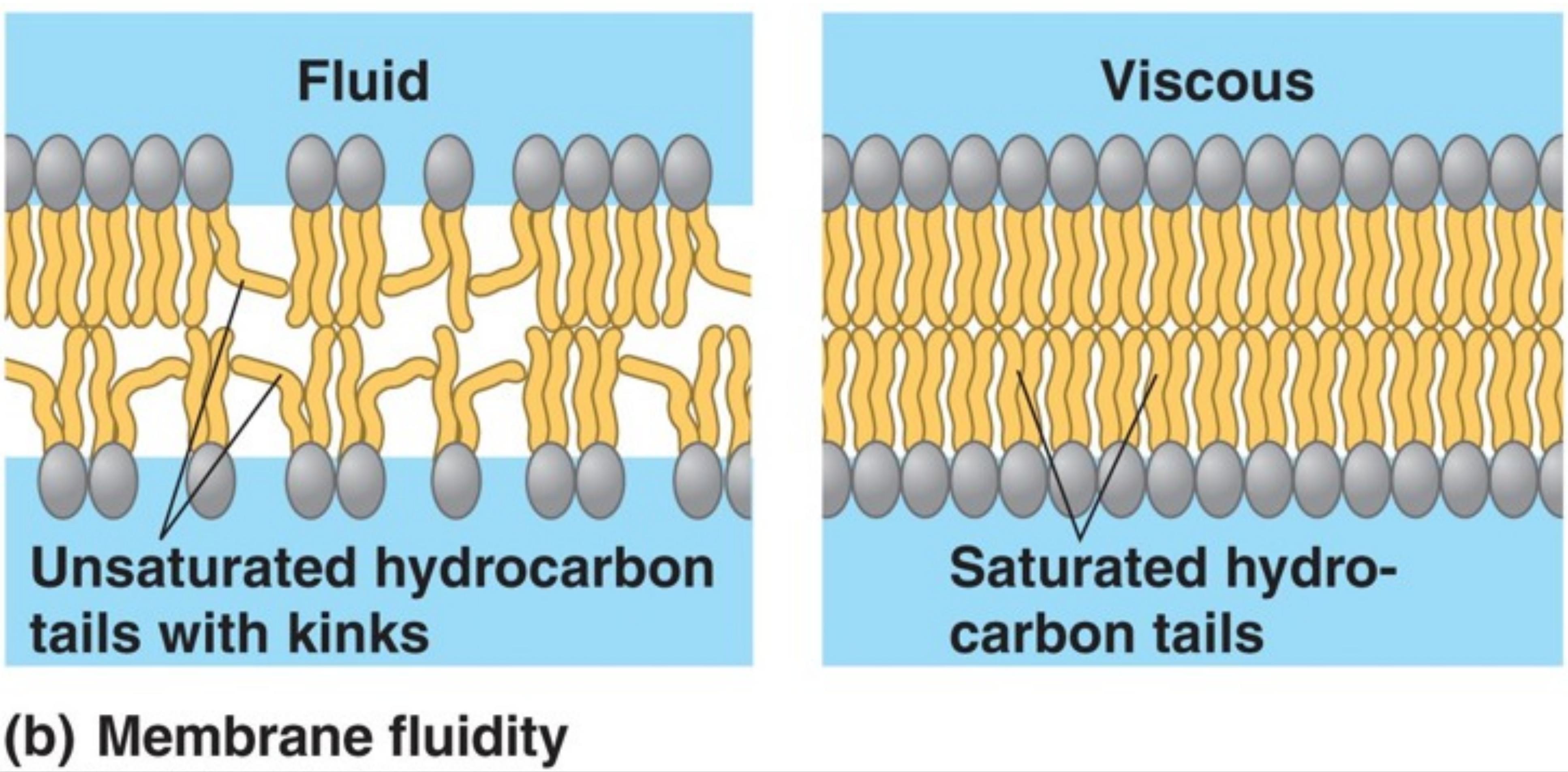
- Membranes are static sheets, they are held together by weak hydrophobic interactions.
- The lipids and proteins both move laterally although the lipids move much more freely.



(a) Movement of phospholipids

Bacterial Barriers-Fluid

- Membrane fluidity is directly correlated with temperature.
  - The higher the temperature the more fluid the membrane
- The type of fatty acid tails in the phospholipids also effect fluidity
- Membrane fluidity is important because it effects membrane permeability



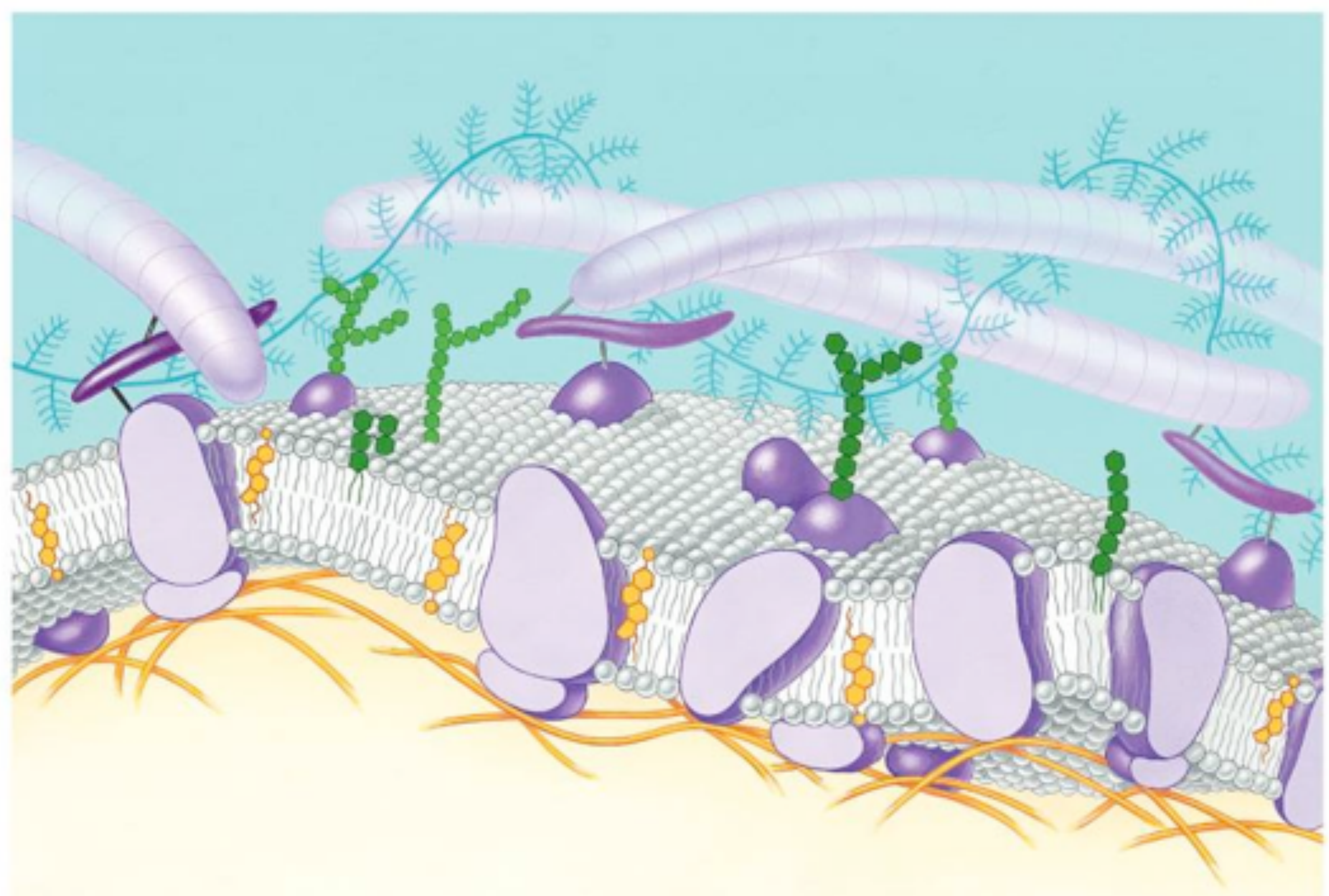
The Evolution of Different Membrane Lipid Composition

- Variations in lipid composition appears to be an evolutionary adaptation.
  - *Fish that live in cold water have a high proportion of unsaturated fatty acids.*
  - ***Bacteria living in thermal hot springs show a high proportion of saturated fatty acids.***

Bacterial Barriers-Sidedness

- **Membranes have distinct inside and outside surfaces.**
- The proportion and percentage of lipids and proteins is fairly consistent even among different species
- However the types lipids and the shapes of the proteins can vary greatly

Membranes are also are described as being a <u>mosaic</u> since each has a variety of unique proteins



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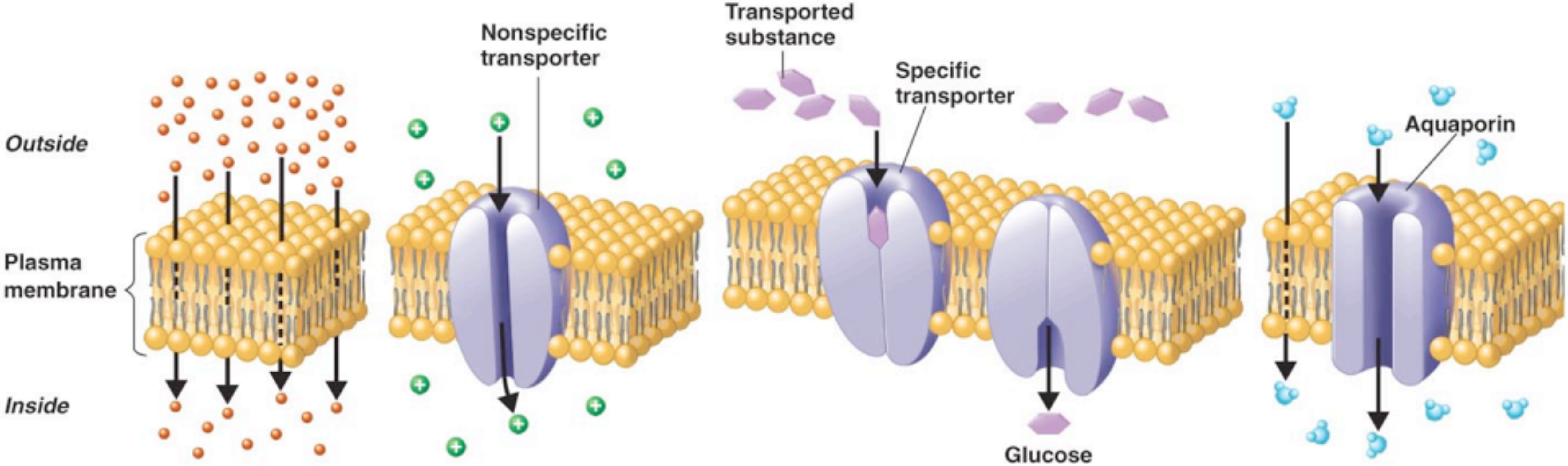
Bacterial Barriers-Transport

- **Membranes have distinct proteins that aid in transport.**
- Review different proteins and their associated transport



(a) Simple diffusion through the lipid bilayer
(b) Facilitated diffusion through a nonspecific transporter
(c) Facilitated diffusion through a specific transporter
(d) Osmosis through the lipid bilayer (left) and an aquaporin (right)

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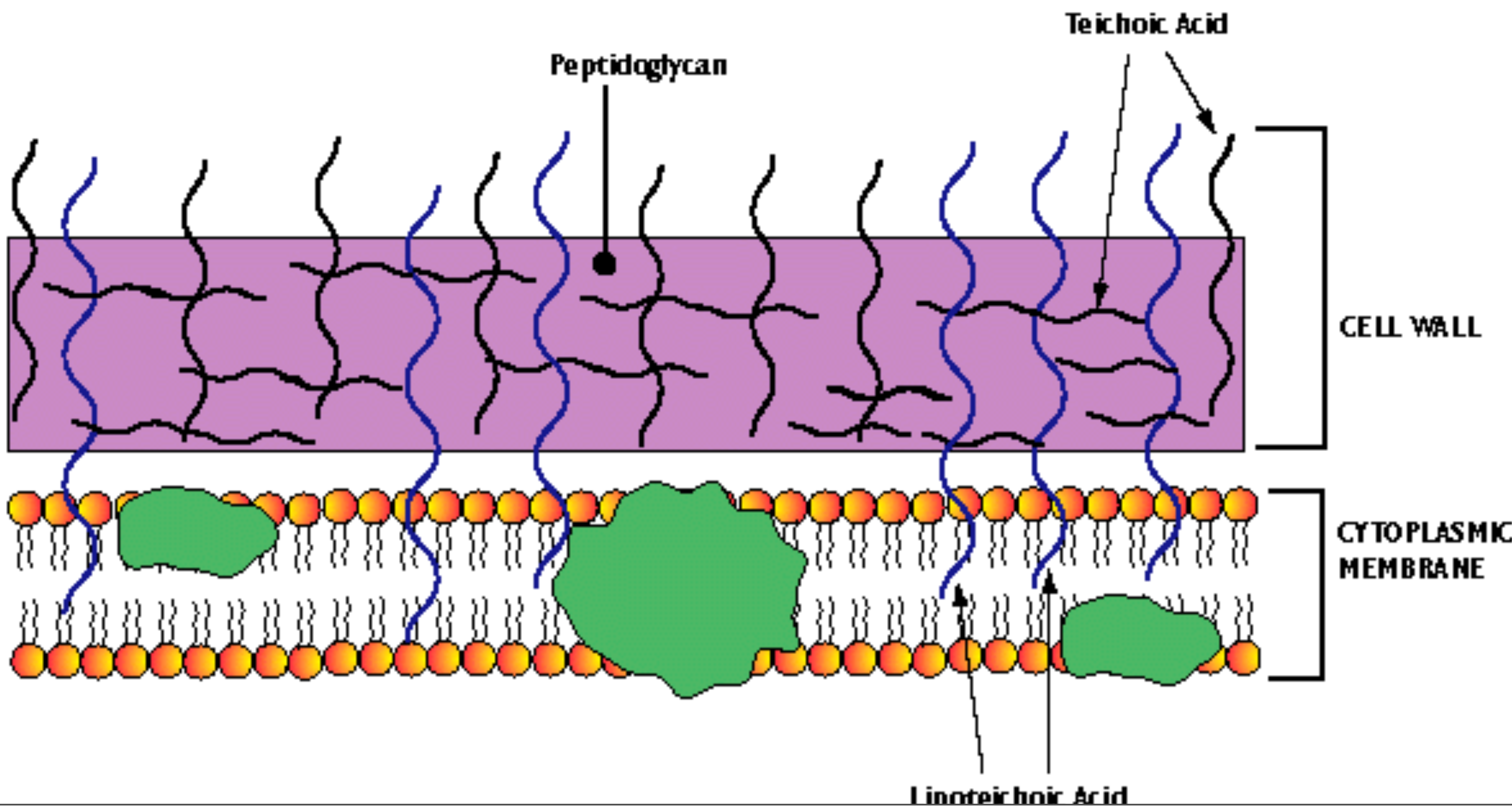
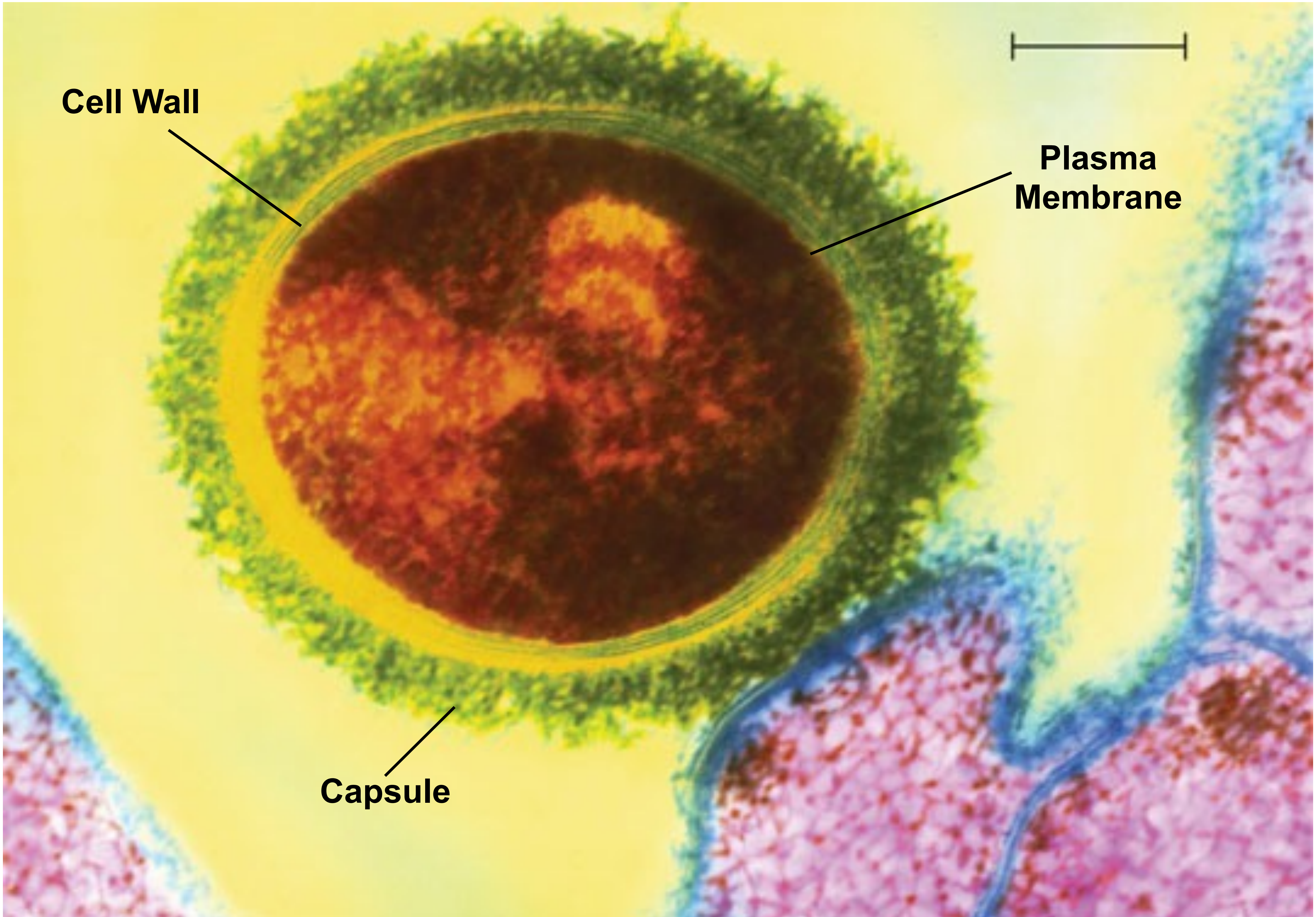
Bacterial Cell walls

Bacterial cell walls are different from eukaryotic cell walls like those found in fungi and plants. Plants and fungal cell walls are composed of cellulose or chitin. Bacterial cell walls are composed of **peptidoglycan**, a sugars crossed linked with polypeptides.



Bacterial Capsules

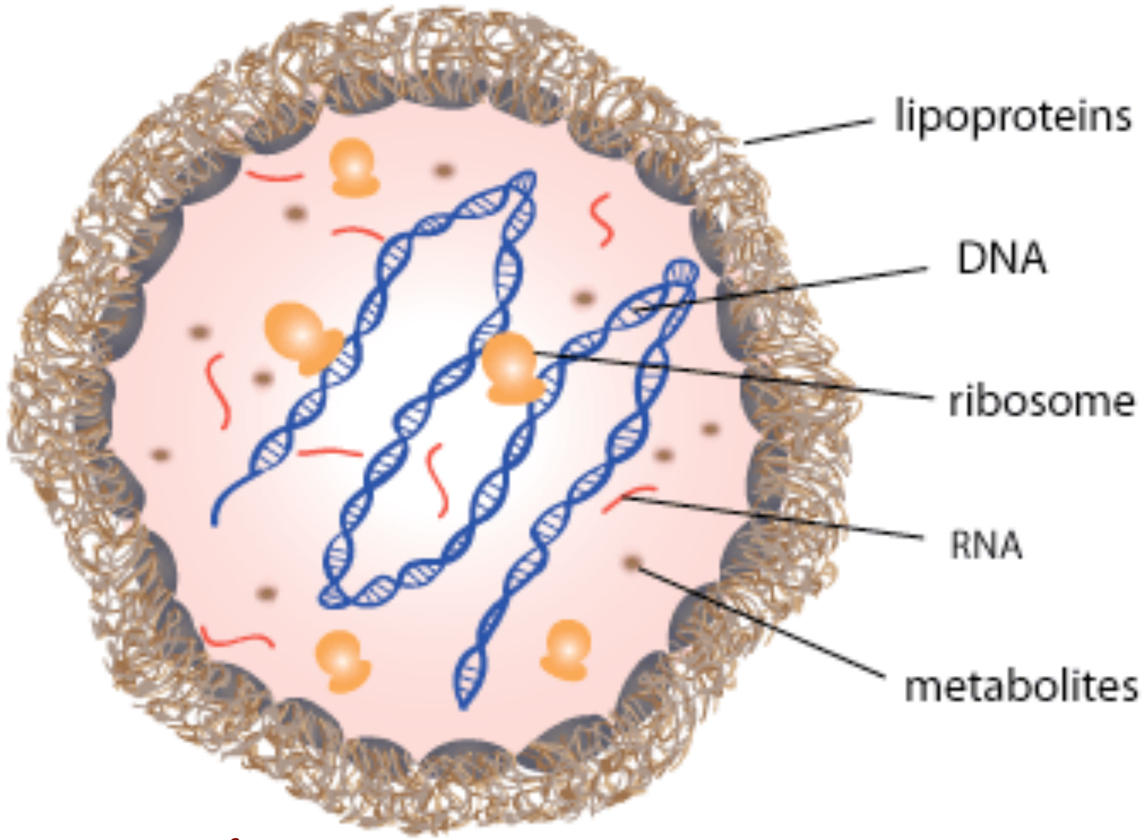


Bacterial Barriers- 3 Forms

- Bacteria come in three forms in terms of these barriers and how they are used.
- **1. Mycoplasmas**
  - Lack a cell wall they only have a lipopolysaccharide layer.

They are the smallest, simplest bacteria.

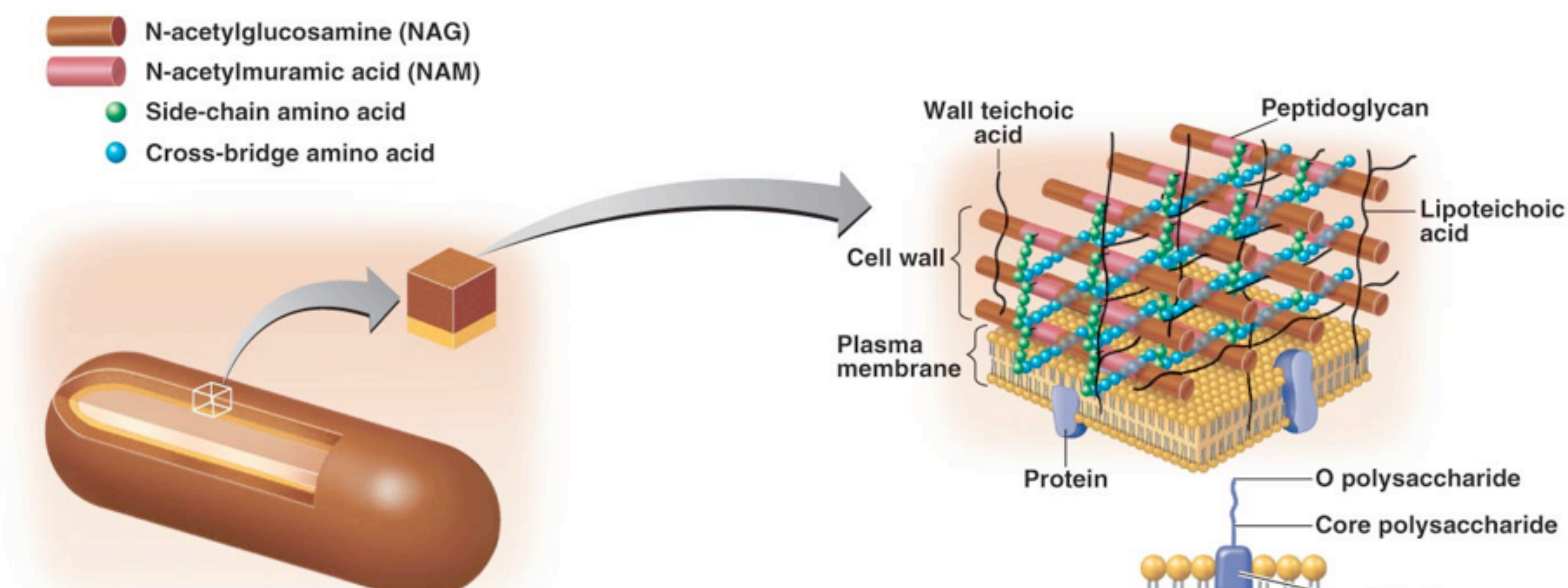
They are parasites, and resistant to many common antibiotics-tough to treat



They must live in isotonic environments

Bacterial Barriers- 3 Forms

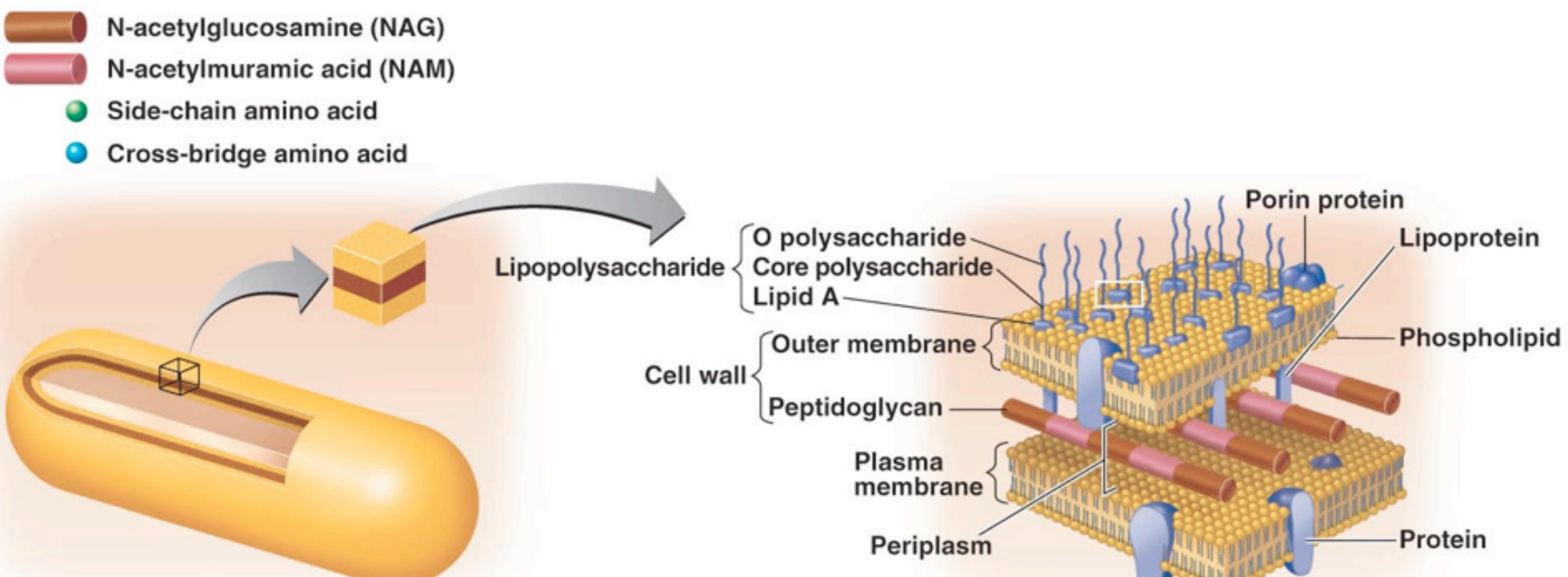
- Bacteria come in three forms in terms of these barriers and how they are used.
- **2. Gram Positive Bacteria**
  - Thick cell wall and a plasma membrane.



(b) Gram-positive cell wall

Bacterial Barriers- 3 Forms

- Bacteria come in three forms in terms of these barriers and how they are used.
- **3. Gram Negative Bacteria**
  - Outer membrane, thin cell wall and a plasma membrane.

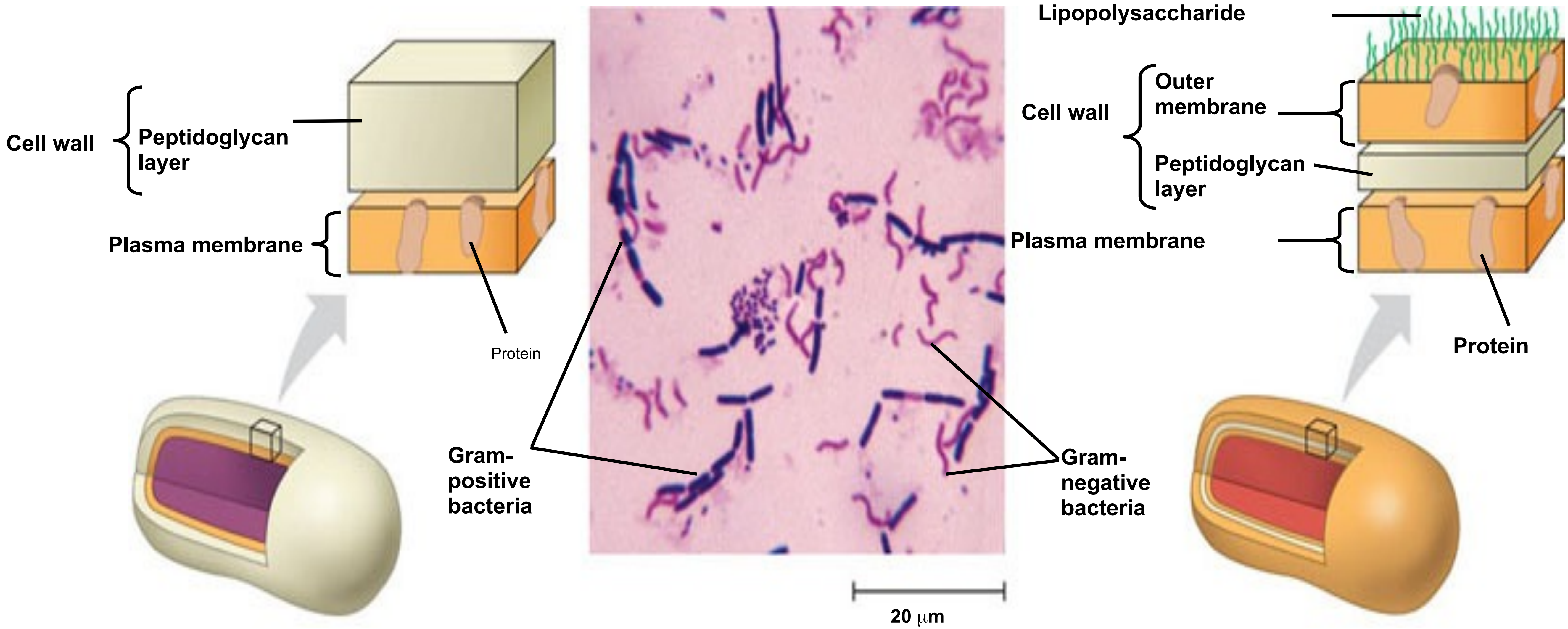


(c) Gram-negative cell wall

Gram Staining

Gram staining separates bacteria into two groups based upon the structure of their cell walls.

Valuable diagnostic tool used in medicine, helps determine type of infection.



Gram-positive. **Gram-negative.**

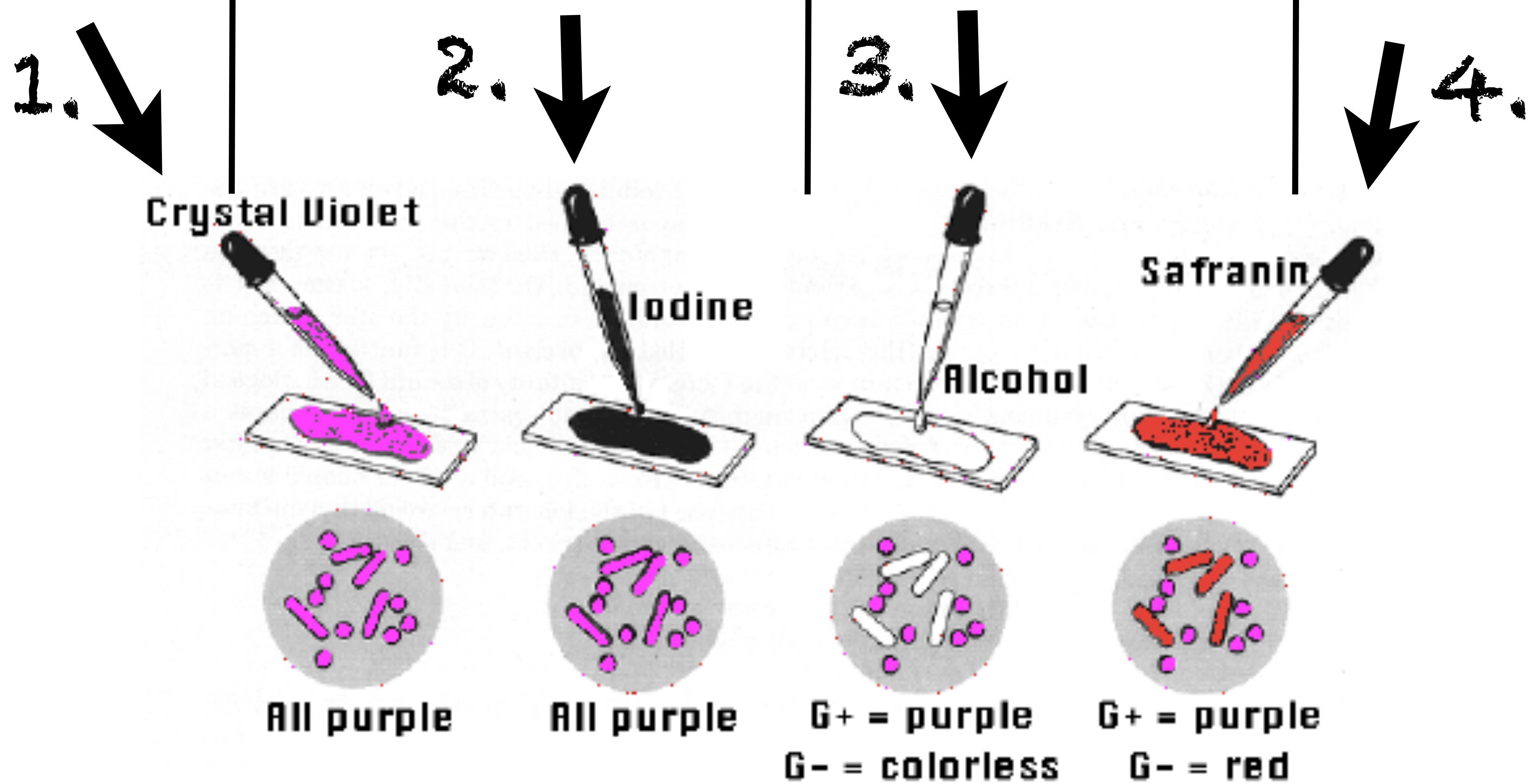
Gram Staining

Crystal Violet (CV) penetrates cell wall of all bacteria

Iodine penetrates cell wall, binds to CV and locks it into the cell

Alcohol rinses the CV/iodine complex out of gram negative bacteria because cell wall is so thin

A red dye is used to stain the gram negative bacteria that lost their purple color



COMPARISON OF GRAM NEGATIVE AND GRAM POSITIVE BACTERIA

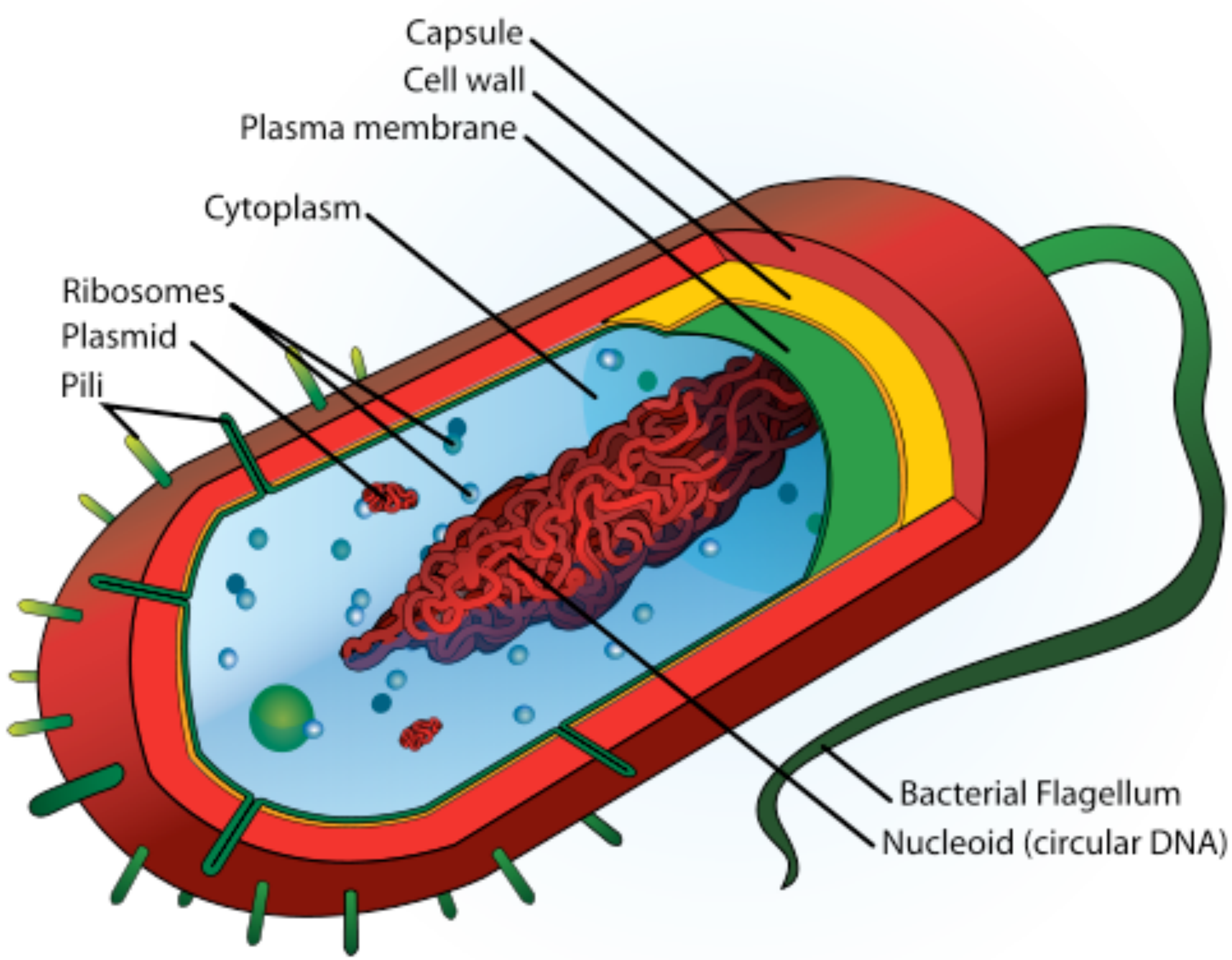
CHARACTERISTIC	GRAM POSITIVE	GRAM NEGATIVE
GRAM STAINED COLOR	Purple	Pink to Red
CELL SHAPE(S)	Rods and Cocci	Mostly rods, few cocci, spirilli; some pleomorphic
ENDOSPORE PRODUCTION	Common in 2 Genera	Virtually Unknown
CELL WALL COMPOSITION	1-4% Lipid (low); Thick, Multilayered Peptidoglycan (up to 30 layers)	11-22% Lipid (high); 3 Separate Layers (inner one is Peptidoglycan - 1 to 2 layers only)
CELL WALL NATURE	Rigid, Strong	Flexible
PENICILLIN SENSITIVITY	High (penicillin interferes with peptidoglycan synthesis)	Low
LYSOZYME SENSITIVITY	Wall is Dissolved (protoplast formed)	Wall is Weakened (spheroplast formed)
INHIBITION BY BASIC DYES (e.g. C.V.)	High	Low
PHYSICAL DISRUPTION SENSITIVITY (heat, alcohol)	Low	High
EXOTOXINS	Common (e.g. *Clostridium botulinin*, *Clostridium tetani*)	Rare (e.g. *Pseudomonas, E. coli*)
ENDOTOXINS	Unknown	Common (*Salmonella, Shigella*)

Bacteria: Other Forms

- **?4. Capsulated Bacteria**
  - Posses plasma membrane, cell wall and sticky, mucous layer called a capsule.

More resistant to antibiotics and desiccation

The famous "transformation" experiments" (smooth & rough) revolved around this feature

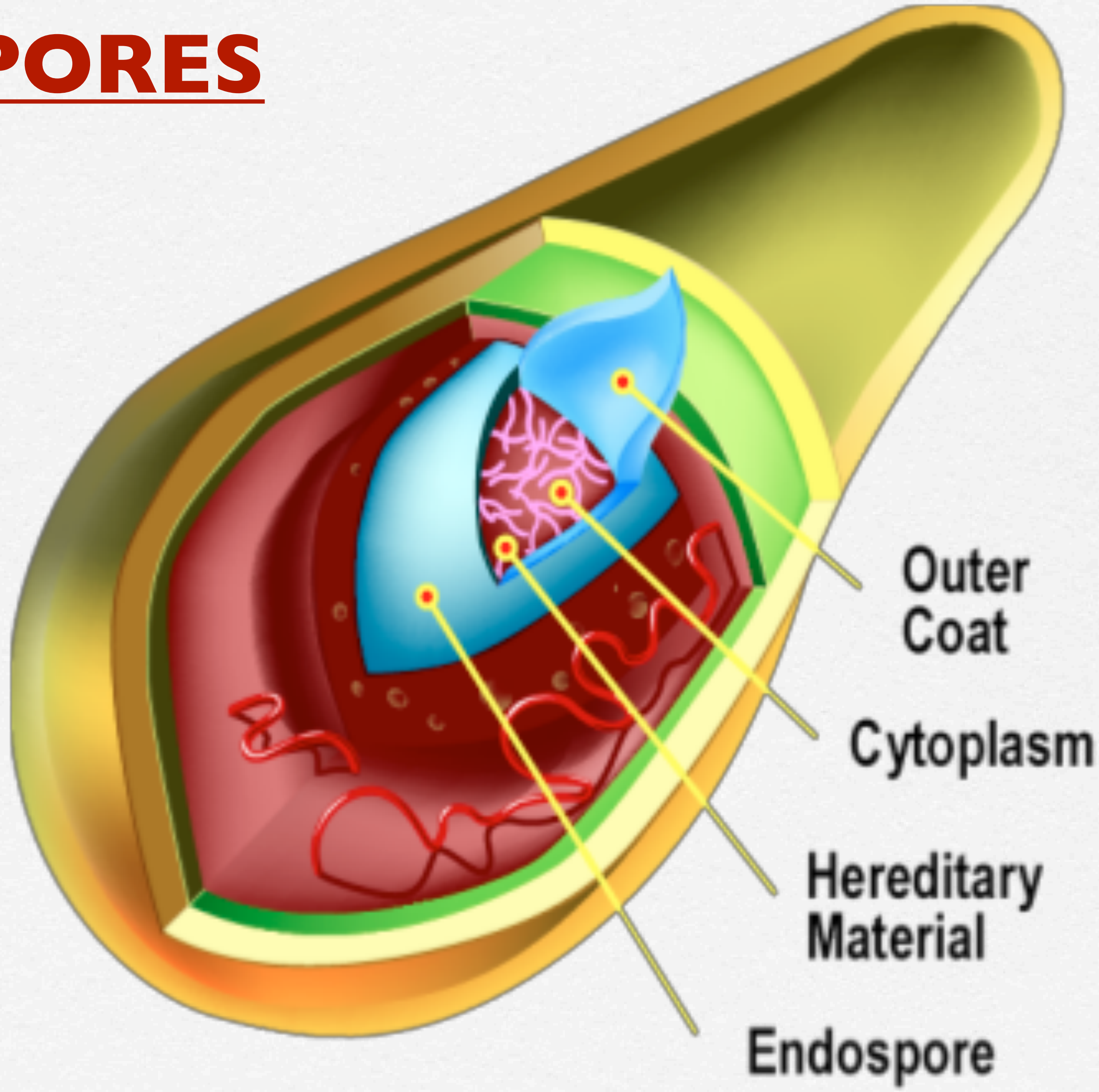


Bacterial Endospores

- When environmental conditions become hostile some bacteria can form tough, protective coat around its DNA called an *endospore*.
- Endospores allow bacteria lie dormant for millions of years or until conditions improve.
- Endospores survive without nutrition and resist extreme heat, freezing, UV radiation, desiccation and chemical disinfectants
  - EX. *Bacillus anthracis* (anthrax)
  - EX. *Clostridium tetani* (tetanus)

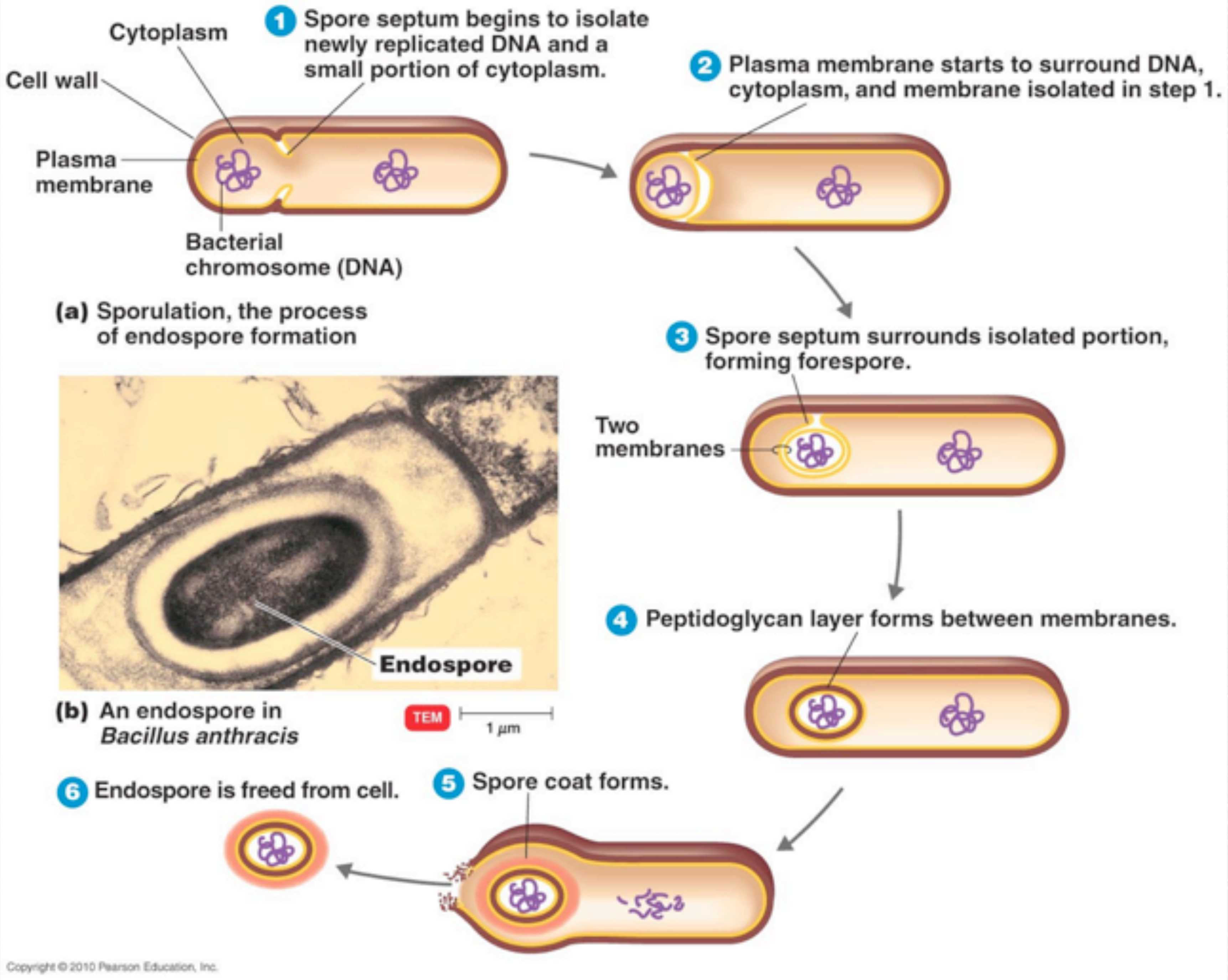
Bacterial Endospores

- **ENDOSPORES**



Bacterial Endospores

- **Endospore Formation**



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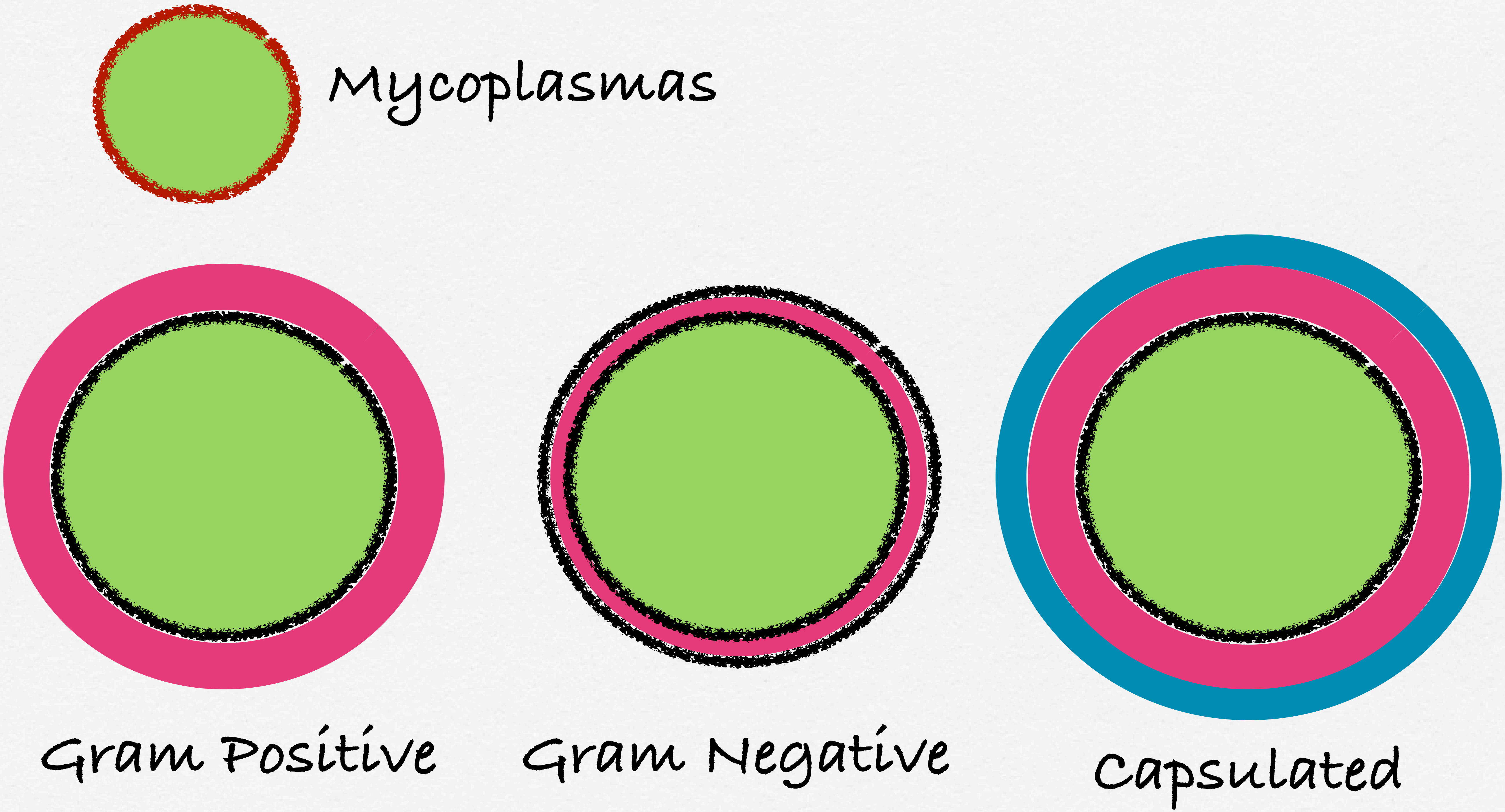
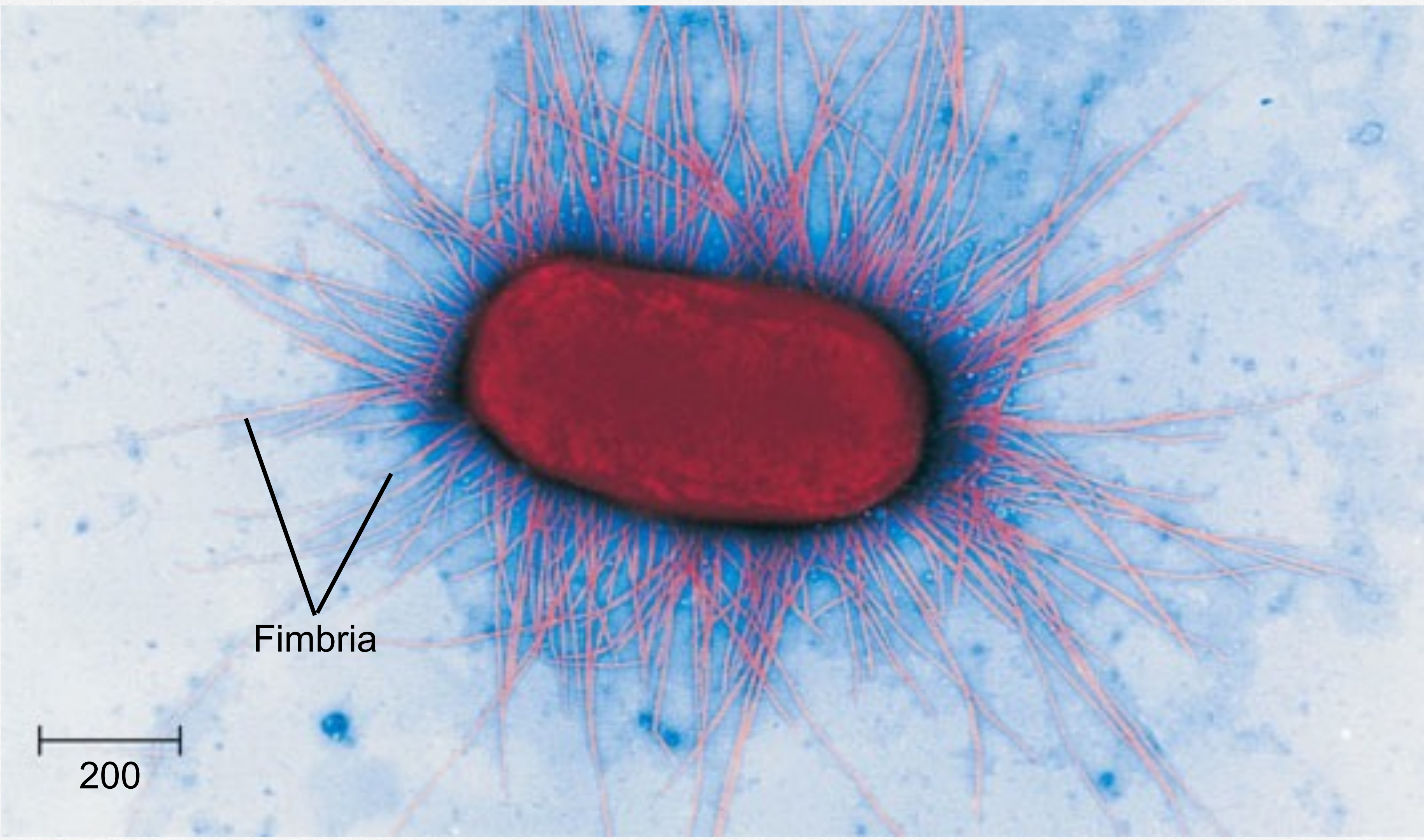
Summary of Bacterial Forms



Bacterial Surface Structures

- **Fimbriae and Pili**



These structures help bacteria to stick to each other or a host

Bacterial Locomotion

- ***For many organisms, Responding to environmental stimuli often involves moving to or away from a stimulus***.
    - ***Locomotion***- is the ability to move place to place, the act of self propulsion.
    - Bacteria exhibit ***taxi***, the movement toward or away from stimuli

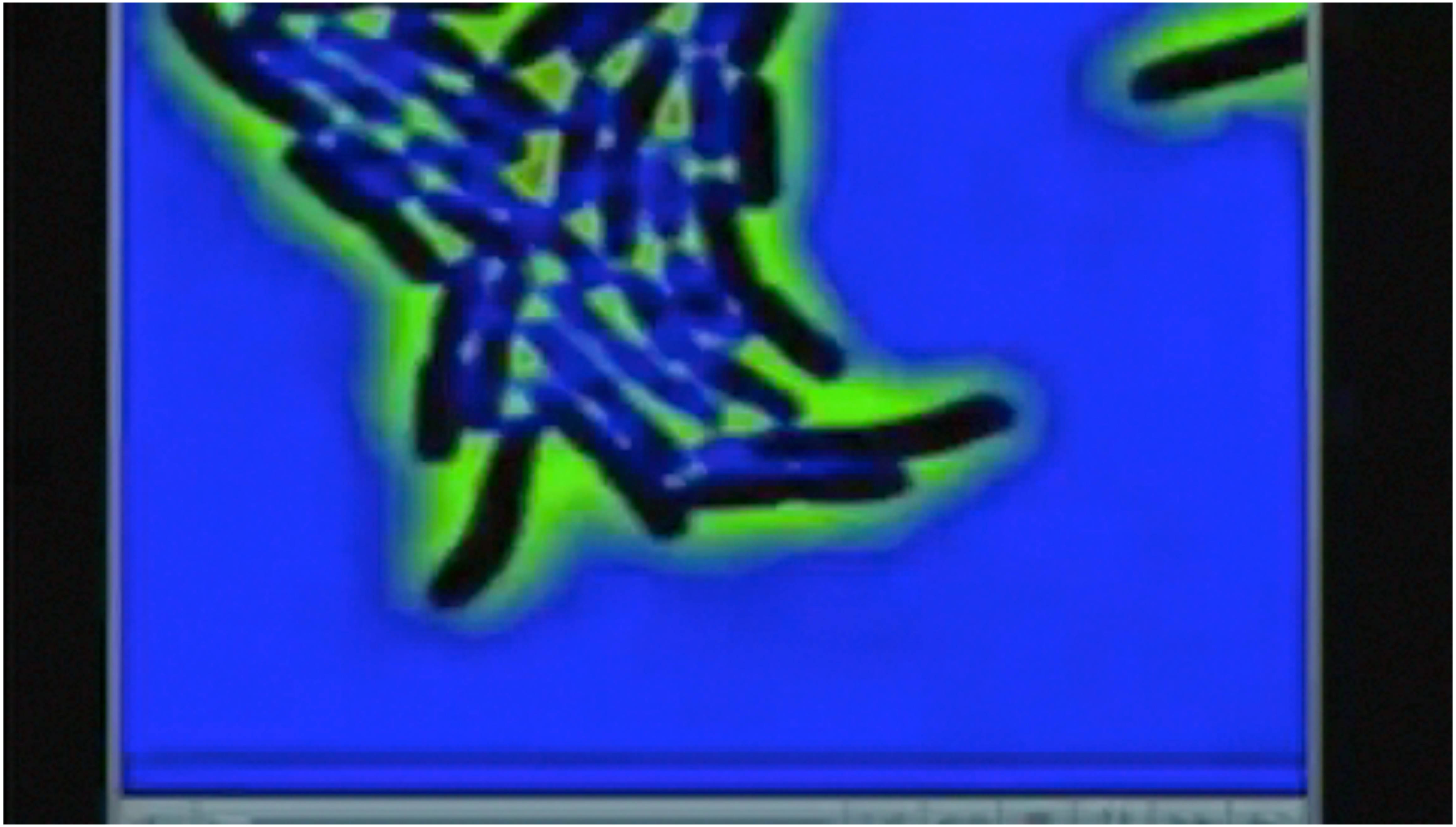
Trade-Offs of Locomotion

- **Motility certainly has its advantages.**
  - Helps to search and obtain food.
  - Allows organisms to disperse or migrate
  - Helps organisms to avoid predation or other dangerous stimuli
- **Motility also has a price**
  - Energetically it is expensive!

Bacterial Locomotion

- **Bacteria move a number a different ways.**
  - **Swimming**
    - uses flagella which vary in position and number on different bacteria
    - rate of 10-60 cell lengths/sec, a cheetah moves at a rate of 25 body lengths/sec (on our scale equivalent to 190mph)
  - **Gliding and/or Twitching**
- uses a “grappling hook” that is extended, anchored and retracted with great force
  - Move vertically by **adjusting buoyancy**

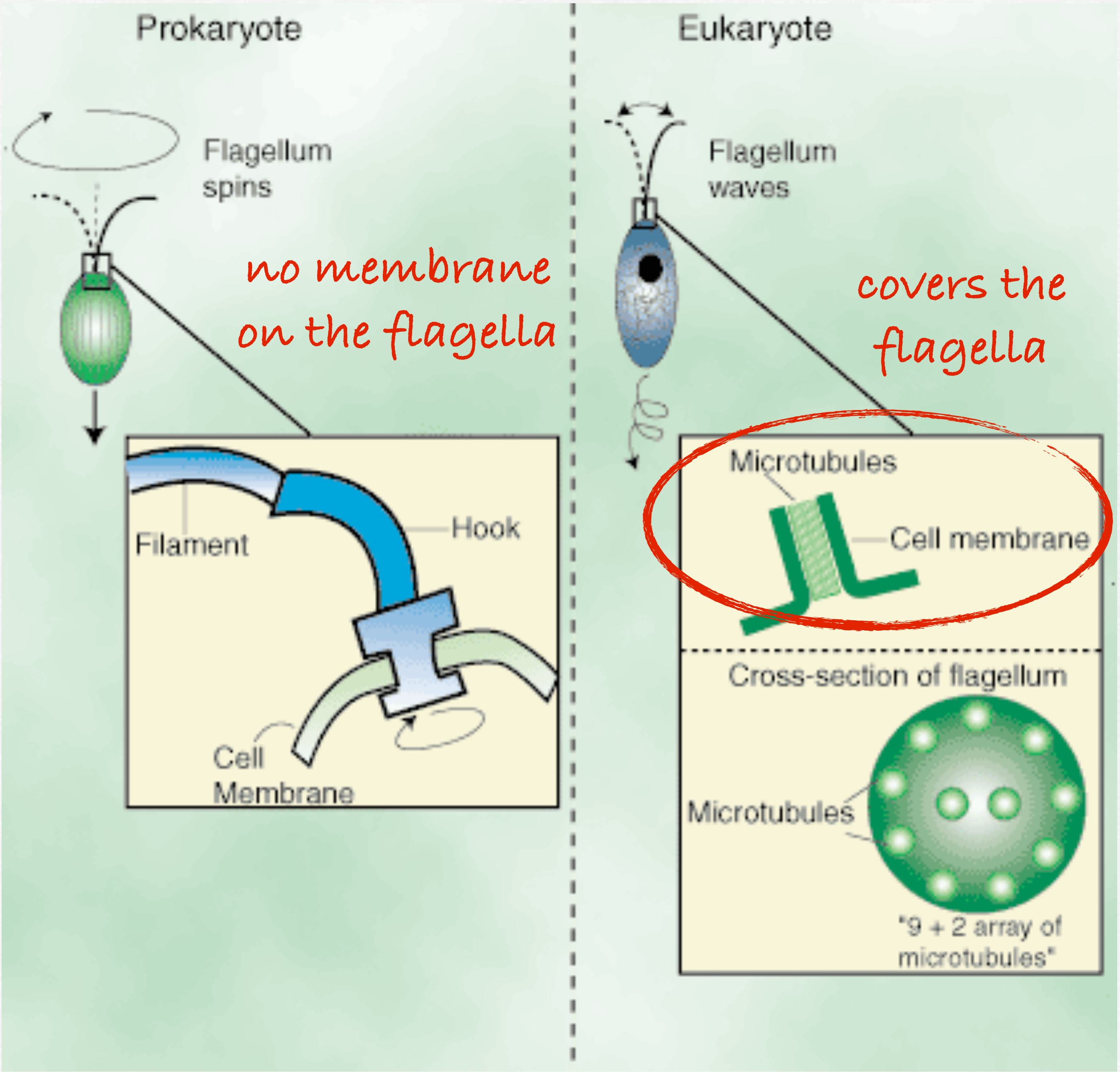
Bacterial Flagella



Bacteria invented the wheel!

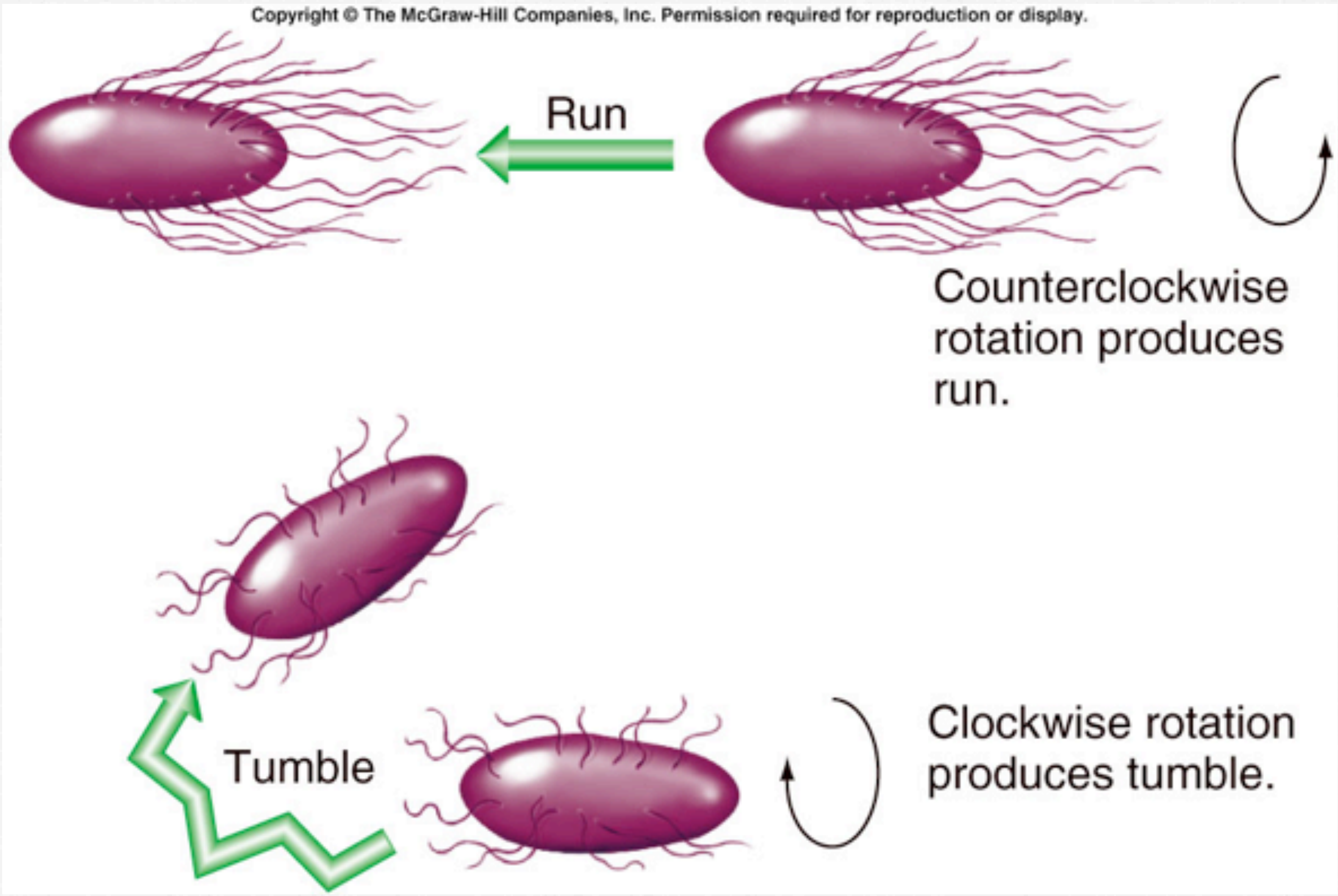
Bacterial Flagella

- **Differs in structure and function of eukaryotic flagella.**
  - Eukaryotic flagella produces a "whip-like" motion
    - wider
  - Prokaryotic flagella produces a "propeller" motion
    - thinner



Bacterial Flagella

- **Prokaryotic flagella can navigate by changing the rotation of its flagella**
  - Clockwise rotation causes the bacteria to "tumble" and change direction
  - Counter-Clockwise rotation causes the bacteria to "run" in one straight or curved



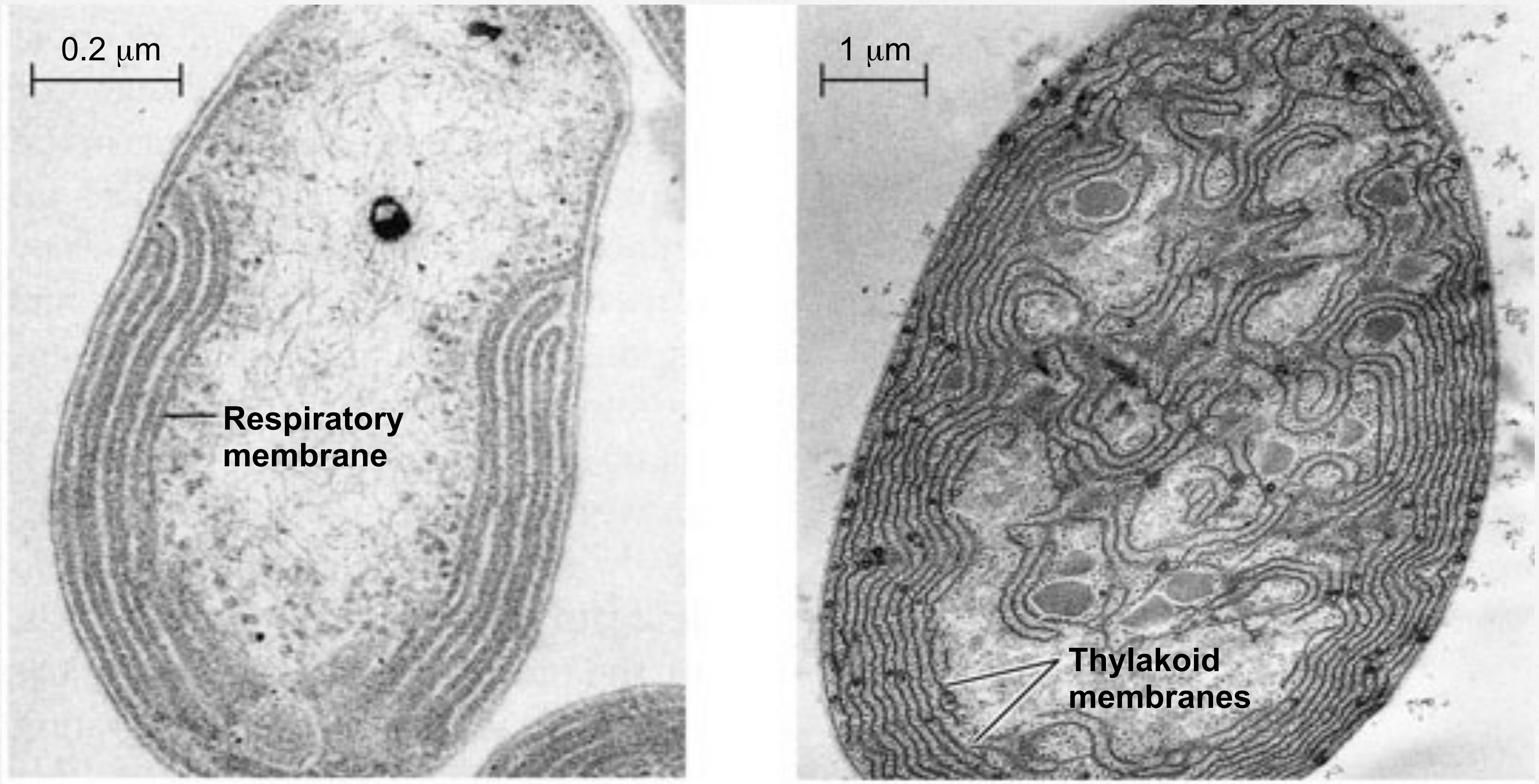
Bacterial Organelles

- Prokaryotic cells are simple
  - They have cytosol
  - They have ribosomes
  - They have inclusions
    - *deposits of nutrient/chemical reserves*
  - They lack membrane bound organelles.
  - *They lack the complex "compartmentalization" found in eukaryotic cells*

Bacterial Organelles

- Prokaryotic cells make up for the lack of specialized membrane bound organelles such as *mitochondria* and *chloroplasts* with specialized membranes.

Some have membranes that perform metabolic functions.

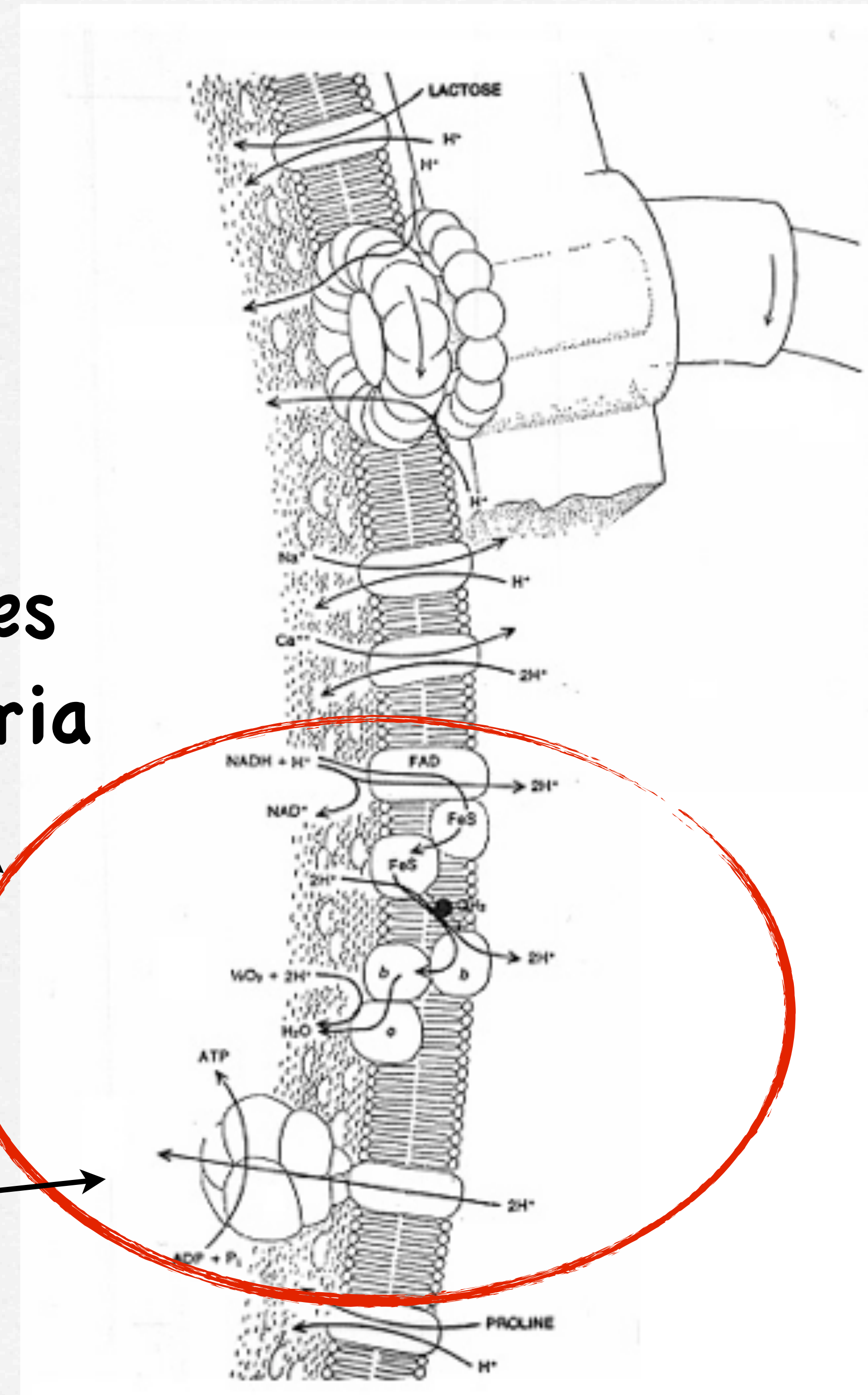


(a) Aerobic prokaryote (b) Photosynthetic prokaryote

Bacterial Organelles

Some have membranes that perform metabolic functions, like cellular respiration.

Electron Transport Chain, found in eukaryotic mitochondria here it resides in the plasma membrane of the bacteria



ATP Synthase

How do bacteria process energy?

- As a group bacteria can use any and all nutritional mode.

- Phototrophs: obtain energy from light
- Chemotrophs: obtain energy from chemicals
- Autotrophs: obtain carbon from CO_2
- Heterotrophs: obtain carbon from organic sources
- COMBINING THE DIFFERENT SOURCES OF ENERGY AND CARBON RESULTS IN 4 MAJOR NUTRITIONAL MODES.

Table 27.1 Major Nutritional Modes

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

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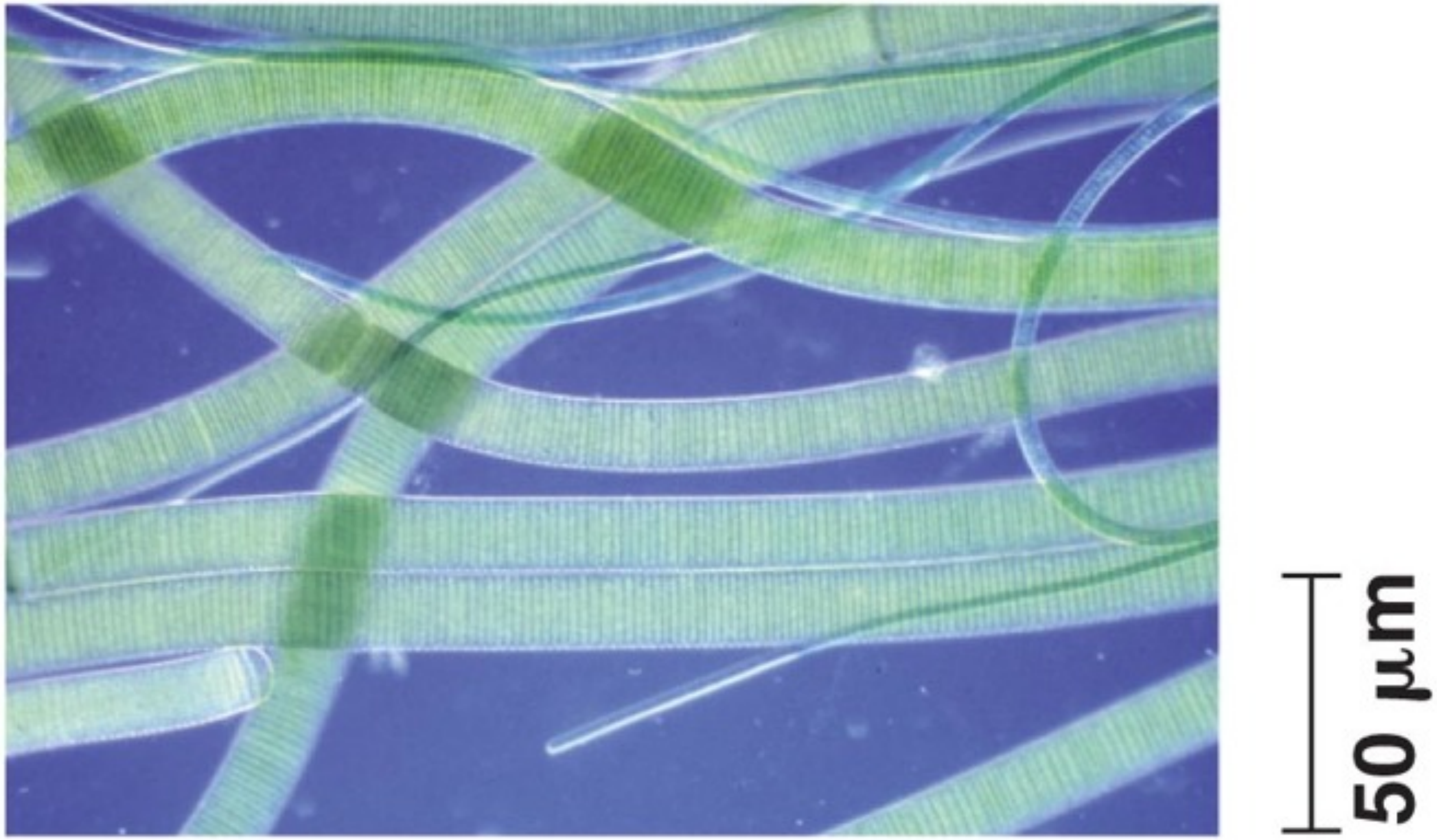
Cyanobacteria PHOTOAUTOTROPHS

Important component of phytoplankton

Some also fix nitrogen



Two species of *Oscillatoria*, filamentous cyanobacteria (LM)

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PHOTOAUTOTROPHS

Photosynthesis with water:

$$CO_2 + H_2O \xrightarrow[\text{bacteriochlorophyll}]{\text{light}} O_2 + CH_2O$$

Photosynthesis with water:

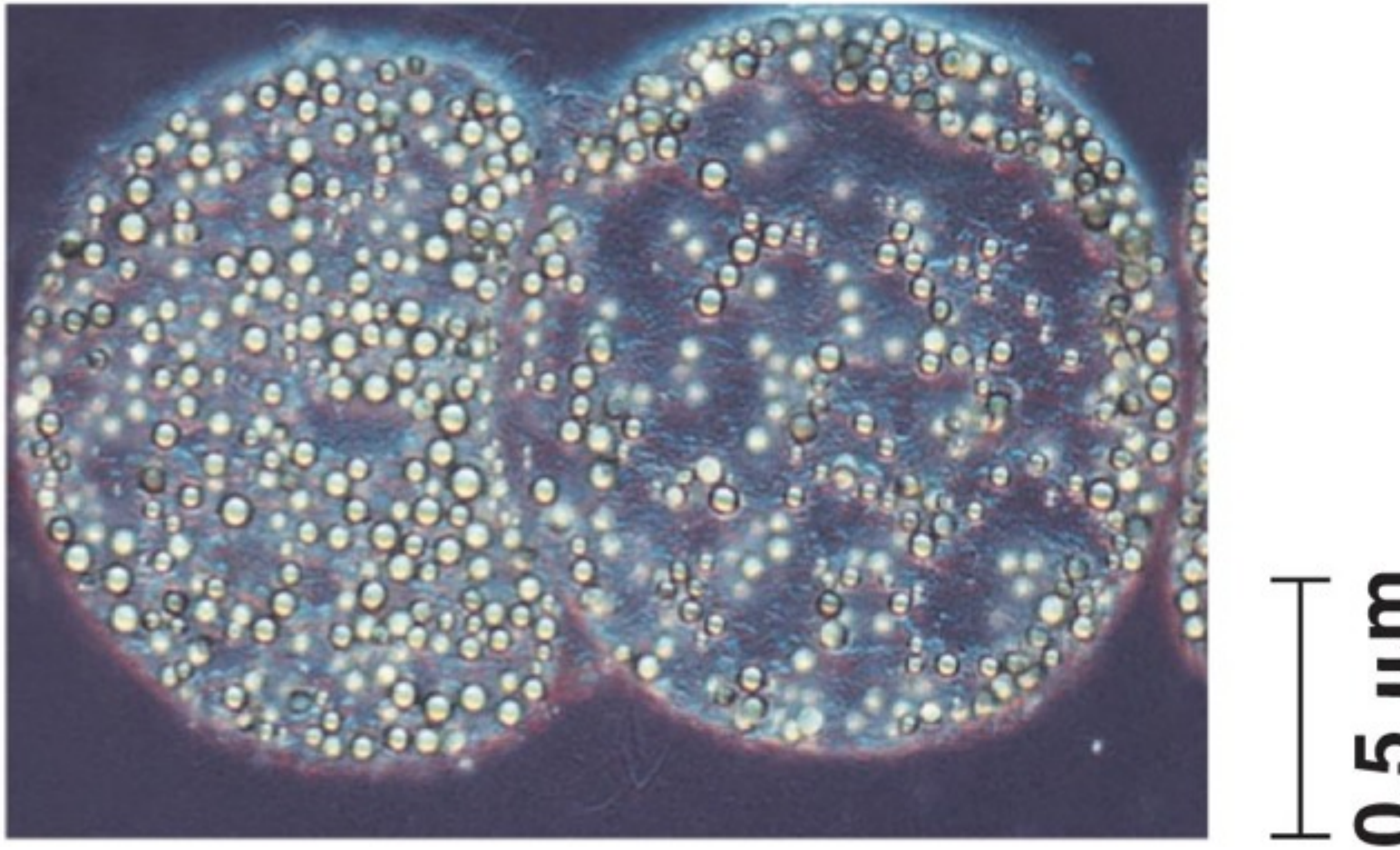
$$CO_2 + H_2S \xrightarrow[\text{bacteriochlorophyll}]{\text{light}} S_x + CH_2O$$

Gamma Proteobacteria

CHEMO-AUTOTROPHS

These bacteria acquire energy through hydrogen sulfide

This group is responsible for food poisoning...salmonella, cholera and e-coli



Thiomargarita namibiensis containing sulfur wastes (LM)

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CHEMOAUTOTROPHS

Nitrification:

$$CO_2 + NH_4^+ \longrightarrow NO_2^- + CH_2O$$

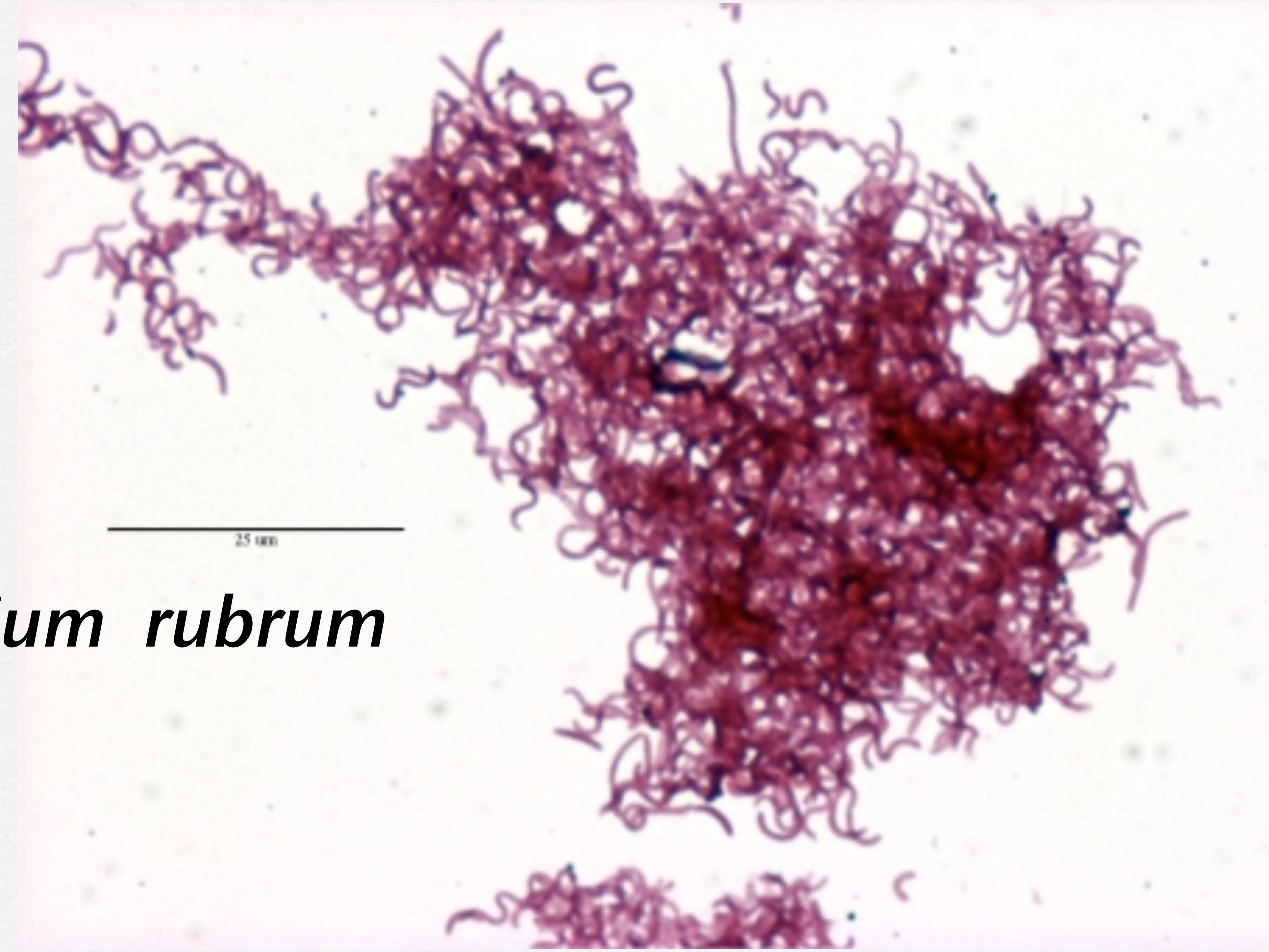
To blame for the biological corrosion of metals

Often uses heavy metal ions in its Redox reactions.

Can you suggest an environmental application for these bacteria?

Clean up of heavy metals in polluted soils

Purple Bacteria   PHOTOHETEROTROPH



Rhodospirillium rubrum

PHOTOHETEROTROPHS

Photoheterotrophic pathway:

$$C_2H_4O_2^- + H_2O \xrightarrow[\text{bacteriochlorophyll, spirillaxanthin}]{\text{light}} O_2 + CH_2O$$

unique to certain aquatic and salt-loving prokaryotes

Actinomycetes

CHEMOHETEROTROPHS

This particular species produces very useful antibiotics

Decomposers

***Streptomyces*, the source of many antibiotics (colorized SEM)**

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CHEMOHETEROTROPHS

Respiration: This is the mode that we use as humans.

$$CH_2O + H_2O \longrightarrow CO_2 + H_2O + ATP$$

IMPORTANT

Recall: Bacteria do not have mitochondria so glycolysis and the citric acid cycle takes place in the cytosol while oxidative phosphorylation takes place in the...

mesosomes (specialized infoldings of the plasma membrane).

Recall: Not all bacteria are aerobic (require oxygen).

There are other pathways that do not require oxygen, they are generically called fermentation.

Bacterial Energy Metabolism

- **Every cell uses ATP as its energy currency or cellular fuel.**
- **Autotrophs utilizes solar energy to build organic molecules out of carbon dioxide**
  - **Photosynthesis**
- **Heterotrophs and autotrophs utilize the chemical energy in organic molecules to produce ATP**
  - **Cell respiration**
- **Most** eukaryotic cells and **some** prokaryotic carry out aerobic respiration
  - It is likely that even anaerobic cells exchange some gases
- Both photosynthesis and aerobic cell respiration require the exchange of carbon dioxide and oxygen.

Bacterial Energy Metabolism

- Not all bacteria require oxygen!
- Every cell uses ATP as its energy currency or cellular fuel.
- But not all ATP production requires oxygen.
- Aerobic cell respiration utilizes the chemical energy in organic molecules to produce ATP and it requires oxygen to do so.
  - this type of respiration generates the most ATP and most cells require much ATP, thus they depend on oxygen
- Anaerobic Cell Respiration and Fermentation utilize the chemical energy in organic molecules to produce ATP and BUT they do not require oxygen to do so.
  - these mechanisms generate much less ATP, but some cells (bacteria) do require much ATP, thus they do not require oxygen

Cell Respiration & Fermentation

- Both Aerobic and Anaerobic Respiration harvest chemical energy from organic molecules and produce ATP
  - BOTH REQUIRE membranes and oxygen (or some other electron acceptor)
    - (they also need proton gradients, electron carriers, electron acceptors and ATP synthase enzymes)
- Fermentation also harvests chemical energy from organic molecules and produces ATP
  - But DOES NOT REQUIRE membranes and oxygen

Respiration: Aerobic vs. Anaerobic

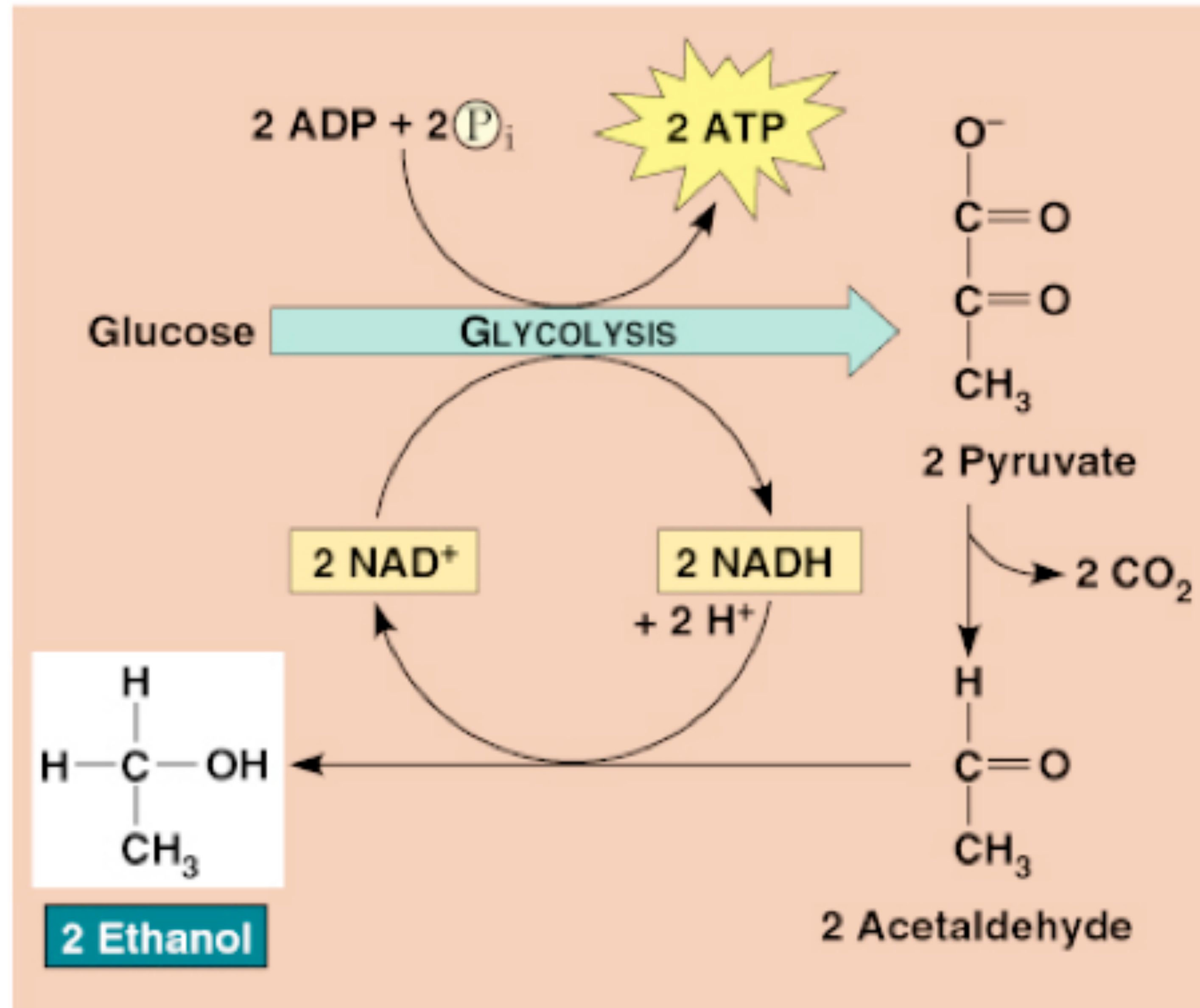
- Aerobic and Anaerobic Respiration utilize membranes, proton gradients, electron carriers, electron acceptors and ATP synthase enzymes.
- In aerobic respiration oxygen serves as the final electron acceptor in the electron transport chain and integral component in respiration.
  - **Aerobic Respiration requires oxygen.**
- In anaerobic respiration a molecule other than oxygen serves as the final electron acceptor in the electron transport chain.
  - **Anaerobic Respiration does not require oxygen.**

Bacteria: Alcohol Fermentation

- Fermentation, Aerobic Respiration and Anaerobic Respiration all three breakdown organic molecules into a 3 carbon compound called pyruvate, produce 2 ATP and harvest electrons (this called Glycolysis).
- Technically the difference lies in the fate of these electrons, but we will learn about this later.
  - *When electrons are carried away to an electron transport chain we call that mechanism respiration.*
  - *When electrons are transferred to another organic molecule we call that fermentation.*
- **Fermentation is special type of glycolysis neither requires oxygen!**

Bacteria: Alcohol Fermentation

- Two common types include alcohol fermentation (prokaryotes) and lactic acid fermentation (eukaryotes).



(a) Alcohol fermentation

Aerobic vs. Anaerobic Bacteria

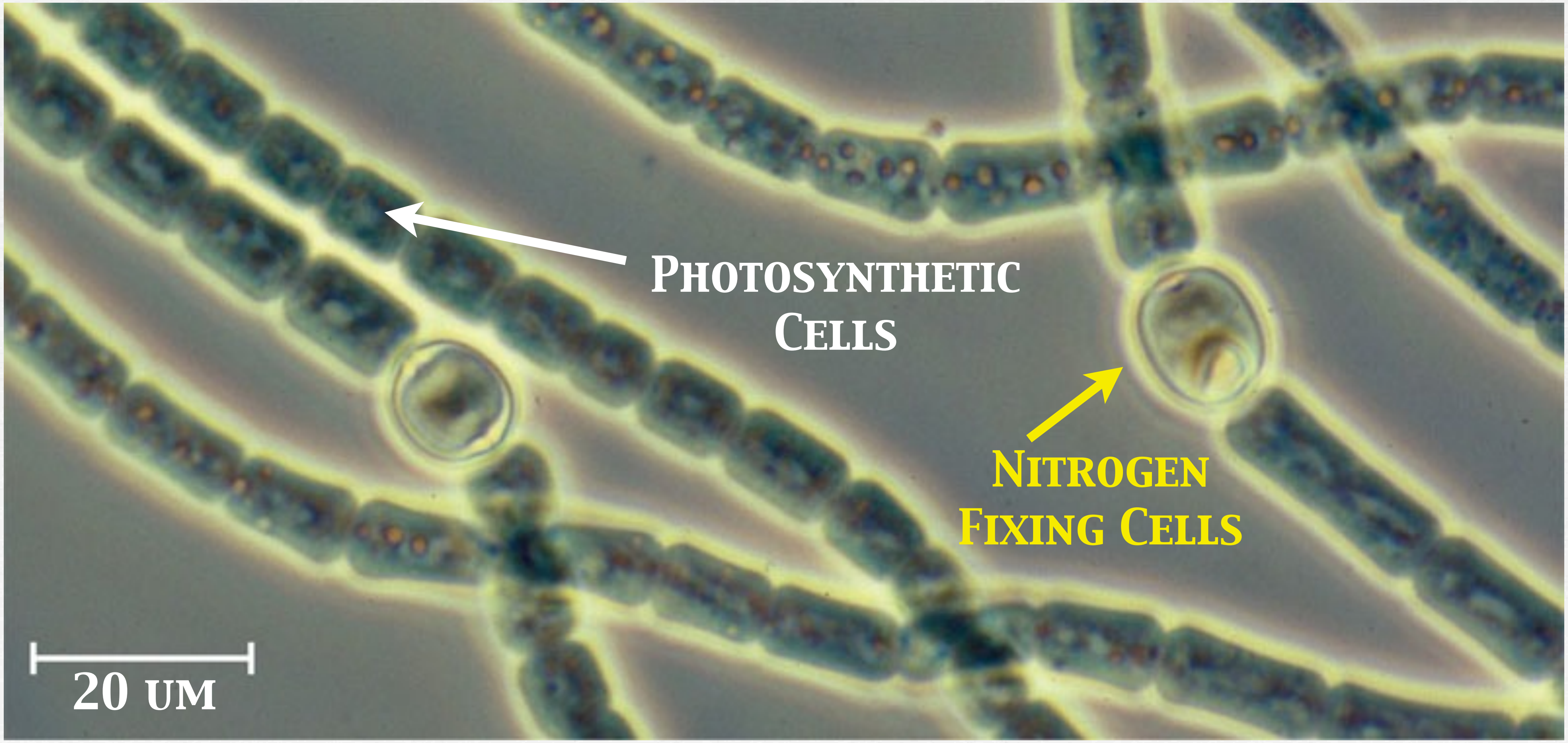
- Obligate Aerobes require oxygen to survive.
- Obligate Anaerobes can not use oxygen and is toxic.
- Aerotolerant organisms can not use oxygen but can tolerate it.
- Facultative anaerobes can survive without oxygen but they can utilize oxygen if present.
- Microaerophiles require oxygen but in very small concentrations

Bacterial Nitrogen Metabolism

- Bacteria can metabolize nitrogen from a variety of different forms
    - *Eukaryotes can only utilize a limited number of nitrogen compounds*
- Cyanobacteria only need CO_2, N_2, H_2O and some minerals
    - *Cyanobacteria play an important role ecologically as they make nitrogen compounds more readily available to aquatic producers nitrogen compounds*
        - *they are one of few "nitrogen fixers"*

Bacterial Metabolic Cooperation

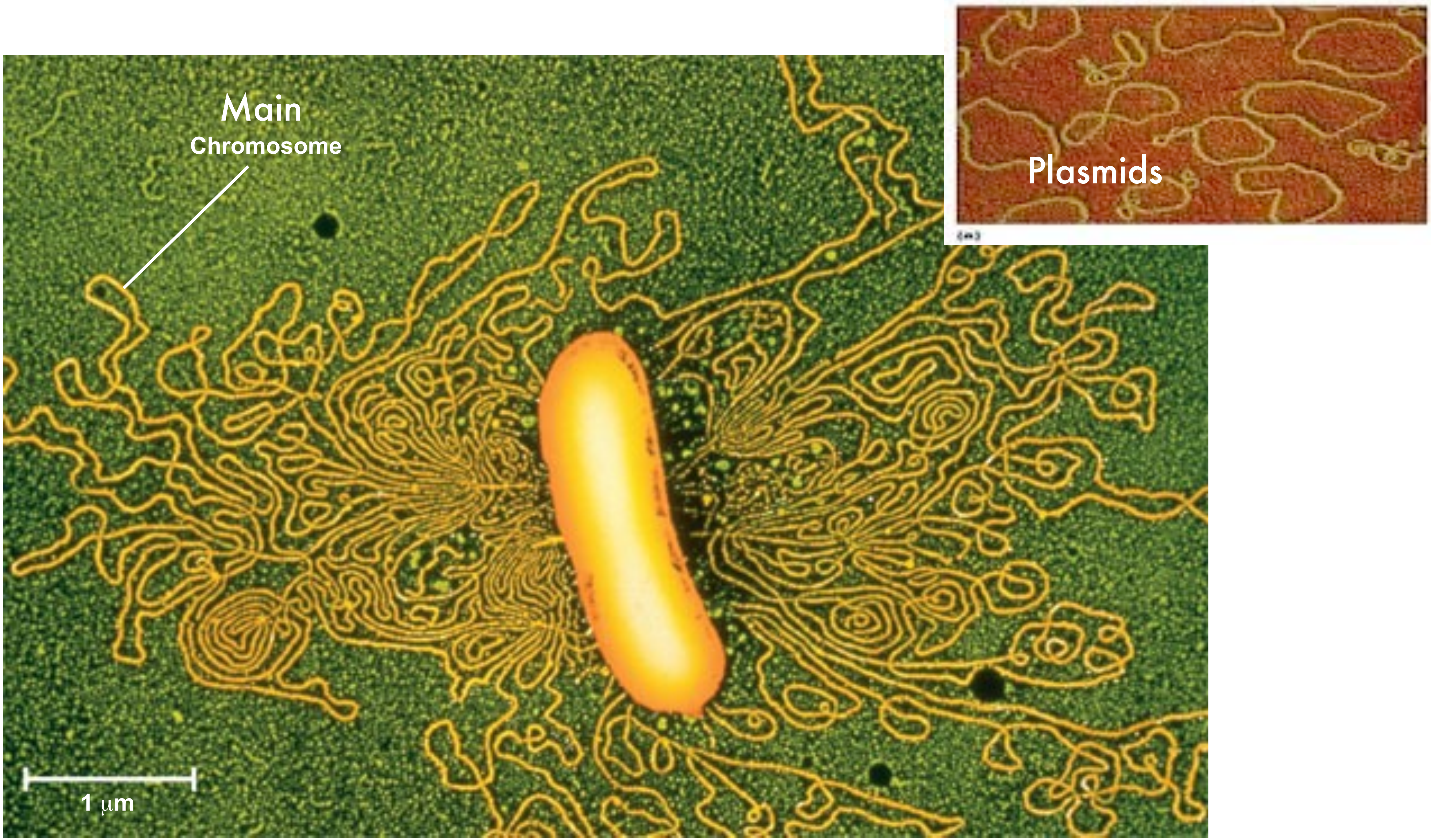
- Some bacteria cooperate with each other so that each may use a resource that would otherwise be unavailable to them.



Where do bacteria store their DNA?

- Bacterial DNA is found in a large circular chromosome with very few proteins.
- The chromosome is located in a nucleoid region.
  - *remember no membrane bound organelles like a nucleus*
- Some bacteria have small circular accessory chromosome called plasmids.
  - *these reproduce independent from the main chromosome*
  - *these are often utilized in the biotech industry*
  - *they often carry resistant type genes (called r plasmids)*

Bacterial Chromosome



How do bacteria reproduce?

- Prokaryotes reproduce asexually and very quickly in favorable environments.
- Ideal conditions bacteria can reproduce every 1-3 hours.
  - some as fast as every 20 minutes and others slower every few days.
- If ideal conditions were unlimited, a single bacteria could produce a colony that outweighed the earth in two days.

In reality reproduction is limited...nutrients limited, waste becomes toxic, they are consumed, competition increases, etc

How do bacteria reproduce?

- Prokaryotes are small, they have short generations and reproduce by binary fission.
- As a result bacterial colonies can approach the trillions, they reproduce at incredible rates and adapt quickly to environmental challenges.

Binary Fission

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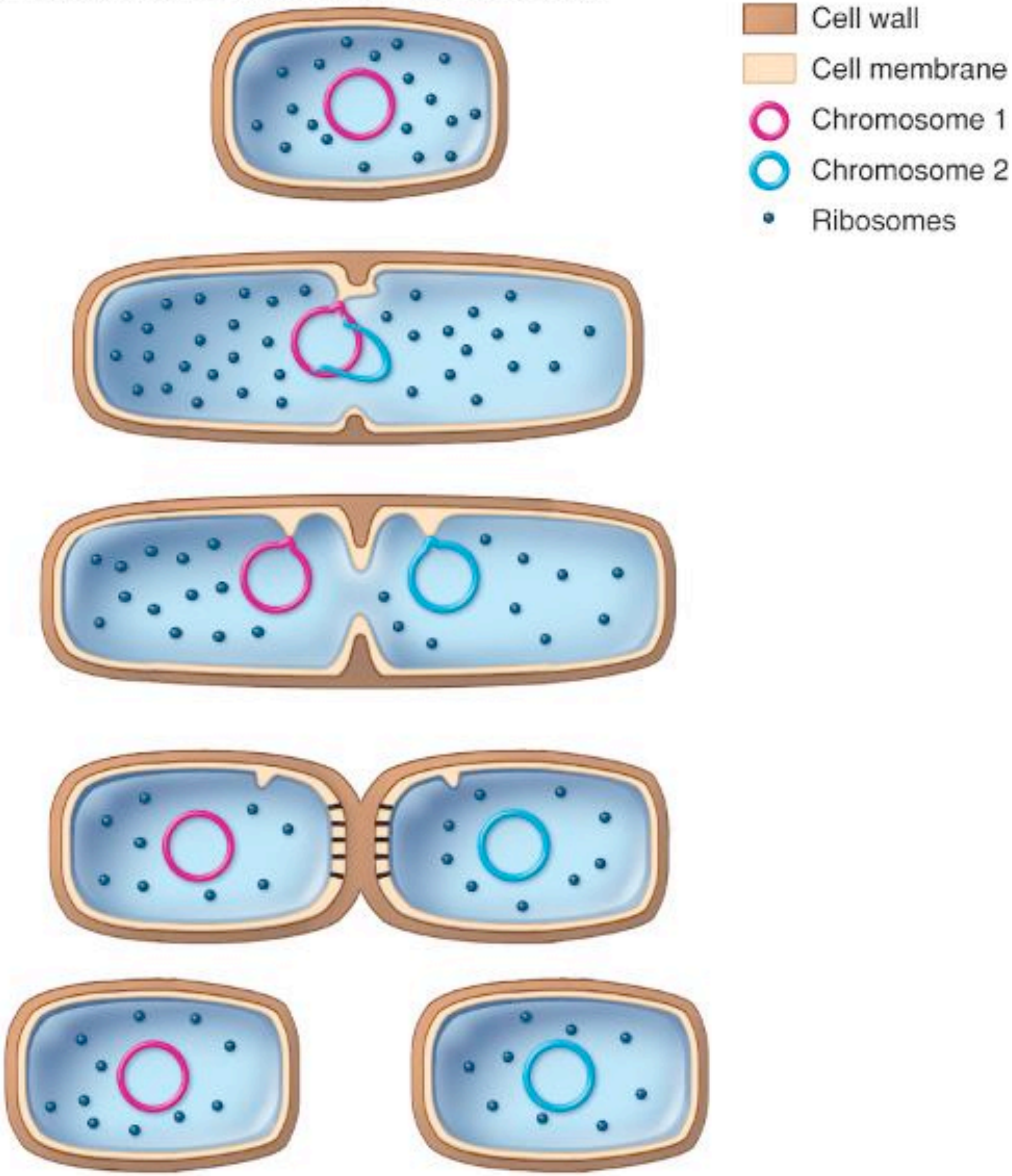
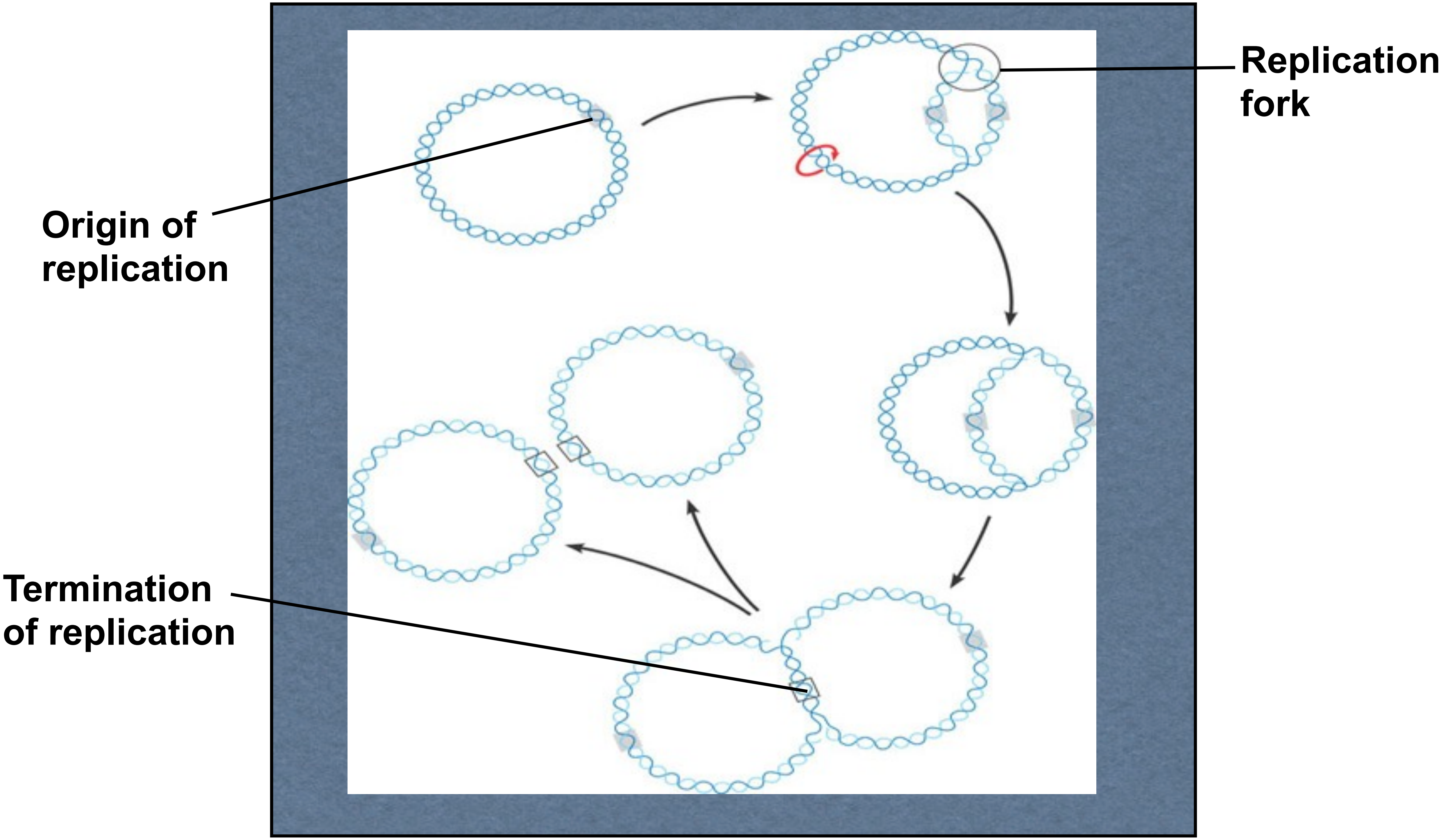
1. A young cell at early phase of cycle
2. A parent cell prepares for division by enlarging its cell wall, cell membrane, and overall volume. Midway in the cell, the wall develops notches that will eventually form the transverse septum, and the duplicated chromosome becomes affixed to a special membrane site.
3. The septum wall grows inward, and the chromosomes are pulled toward opposite cell ends as the membrane enlarges. Other cytoplasmic components are distributed (randomly) to the two developing cells.
4. The septum is synthesized completely through the cell center, and the cell membrane patches itself so that there are two separate cell chambers.
5. At this point, the daughter cells are divided. Some species will separate completely as shown here, while others will remain attached, forming chains or doublets, for example.



Bacterial Reproduction

- Keep in mind binary fission is preceded by the replication of the bacterial chromosome.



What mechanisms generate genetic variation in bacteria?

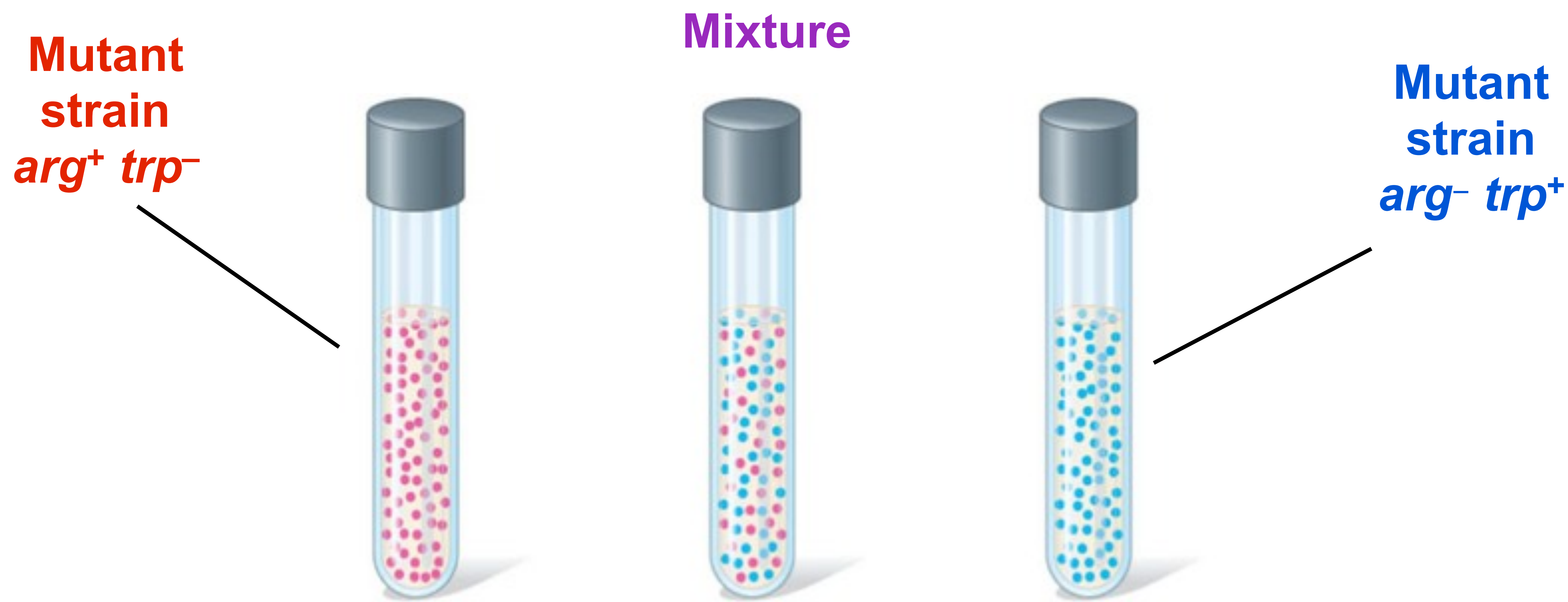
- Bacteria rely on **mutations** to generate their genetic variation.
  - *Ultimately all living organisms rely on mutations, they are the ultimate source of any and all genetic variation.*
- The **rate of asexual bacterial reproduction** is so fast that they can rely on mutations to generate variation from one generation to the next.

Is it likely that bacteria, as ancient as they are, rely solely on mutations?

See next slides for answer

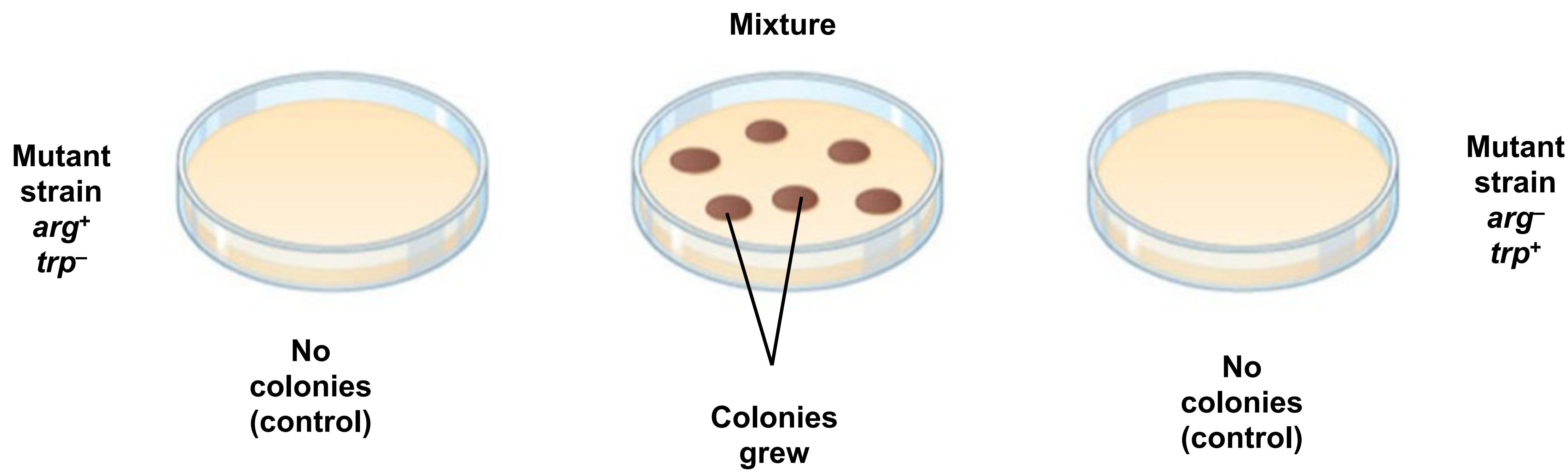
Genetic Recombination in Bacteria?

EXPERIMENT Researchers had two mutant strains, one that could make arginine but not tryptophan (*arg*⁺ *trp*⁻) and one that could make tryptophan but not arginine (*arg*⁻ *trp*⁺). Each mutant strain and a mixture of both strains were grown in a liquid medium containing all the required amino acids. Samples from each liquid culture were spread on plates containing a solution of glucose and inorganic salts (minimal medium), solidified with agar.



RESULT Only the samples from the mixed culture, contained cells that gave rise to colonies on minimal medium, which lacks amino acids.

Genetic Recombination in Bacteria?



CONCLUSION **Because only cells that can make both arginine and tryptophan (*arg*$^+$ *trp*$^+$ cells) can grow into colonies on minimal medium, the lack of colonies on the two control plates showed that no further mutations had occurred restoring this ability to cells of the mutant strains. Thus, each cell from the mixture that formed a colony on the minimal medium must have acquired one or more genes from a cell of the other strain by genetic recombination.**

Apparently they do not rely solely on mutations!

Gene Transfer & Genetic Recombination

- Because of experiments like this one, today we know that bacteria generate variation in number of different ways.
  - *This is no way diminishes the importance or significance of mutations.*
- Bacteria can bring together DNA from one bacteria to another in the following ways:
  - **Transformation**
  - **Transduction**
  - **Conjugation**

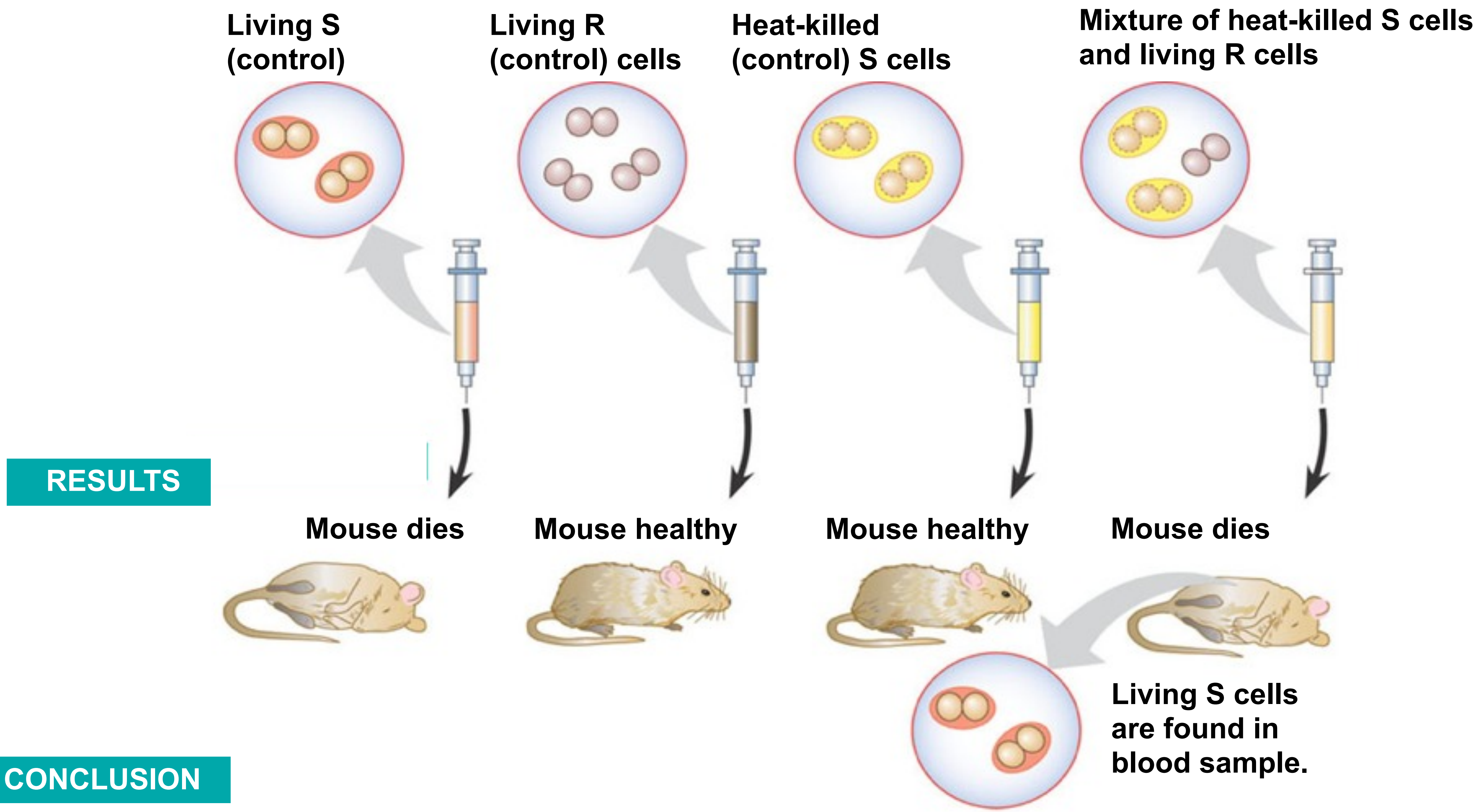
Transformation

- Bacteria can uptake naked DNA from their surroundings and incorporate these genes into their own genome.
  - *Bacteria will not take up any DNA they are able recognize closely related species/DNA.*
- Transformation will can alter a bacteria's genetic make up thus its phenotype
- Recall Griffith's Experiment:

1928 Frederick Griffith

EXPERIMENT

Bacteria of the "S" (smooth) strain of *Streptococcus pneumoniae* are pathogenic because they have a capsule that protects them from an animal's defense system. Bacteria of the "R" (rough) strain lack a capsule and are nonpathogenic. Frederick Griffith injected mice with the two strains as shown below:



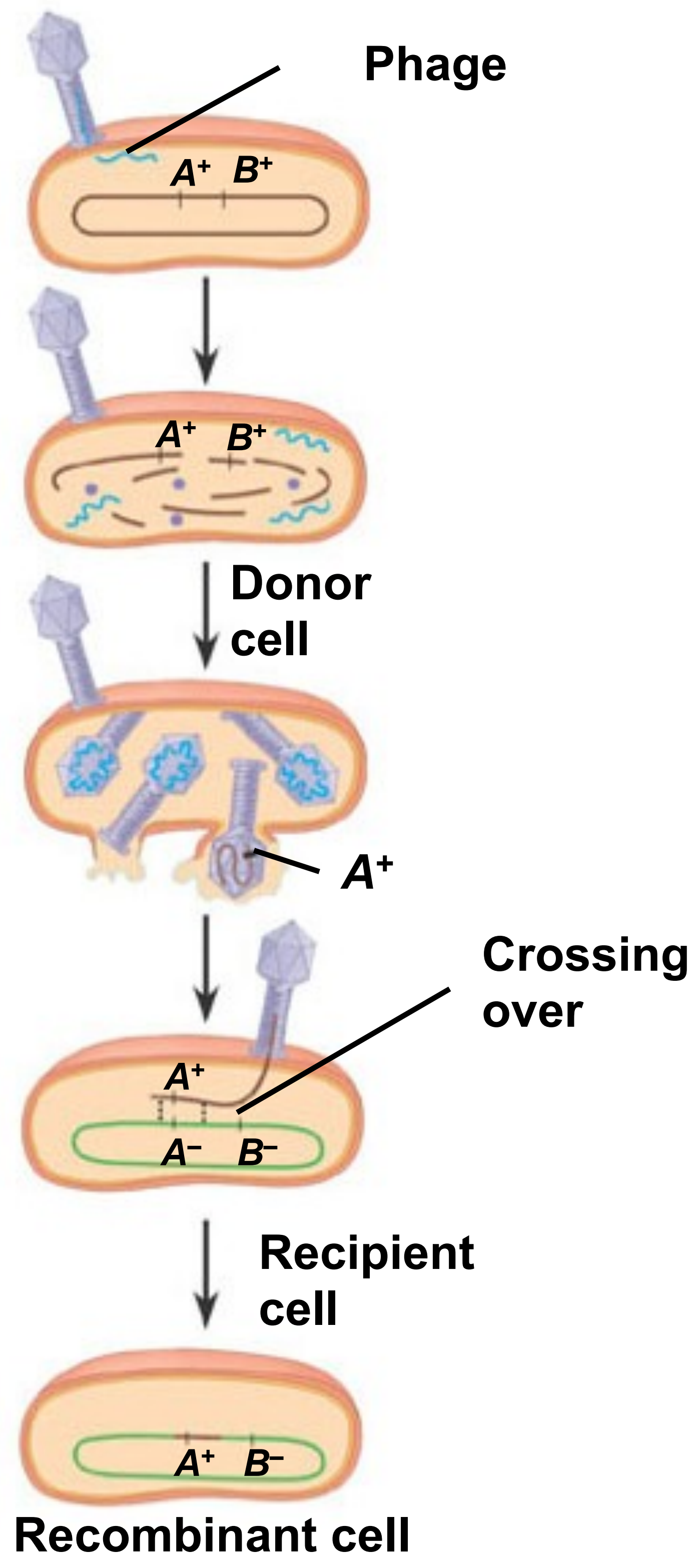
CONCLUSION

Griffith concluded that the living R bacteria had been transformed into pathogenic S bacteria by an unknown, heritable substance from the dead S cells.

Transduction

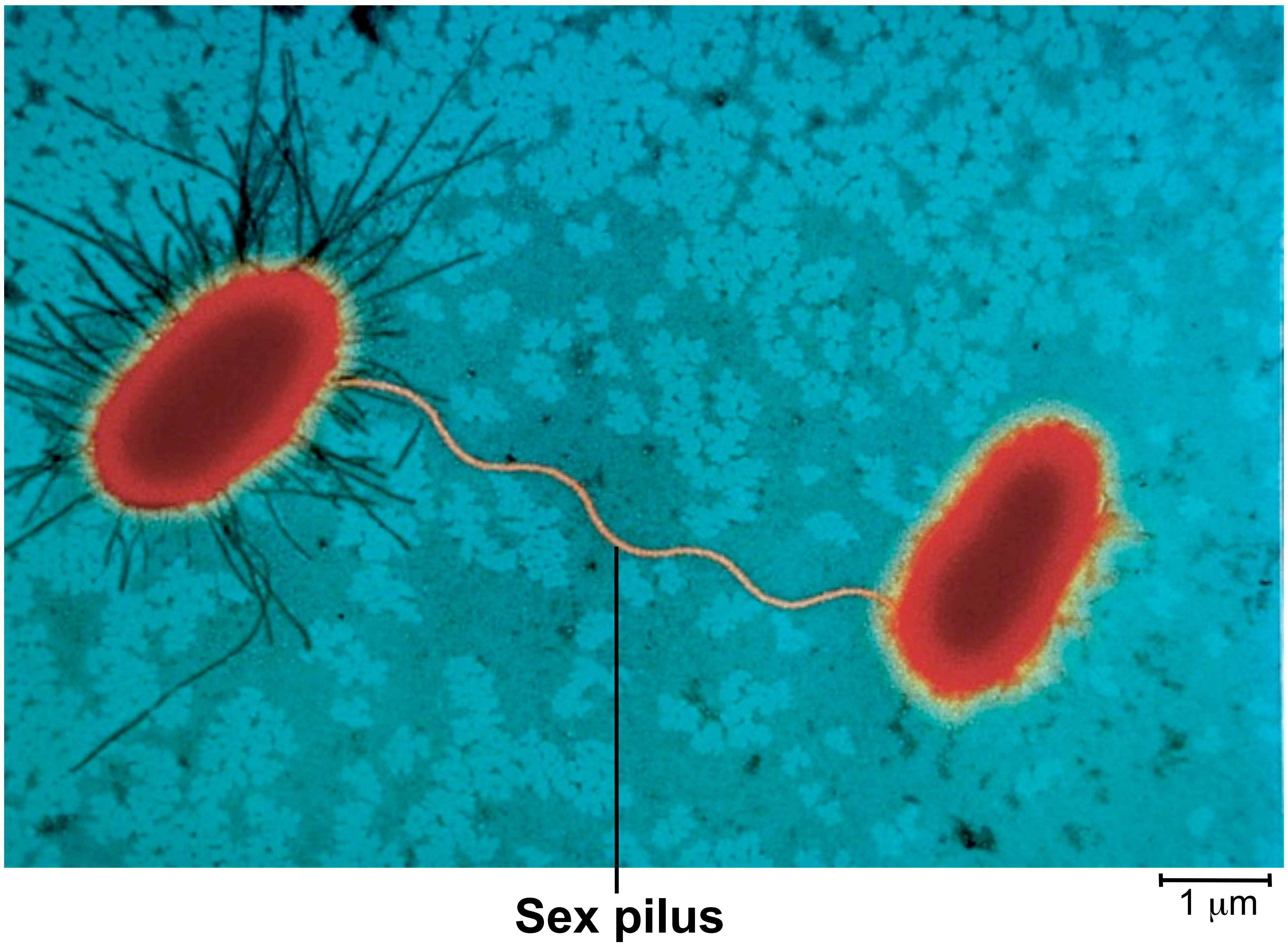
- Sometimes bacteriophages (viruses) can accidentally transfer bacterial genes between two different bacteria.

1. **Phage infects bacterial cell that has alleles A^+ and B^+**
2. **Host DNA (brown) is fragmented, and phage DNA and proteins are made. This is the donor cell.**
3. **A bacterial DNA fragment (in this case a fragment with the A^+ allele) may be packaged in a phage capsid.**
4. **Phage with the A^+ allele from the donor cell infects a recipient A^-B^- cell, and crossing over (recombination) between donor DNA (brown) and recipient DNA(green) occurs at two places (dotted lines).**
5. **The genotype of the resulting recombinant cell (A^+B^-) differs from the genotypes of both the donor (A^+B^+) and the recipient (A^-B^-).**



Conjugation

- DNA is transferred between two bacterial cells of the same species while they remain temporarily joined.



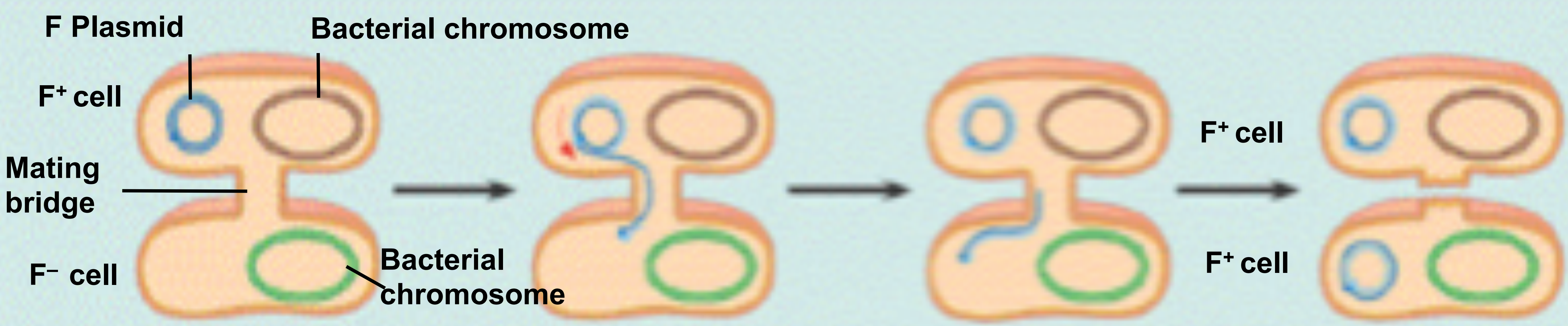
Is this Sex? NO, but there are some striking similarities

Conjugation

- Bacterial cells that posses a certain plasmid, called an F plasmid can transfer DNA to another cell.
    - *We call these "donor" type bacteria F+ bacteria.*
- Bacterial cells that do not posses a certain plasmid, called an F plasmid can not transfer DNA to another cell.
    - *We call these "recipient" type bacteria F- bacteria.*

Conjugation

- Below you will see a F+ bacteria transferring a copy of its F+ plasmid to a F- bacteria thereby changing it to a F+ bacteria . No recombination here just plasmid transfer



A cell carrying an F plasmid (an F+ cell) can form a mating bridge with an F– cell and transfer its F plasmid.

A single strand of the F plasmid breaks at a specific point (tip of blue arrowhead) and begins to move into the recipient cell. As transfer continues, the donor plasmid rotates (red arrow).

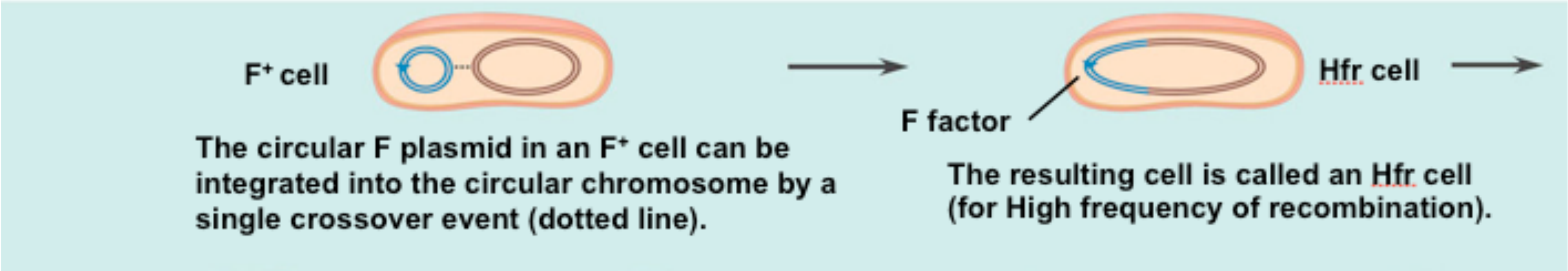
DNA replication occurs in both donor and recipient cells, using the single parental strands of the F plasmid as templates to synthesize complementary strands.

The plasmid in the recipient cell circularizes. Transfer and replication result in a compete F plasmid in each cell. Thus, both cells are now F+.

1. 2. 3. 4.

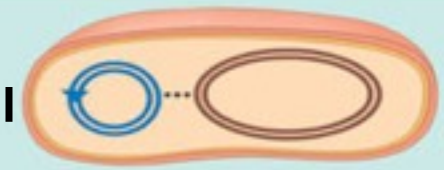
Conjugation

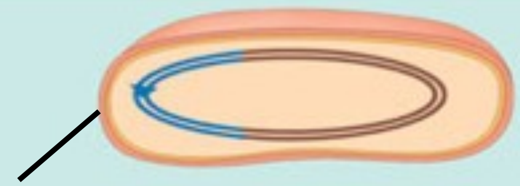
- Bacteria can move a plasmid into its main chromosome, if it moves the F plasmid then we call this bacteria a Hfr cell.
  - *These Hfr cells can still donate DNA and may lead to bacterial recombination.*



Conjugation

F⁺ cell





F factor

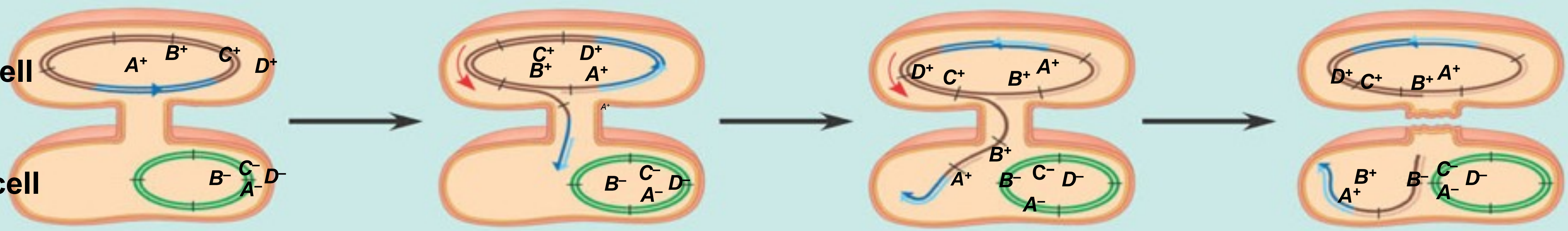
Hfr cell

The circular F plasmid in an F⁺ cell can be integrated into the circular chromosome by a single crossover event (dotted line).

The resulting cell is called an Hfr cell (for High frequency of recombination).

Hfr cell

F⁻ cell



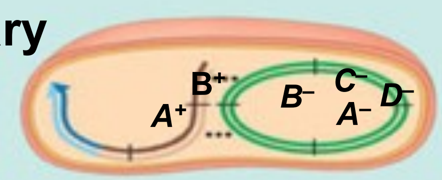
Since an Hfr cell has all the F-factor genes, it can form a mating bridge with an F⁻ cell and transfer DNA.

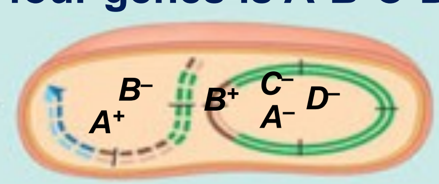
A single strand of the F factor breaks and begins to move through the bridge. DNA replication occurs in both donor and recipient cells, resulting in double-stranded DNA

The location and orientation of the F factor in the donor chromosome determine the sequence of gene transfer during conjugation. In this example, the transfer sequence for four genes is A-B-C-D.

The mating bridge usually breaks well before the entire chromosome and the rest of the F factor are transferred.

Temporary partial diploid





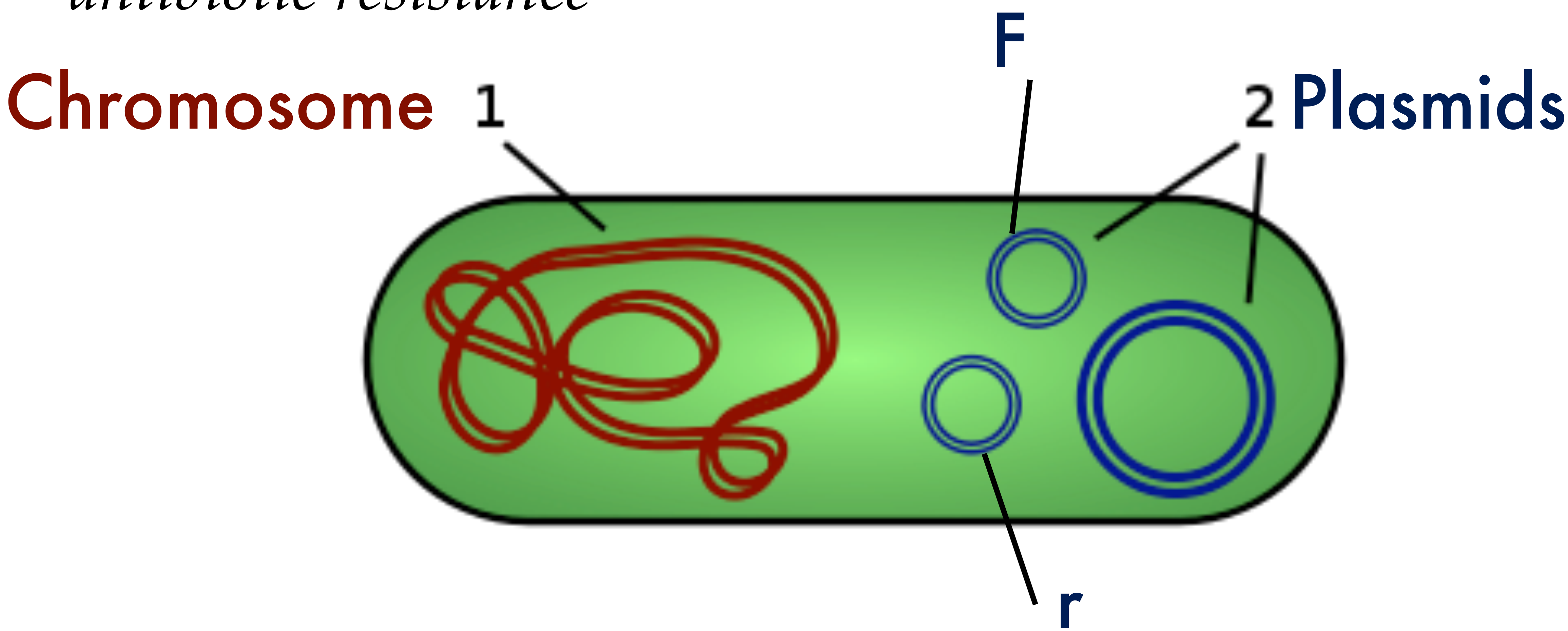
Recombinant F⁻ bacterium

Two crossovers can result in the exchange of similar (homologous) genes between the transferred chromosome fragment (brown) and the recipient cell's chromosome (green).

The piece of DNA ending up outside the bacterial chromosome will eventually be degraded by the cell's enzymes. The recipient cell now contains a new combination of genes but no F factor; it is a recombinant F⁻ cell.

Conjugation

- Bacteria posses numerous plasmids.
  - *We have seen that F plasmids, carry genes that allow gene transfer.*
  - *Some bacteria have r plasmids, these carry genes for antibiotic resistance*

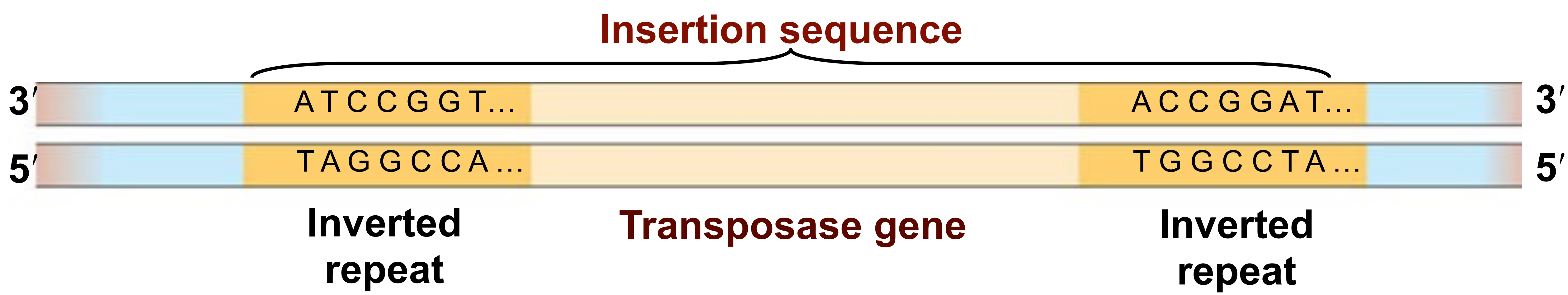


Transposable Elements

- Bacteria posses genes that can move themselves and other genes from one place to another.
  - *Transposable elements can move around in the genome.*
  - *They are sometimes called "jumping genes"*
  - *They allow bacteria to shuffle existing genes*

Insertion Sequences

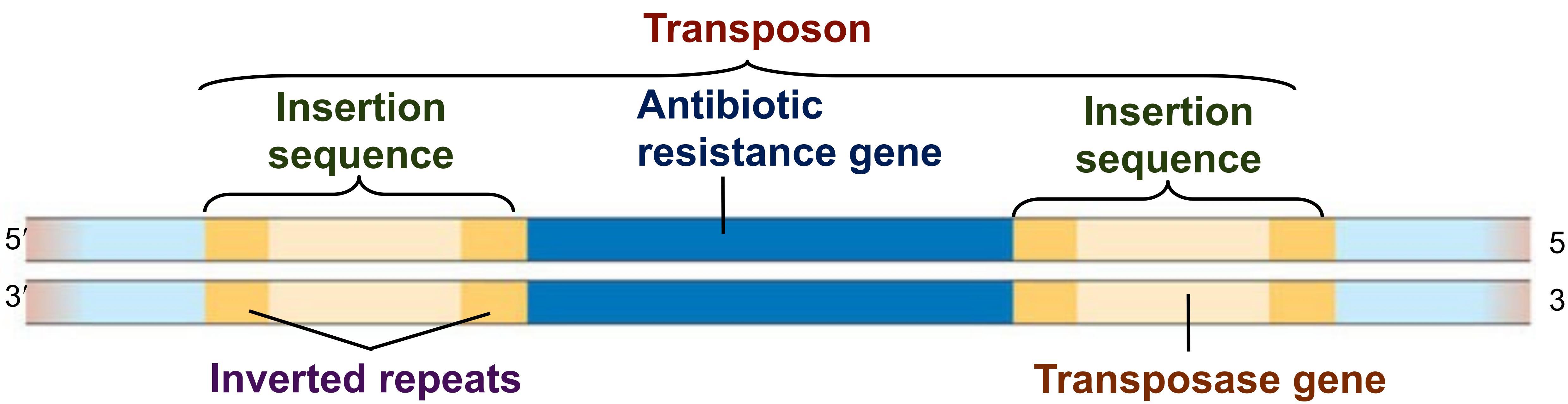
- Insertion sequences contain the gene that is responsible for this trait of that gives bacteria to shuffle genes.
  - The insertion contains a single gene that codes for transposase
    - *An enzyme that catalyzes movement of the insertion sequence from one site to another within the genome.*



Insertion sequences, the simplest transposable elements in bacteria, contain a single gene that encodes transposase, which catalyzes movement within the genome. The inverted repeats are backward, upside-down versions of each other; only a portion is shown. The inverted repeat sequence varies from one type of insertion sequence to another.

Transposons

- Transposons are insertion sequences that carry additional genes.
  - They carry the gene for transposase and others such as antibiotic resistant genes.



Transposons contain one or more genes in addition to the transposase gene. In the transposon shown here, a gene for resistance to an antibiotic is located between twin insertion sequences. The gene for antibiotic resistance is carried along as part of the transposon when the transposon is inserted at a new site in the genome.

Bacteria as Pathogens

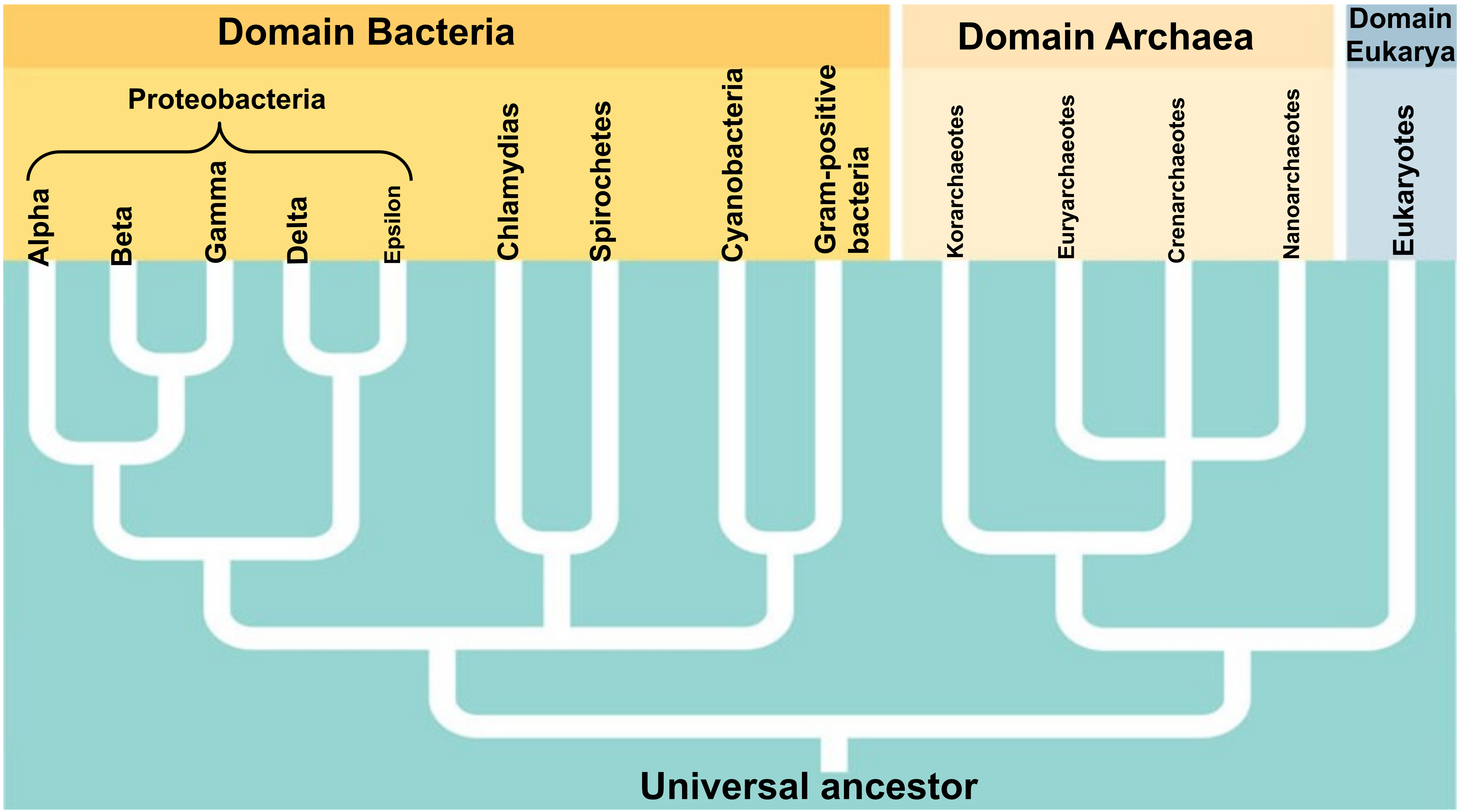
- Bacteria cause about half of all human disease
- They often exert there effects by excreting exotoxins and endotoxins.

Ecological Roles of Bacteria

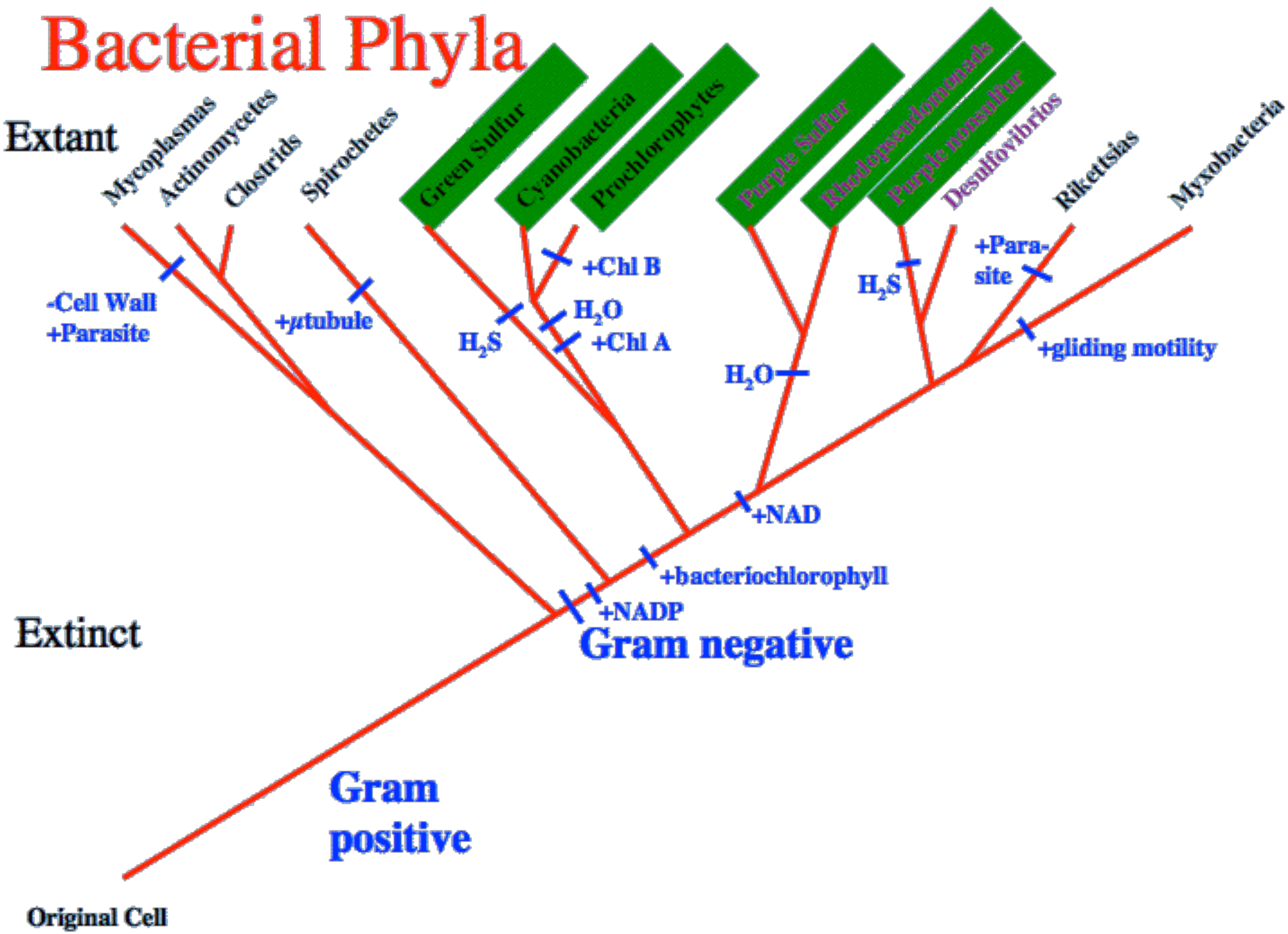
- The ecological roles are so important and numerous that almost every other living organism depends on bacteria for their survival.
  - They cycle nutrients (decomposers)
  - They make nitrogen available (nitrogen fixers)
  - They are frequent symbionts with other organisms (mutualism)
  - Humans use them for a variety of applications (gene cloning, environmental clean up, antibiotics, mining)

Classification of Bacteria

- Analyzing DNA and proteins has led to a more complete picture of bacteria evolution and classification.



Classification of Bacteria



Classification of Bacteria

- The Prokaryotic and Eukaryotic comparisons are particularly important in AP Biology.

Table 27.2 A Comparison of the Three Domains of Life

CHARACTERISTIC	DOMAIN		
	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 protein synthesis	Formyl-methionine	Methionine	Methionine
Introns (noncoding parts of genes)	Rare	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