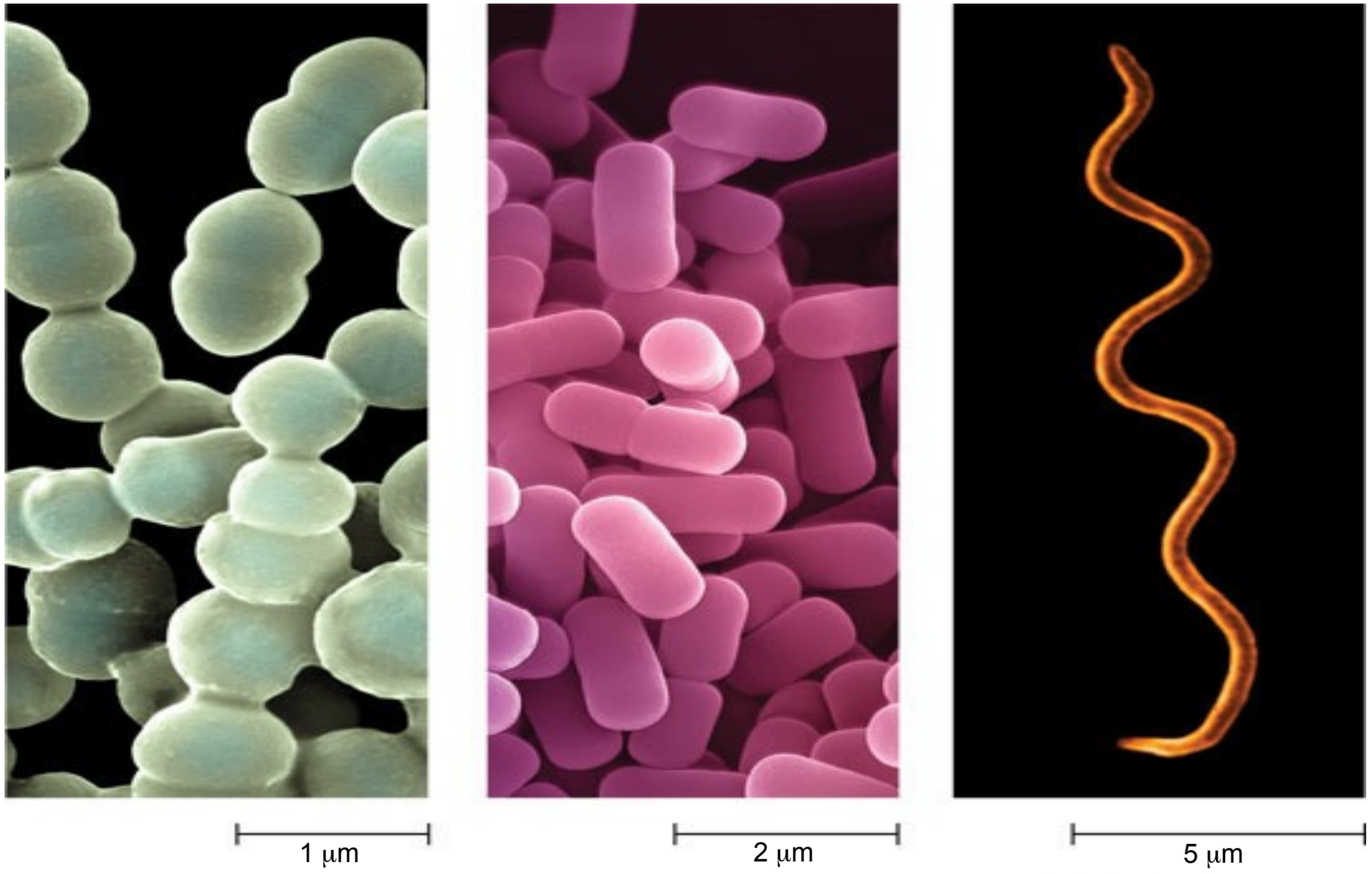
Structure & Function of Bacteria

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**

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.

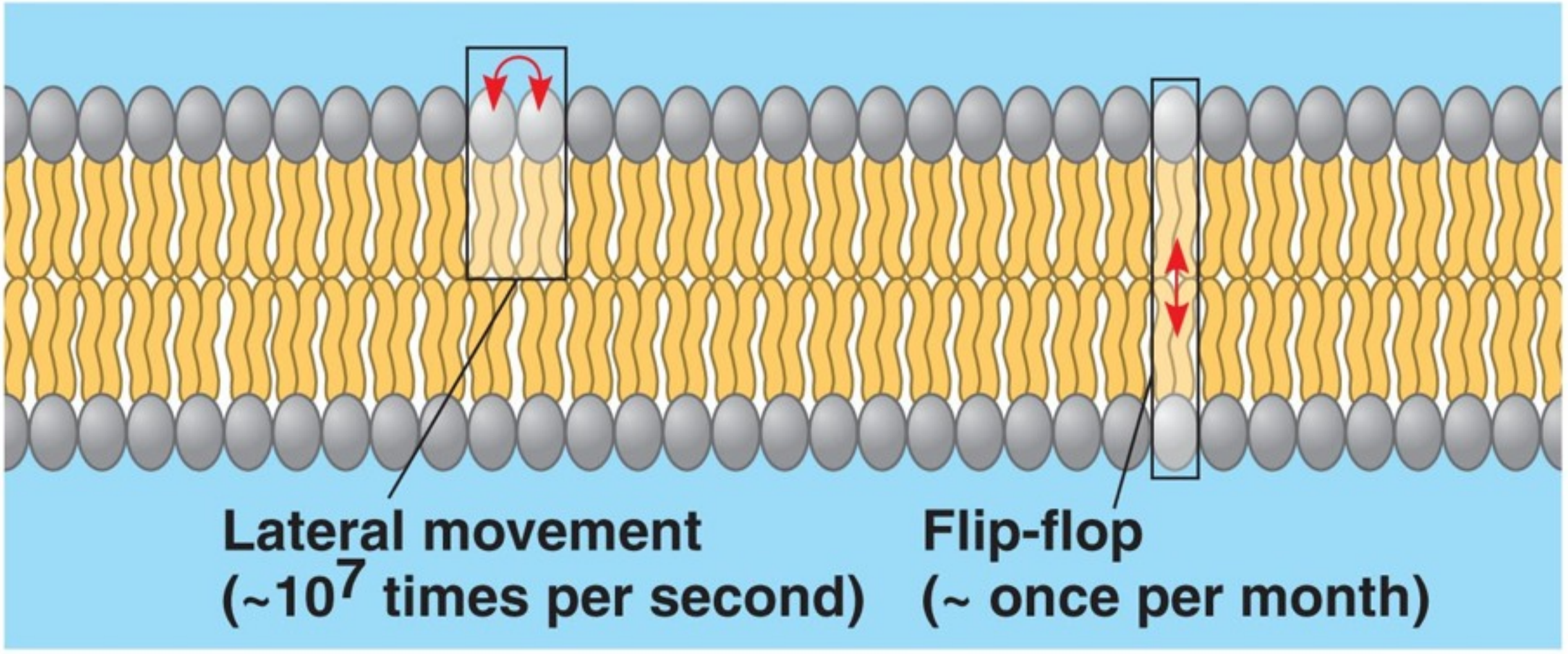
Bacterial Barriers- Plasma Membranes

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

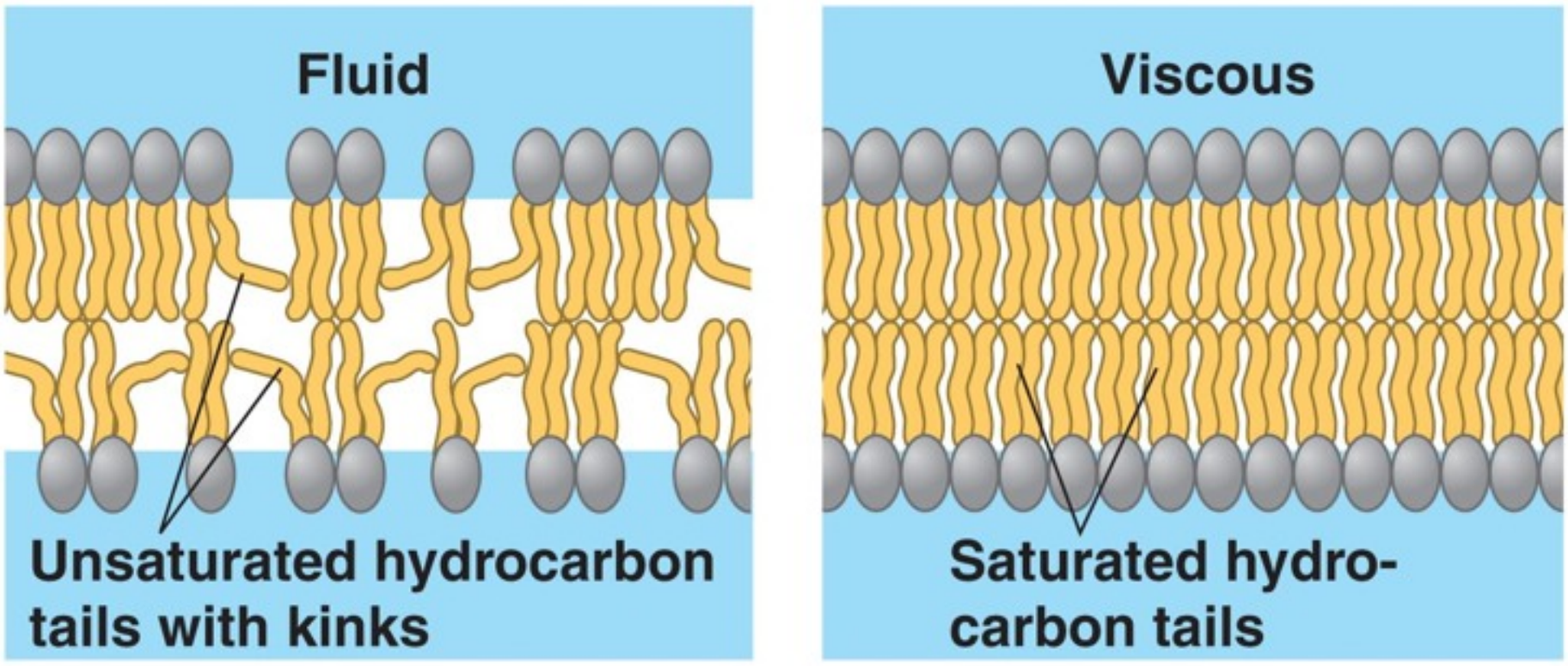
- Membranes are static sheets, they are held together by weak hydrophobic interactions.
- The lipids and proteins both move laterally although the lipids move much more freely.



(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



(b) Membrane fluidity

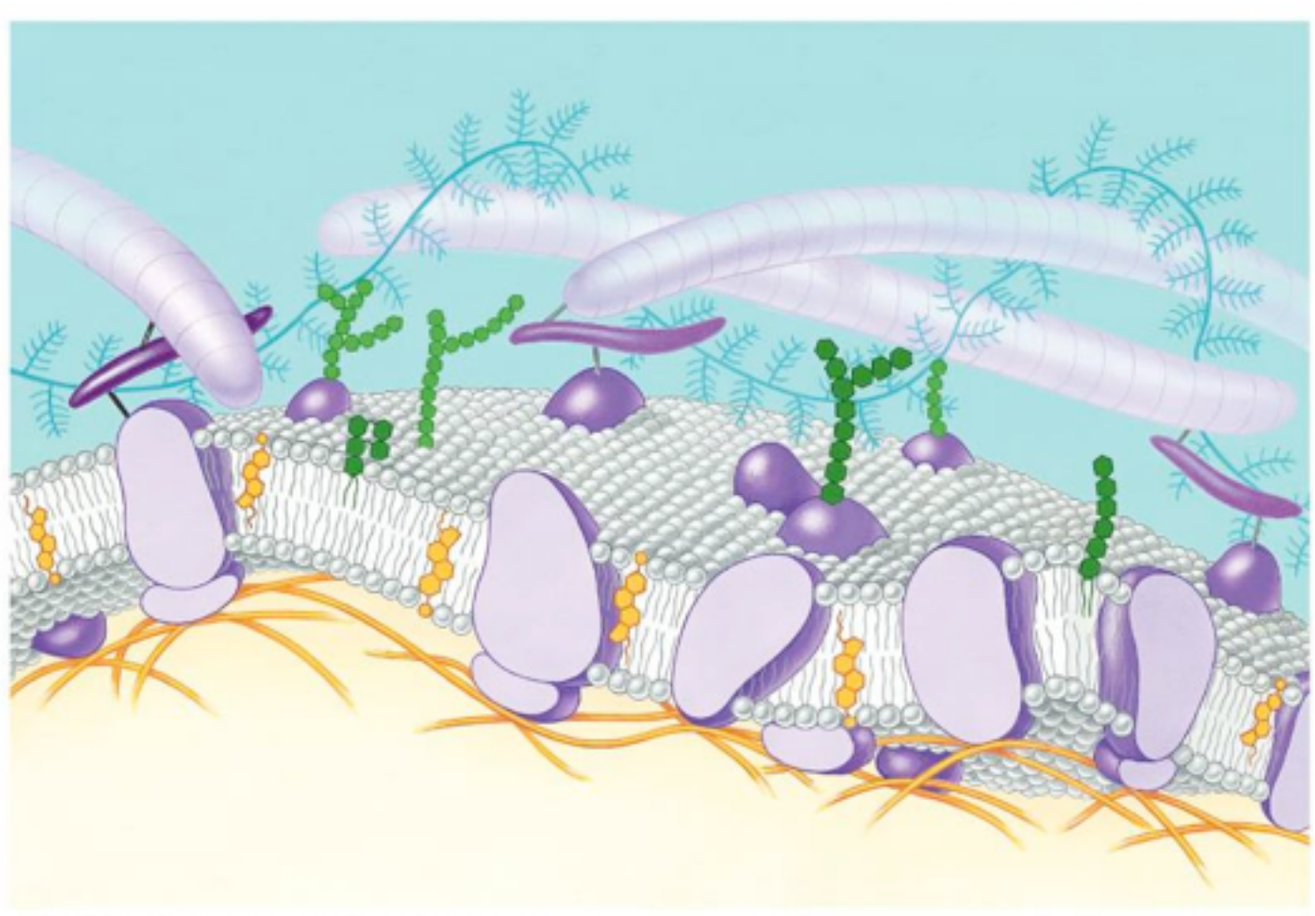
The Evolution of Different Membrane Lipid Composition

- 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 mosaic since each has a variety of unique proteins



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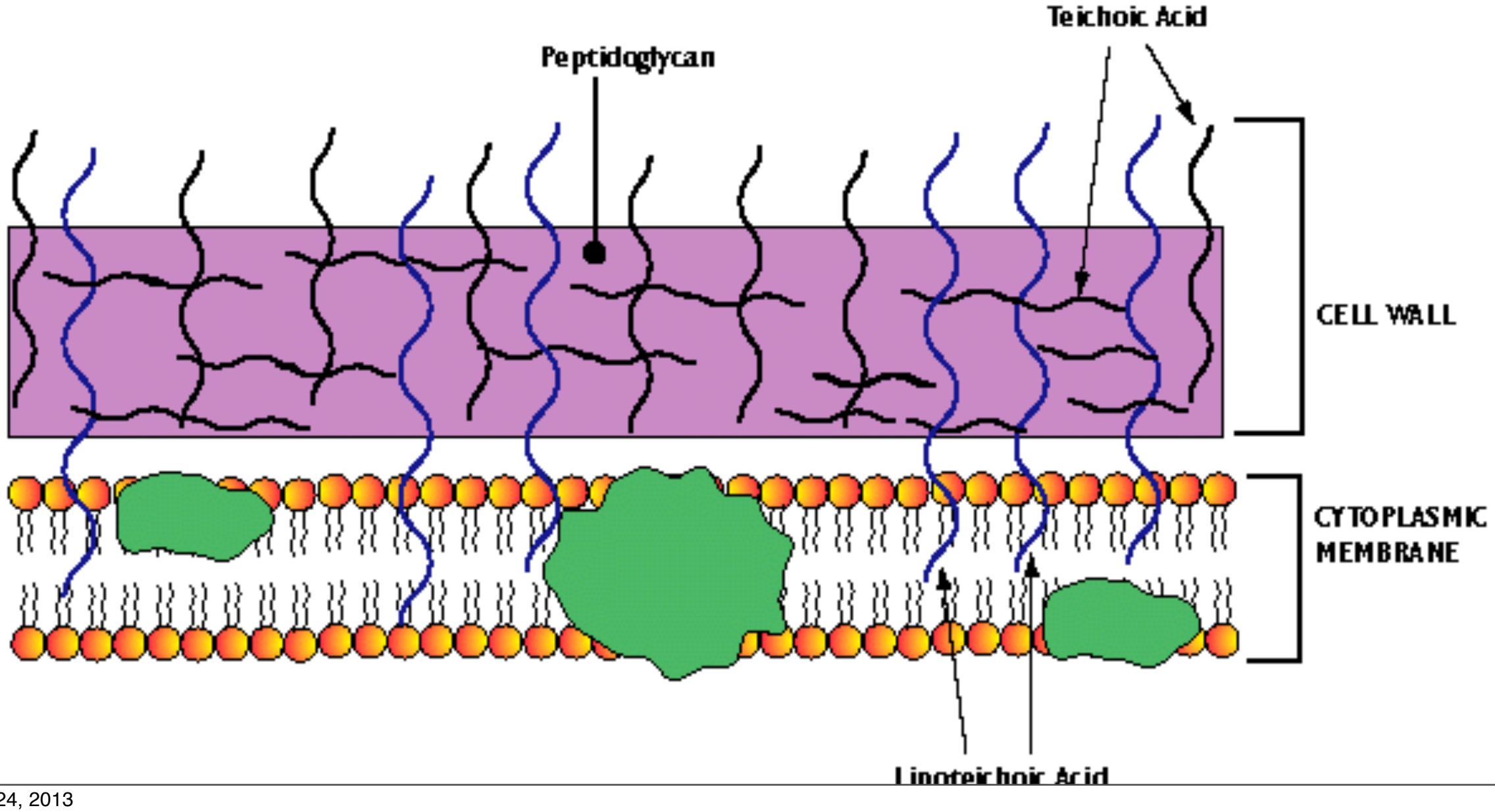
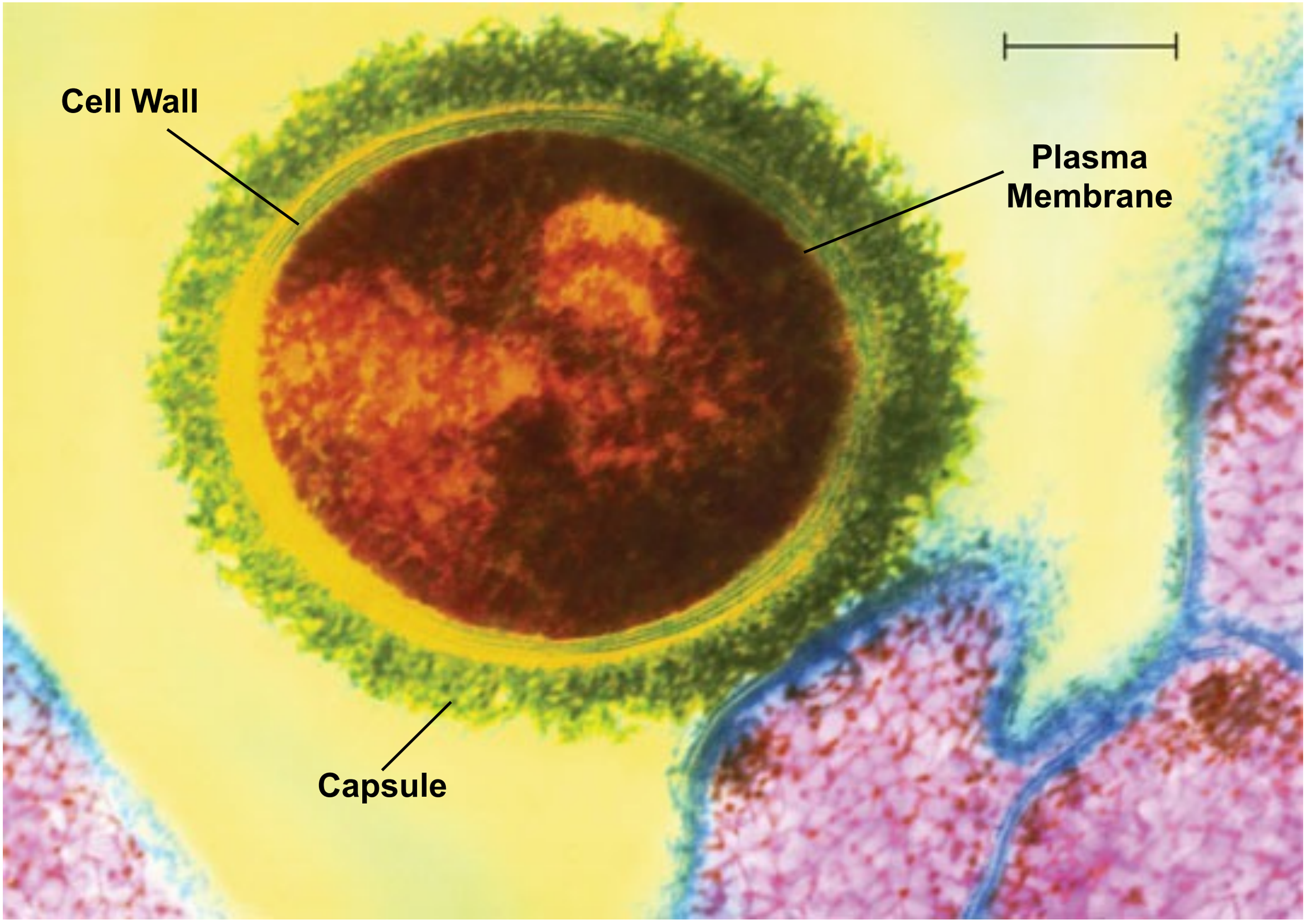
Bacterial Cell walls

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

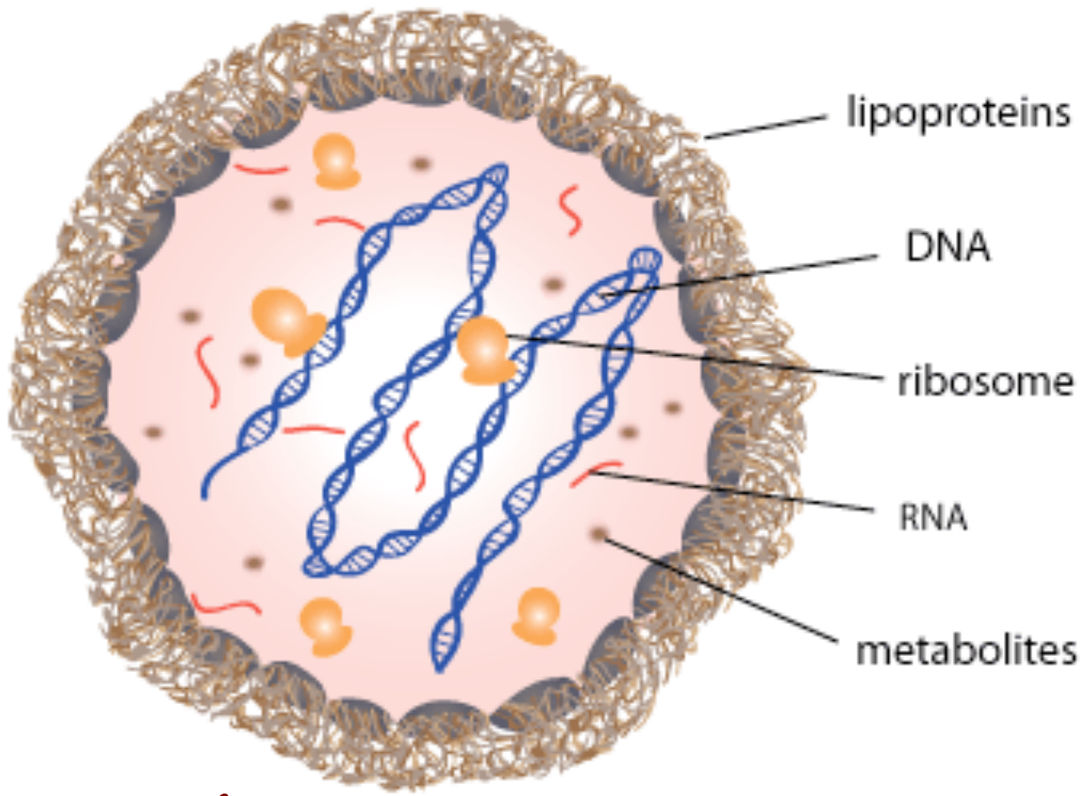


Bacterial Barriers- 3 Forms

- 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.

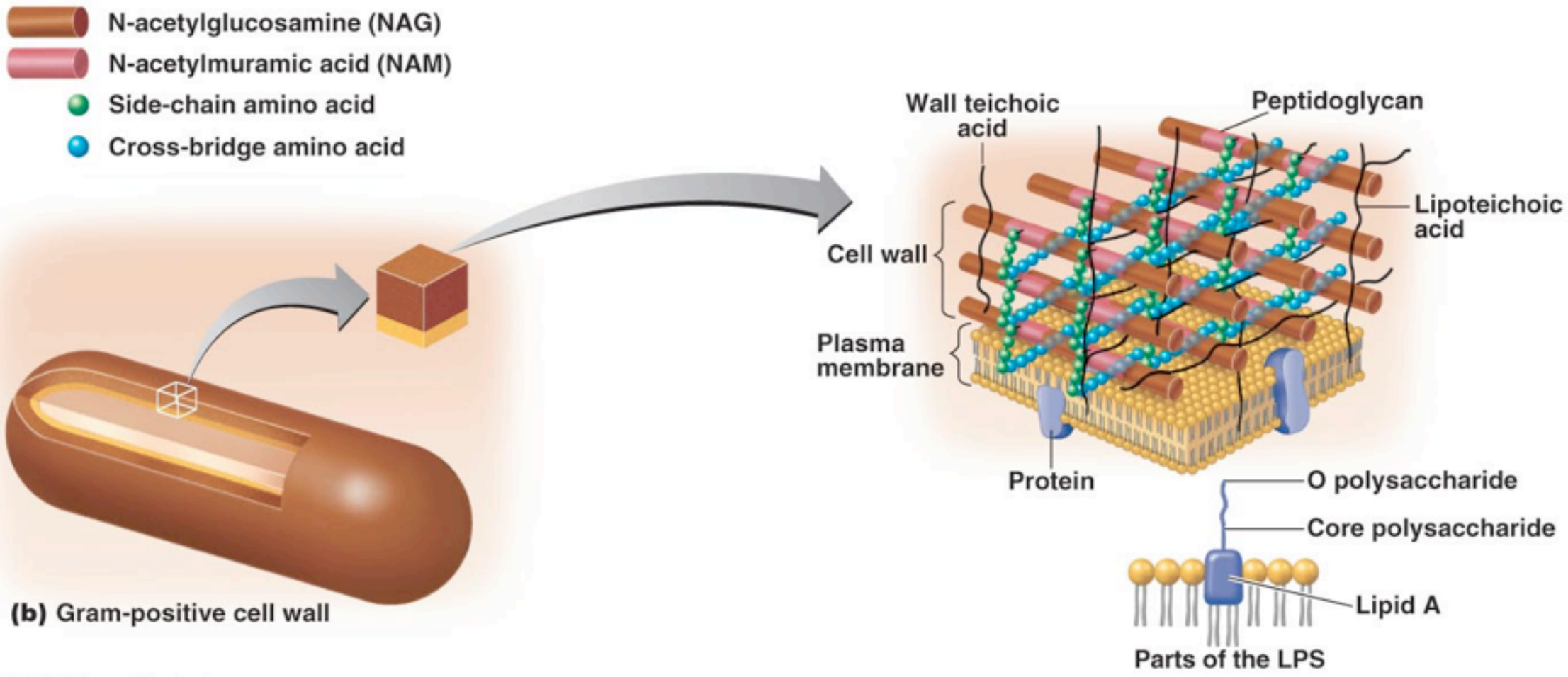
They are parasites, and resistant to many common antibiotics-tough to treat



They must live in isotonic environments

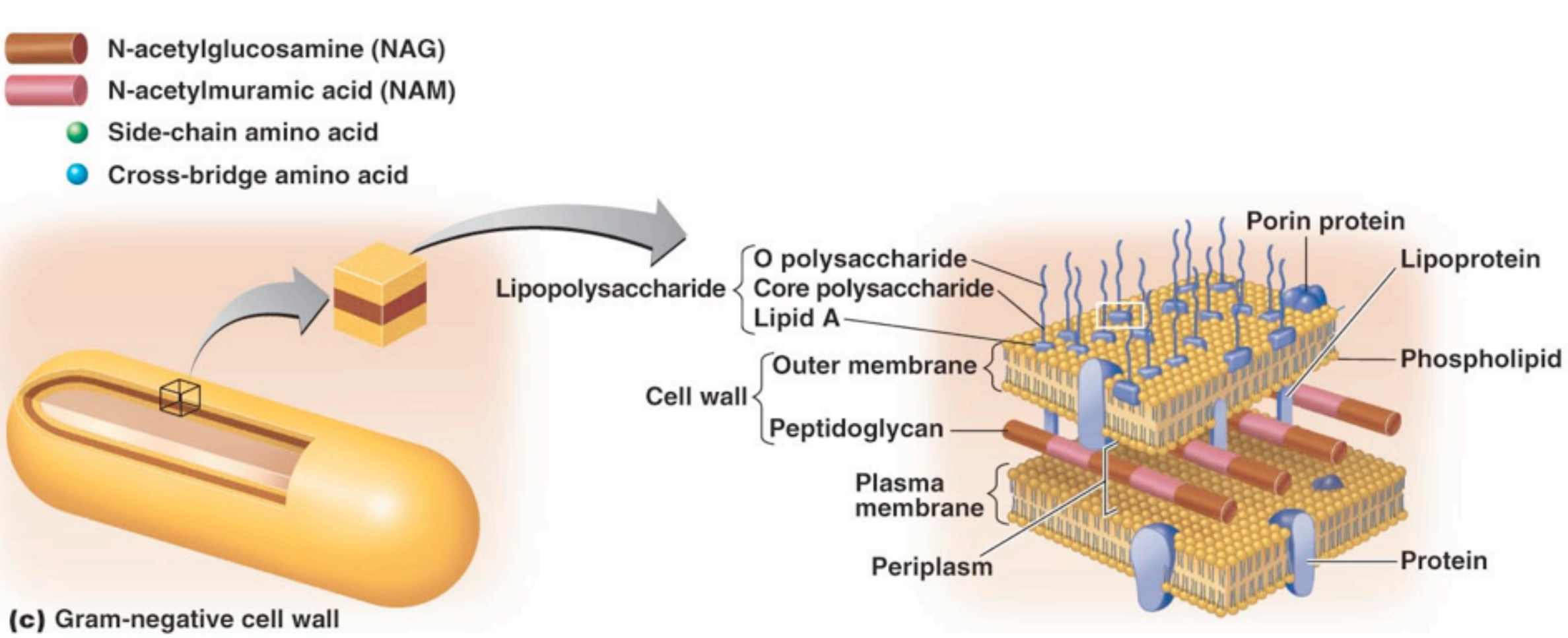
Bacterial Barriers- 3 Forms

- 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.



Bacterial Barriers- 3 Forms

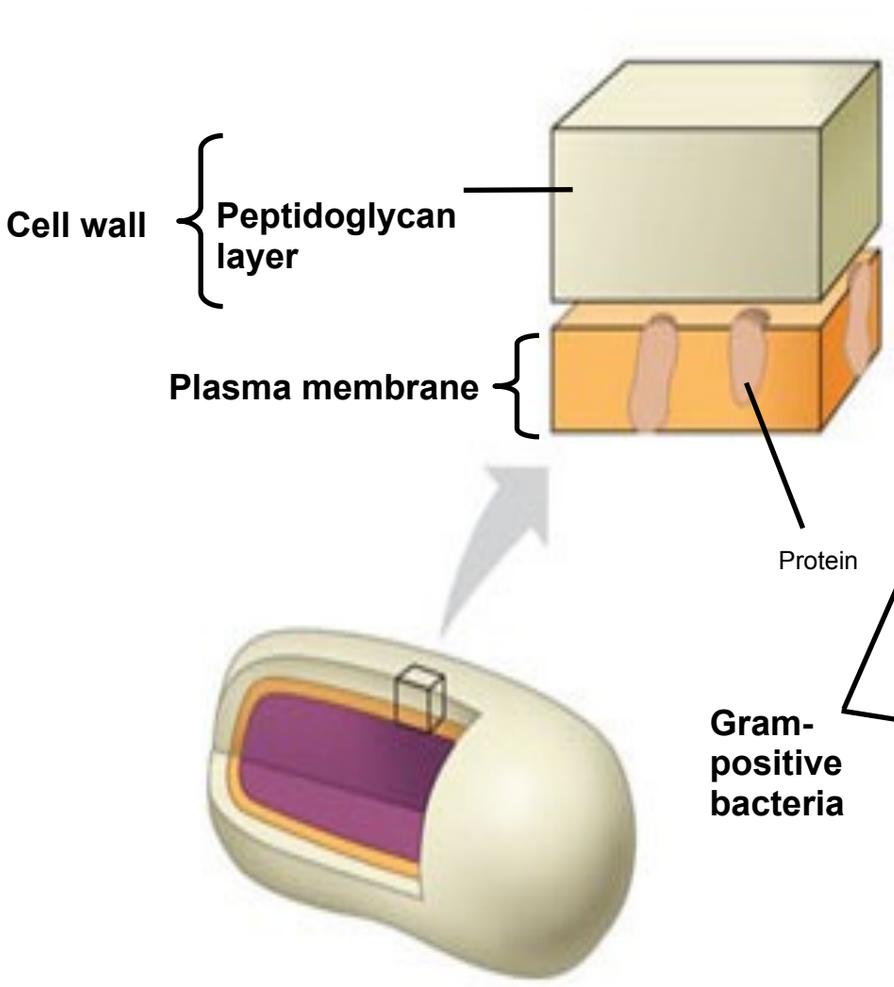
- Bacteria come in three forms in terms of these barriers and how they are used.
- **3. Gram Negative Bacteria**
  - Outer membrane, thin cell wall and a plasma membrane.

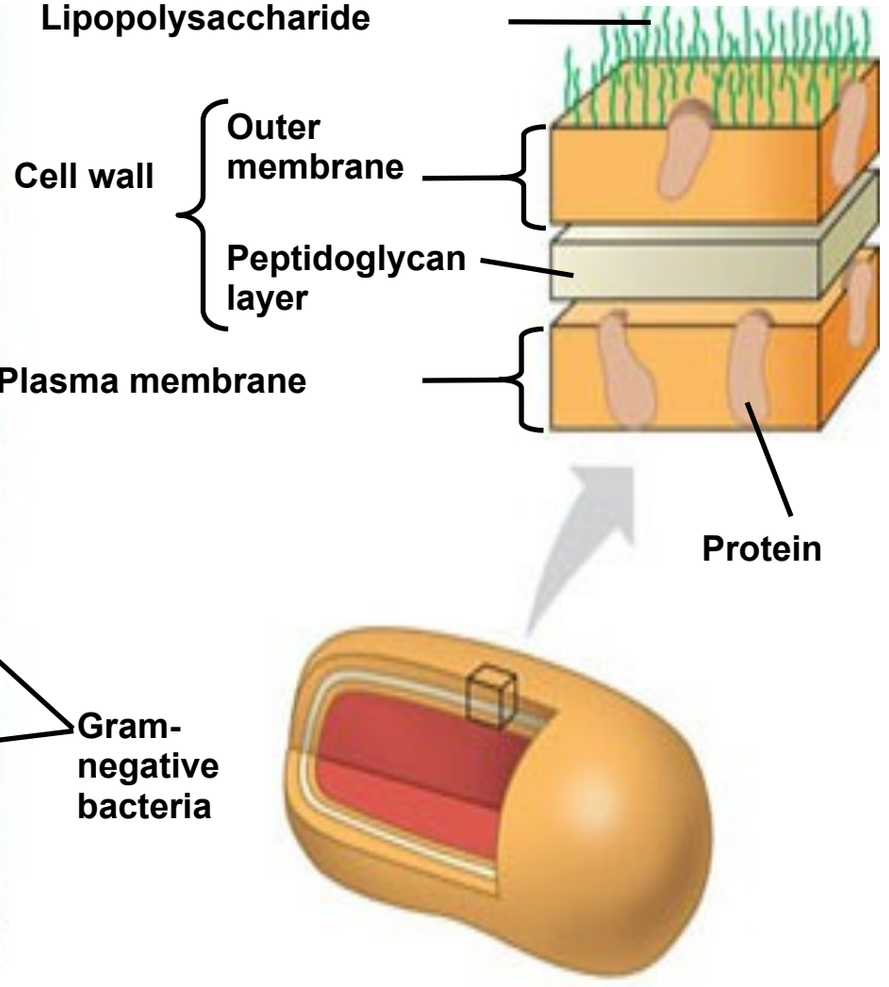


Gram Staining

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.

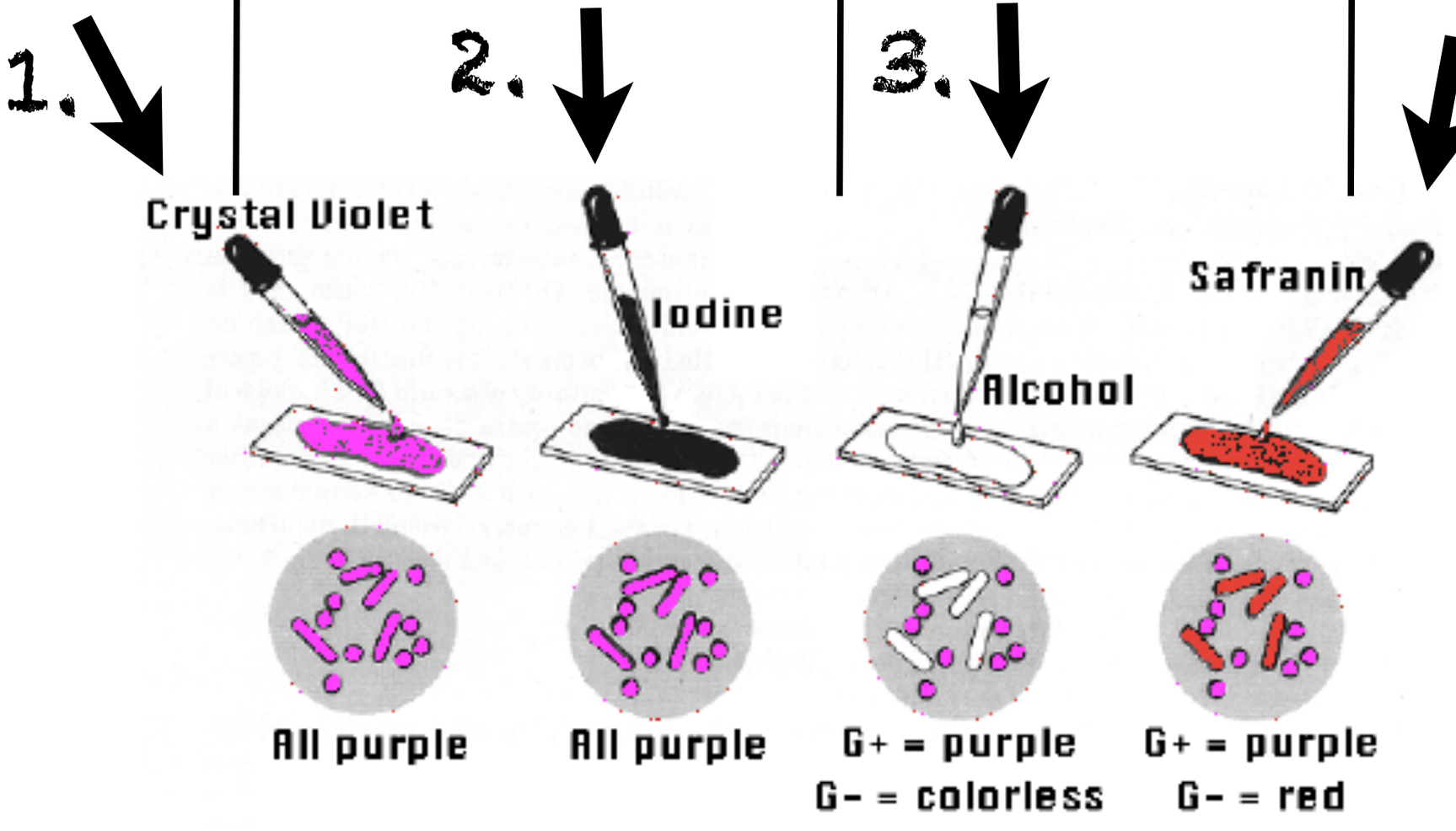
Gram Staining

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

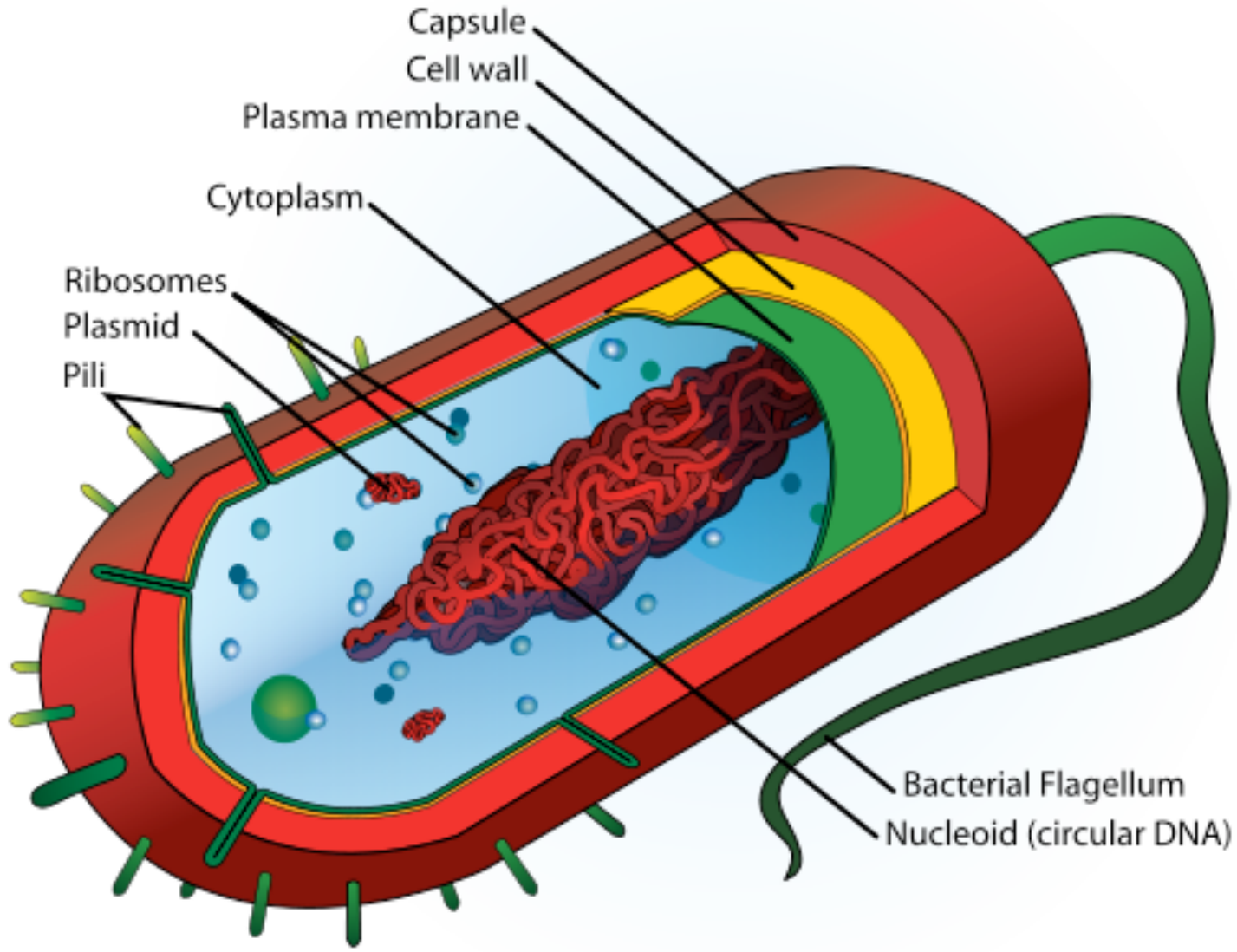
CHARACTERISTIC	GRAM POSITIVE	GRAM NEGATIVE
GRAM STAINED COLOR	Purple	Pink to Red
CELL SHAPE(S)	Rods and Cocci	Mostly rods, few cocci, spirilli; some pleomorphic
ENDOSPORE PRODUCTION	Common in 2 Genera	Virtually Unknown
CELL WALL COMPOSITION	1-4% Lipid (low); Thick, Multilayered Peptidoglycan (up to 30 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

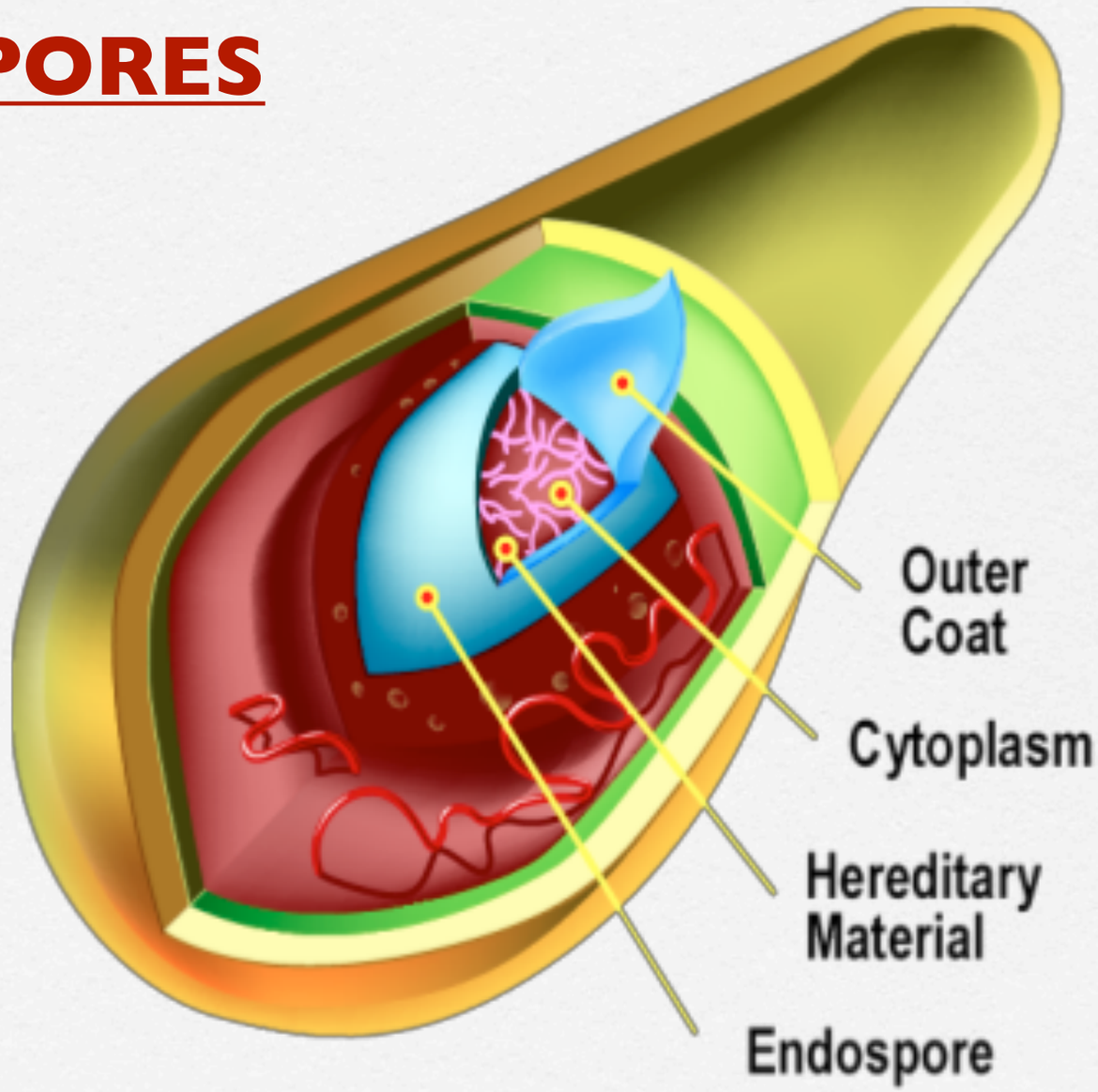


Bacterial Endospores

- 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)

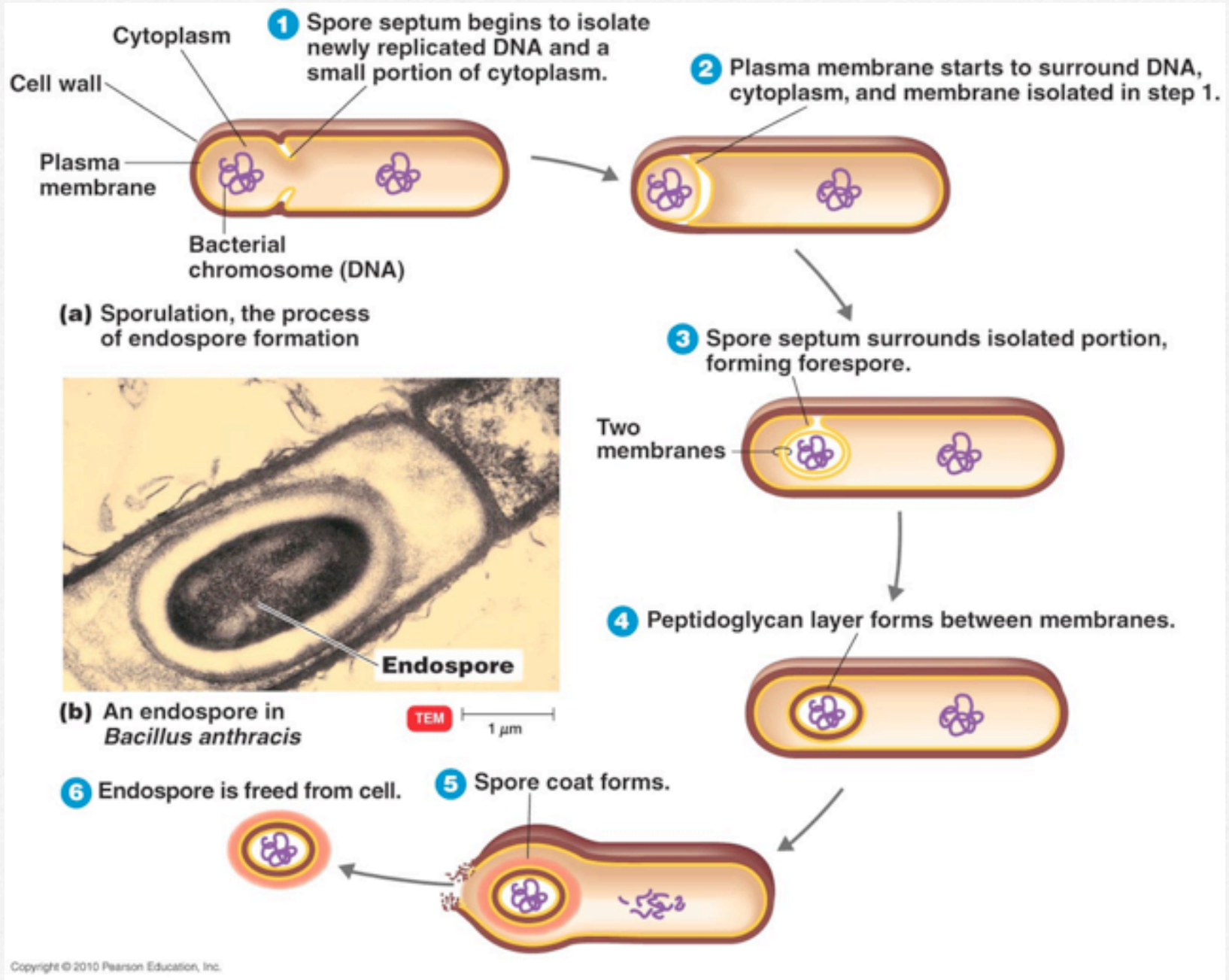
Bacterial Endospores

- **ENDOSPORES**

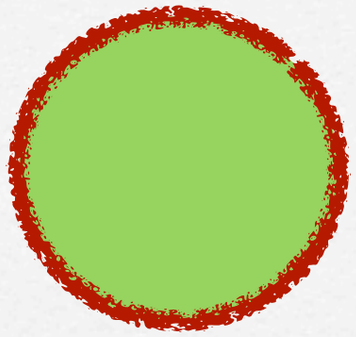


Bacterial Endospores

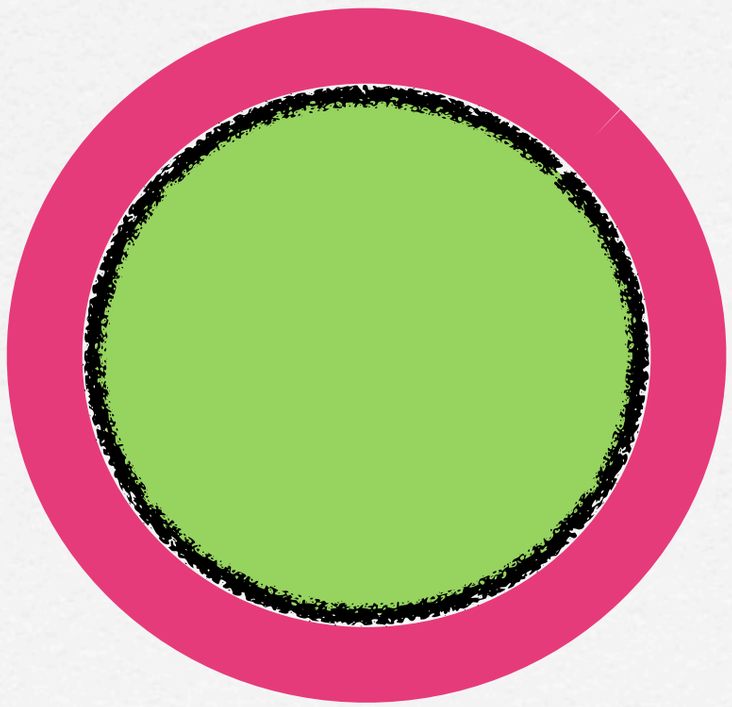
- **Endospore Formation**



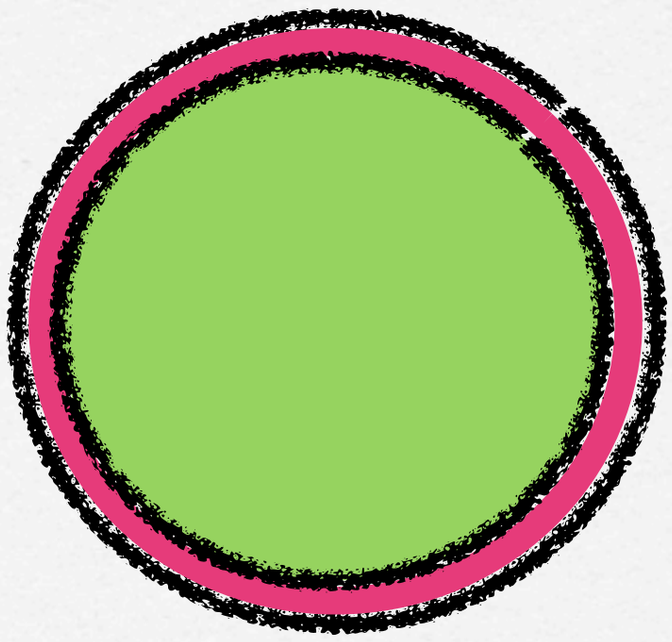
Summary of Bacterial Forms



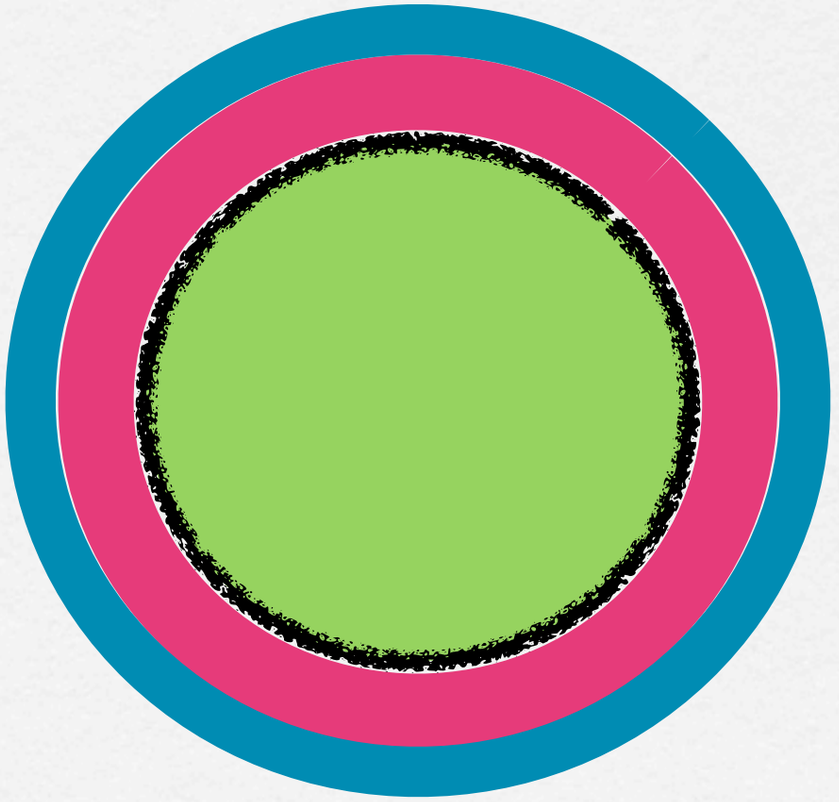
Mycoplasmas



Gram Positive



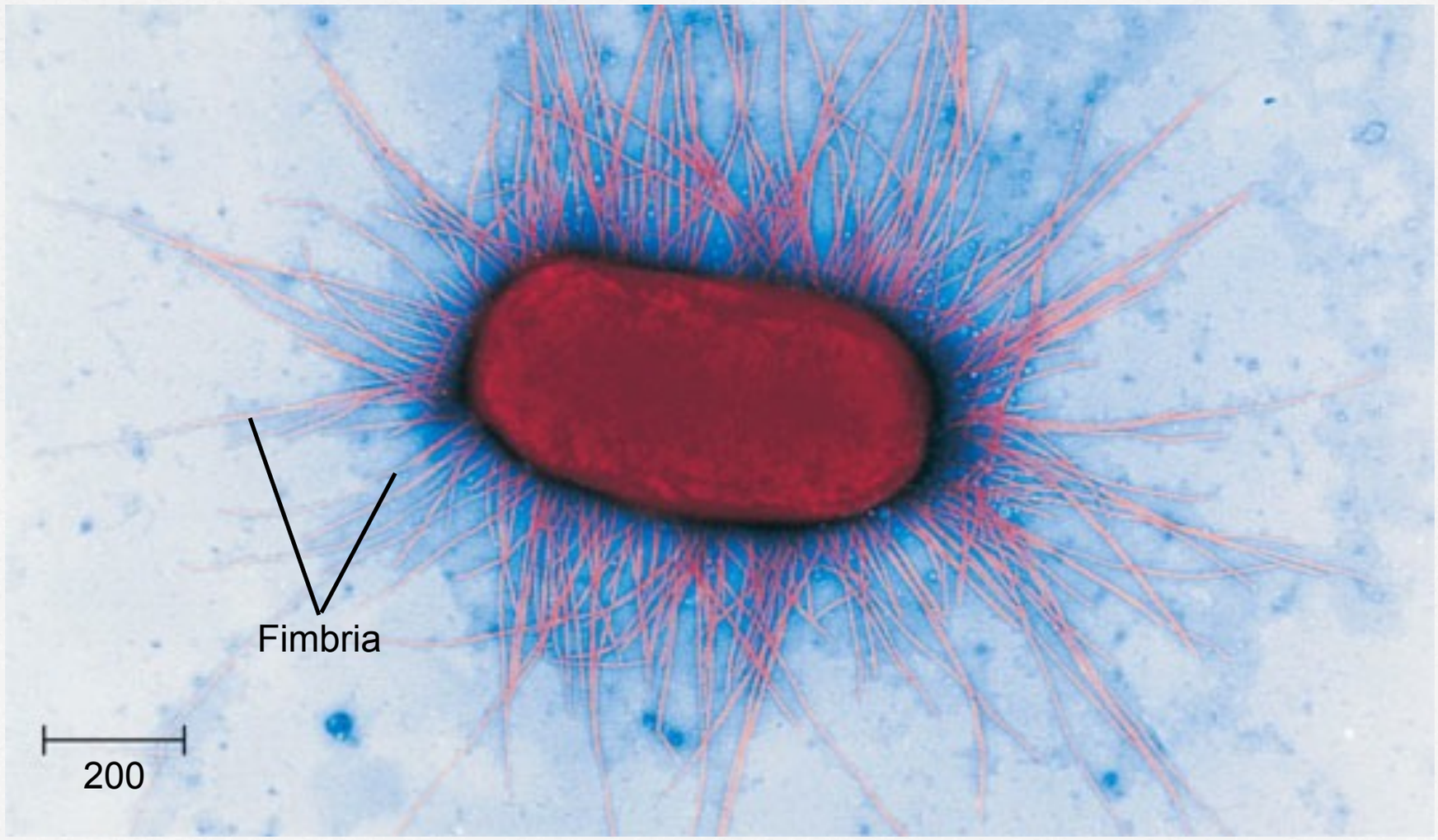
Gram Negative



Capsulated

Bacterial Surface Structures

- **Fimbriae and Pili**



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

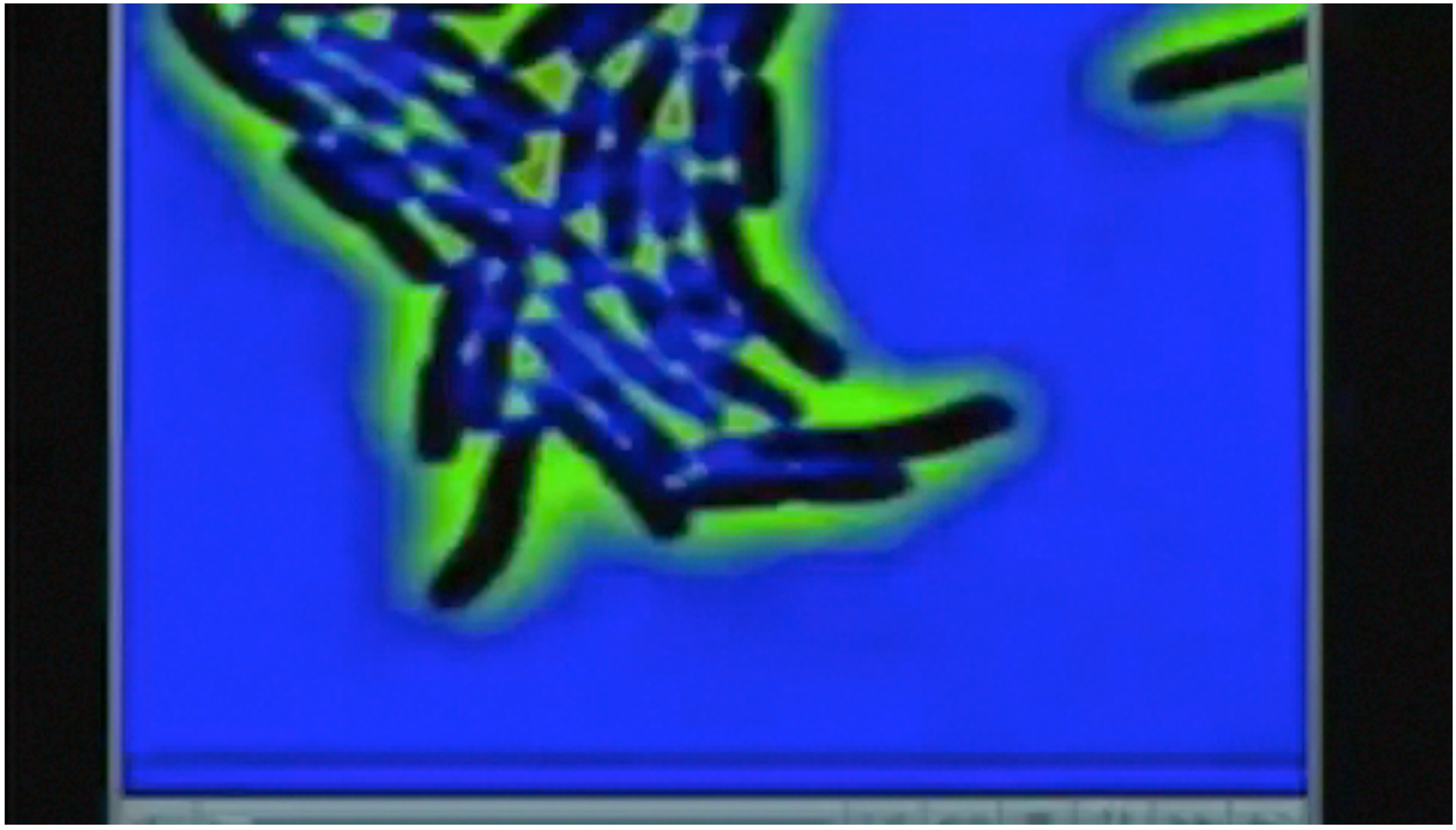
Bacterial Locomotion

- ***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!

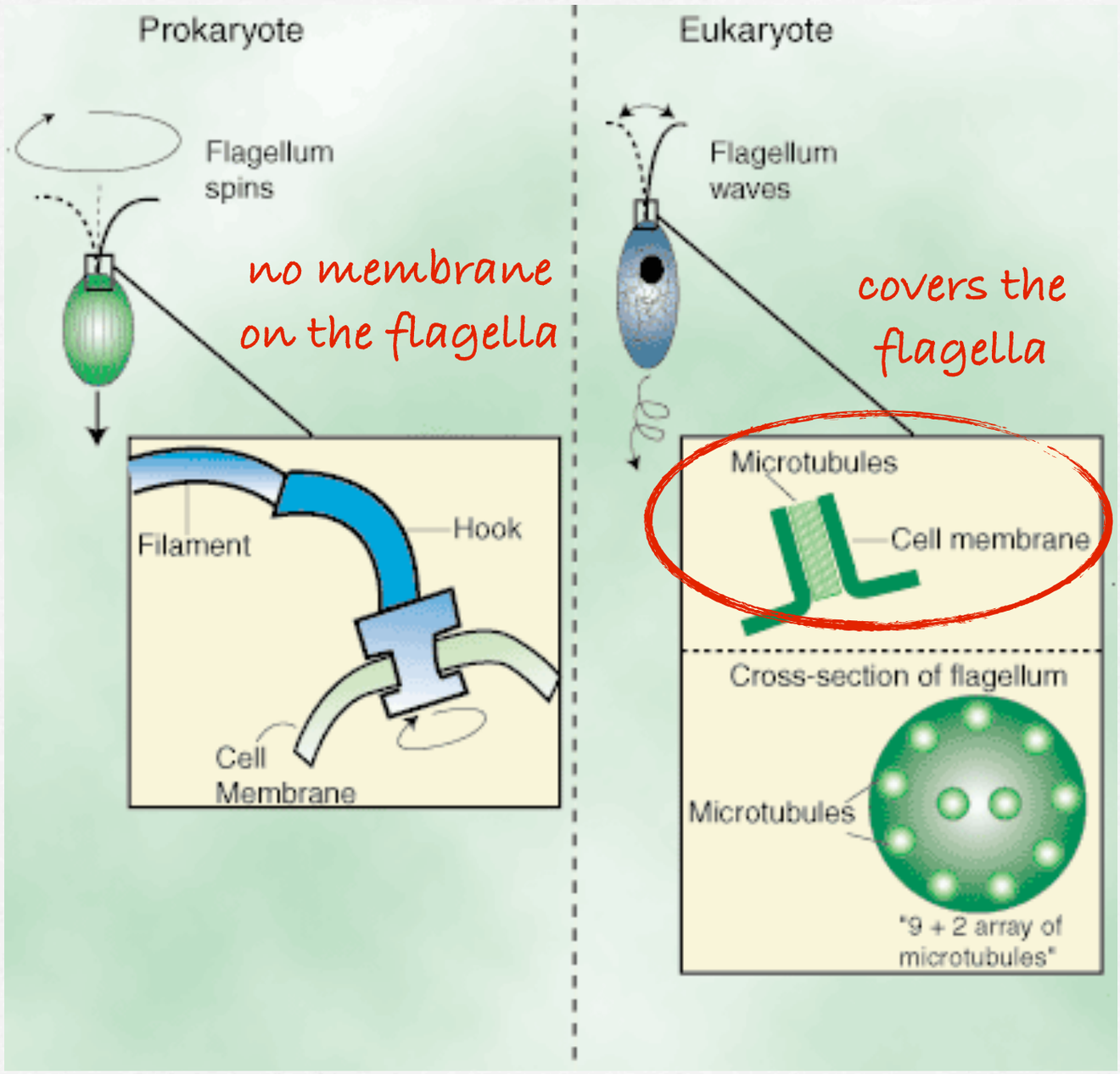
Bacterial Flagella



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



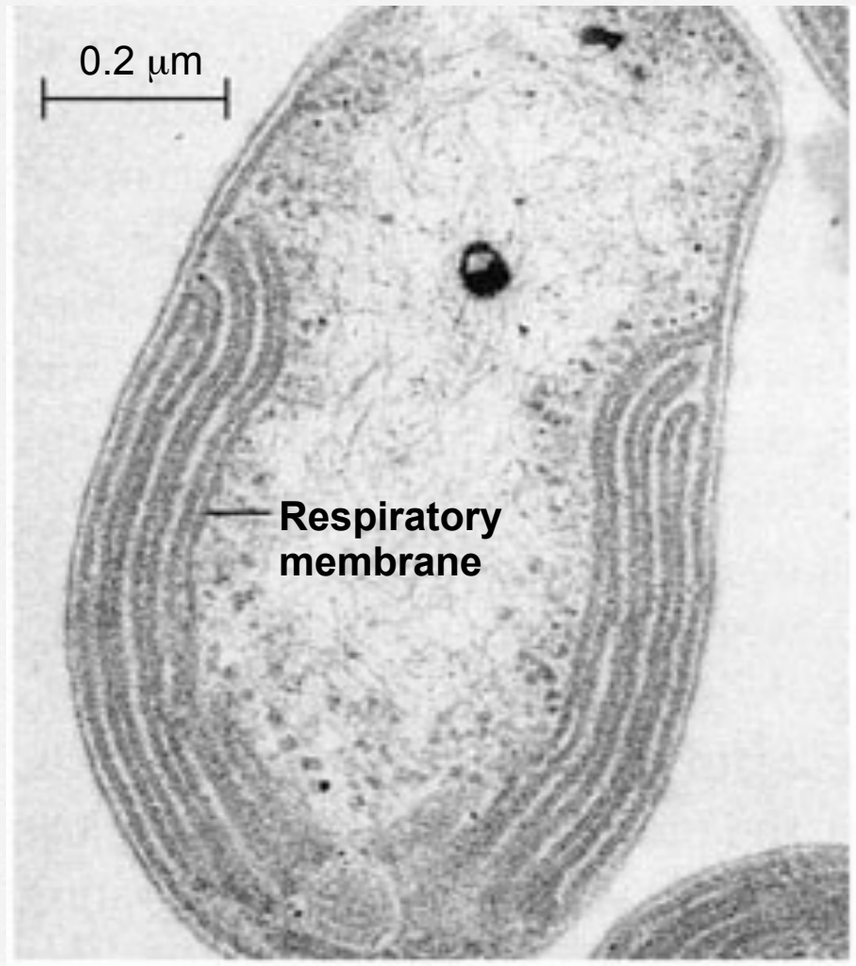
Bacterial Organelles

- 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*

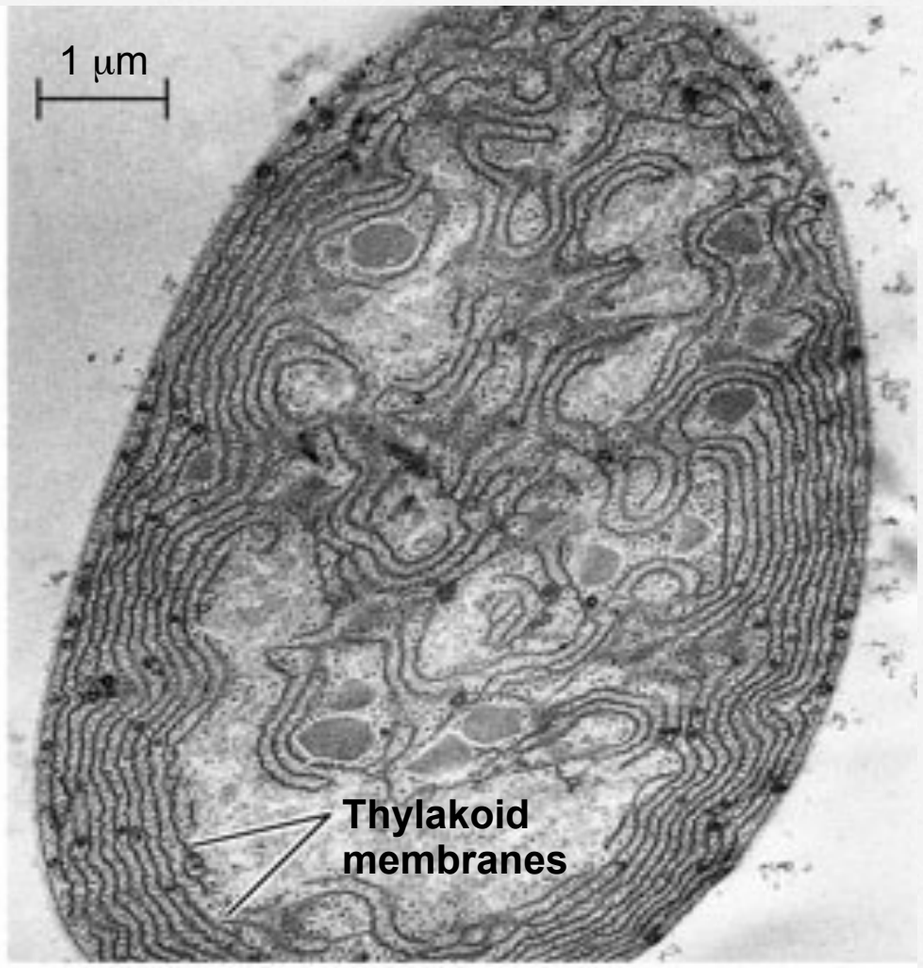
Bacterial Organelles

- 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

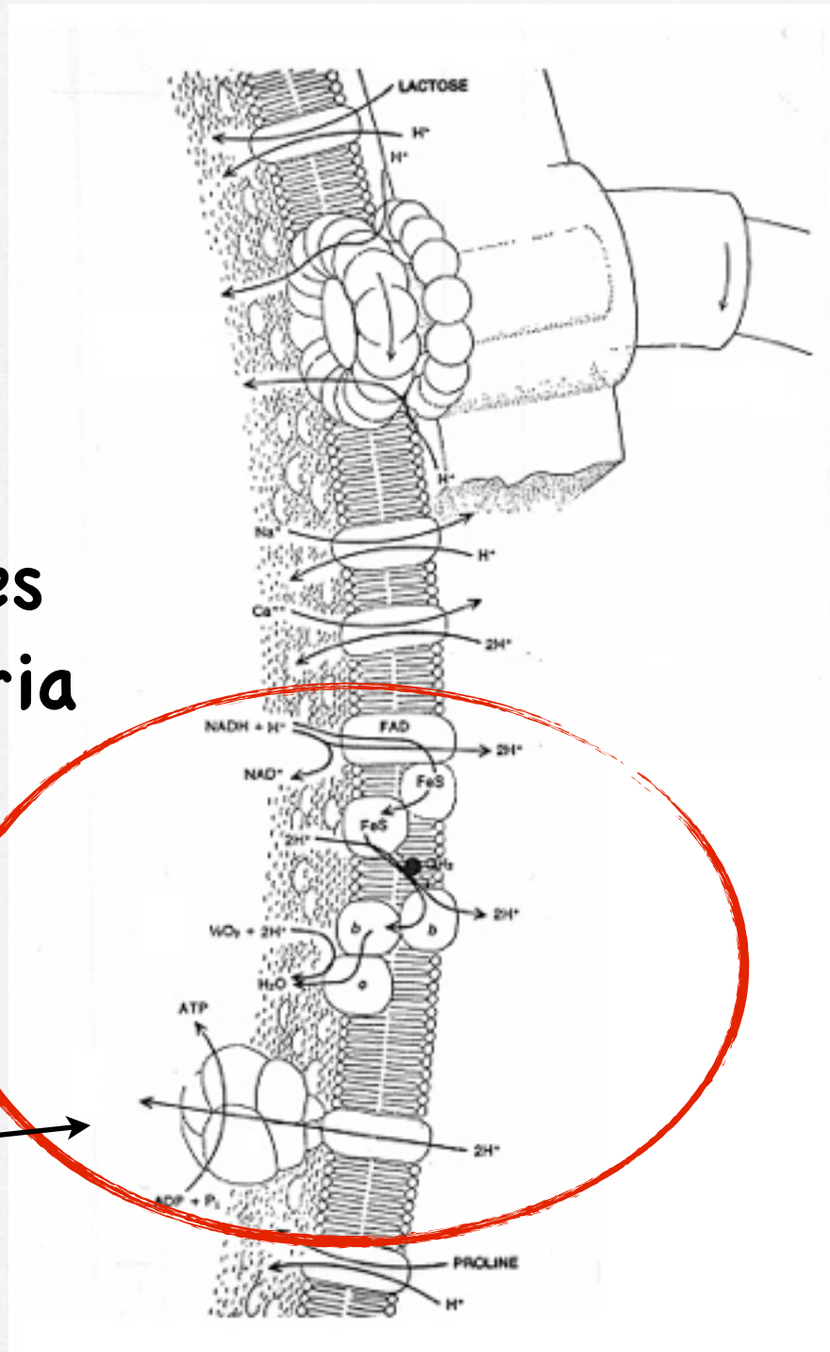


(b) Photosynthetic prokaryote

Bacterial Organelles

Some have membranes that perform metabolic functions, like <u>cellular respiration</u>.

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



ATP Synthase

How do bacteria process energy?

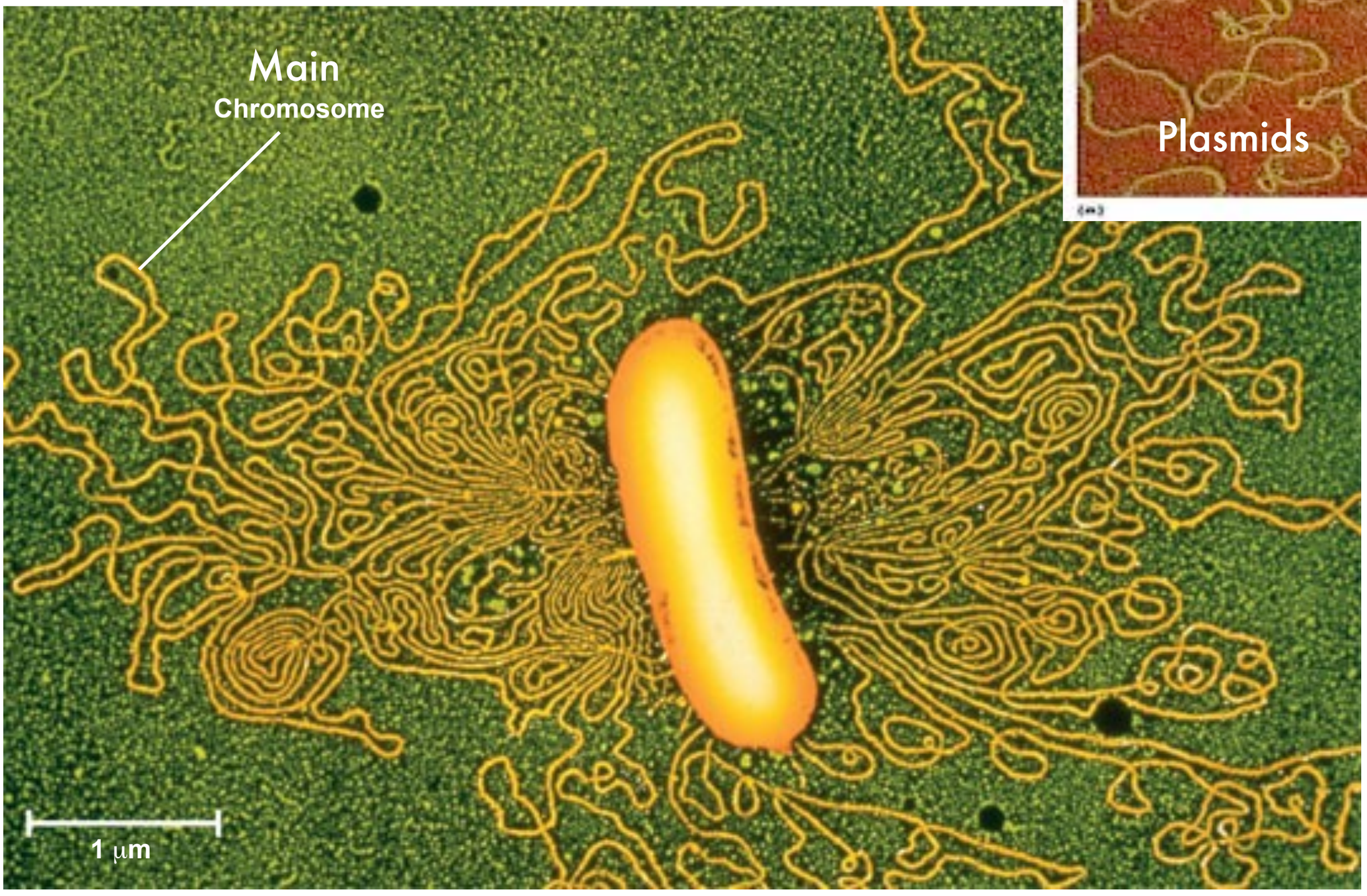
- As a group bacteria can use any and all nutritional mode.

- 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.**

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?

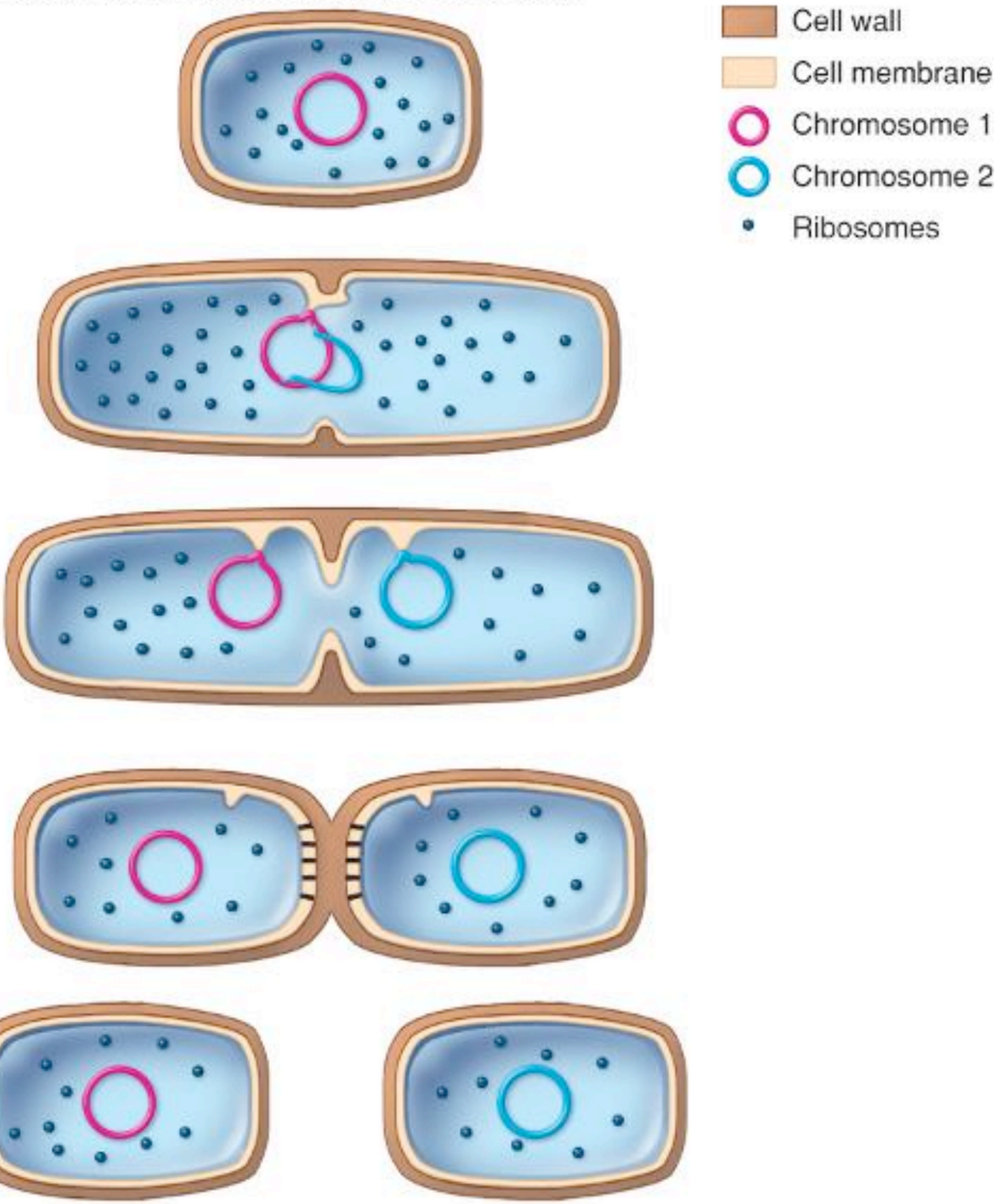
- Prokaryotes reproduce asexually and very quickly in favorable environments.
- Ideal conditions bacteria can reproduce every 1-3 hours.
  - some as fast as every 20 minutes and others slower every few days.
- If ideal conditions were unlimited, a single bacteria could produce a colony that outweighed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



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.

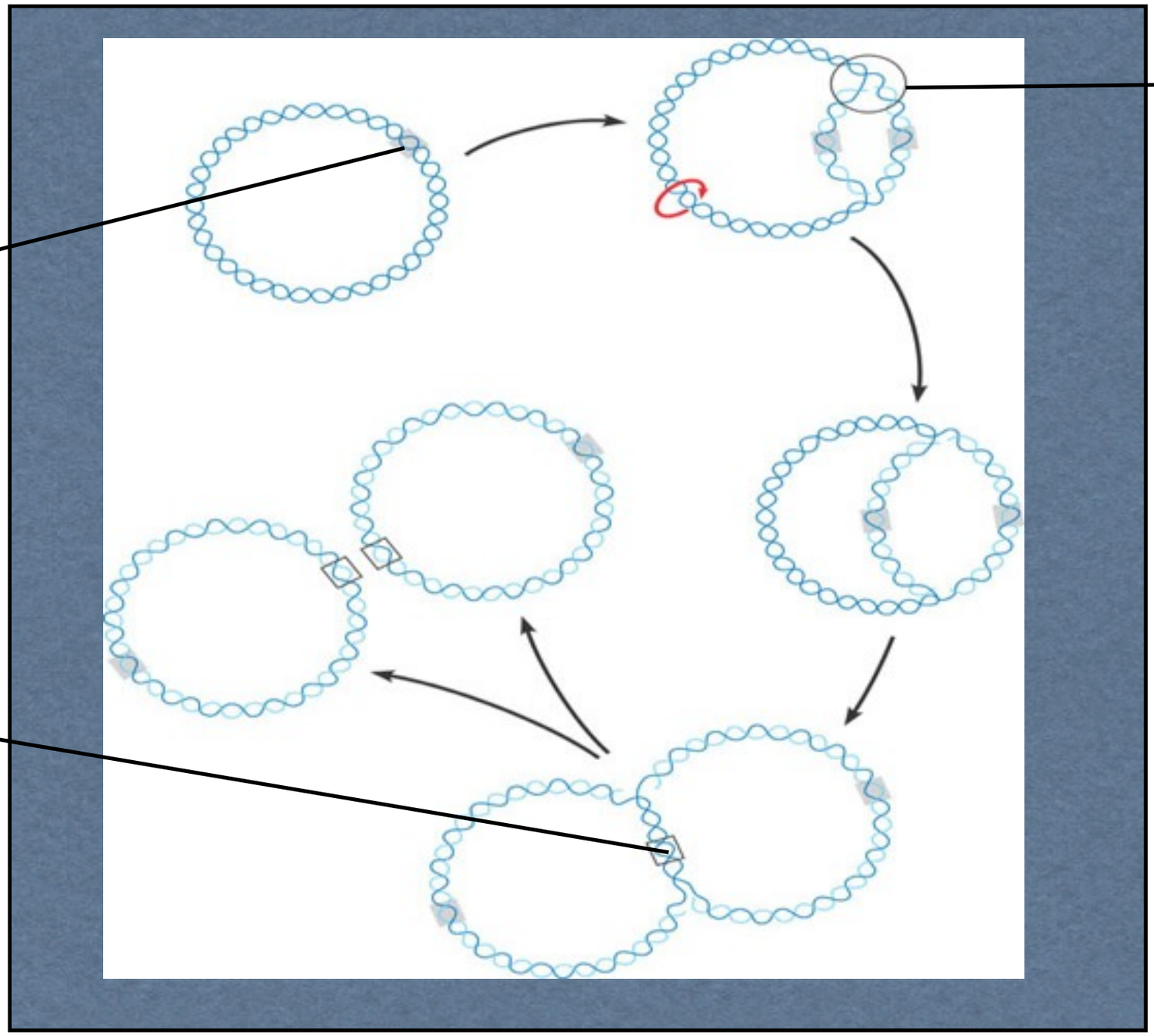
3. The septum wall grows inward, and the chromosomes are pulled toward opposite cell ends as the membrane enlarges. Other cytoplasmic components are distributed (randomly) to the two developing cells.

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?

No, BUT we will not cover this in MYP

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.