Chapter 3:

Cell Structure and Function

Characteristics of Living Organisms

- All living organisms are made up of ***cells***
- They share the following four processes:
  - **Growth:** Increase in size
  - **Reproduction:** Increase in number
  - **Responsiveness**: React to environment
  - **Metabolism:** Chemical reactions to provide energy and structures needed to grow, reproduce, and respond to environment

Distinguishing Features of *Prokaryotic* Cells:

1. DNA is:
   - **Not** enclosed within a **nuclear membrane**.
   - A **single circular** chromosome.
   - **Not** associated with **histone** proteins.
2. **Lack** membrane-enclosed organelles like mitochondria, chloroplasts, Golgi, etc.
3. Cell walls usually contain **peptidoglycan**, a complex polysaccharide.
4. Divide by **binary fission**.

Distinguishing Features of *Eukaryotic* Cells:

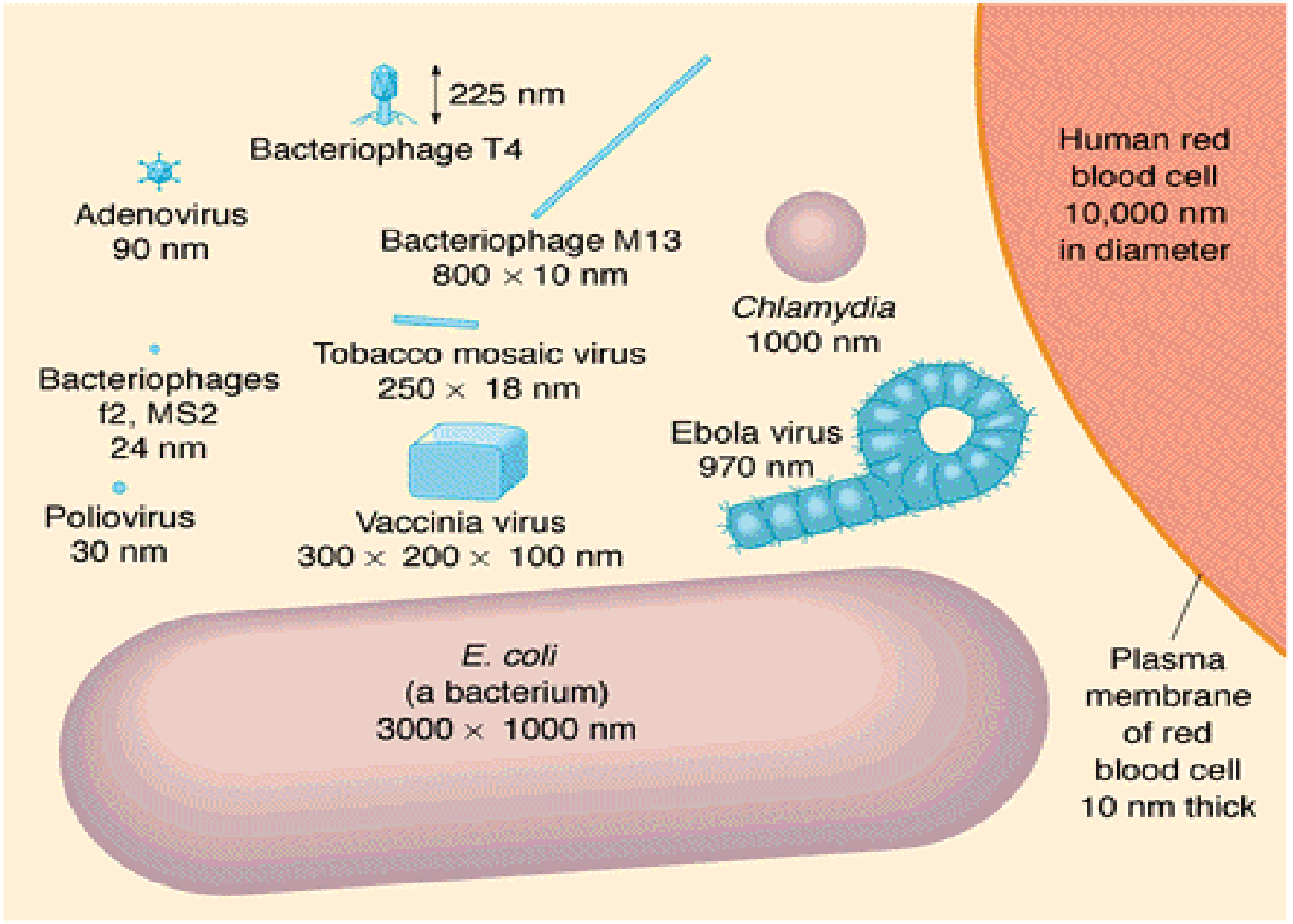
1. DNA is:
   - Enclosed within a **nuclear membrane**.
   - **Several linear** chromosomes.
   - Associated with **histones** and other proteins.
2. **Have** membrane-enclosed organelles like mitochondria, chloroplasts, Golgi, endoplasmic reticulum, etc.
3. Divide by mitosis.

The Prokaryotic Cell: Size, Shape, and Arrangement of Bacterial Cells

Cell Size:

- Dimensions of **most** bacterial cells:
  - **Diameter**: 0.2 to 2.0 μm.
    - Human red blood cell is about 7.5-10 μm in diameter.
  - **Length**: 2 to 8 μm.
    - Some cyanobacteria are up to 60 μm long.
- Bacterial cells have **large surface to volume ratios.** Therefore all parts of the cell:
  - Are close to the surface.
  - Can be quickly reached by nutrients.

Bacterial Cell Size Compared to Eukaryotic Cells and Viruses



The Prokaryotic Cell: Size, Shape, and Arrangement of Bacterial Cells

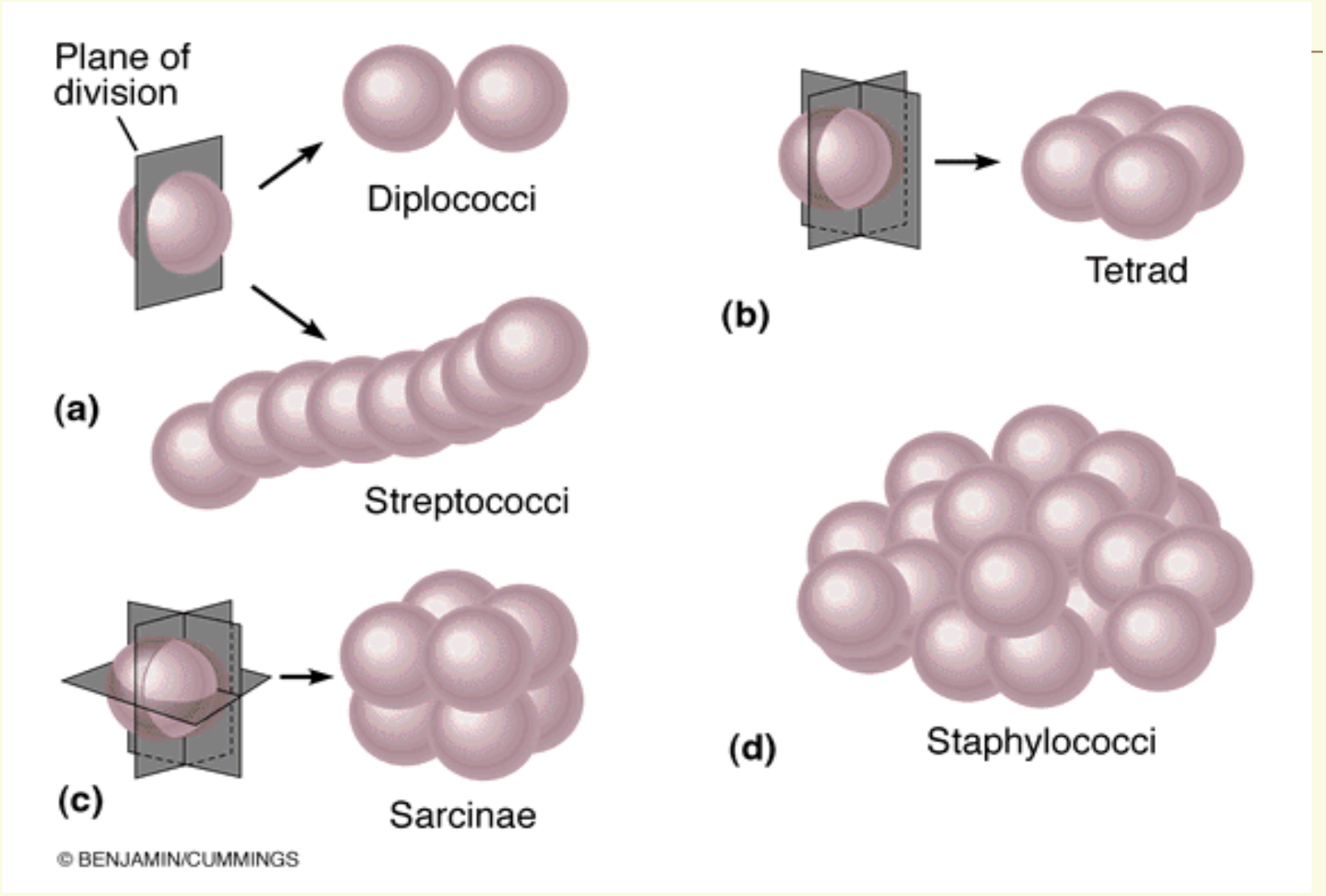
Bacterial Cell Shapes & Arrangements:

- **Coccus** (plural: cocci): Spherical.

  May have the following arrangements:

  - **Diplococci**: A pair of attached cocci. Remain attached after dividing.
  - **Streptococci**: Chainlike arrangement.
  - **Tetrads**: Groups of four. Divide in two planes.
  - **Sarcinae**: Groups of eight. Divide in three planes.
  - **Staphylococci**: Grapelike clusters. Divide in multiple planes

Common Arrangements of Cocci

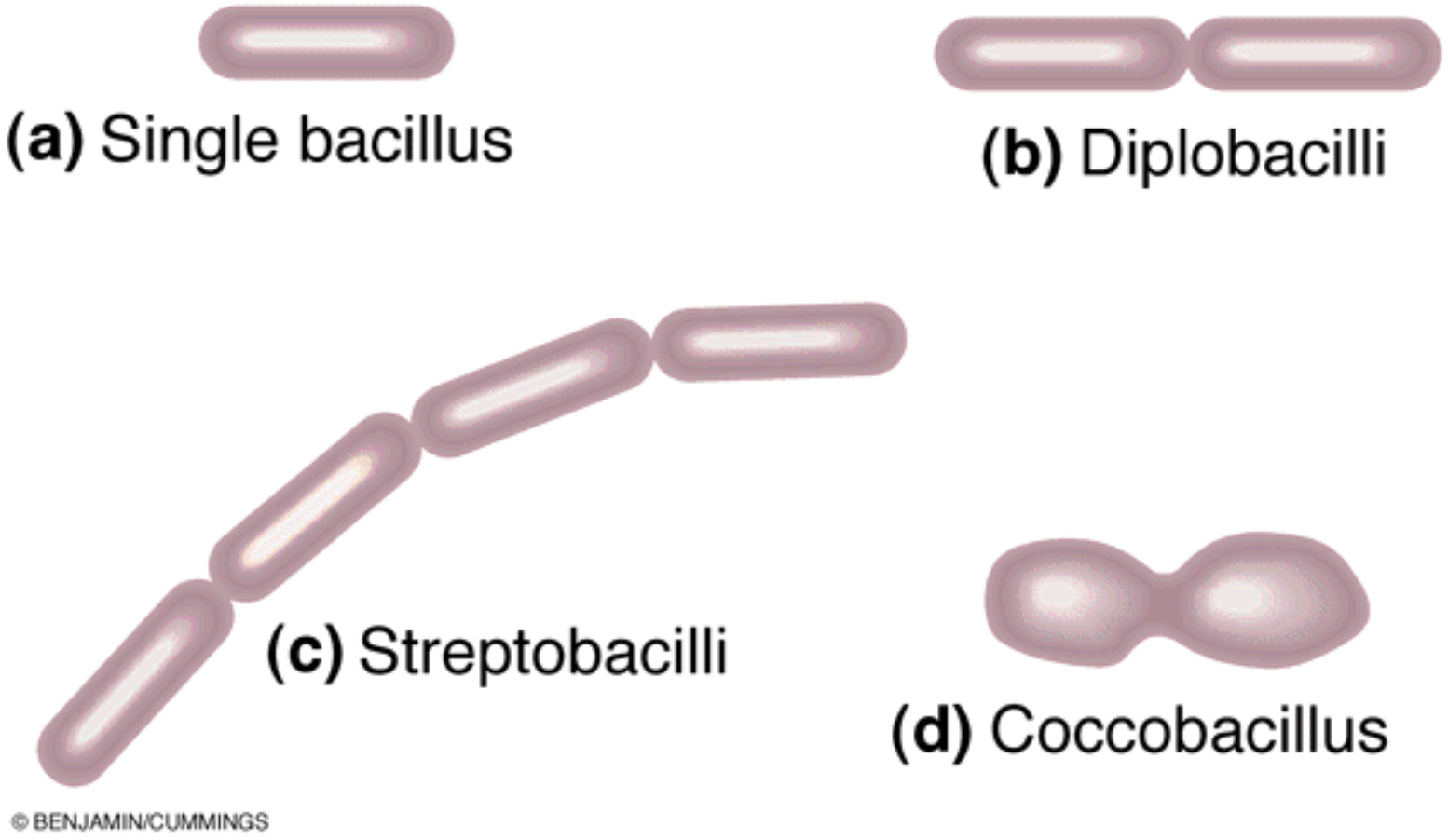


The Prokaryotic Cell: Size, Shape, and Arrangement of Bacterial Cells

Bacterial Cell Shapes & Arrangements:

- **Bacillus** (plural: bacilli): Rod-shaped. Most bacilli appear as single rods but may see:
  - **Diplobacilli**: A pair of attached bacilli. Remain attached after dividing.
  - **Streptobacilli**: Chainlike arrangement.
- **Coccobacillus**: Intermediate shape between coccus and bacillus. Oval rods.

Different Types of Bacilli

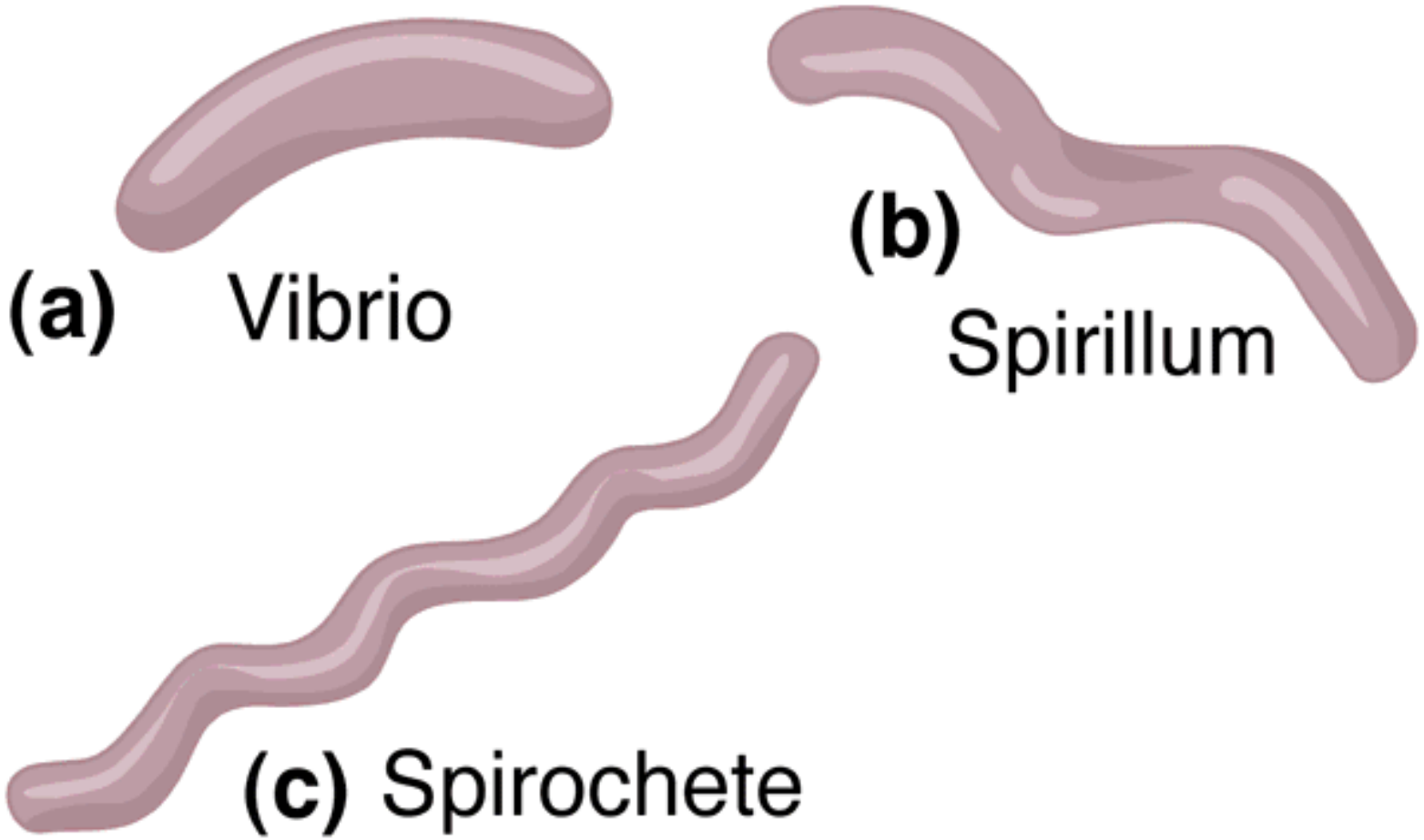


The Prokaryotic Cell: Size, Shape, and Arrangement of Bacterial Cells

Bacterial Cell Shapes & Arrangements :

- **Spiral Bacteria**: Have one or more twists:
  - **Vibrio**: A comma shaped cell. Look like curved rods.
  - **Spirilla**: Helical, corkscrew shaped bacteria with **rigid** bodies.
    - Use whiplike **external flagella** to move.
  - **Spirochetes**: Helical bacteria with **flexible** bodies.
    - Use **axial filaments** (internal flagella) to move.

Spiral Shaped Bacteria



The Prokaryotic Cell: Size, Shape, and Arrangement of Bacterial Cells

Bacterial Cell Shapes & Arrangements :

- **Other less common shapes:**
  - Star
  - Flat and square
  - Triangular
- **Pleomorphic bacteria**: Have several possible shapes. Found in a few groups:
  - *Corynebacterium*
  - *Rhizobium*

Most bacteria are **monomorphic**: Maintain a single shape. However environmental factors may affect cell shape.

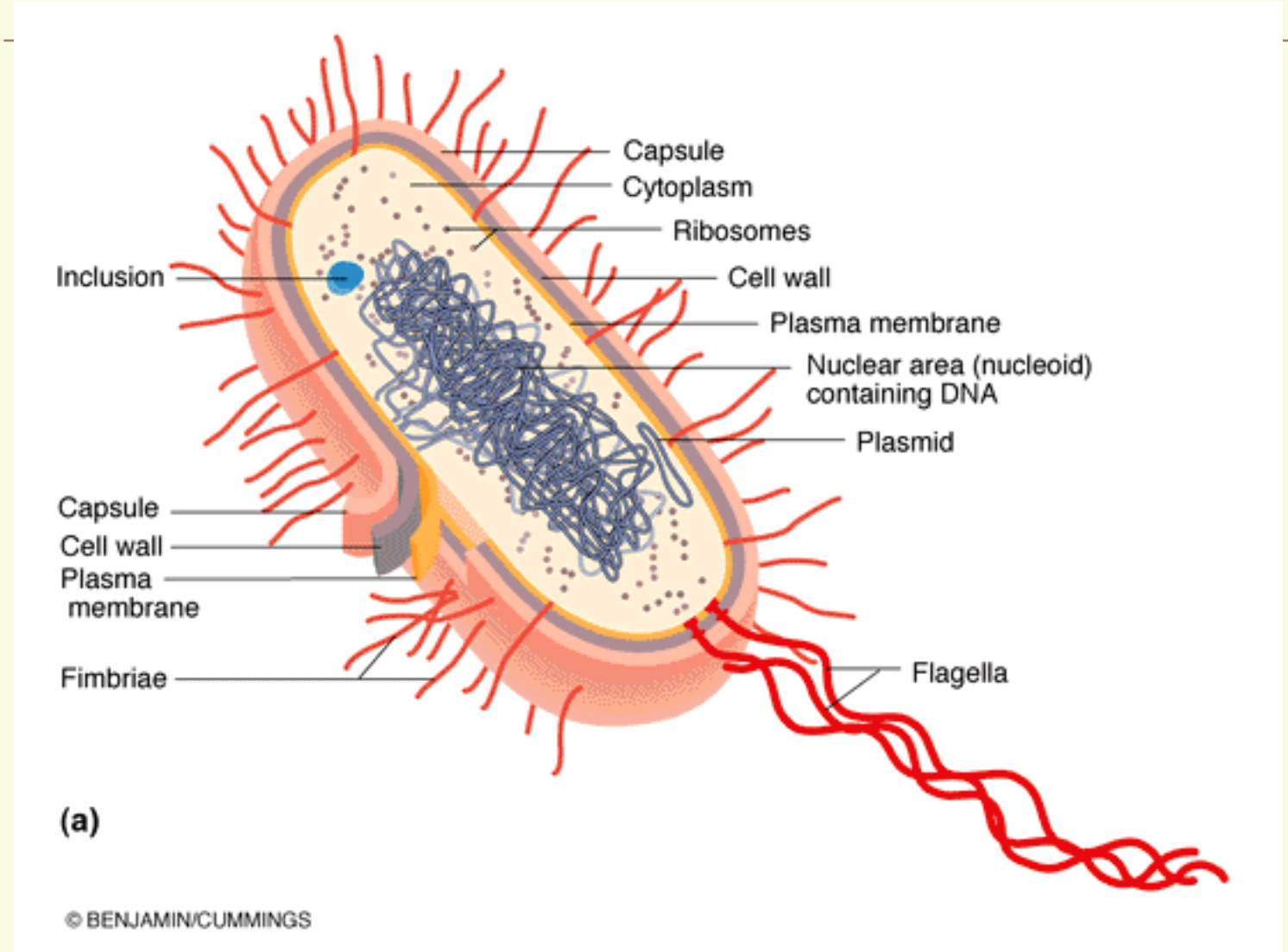
The Prokaryotic Cell Structure

I. Structures External to the Cell Wall

1. Glycocalyx: "Sugar coat".

- All polysaccharide containing substances found external to the cell wall, from the thickest **capsules** to the thinnest **slime layers**.
- All bacteria have at least a thin slime layer.
- Chemical composition varies widely with species.
  - A glycocalyx made of sugars is called an **extracellular polysaccharide** (**EPS**).
- The glycocalyx may have several functions:
  - Attachment to host cells.
  - Source of nutrition.
  - Prevent dehydration.
  - Escape host immune system.

Prokaryotic Cell Structure



Prokaryotic Cell Structure
I. Structures External to the Cell Wall

1. Glycocalyx: "Sugar coat".

- **A. Capsules:** Organized polysaccharide substance that is **firmly attached** to the cell wall.
  - Not formed by all bacteria.
  - Important in virulence.
    - Anthrax bacteria only cause anthrax if have protein capsule.
    - Only *Streptococcus pneumoniae* with capsule cause pneumonia.
  - Help bacteria escape the host immune system, by preventing destruction by phagocytosis.
  - When bacteria lose their capsules they become less likely to cause disease and more susceptible to destruction.

Prokaryotic Cell Structure

I. Structures External to the Cell Wall

1. Glycocalyx:

B. Slime Layer: Thin polysaccharide substance that is loosely attached to the cell wall.

- Not formed by all bacteria.
- Important for virulence.
  - Oral bacteria stick to teeth due to slime layer and with time produce dental plaque.
- Allow bacteria to adhere to objects in their environment so they can remain near sources of nutrients or oxygen.
  - Rock surfaces
  - Plant roots
- Help bacteria trap nutrients near cell and prevent dehydration.

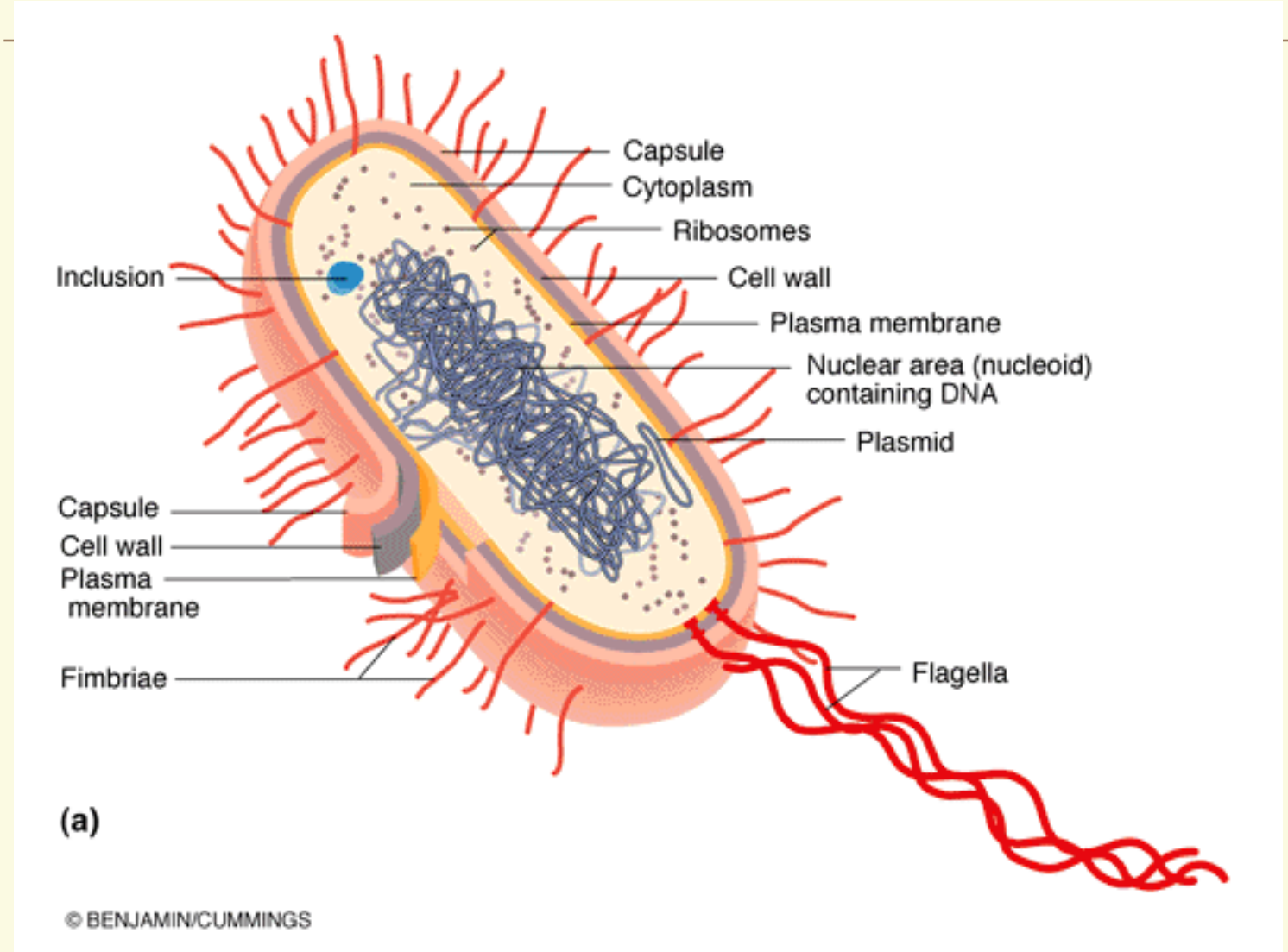
Prokaryotic Cell Structure

I. Structures External to the Cell Wall

2. Flagella (Sing. Flagellum):

- About half of all known bacteria are motile, most use flagella.
- Long, thin, helical appendages.
- A bacterium may have one or several flagella, which can be in the following arrangements:
  - **Monotrichous**: Single polar flagellum at one end.
  - **Amphitrichous**: Two polar flagella, one at each end.
  - **Lophotrichous**: Two or more flagella at one or both ends.
  - **Peritrichous**: Many flagella over entire cell surface.

Prokaryotic Cell Structure



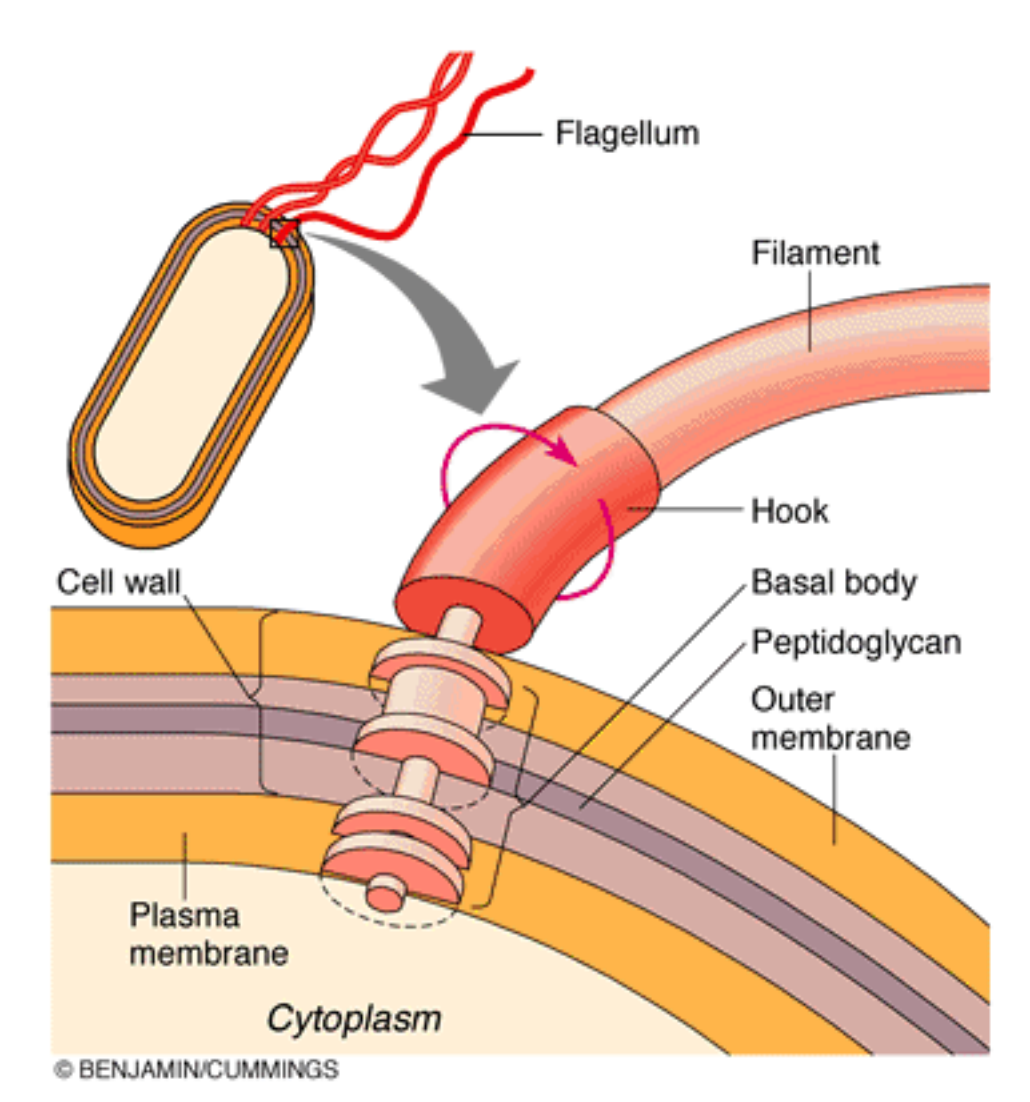
Prokaryotic Cell Structure

I. Structures External to the Cell Wall

2. Flagella (Sing. Flagellum):

- Flagella have three basic parts:
  - **1. Filament:** Outermost region.
    - Contains globular protein flagellin.
    - Not covered by a sheath like eukaryotic filaments.
  - **2. Hook:** Wider segment that anchors filament to basal body.
  - **3. Basal Body:** Complex structure with a central rod surrounded by a set of rings.
    - Gram negative bacteria have 2 pairs of rings.
    - Gram positive bacteria only have one pair of rings.

Flagellum of Gram-Negative Bacterium



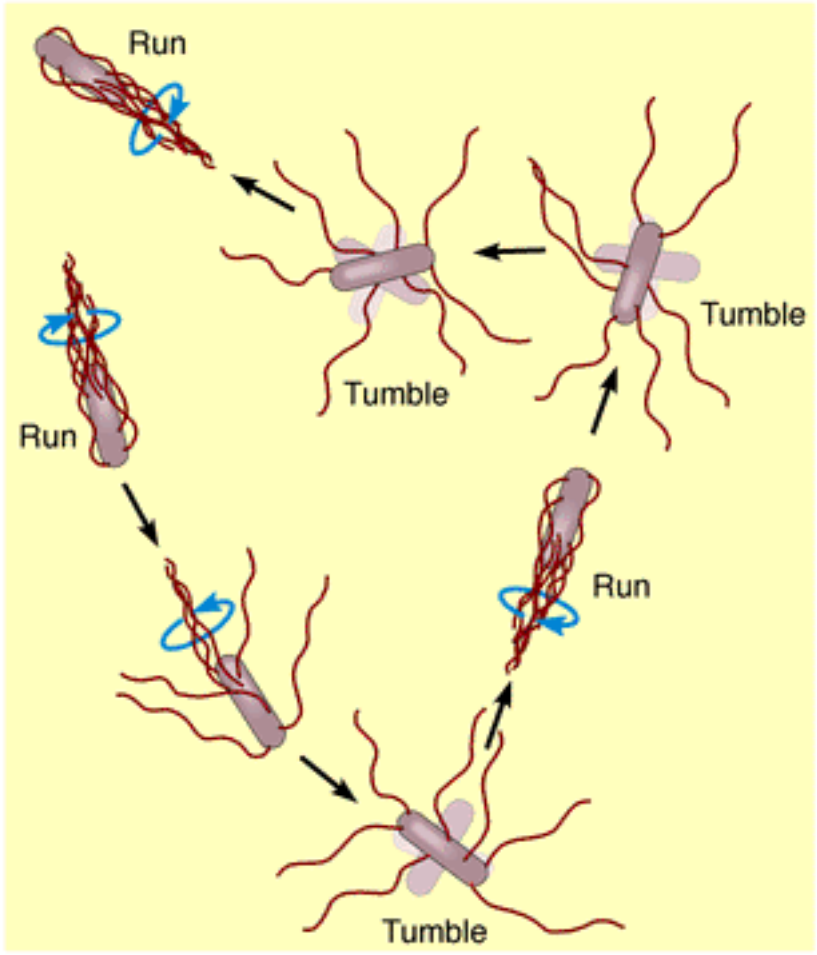
Prokaryotic Cell Structure

I. Structures External to the Cell Wall

2. Flagella (Sing. Flagellum):

- Bacterial flagella move by **rotation** from basal body.
- Flagellar movement may be either clockwise or counterclockwise.
- Bacteria may be capable of several patterns of motility.
  - **Runs or swims:** Bacterium moves in one direction.
  - **Tumbles:** Bacterium changes direction. Caused by reversal of flagellar rotation.

Patterns of Bacterial Motility



Prokaryotic Cell Structure

I. Structures External to the Cell Wall

2. Flagella (Sing. Flagellum):

- **Taxis**: Movement of a cell toward or away from a particular stimulus.
  - **Chemotaxis**: Movement in response to a chemical stimulus.
  - **Phototaxis**: Movement in response to a light stimulus.
- **Flagellar protein H antigens** are used to identify important pathogens.
  - **E. coli O157:H7**: Causes bloody diarrhea associated with foodborne epidemics. Causes 200-500 deaths per year.

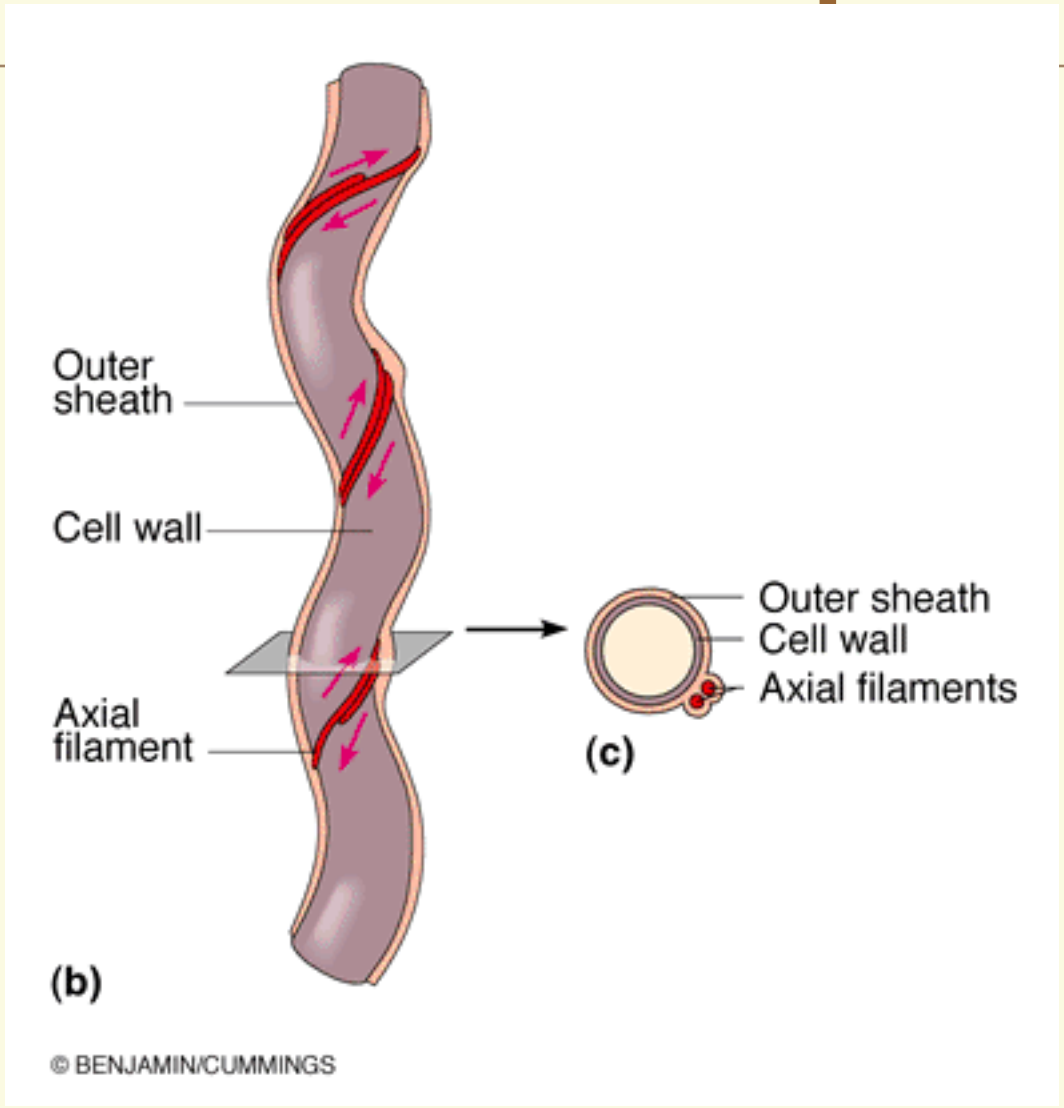
Prokaryotic Cell Structure

I. Structures **External** to the Cell Wall

3. Axial Filaments (Endoflagella):

- Bundles of fibers that are anchored at ends of the cell beneath the outer sheath.
- Spiral around the cells.
- Have similar structure to flagella.
- Rotation of endoflagella produces a **corkscrew** motion.
- May enable bacteria to penetrate body tissues.
- Found in **spirochetes**:
  - ***Treponema pallidum***: Cause of syphilis.
  - ***Borrelia burgdorferi***: Cause of Lyme disease.

Axial Filaments in Spirochetes



Prokaryotic Cell Structure

I. Structures External to the Cell Wall

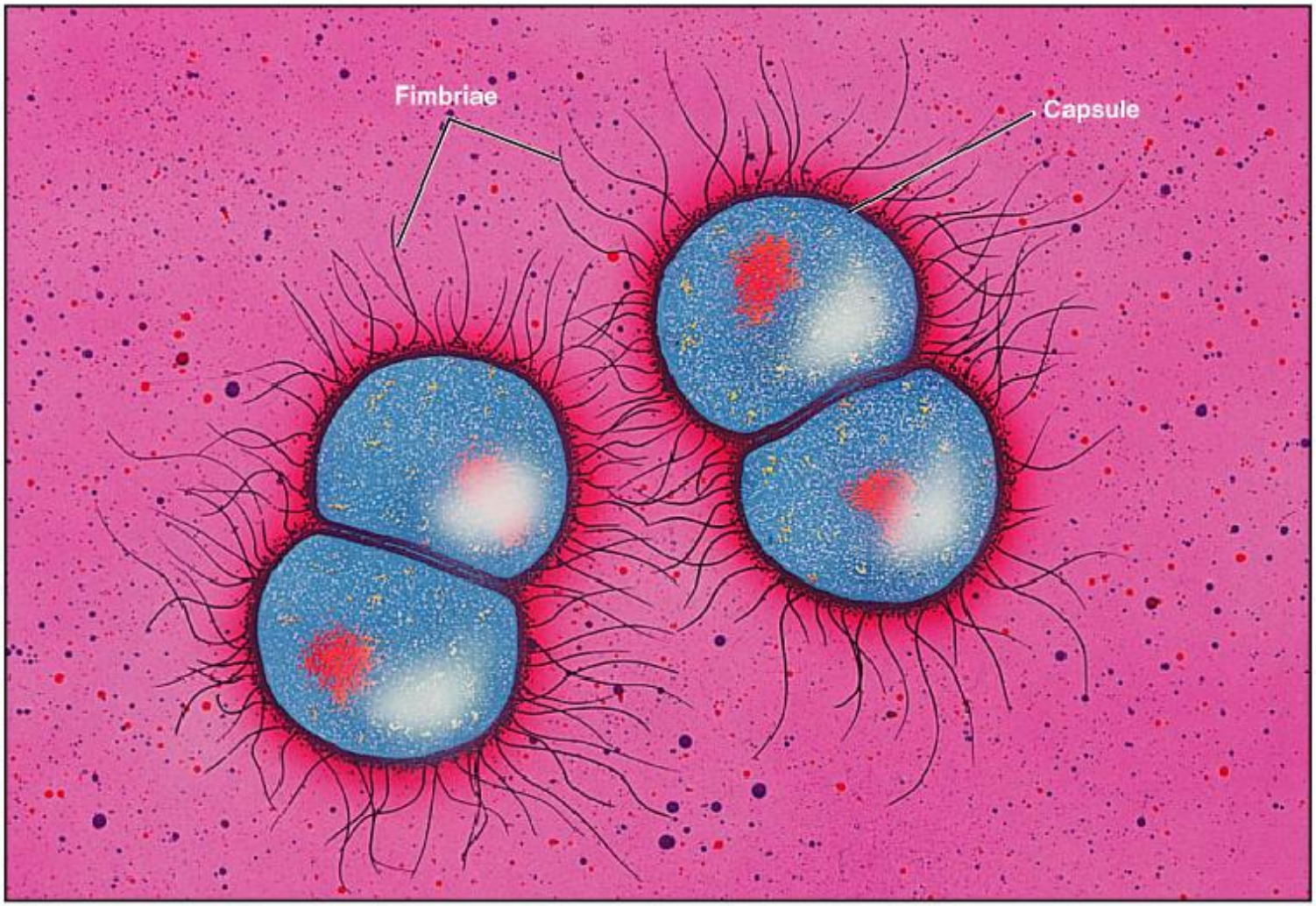
4. Fimbriae and Pili:

- Hairlike appendages that are shorter, straighter, and thinner than flagella.
- Used for **attachment** rather than motility.

A. Fimbriae (Sing: fimbria)

- May occur at poles or over entire cell surface.
- Like glycocalyx, enable bacteria to **adhere** to surfaces. Important for colonization of host tissue.
  - ***Neisseria gonorrhoeae***: Causes gonorrhea. Attach to sperm cells and mucous membranes through fimbriae.
  - Bacteria can attach to broth surface via fimbriae, forming a film-like layer called **pellicle**.
  - Important in the formation of **biofilms.**

Neisseria gonorrhea Diplococci



Prokaryotic Cell Structure

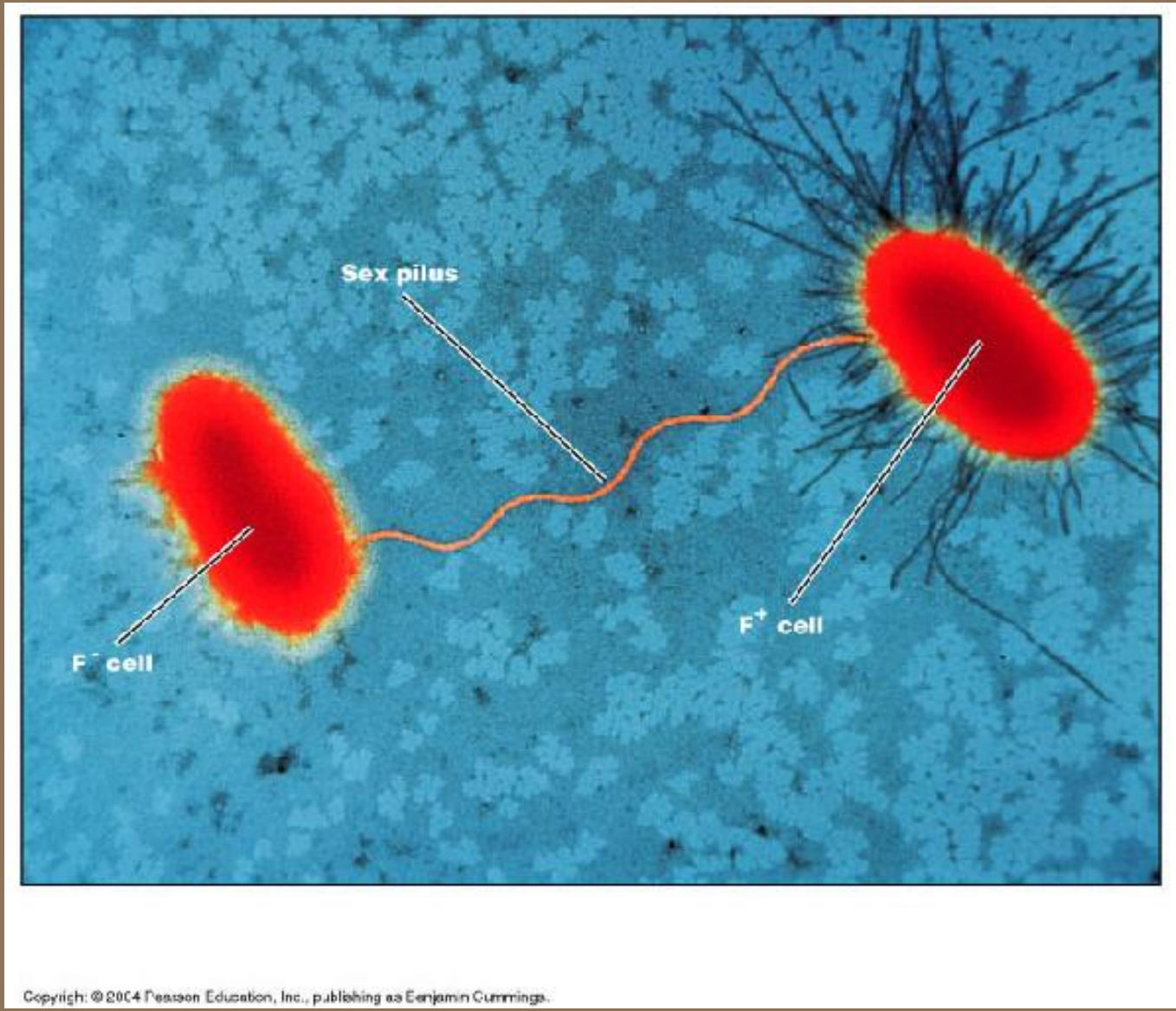
I. Structures External to the Cell Wall

4. Fimbriae and Pili:

B. Pili (Sing: pilus): Conjugation or sex pili

- Only found in certain groups of bacteria.
- Longer than fimbriae.
- Cells only have one or two sex pili.
- Attach two cells together, and allow the **transfer** of **genetic material** (DNA) between cells.
- Medically important because allow for the **transfer of antibiotic resistance genes** from one cell to another.

Bacterial Conjugation through Sex Pilus



Prokaryotic Cell Structure

II. The Cell Wall

General Characteristics:

- **Semirigid** structure that lies outside the cell membrane in almost all bacteria.
- **Two major functions**:
  1. **Maintains** characteristic **shape** of cell.
  2. **Prevents** the cell from **bursting** when fluids flow into the cell by osmosis.
- Contributes to bacterial ability to cause disease.
- Site of action of some **antibiotics**.
- Very **porous** and does not regulate passage of materials into the cell.

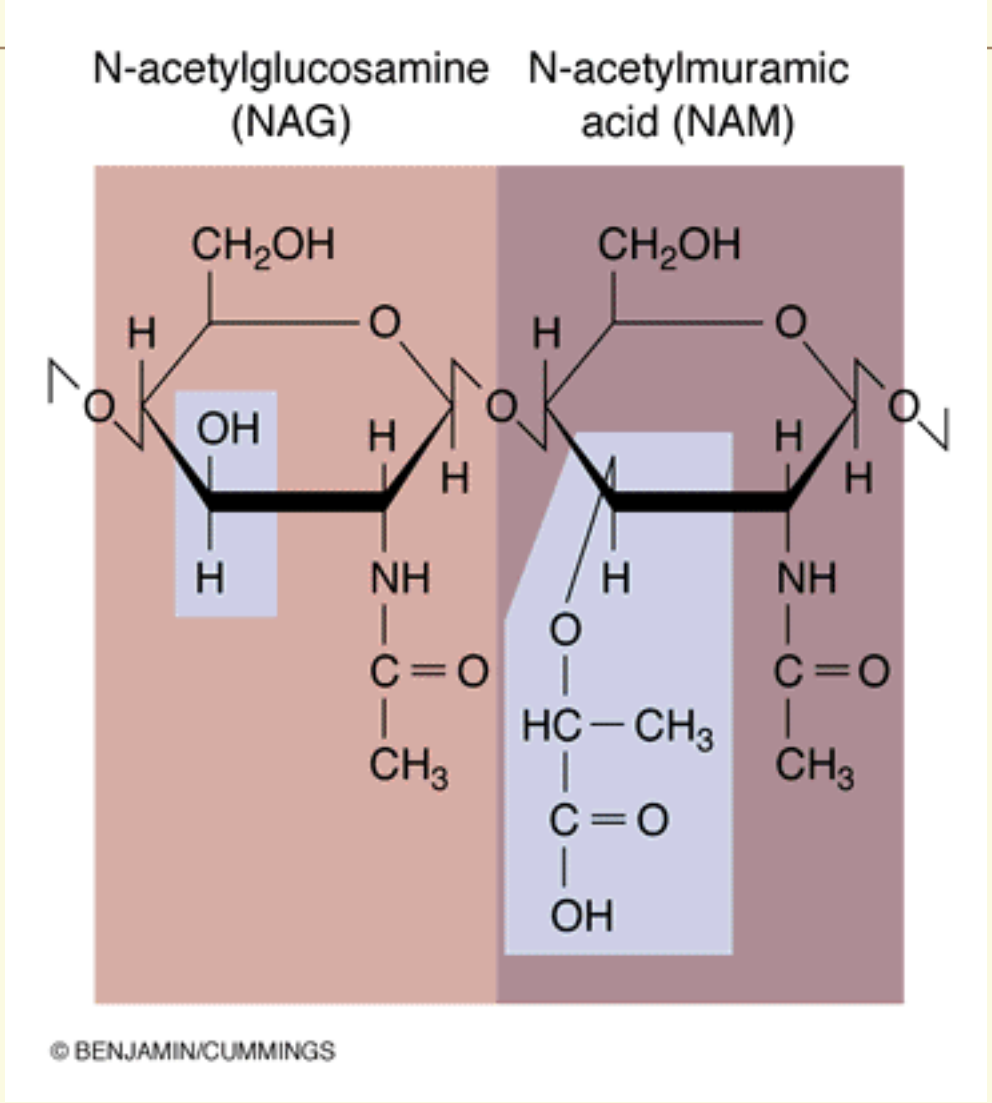
Prokaryotic Cell Structure

II. The Cell Wall

Composition:

- **Peptidoglycan (Murein):** Made up of a repeating disaccharide attached by polypeptides to form a lattice.
- Peptidoglycan is one immense covalently linked molecule, resembling multiple layers of chain link fence.
  - **Disaccharide** component: Made up of two monoscaccharides:
    - **N-acetylglucosamine (NAG)**
    - **N-acetylmuramic acid (NAM)**
  - Alternating disaccharides (NAG-NAM) are linked together in rows of 10 to 65 molecules.

NAG-NAM Peptidoglycan Disaccharide



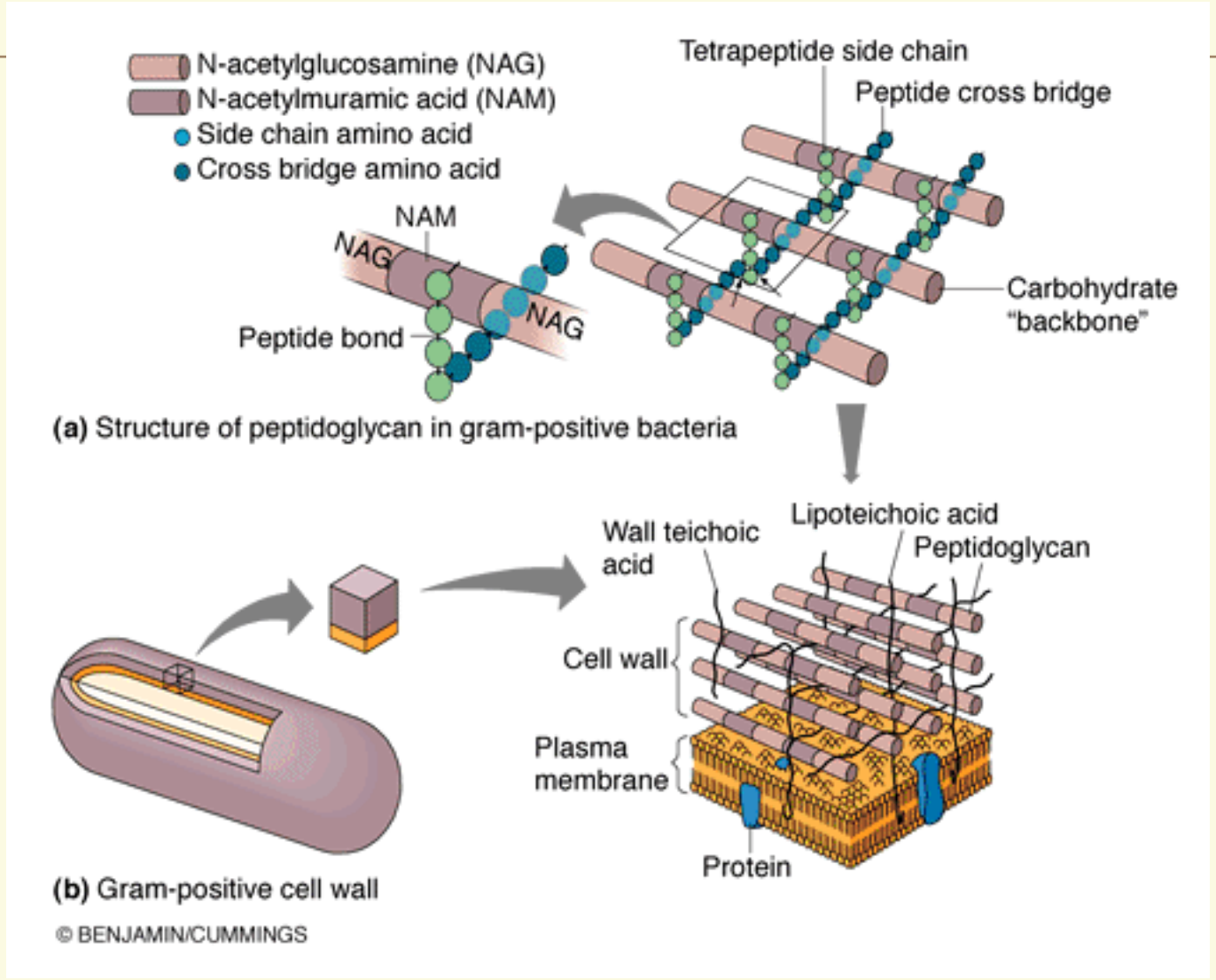
Prokaryotic Cell Structure

II. The Cell Wall

Composition:

- **Peptidoglycan (Murein):.**
  - Adjacent disaccharide rows are **linked together by polypeptide chains** which vary in composition, but always contain **tetrapeptide side chains**.
  - **Parallel tetrapeptide side chains** may be directly linked together or linked by a polypeptide cross-bridge.
  - **Penicillin** interferes with the final linking of peptidoglycan rows by peptide cross bridges. As a result, the cell wall is greatly weakened and cell undergoes **lysis**.

A. Peptidoglycan Structure
B. Gram-Positive Cell Wall Structure



Prokaryotic Cell Structure

II. The Cell Wall

Gram-Positive Cell Walls:

- Consist of **several layers** of **peptidoglycan**, which form a **thick**, **rigid** structure (20-80 nm).
- Also contain **teichoic acids**, which are made up of an alcohol and a phosphate group. Two types:
  - **Lipoteichoic acids**: Span cell wall, linked to cell membrane.
  - **Wall teichoic acids**: Linked to peptidoglycan layer.
- **Teichoic acids** are negatively charged and:
  - Bind to and regulate movement of cations into cell.
  - Regulate cell growth and prevent cell lysis.
  - Can be used to identify bacteria.

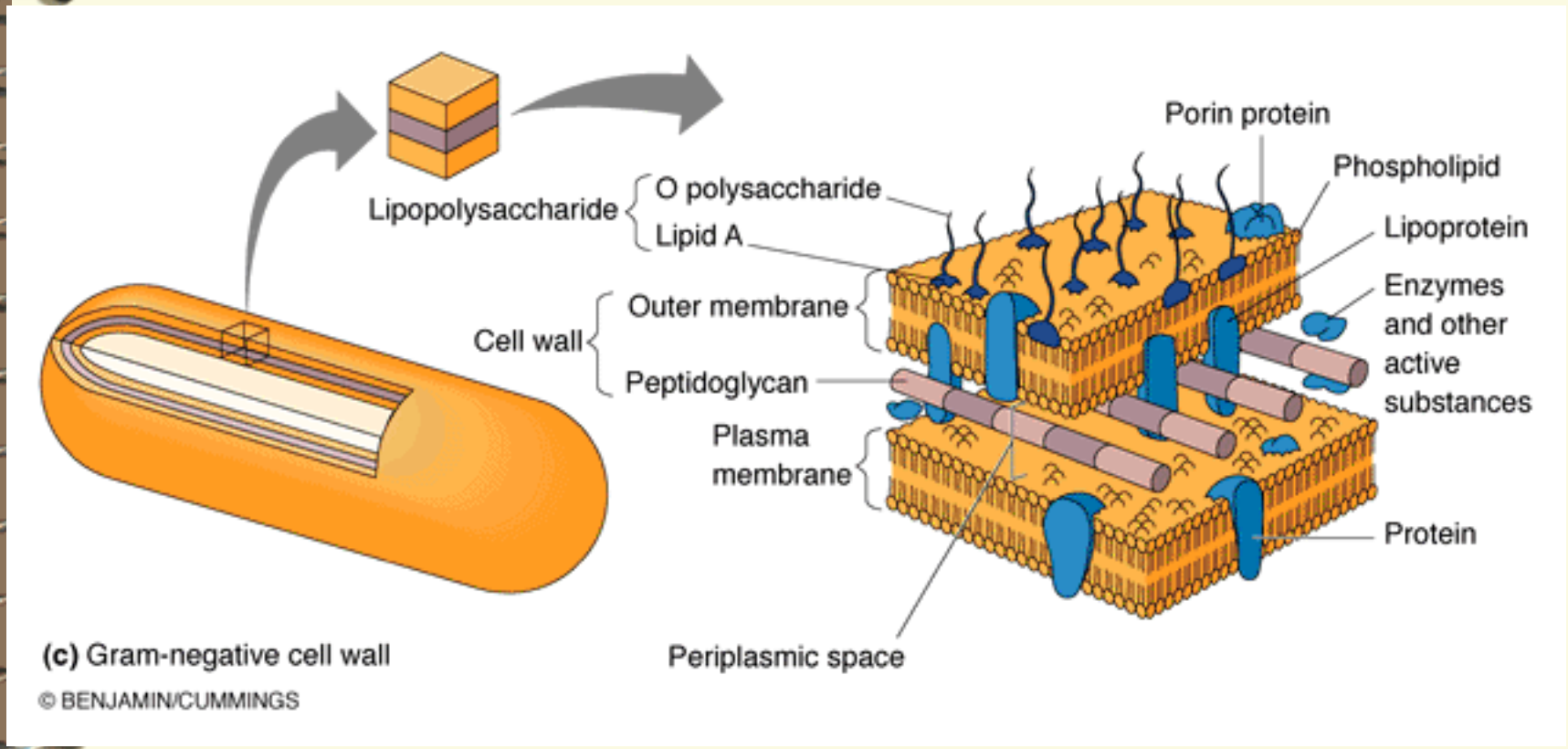
Prokaryotic Cell Structure

II. The Cell Wall

Gram-Negative Cell Walls:

- Cell wall is **thinner**, more **complex** and more susceptible to mechanical breakage than that of Gram-positive bacteria.
- Consist of **one** or a **few peptidoglycan layers** and an **outer membrane**.
- Peptidoglycan is bonded to **lipoproteins** in:
  - **Outer membrane**
  - **Periplasmic space**: Region between outer membrane and plasma membrane.
- Periplasmic space contains degradative enzymes and transport proteins.

Gram-Negative Cell Wall Structure



II. The Cell Wall

Gram-Negative Cell Walls:

Outer Membrane (OM):

- Consists of:
  - **Phospholipid bilayer**
  - **Lipopolysaccharides** (LPS) with two components:
    - **O polysaccharides**: Antigens, used to identify bacteria.
    - **Lipid A**: Endotoxin causes fever and shock.
  - **Porins**: Membrane proteins that allow the passage of nucleotides, disaccharides, peptides, amino acids, vitamins, and iron.
  - **Lipoproteins**
- **Functions of Outer Membrane:**
  - Evade phagocytosis and complement due to strong negative charge.
  - Barrier to antibiotics (penicillin), digestive enzymes (lysozyme), detergents, heavy metals, dyes, and bile salts.

II. The Cell Wall

Atypical Cell Walls:

1. Acid-Fast Bacteria:

- Cell wall is thick like that of Gram-positive bacteria.
- Contains **60% lipids** and much less peptidoglycan. Has a waxy consistency.
- Lipids make cells impermeable to many stains, and protect them from acids, alkalis, and antibiotics.
- Organisms **grow slowly** because nutrients penetrate inefficiently and cells spend a lot of energy making lipids.
- Stain as Gram-positive.

II. The Cell Wall

Atypical Cell Walls:

2. Mycoplasmas:

- **Smallest** known bacteria that can grow and reproduce **outside** of host cells.
- They **have no cell wall**.
- Pass through most bacterial filters. Originally mistaken for viruses.
- Unique plasma membrane contains lipids called **sterols**, which protect them from osmotic lysis.

3. Archaebacteria

- May lack cell walls or have cell walls without peptidoglycan.
- Instead of peptidoglycan, may have **pseudomurein**.

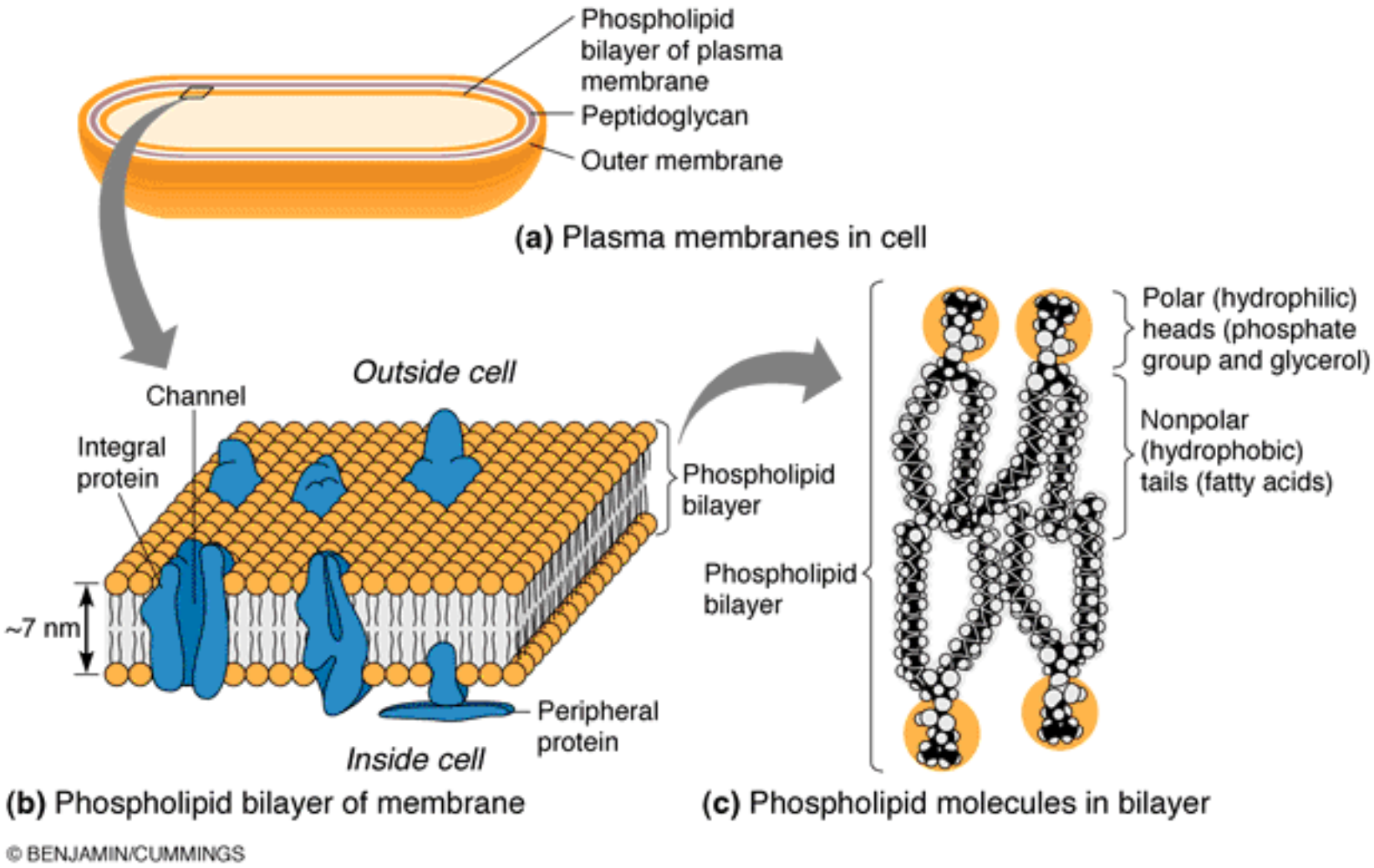
Prokaryotic Cell Structure

III. Structures Internal to the Cell Wall

1. The Plasma (Cytoplasmic) Membrane:

- Thin structure inside of cell wall that surrounds the cytoplasm.
- Phospholipid bilayer with proteins (**Fluid mosaic** model).
  - **Integral** membrane proteins: Penetrate membrane completely.
  - **Peripheral** membrane proteins: On inner or outer membrane surface.
- Lack sterols and are less rigid than eukaryotic membranes.
  - Exception: Mycoplasmas

Structure of Plasma Membrane



Prokaryotic Cell Structure

III. Structures Internal to the Cell Wall

Functions of the Plasma (Cytoplasmic) Membrane:

1. **Selective barrier** that regulates the passage of materials in and out of the cell.
   - **Impermeable** to large proteins, ions, and most polar molecules.
   - **Permeable** to water, oxygen, carbon dioxide, some simple sugars, and small nonpolar substances.
2. **Nutrient breakdown and energy (ATP) production:** Site of cellular respiration.
3. **Synthesis of cell wall components**
4. **Assists with DNA replication**

Prokaryotic Cell Structure

III. Structures Internal to the Cell Wall

Functions of the Plasma (Cytoplasmic) Membrane:

5. **Site of photosynthesis:** Photosynthetic bacteria have membrane extensions called thylakoids, where photosynthesis occurs.
6. **Secretes proteins**
7. **Contains bases of flagella**
8. **Responds to chemical substances in the environment**

Prokaryotic Cell Structure

III. Structures Internal to the Cell Wall

- **Destruction of the Plasma Membrane:** Several antimicrobial agents damage the integrity of the plasma membrane.

They commonly cause leakage of intracellular contents and cell death:

1. **Alcohols**
2. **Quaternary ammonium compounds**
3. **Antibiotics (Polymyxins)**

Prokaryotic Cell Structure
III. Structures Internal to the Cell Wall

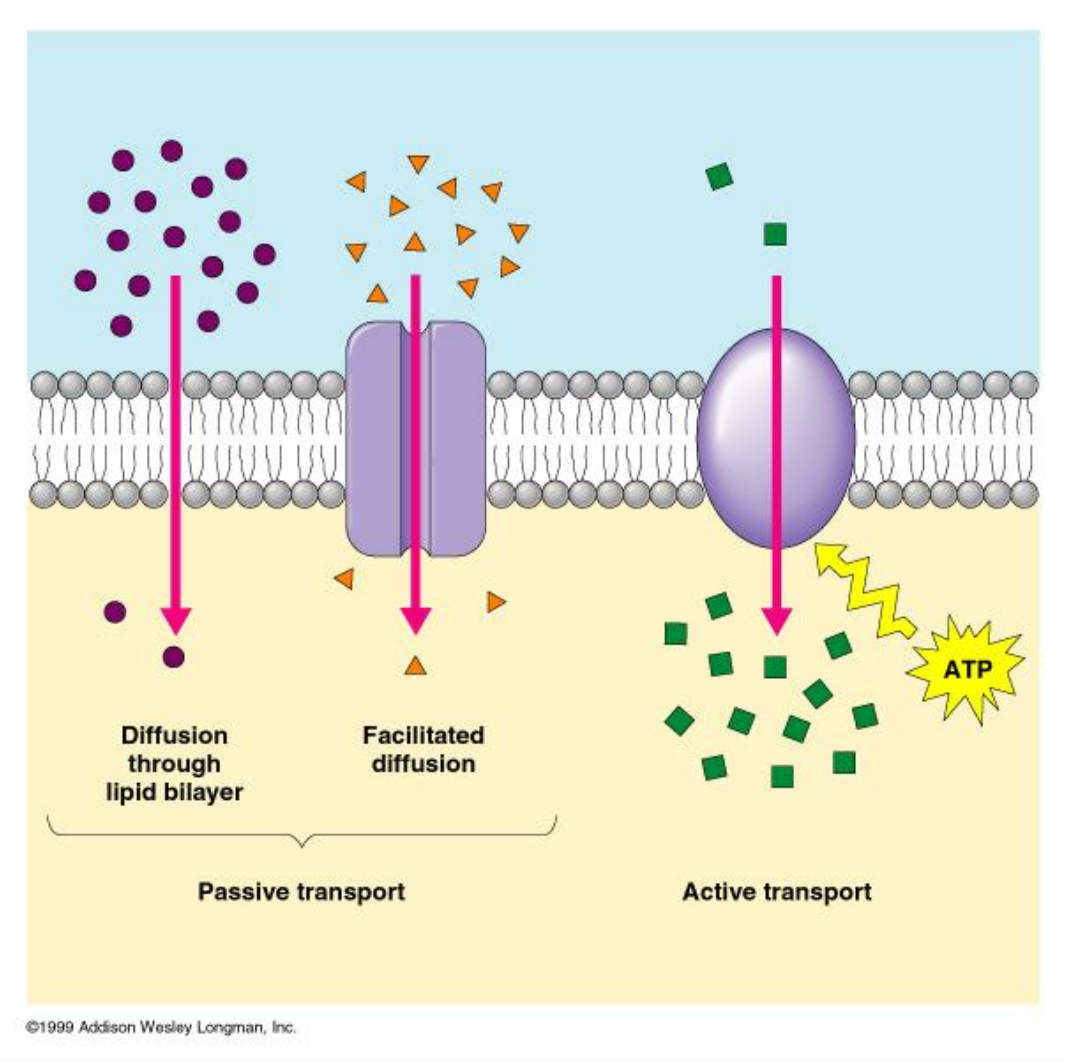
Movement of Materials Across Membranes:

Can be either a passive or an active process.

Passive Transport Processes:

- Substances move **spontaneously** from an area of **high** concentration to one of **low** concentration.
- Do **not** require energy expenditure (ATP) by the cell.
- Include the following processes:
  - Simple diffusion
  - Facilitated Diffusion
  - Osmosis

Active versus Passive Transport



Prokaryotic Cell Structure

III. Structures Internal to the Cell Wall

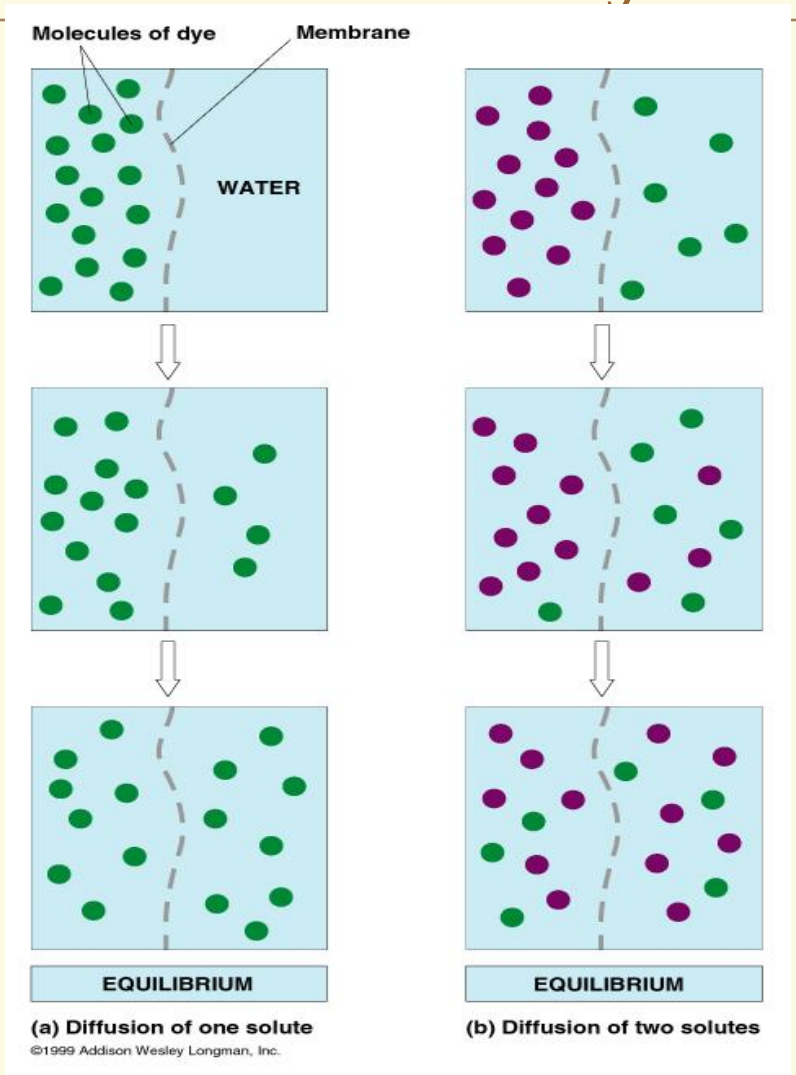
Movement of Materials Across Membranes:

Passive Transport Processes:

1. Simple diffusion:

- Net movement of molecules or ions from an area of **high** concentration to one of **low** concentration.
- **Equilibrium**: Net movement stops when molecules are evenly distributed.
- Used by cells to transport **small molecules** (oxygen, carbon dioxide) across their membranes.
- **Example**: Diffusion of perfume into the air after the bottle is opened.

Simple Diffusion is a Passive Process Equilibrium is Eventually Reached



Prokaryotic Cell Structure

III. Structures Internal to the Cell Wall

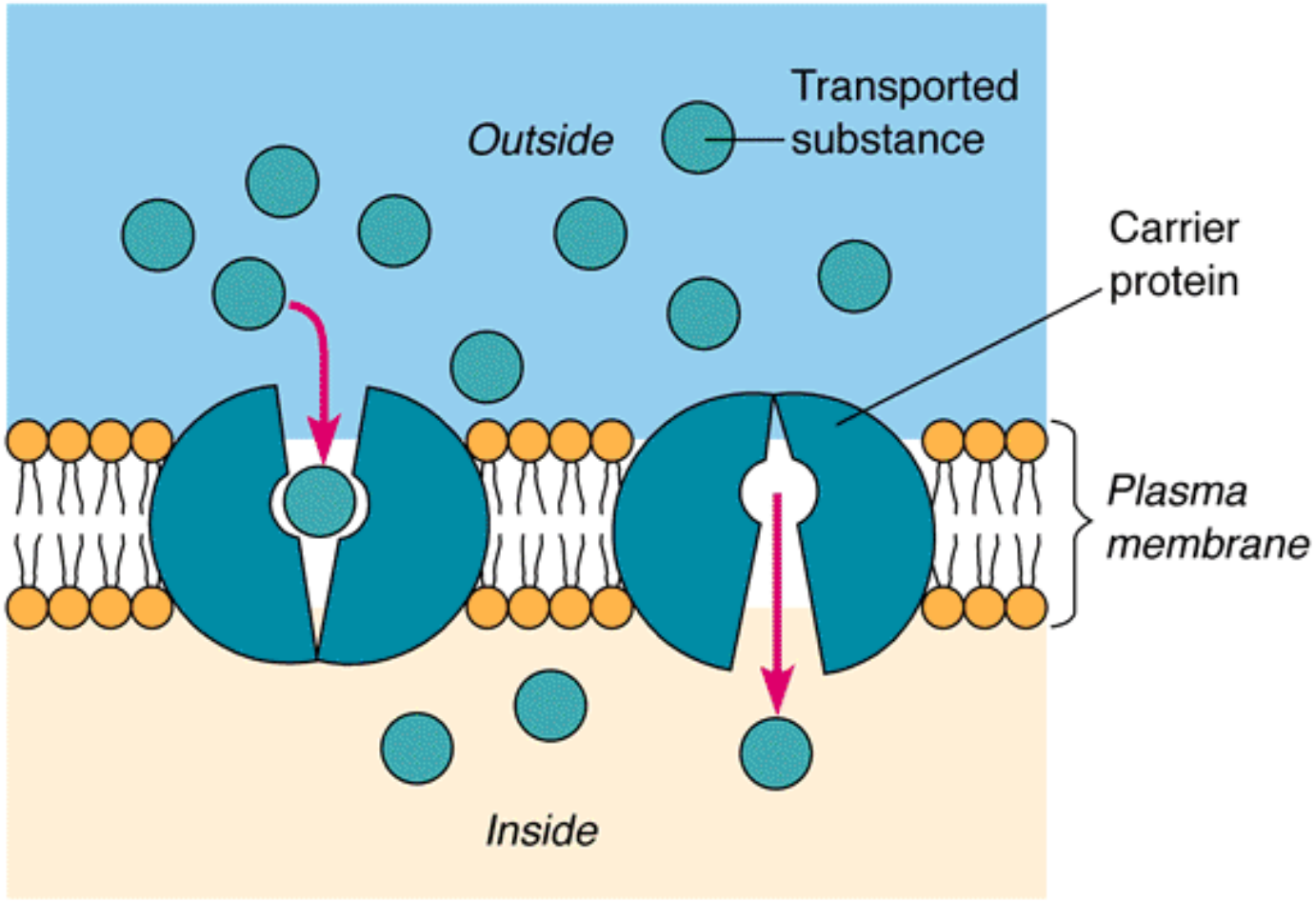
Movement of Materials Across Membranes:

Passive Transport Processes:

2. Facilitated diffusion:

- Net movement of molecules or ions from an area of **high** concentration to one of **low** concentration.
- Substance to be transported combines with a **carrier protein** in plasma membrane.
- Extracellular enzymes may be used to break down large substances before they can be moved into the cell by facilitated diffusion.

Facilitated Diffusion Requires a Membrane Carrier Protein



Prokaryotic Cell Structure
III. Structures Internal to the Cell Wall

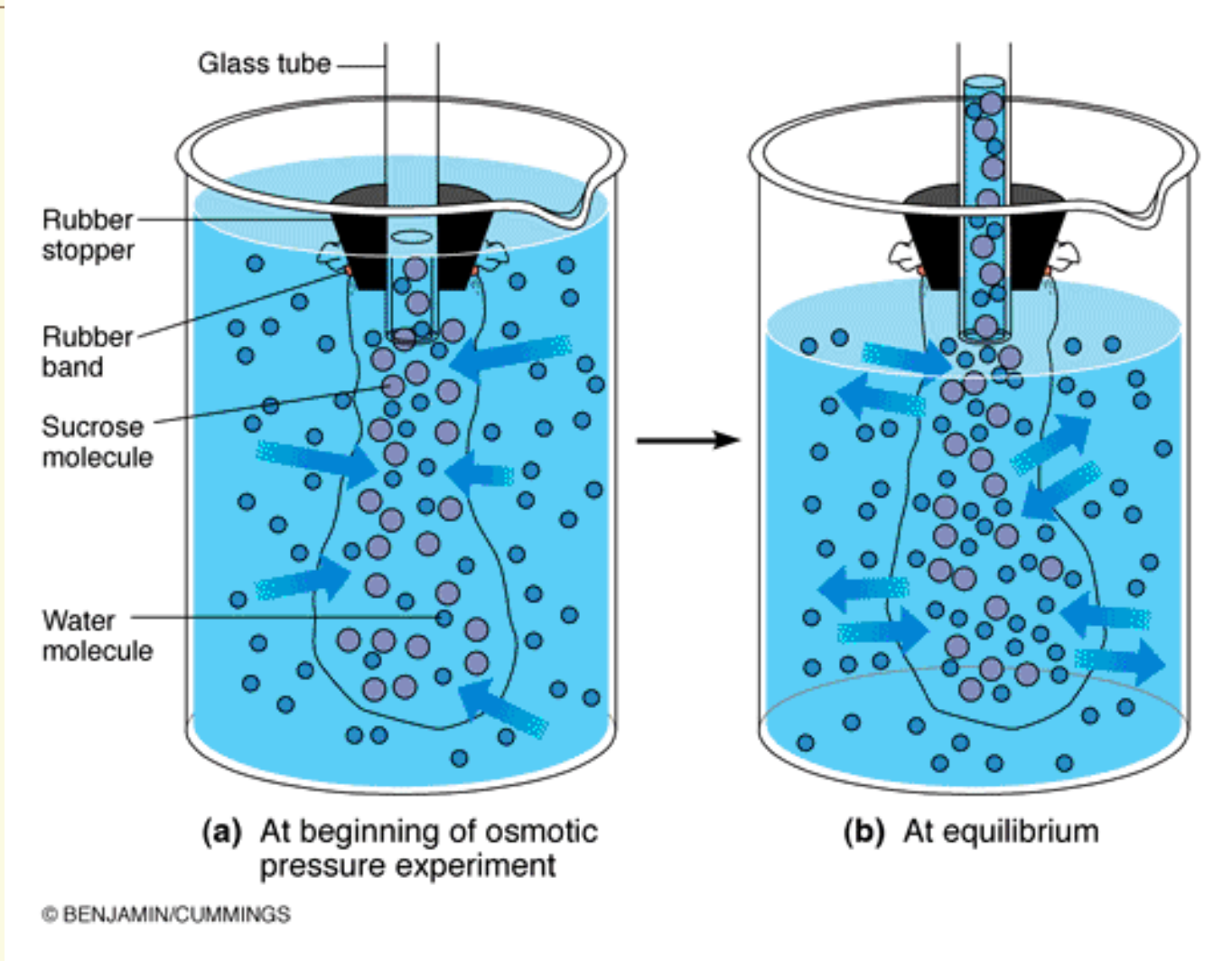
Movement of Materials Across Membranes:

Passive Transport Processes:

3. Osmosis:

- Net movement of **water (solvent)** molecules across a **semipermeable membrane** from an area of **high** concentration to one of **low** concentration of **water**.
- **Osmotic Pressure**: Pressure required to prevent the movement of pure water into a solution.

Osmosis: The diffusion of water across a semipermeable membrane



Passive Transport Processes:

3. Osmosis (Continued):

- Bacterial cells can be subjected to three different types of osmotic solutions:

1. Isotonic: Concentration of solutes (and water) are equal on both sides of a cell membrane (e.g.: 0.9% NaCl, 5% glucose).

Result: No net movement of water into or out of the cell.

2. Hypotonic: Solute concentration is **lower** outside the cell (e.g.: pure water).

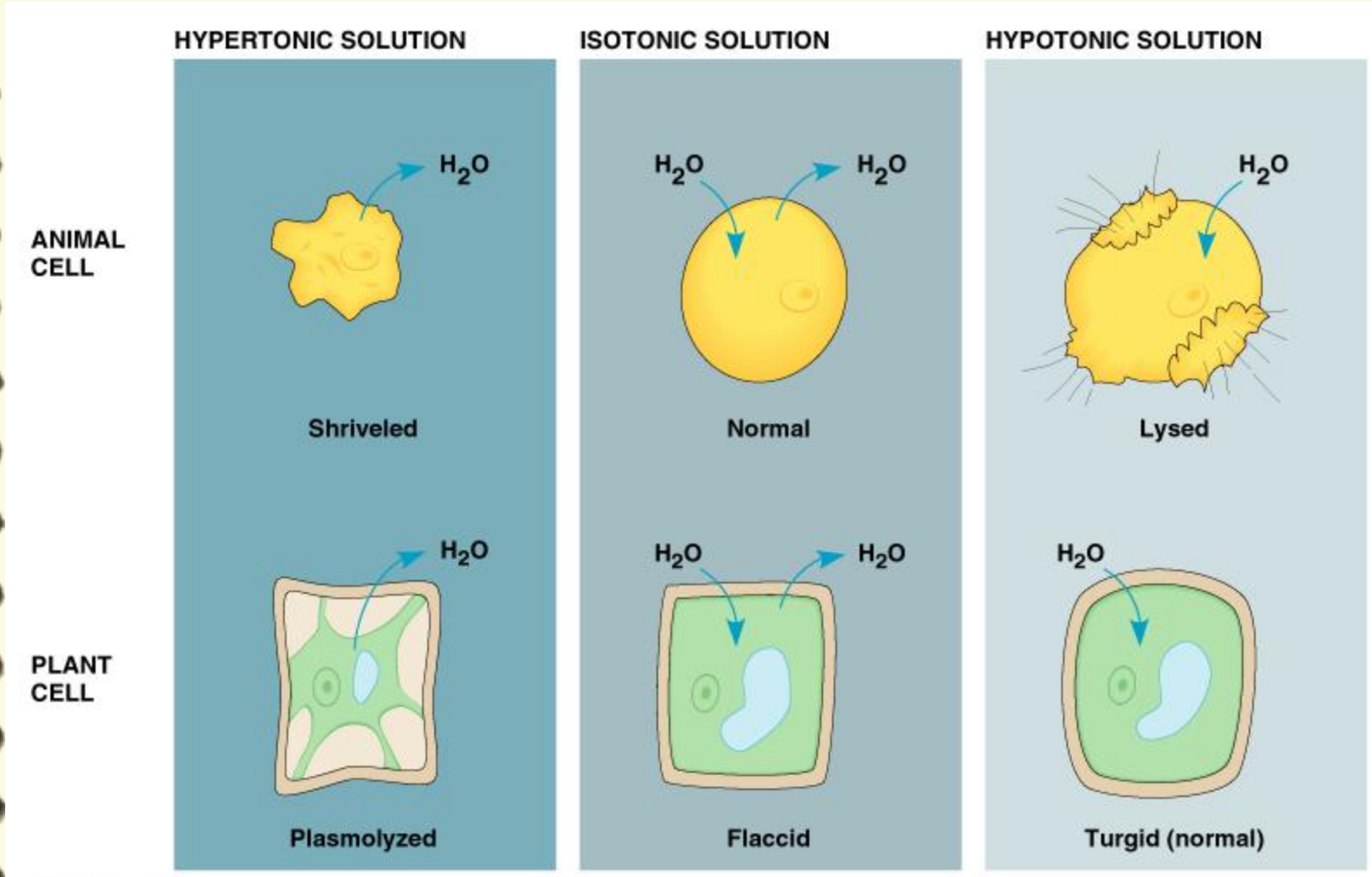
Result: Net movement of water **into** the cell.

Most bacteria live in hypotonic environments. Cell wall protects them from lysis.

3. Hypertonic: Solute concentration is **higher** outside the cell.

Result: Net movement of water **out** of the cell.

Effects of Osmosis on Cells



Movement of Materials Across Membranes:

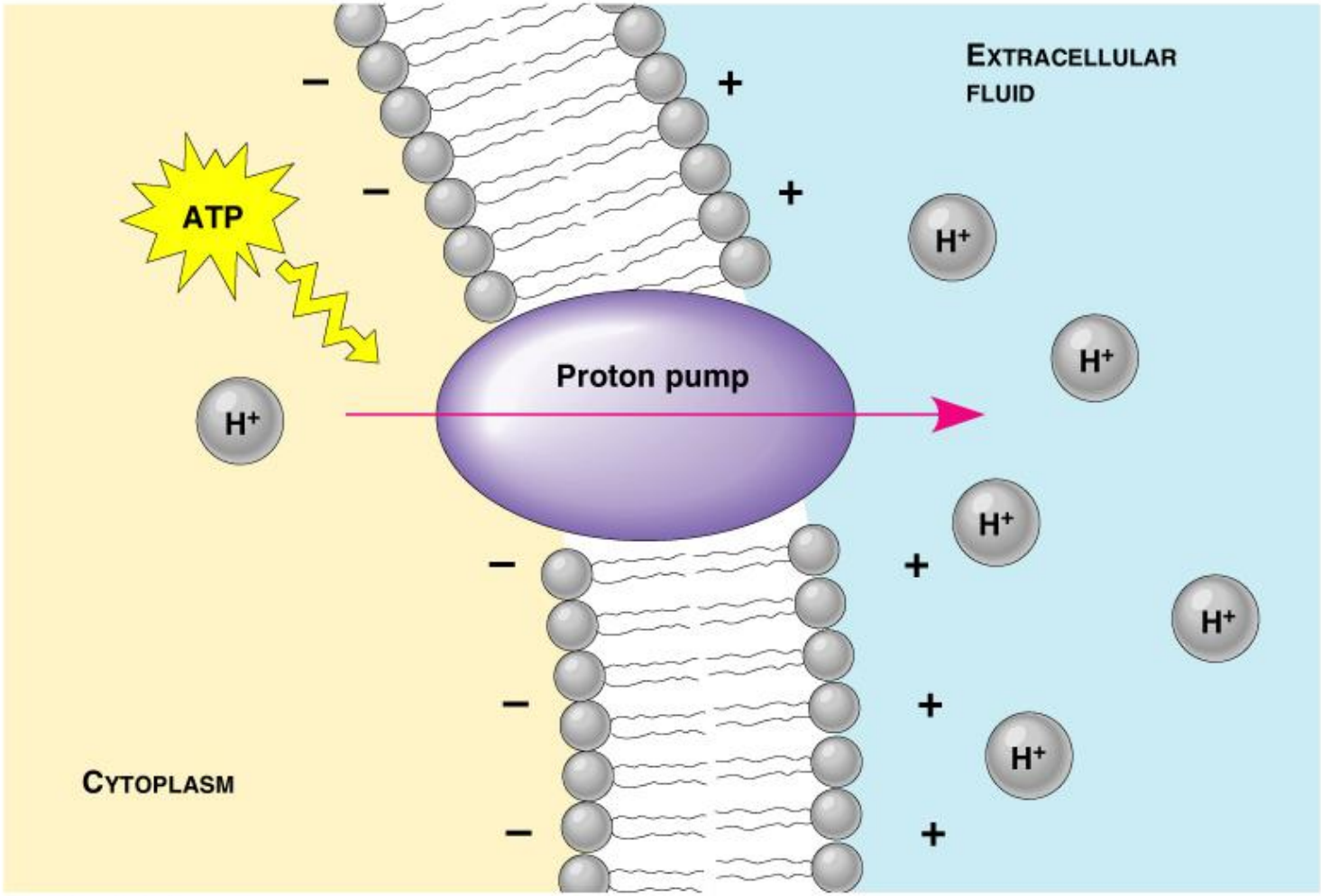
Active Processes:

- Substances are **concentrated**, i.e.: moved from an area of **low** concentration to one of **high** concentration.
- **Require** energy expenditure (**ATP**) by the cell.
- Include the following:
  1. Active transport
  2. Group translocation

1. Active Transport

- Requires **carrier proteins** or **pumps** in plasma membrane.

Active Transport Requires Energy



Movement of Materials Across Membranes:

Active Transport Processes:

2. Group Translocation

- Similar to active transport, but substance transported is chemically **altered** during process.
- **After** modification, the substance **cannot leave** the **cell**.
- **Glucose** is phosphorylated during group translocation in bacterial cells.

Note: Endocytosis (phagocytosis, pinocytosis, etc.) does not occur in prokaryotic cells.

Prokaryotic Cell Structure
III. Structures Internal to the Cell Wall

Cytoplasm

- Substance inside the cell membrane.

  Contains:
  - 80% water
  - Proteins
  - Carbohydrates
  - Lipids
  - Inorganic ions
  - Low molecular weight compounds
- **Lacks a cytoskeleton and cytoplasmic streaming**.

Prokaryotic Cell Structure

The Nuclear Area (Nucleoid):

- Contains a **single chromosome**, a long circular molecule of double stranded DNA.
- The chromosome is attached to the plasma membrane.
- May occupy up to 20% of the intracellular volume.

Plasmids:

- Small, circular, double stranded DNA molecules. Found in many bacterial cells in addition to chromosomal DNA.
- May contain from 5 to 100 genes that are usually not essential for survival.
  - Antibiotic resistance genes
  - Toxins

Prokaryotic Cell Structure
III. Structures Internal to the Cell Wall

Ribosomes:

- The site of **protein** synthesis (**translation**).
- Found in all eukaryotic and prokaryotic cells.
- Made up of **protein** and **ribosomal RNA** (rRNA).
- Prokaryotic ribosomes (**70S**) are smaller and less dense than eukaryotic ribosomes (**80S**).
- Prokaryotic ribosomes have **two subunits**:
  - Small subunit: 30S
  - Large subunit: 50S
- Several **antibiotics** work by inhibiting protein synthesis by prokaryotic ribosomes, without affecting eukaryotic ribosomes.

Prokaryotic Cell Structure
III. Structures Internal to the Cell Wall

Inclusions:

Reserve deposits in the cytoplasm of cells.

Not found in all cell types:

1. Metachromatic Granules:

- Contain inorganic **phosphate** that can be used in the synthesis of **ATP**.
- Stain red with blue dyes.
- Found in bacteria, algae, protozoa, and fungi.
- Characteristic of *Corynebacterium diphtheriae*, causative agent of diphtheria. Useful for identification purposes.

Prokaryotic Cell Structure
III. Structures Internal to the Cell Wall

Inclusions:

2. Polysaccharide Granules:

- Contain glycogen and starch.
- Stain blue or reddish brown with iodine.

3. Lipid Inclusions:

- Contain lipids, detected with fat soluble dyes.

4. Sulfur Granules:

- Contain sulfur and sulfur containing compounds.
- "Sulfur bacteria" (*Thiobacillus*) obtain **energy** by oxidizing sulfur and its compounds.

Prokaryotic Cell Structure
III. Structures Internal to the Cell Wall

5. Carboxysomes:

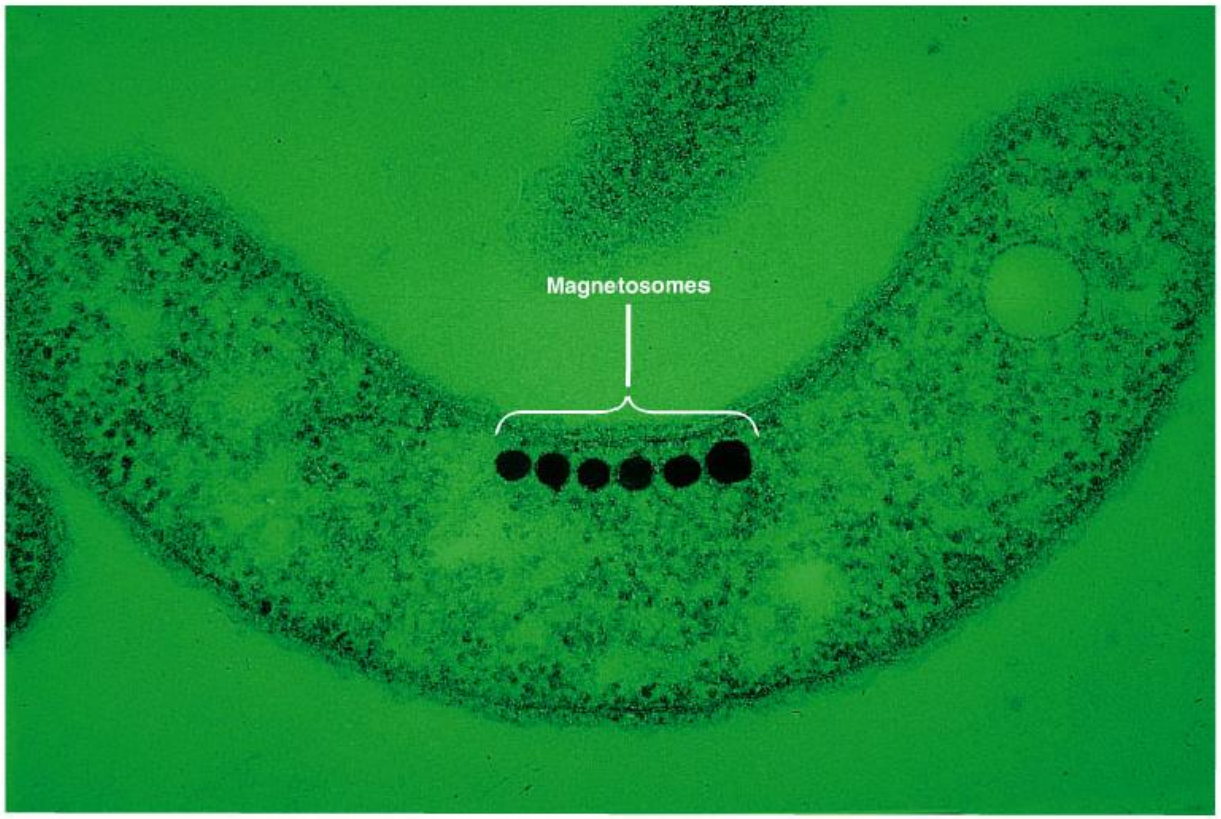
- Contain enzyme ribulose 1,5-diphosphate carboxylase, necessary for **carbon fixation** during **photosynthesis**.
- Found in nitrifying bacteria, cyanobacteria, and thiobacilli.
- **6. Gas Vacuoles:**
- Hollow cavities found in many aquatic bacteria.
- Contain individual gas vesicles, hollow cylinders covered by protein.
- Used to regulate **buoyancy** so cells can remain at appropriate water depth.

Prokaryotic Cell Structure
III. Structures Internal to the Cell Wall

7. Magnetosomes:

- Contain iron oxide (Fe_2O_3), which acts like a magnet.
- Formed by several aquatic gram-negative bacteria.
- Enable bacteria to respond to magnetic fields (**magnetotaxis**).
  - In Northern hemisphere swim towards North Pole.
  - In Southern hemisphere swim towards South Pole.
  - Also swim downwards in water, towards sediments where their food is abundant.
- May help decompose hydrogen peroxide.
- Used industrially to make magnetic audio/data tapes.

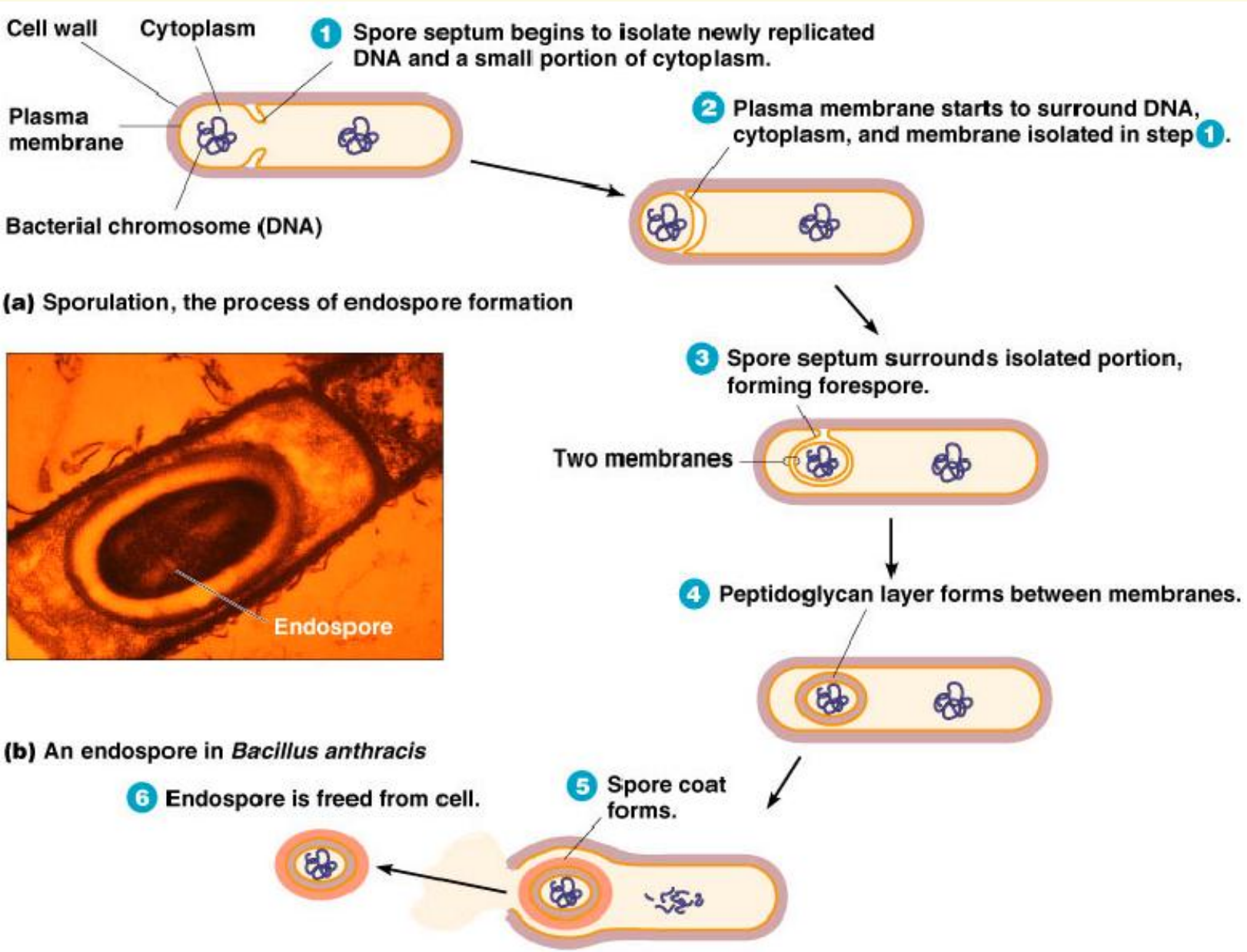
Magnetosomes in *Magnetospirillum magnetotacticum*



Prokaryotic Cell Structure
III. Structures Internal to the Cell Wall

Endospores:

- Specialized "resting" cells formed by certain Gram-positive bacteria.
  - Genus *Bacillus*
  - Genus *Clostridium*
- Highly durable dehydrated cells with thick cell walls and additional layers.
- Can **survive** extreme temperatures, disinfectants, acids, bases, lack of water, toxic chemicals, and radiation.
  - Endospores of some thermophilic bacteria can survive 19 hours of boiling.
  - Concern in food and health industries.

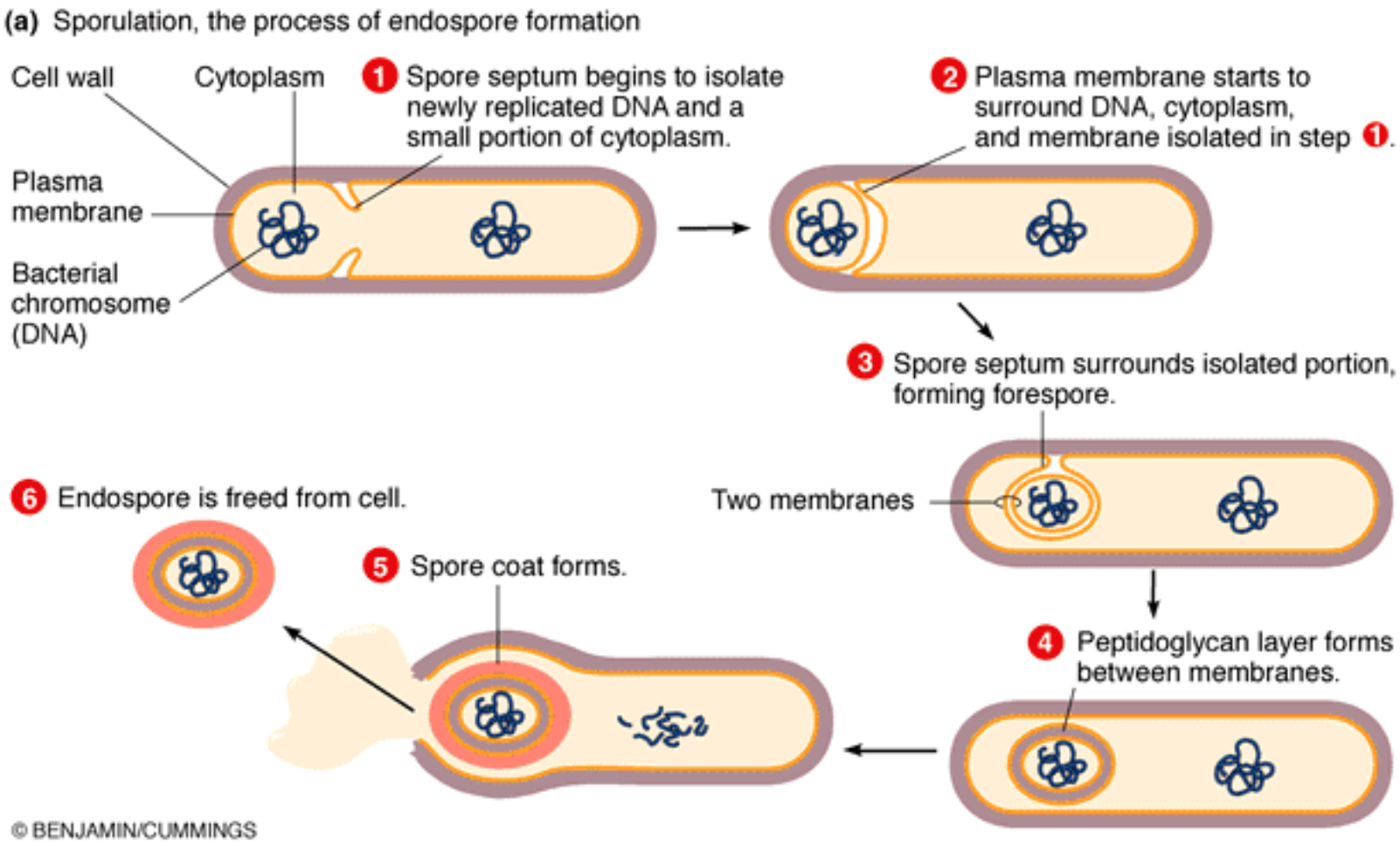


Prokaryotic Cell Structure

Process of Sporulation: One cell produces one spore.

1. Newly replicated DNA is isolated by an ingrowth of the plasma membrane called a **spore septum**.
2. Spore septum becomes a double-layered membrane that surrounds chromosome and cytoplasm (**forespore**).
3. **Peptidoglycan** layer forms between membranes of forespore.
4. **Spore coat** forms: Thick layer of protein around the outer membrane. Makes endospore resistant to many harsh chemicals.
5. **Maturation**: Cell wall ruptures, endospore is released.

Process of Spore Formation



Prokaryotic Cell Structure

Sporulation

- May be part of normal life cycle or triggered by adverse environmental conditions.
- Endospores do **not** carry out metabolic reactions, unlike normal **vegetative** cells.
- Endospores can remain dormant for thousands of years.
- **Germination**: Endospore returns to its vegetative state. Usually occurs when environmental conditions become more favorable. Triggered by physical or chemical damage to the spore coat.

Sporulation **Germination**

Vegetative Cell ----------> Endospore ----------> Vegetative Cell

(Metabolically active) (Not metabolically active) (Metabolically active)

Eukaryotic Cell Structure

- **Include: Protist, fungi, plant, and animal cells**
  - **Larger** than prokaryotic cells.
    - Diameter ranges from 10 to 100 um (versus 0.2 to 2.0 um)
  - **Nucleus:** Protects and houses DNA.
  - **Membrane-bound Organelles:** Internal structures with specific functions.
  - **Compartmentalization of Function:** Organelles allow special locations for different chemical reactions and functions.
    - **Separate and store compounds**
    - **Store energy**
    - **Work surfaces**
    - **Maintain concentration gradients**

Membrane-Bound Organelles of Eukaryotic Cells

- Nucleus
- Rough Endoplasmic Reticulum (RER)
- Smooth Endoplasmic Reticulum (SER)
- Golgi Apparatus
- Lysosomes
- Vacuoles
- Chloroplasts
- Mitochondria

Figure 7.7 An animal cell

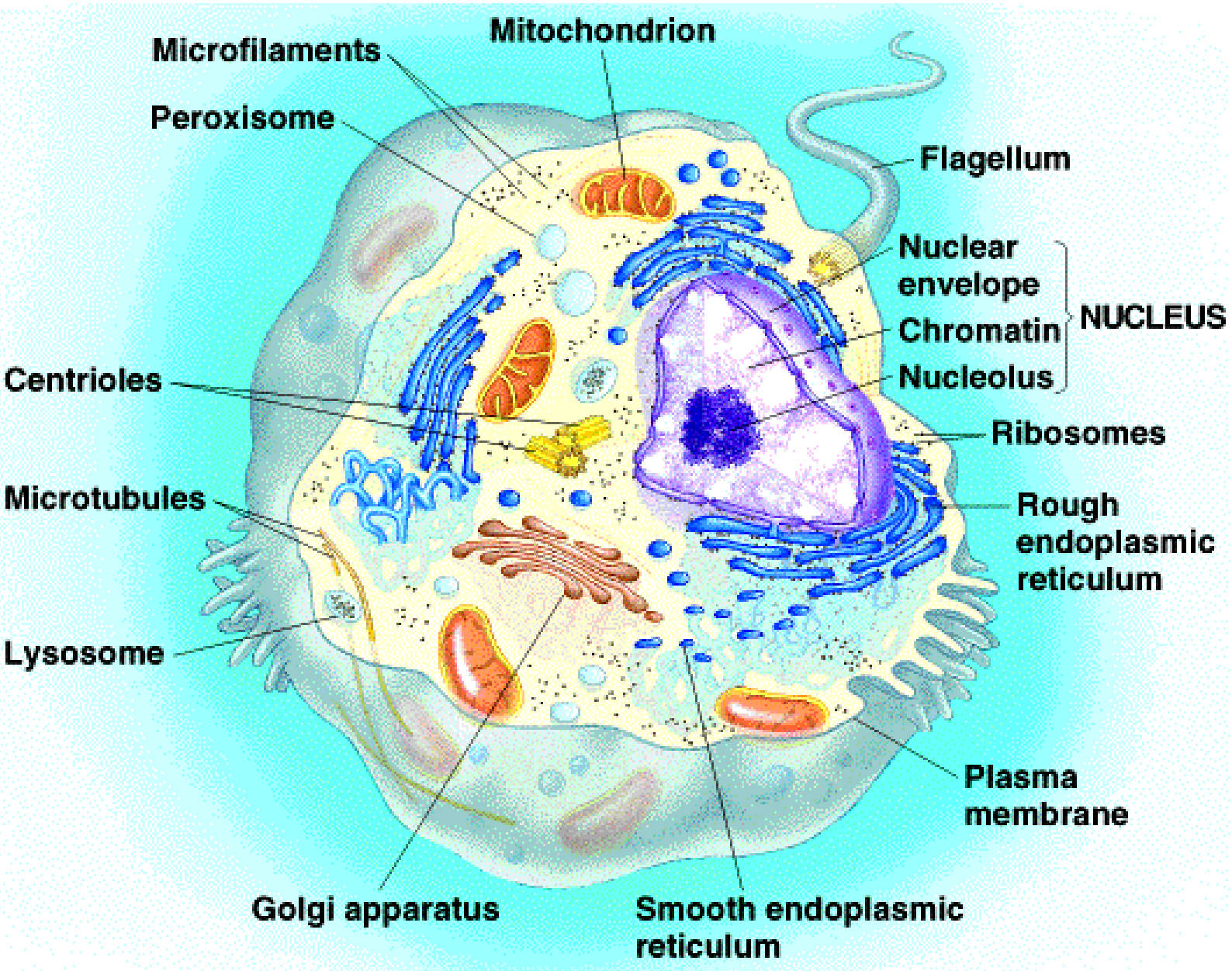
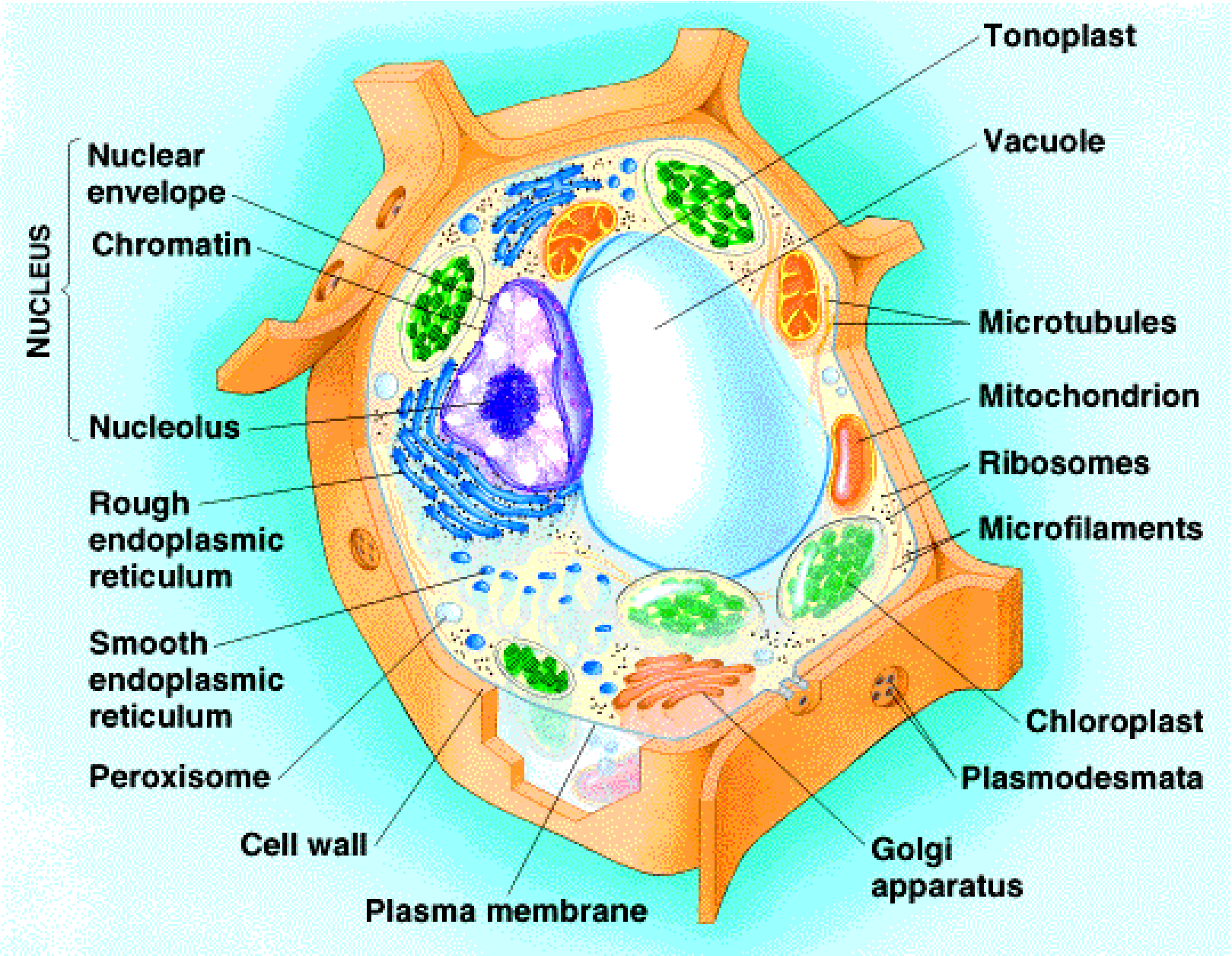


Figure 7.8 A plant cell



Eukaryotic Cell Structure

The Cell Wall and Glycocalyx

- Cell wall is **not** found in **all** eukaryotic cells:
  - **Protozoa** have a flexible outer layer called a **pellicle**, instead of a cell wall.
  - **Animal** cells have a sticky **glycocalyx** surrounding the cell membrane. Important for attachment, strength, and cell-cell recognition.
- When present, cell wall is chemically simpler than prokaryotic cell wall and **lacks peptidoglycan**.
  - **Eukaryotic cell wall composition:**
    - **Algae** and **plants**: Cellulose
    - **Fungi**: Chitin (polysaccharide)
    - **Yeasts**: Glucan and mannan (polysaccharides)

Eukaryotic Cell Structure

The Cell Membrane

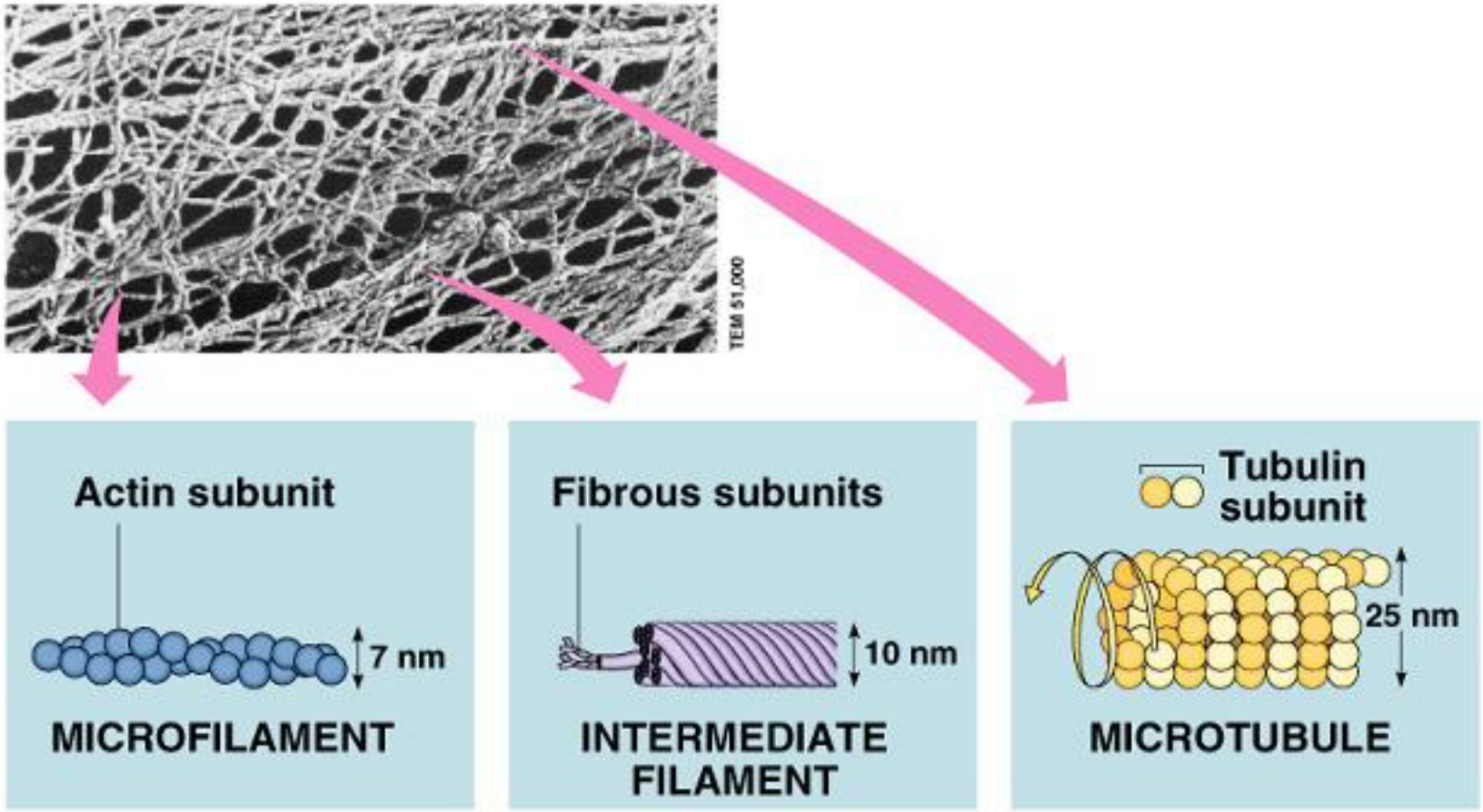
- ~~Similar to prokaryotic cell membranes, but:~~
  - Have **different** membrane **proteins**
  - Contain **carbohydrates** that are important for cell-cell recognition and serve as sites for bacterial attachment.
  - Contain **sterols** which increase resistance to **osmotic lysis**.
- Movement across eukaryotic cell membranes:
  - Simple diffusion, facilitated diffusion, osmosis, and active transport.
  - **Endocytosis**: Process in which plasma membrane encircles particles outside of cell.
    - **Phagocytosis**: Pseudopods engulf particle. Used by WBCs.
    - **Pinocytosis**: Small drops of fluid are brought into the cell.
  - Group translocation does not occur.

Eukaryotic Cell Structure

The Cytoplasm:

- Many **enzymes** are sequestered in **organelles**.
- Contains the **cytoskeleton**: A complex network of thread and tube-like structures, which provides support, shape, and movement.
  - **1. Microfilaments**: Smallest fibers
    - Actin & mysoin fibers in **muscle** cells
    - "Amoeboid motion" of white blood cells
  - **2. Intermediate filaments**: Medium sized fibers
    - **Anchor** organelles (nucleus) and hold cytoskeleton in place.
    - Abundant in cells with high mechanical stress.
  - **3. Microtubules**: Largest fibers.
    - Work in **cell division**, moving chromosomes
    - **Flagella** and **ciliary movement**.

The Eukaryotic Cytoplasm Has Three Cytoskeleton Components

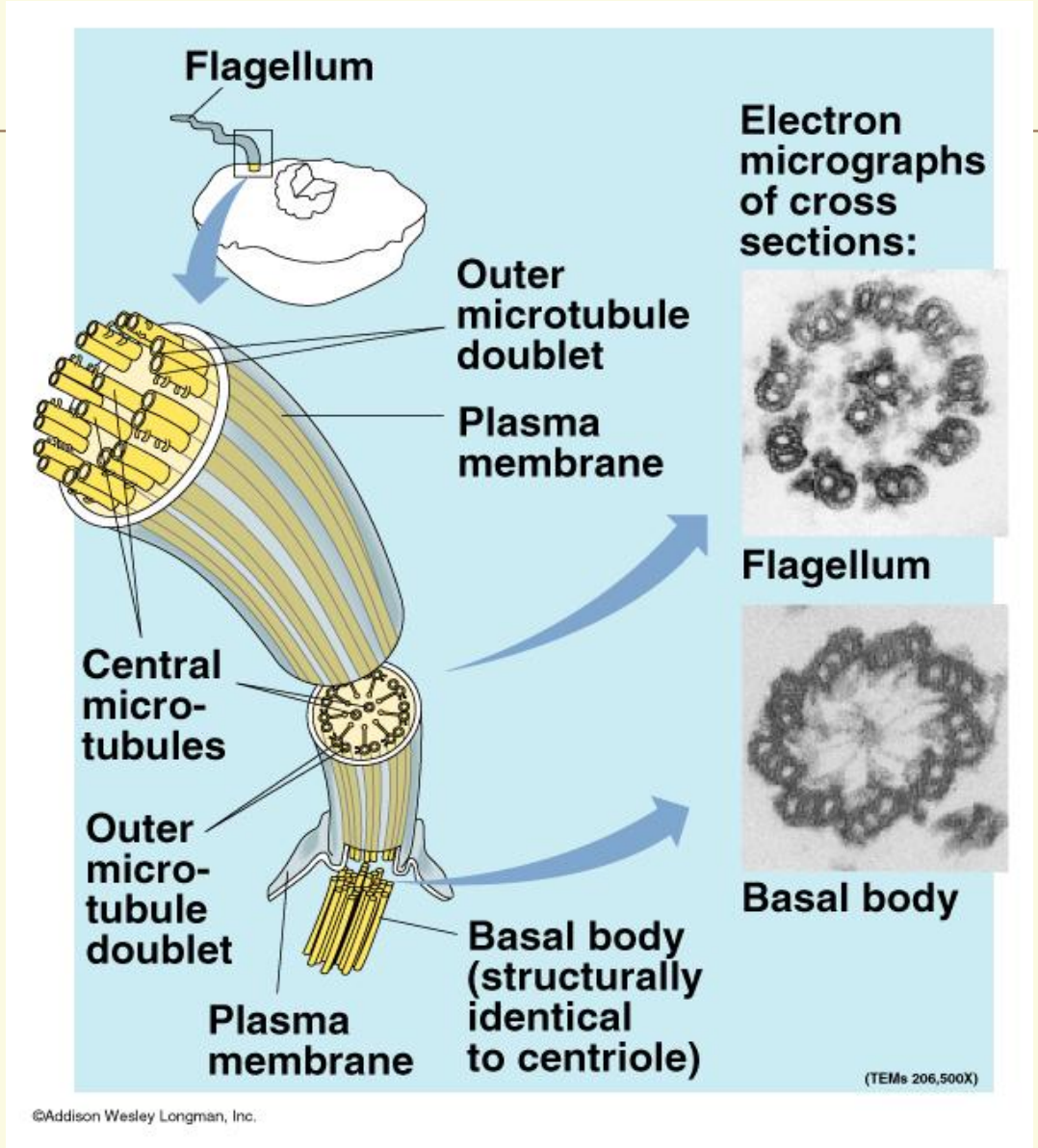


Eukaryotic Cell Structure

Flagella and Cilia

- Projections used for **locomotion** or to **move** substances along cell surface.
- Enclosed by plasma membrane and contain cytoplasm.
- Consist of 9 pairs of **microtubules** in a ring, with 2 single microtubules in center of ring (9 + 2).
  - **Flagella:** Long whip-like projections.
    - Eukaryotic flagella move in **wavelike** manner, unlike prokaryotic flagella.
  - **Cilia:** Short hair-like projections.
    - Human respiratory system uses cilia to remove harmful objects from bronchial tubes and trachea.

Structure of Eukaryotic Flagella



Eukaryotic Cell Structure: Organelles

The Nucleus

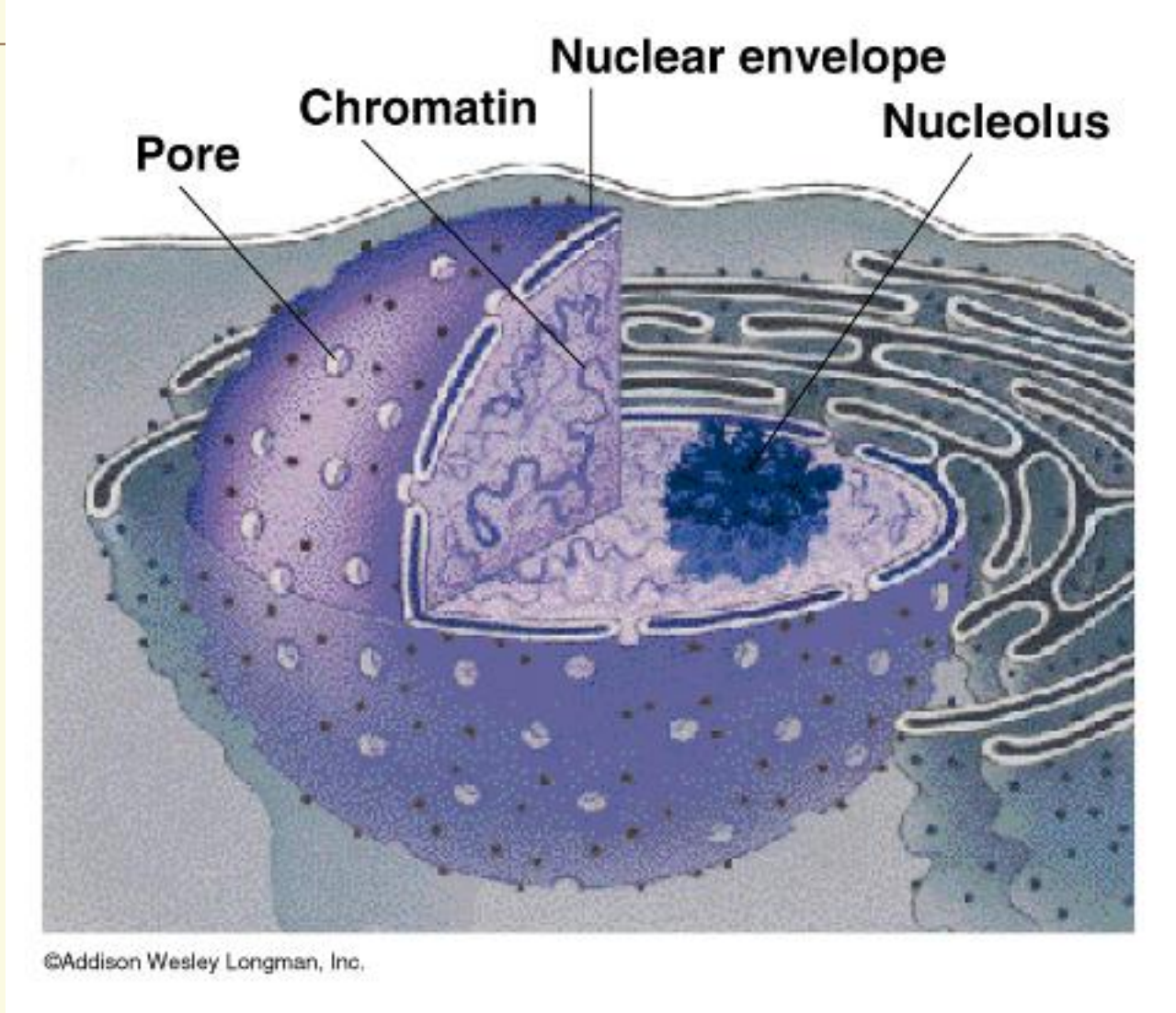
Structure

- **Envelope**: Double nuclear membrane.
- Large nuclear **pores**
- DNA (genetic material) is combined with **histones** and exists in two forms:
  - **Chromatin** (Loose, threadlike DNA. Most of cell life)
  - **Chromosomes** (Tightly packaged DNA. Found only during cell division)
- **Nucleolus**: Dense region where ribosomes are made

Functions

- House and protect cell's genetic information (**DNA**).
- **Ribosome** synthesis

Structure of Cell Nucleus



Eukaryotic Cell Structure
Ribosomes

- The site of **protein** synthesis (**translation**).
- Found in all eukaryotic and prokaryotic cells.
- Made up of **protein** and **ribosomal RNA** (rRNA).
- May be found **free** in the cytoplasm or **associated** with the rough endoplasmic reticulum (**RER**).
- Eukaryotic ribosomes (**80S**) are **larger** and more dense than prokaryotic ribosomes (**70S**).
- Eukaryotic ribosomes have **two subunits**:
  - Small subunit: 40S
  - Large subunit: 60S
- Mitochondria and chloroplasts have 70S ribosomes that are similar to prokaryotic ribosomes.

Eukaryotic Cell Structure: Organelles

The Endoplasmic Reticulum (ER)

- **"Network within the cell"**
- Extensive maze of membranes that branches throughout cytoplasm.
- ER is **continuous with plasma membrane and outer nucleus membrane.**
- **Two types of ER:**
  - **Rough Endoplasmic Reticulum (RER)**
  - **Smooth Endoplasmic Reticulum (SER)**

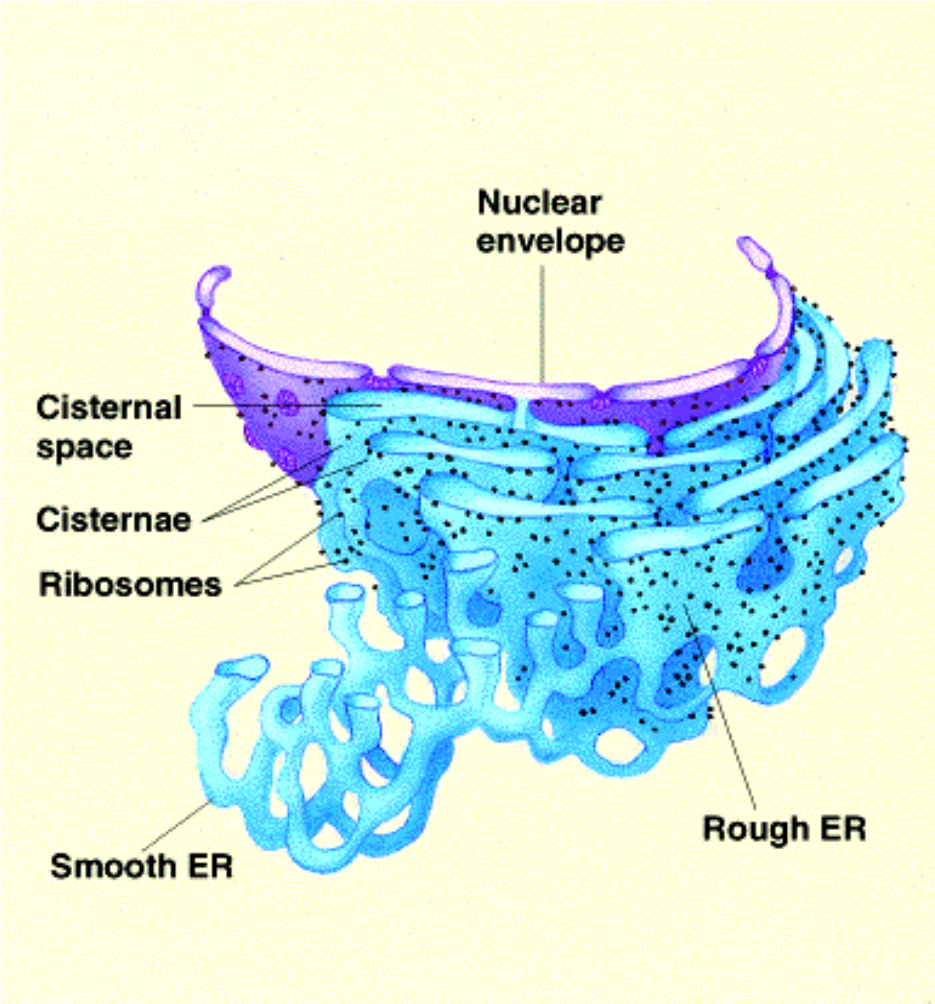
Eukaryotic Cell Structure: Organelles

Rough Endoplasmic Reticulum (RER)

- **Flat**, interconnected, rough membrane sacs
- "**Rough**": Outer walls are covered with **ribosomes**.
  - **Ribosomes**: Protein making "machines".
- May exist free in cytoplasm or attached to ER.
- **RER Functions:**
  - Synthesis and modification of ***proteins***.
  - Synthesis of cell and organelle ***membranes***.
  - Packaging, and transport of ***proteins*** that are ***secreted*** from the cell.
    - Example: Antibodies

Smooth and Rough Endoplasmic Reticulum

Figure 7.11 Endoplasmic reticulum



Eukaryotic Cell Structure: Organelles

Smooth Endoplasmic Reticulum (SER)

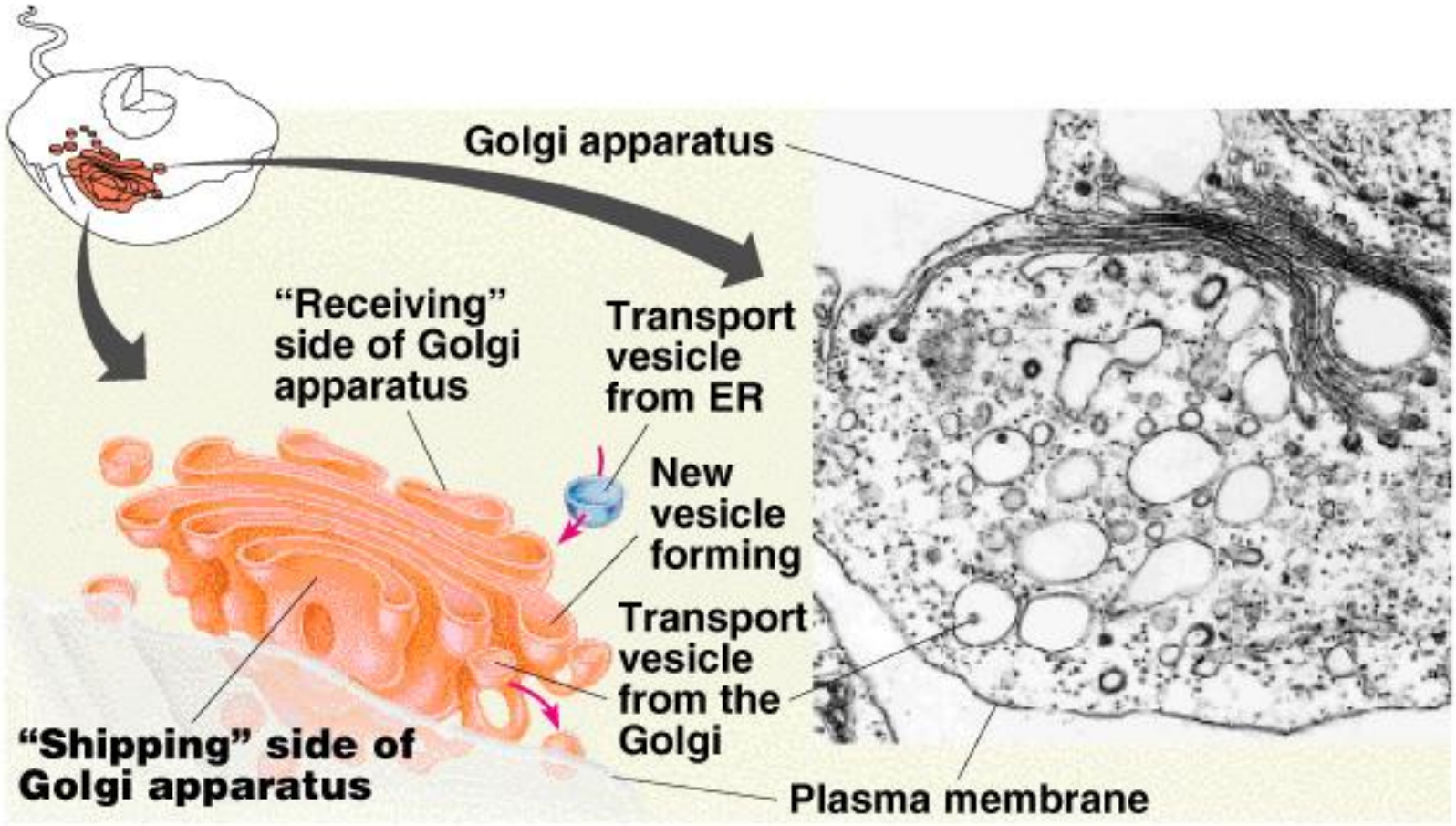
- Network of interconnected tubular smooth membranes.
- "**Smooth**": No ribosomes
- **SER Functions:**
  - **Lipid Synthesis**: Phospholipids, fatty acids, and steroids (sex hormones).
  - Breakdown of toxic compounds (drugs, alcohol, amphetamines, sedatives, antibiotics, etc.).
  - Helps develop tolerance to drugs and alcohol.
  - Regulates sugar release from liver into the blood
  - Calcium storage for cell and muscle contraction.

Eukaryotic Cell Structure: Organelles

Golgi Apparatus

- Stacks of flattened membrane sacs that may be distended in certain regions. Sacs are not interconnected.
- First described in 1898 by Camillo Golgi (Italy).
- Works closely with the ER to secrete proteins.
- **Golgi Functions**:
  - ***Receiving side*** receives proteins in transport vesicles from ER.
  - ***Modifies*** proteins into final shape, sorts, and labels them for proper transport.
  - ***Shipping side*** packages and sends proteins to cell membrane for export or to other parts of the cell.
  - Packages digestive enzymes in ***lysosomes***.

The Golgi Apparatus: Receiving, Processing, and Shipping of Proteins

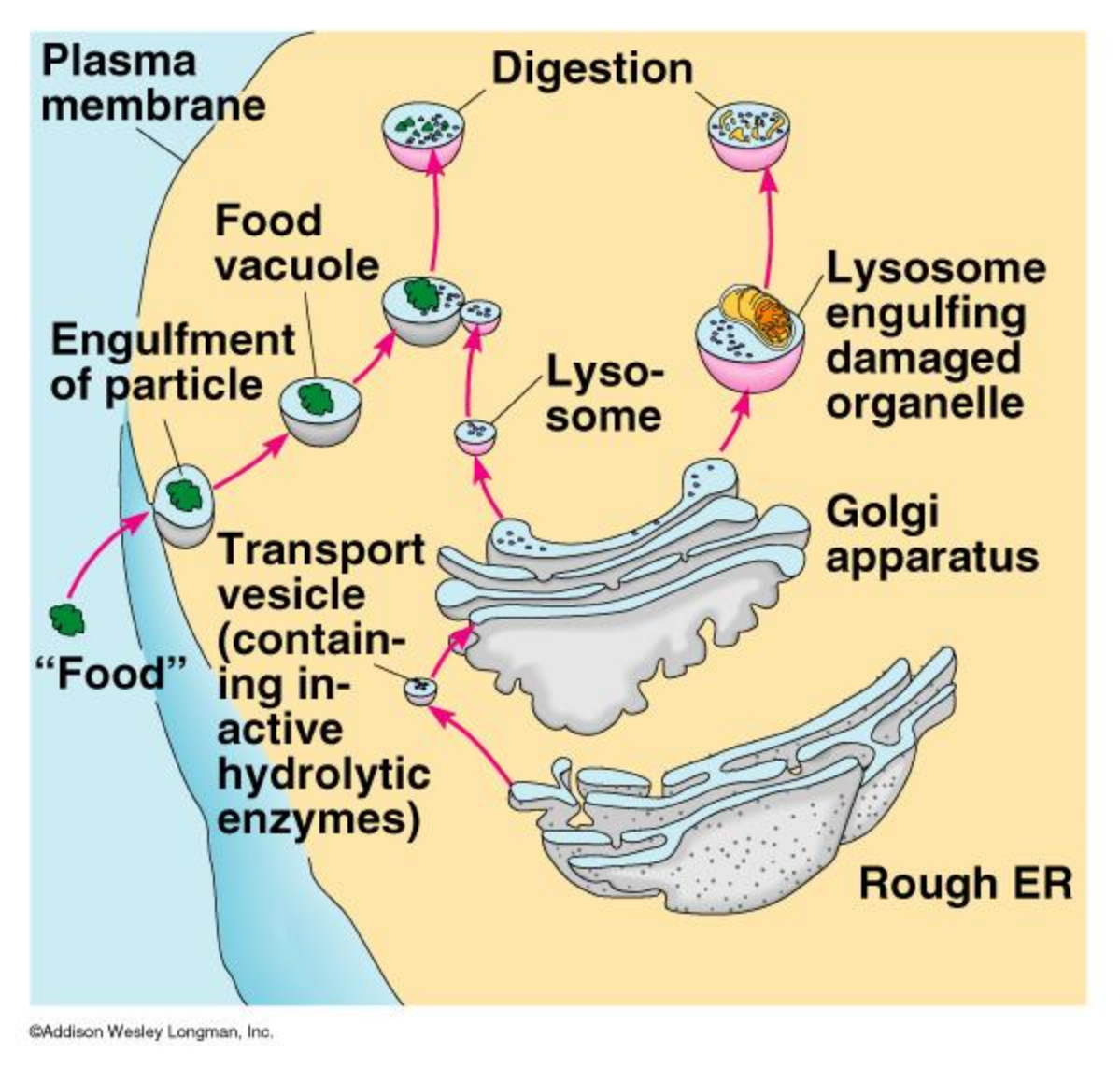


Eukaryotic Cell Structure: Organelles

Lysosomes

- Small vesicles released from Golgi containing at least 40 different ***digestive enzymes***, which can break down carbohydrates, proteins, lipids, and nucleic acids.
- Optimal pH for lysosomal enzymes is about 5
- Found mainly in animal cells.
- **Lysosome Functions:**
  - Molecular garbage dump and ***recycler*** of macromolecules (e.g.: proteins).
  - ***Destruction*** of **foreign material, bacteria, viruses, and old or damaged cell components.** Important in **immunity**.
  - ***Digestion*** of food particles taken in by cell.
  - After cell dies, lysosomal membrane breaks down, causing rapid ***self-destruction***.

Lysosomes: Intracellular Digestion



Eukaryotic Cell Structure: Organelles

Lysosomes, Aging, and Disease

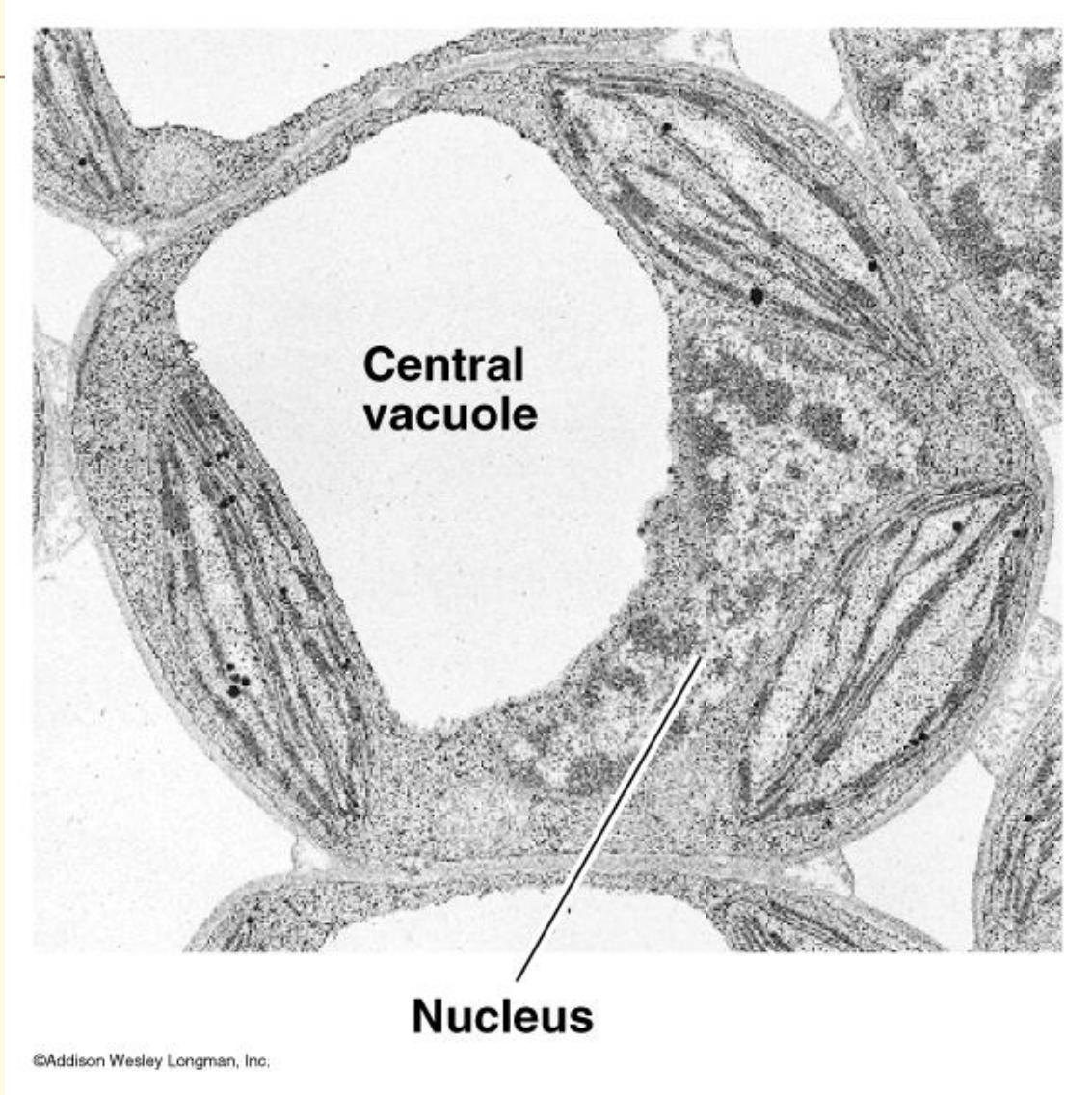
- As we age, our lysosomes become **leaky**, releasing enzymes which cause tissue damage and inflammation.
  - Example: Cartilage damage in *arthritis*
- Steroids or cortisone-like anti-inflammatory agents stabilize lysosomal membranes, but have other undesirable effects.
  - Interfere with normal immune function.
- Genetic diseases from "*mutant*" lysosome enzymes are usually fatal:
  - **Pompe's disease**: Defective glycogen breakdown in liver.
  - **Tay-Sachs disease**: Defective lipid breakdown in brain. Common genetic disorder among Jewish people.

Eukaryotic Cell Structure: Organelles

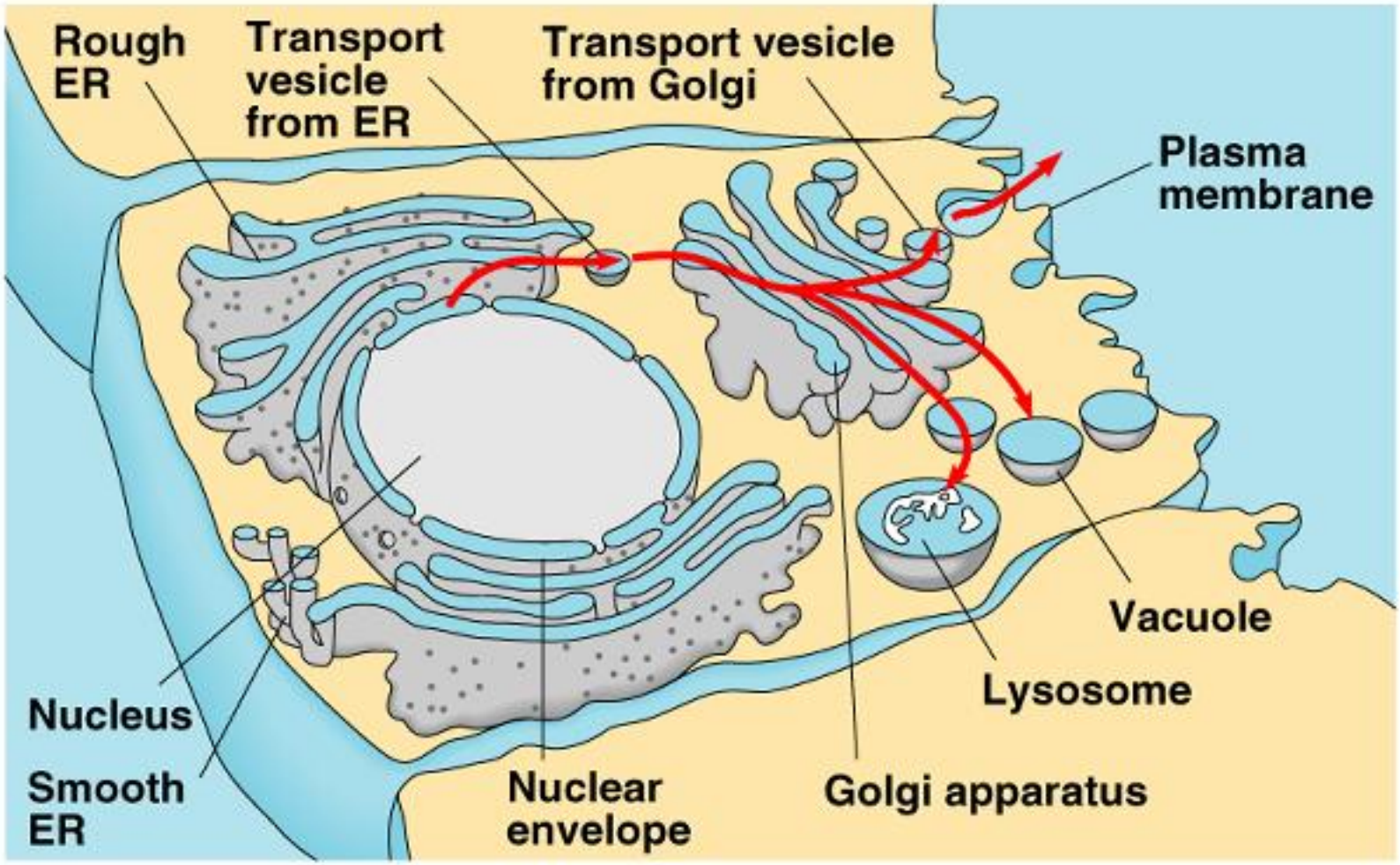
Vacuoles

- Membrane bound sac.
- Different types, sizes, shapes, and functions:
  - **Central vacuole:** In plant cells. Store starch, water, pigments, poisons, and wastes. May occupy up to 90% of plant cell volume.
  - **Contractile vacuole:** Regulate water balance, by removing excess water from cell. Found in many aquatic protists.
  - **Food or Digestion Vacuole:** Engulf nutrients in many protozoa (protists). Fuse with lysosomes to digest food particles.

Central Vacuole in a Plant Cell



Relationships Between Membrane Bound Organelles of Eukaryotic Cells



Eukaryotic Cell Structure: Organelles

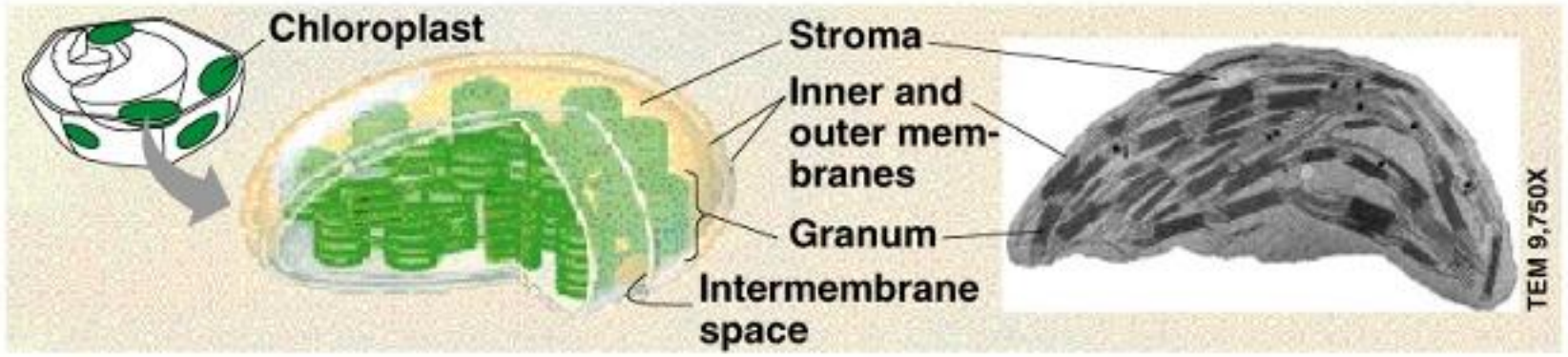
Chloroplasts

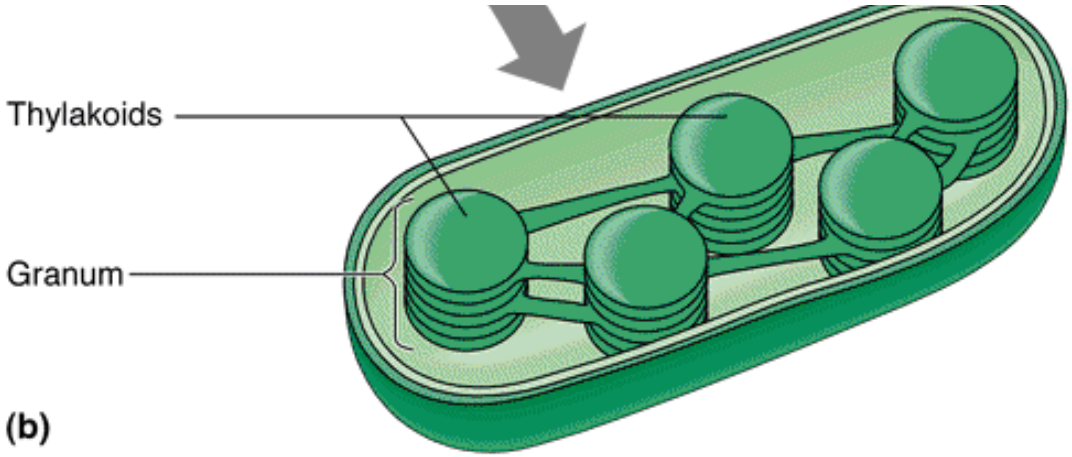
- Site of ***photosynthesis*** in plants and algae.

  CO_2 + H_2O + Sun Light -----> Sugar + O_2

- Number in cell may range from 1 to over 100.
- Disc shaped, with three membrane systems:
  - **Outer membrane**: Covers chloroplast surface.
  - **Inner membrane:** Contains **enzymes** needed to make **glucose** during photosynthesis. Encloses *stroma* (liquid) and *thylakoid* membranes.
  - **Thylakoid membranes**: Contain **chlorophyll**, green pigment that traps solar energy. Organized in stacks called grana.

Chloroplasts Have Three Sets of Membranes





Eukaryotic Cell Structure: Organelles

Chloroplasts

- Contain own DNA, **70 S** ribosomes, and make some proteins. Divide by binary fission to form daughter chloroplasts.
- **Plastid**: Organelle that produces and stores food in plant and algae cells.

  Other plastids include:
  - **Leukoplasts**: Store starch.
  - **Chromoplasts**: Store other pigments that give plants and flowers color.

Eukaryotic Cell Structure: Organelles

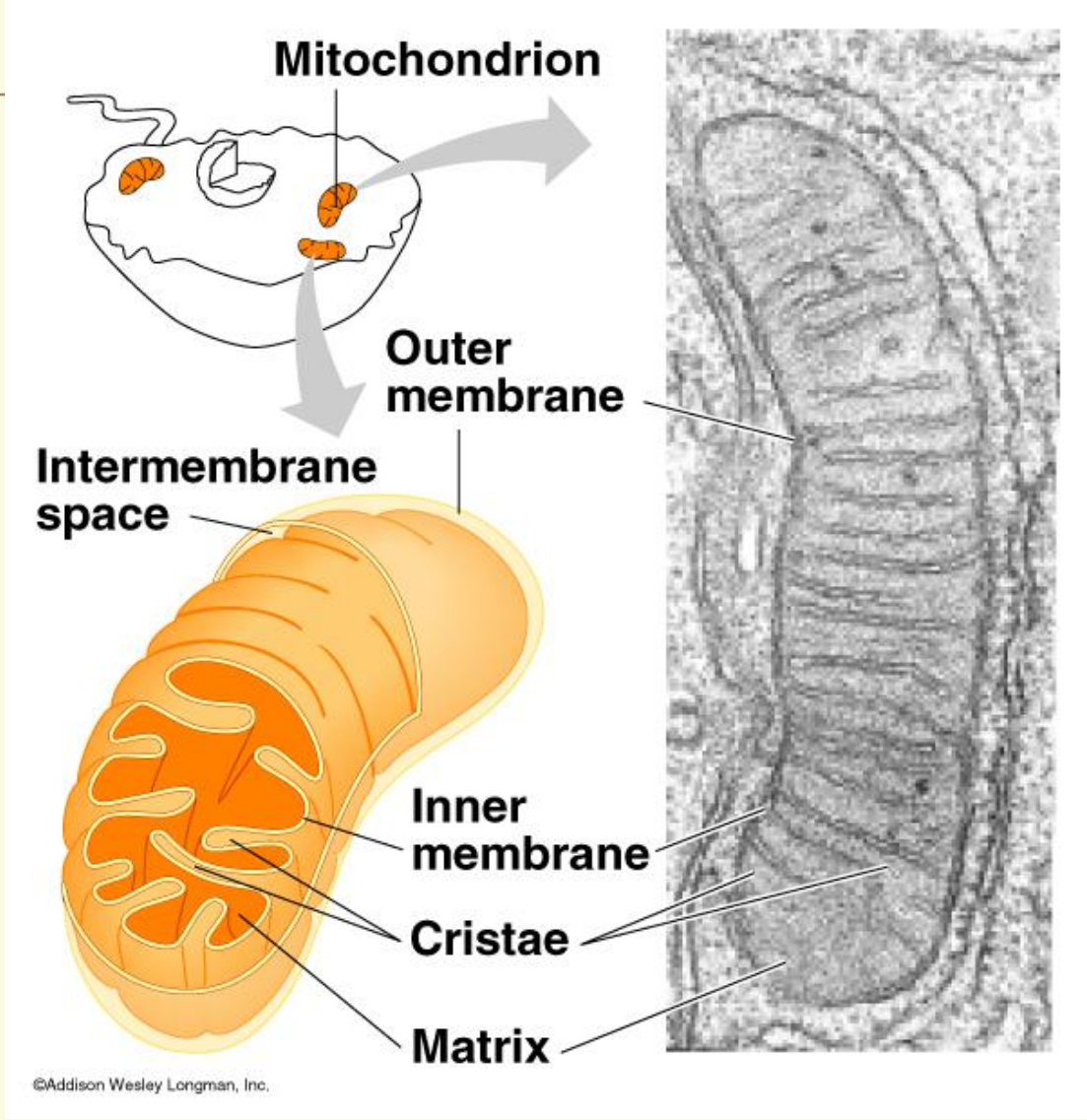
Mitochondria (Sing. Mitochondrion)

- Site of ***cellular respiration***:

  Food (sugar) + O_2 -----> CO_2 + H_2O + ATP

- Change chemical energy of molecules into the useable energy of the **ATP** molecule.
- Oval or sausage shaped.
- Contain their own DNA, 70S ribosomes, and make some proteins. Can divide to form daughter mitochondria.
- **Structure**:
  - Inner/outer membrane
  - Intermembrane space
  - Cristae (inner membrane extensions)
  - Matrix (inner liquid)

Mitochondria: The Cell's Energy Plants



Evolution of Eucaryotes Endosymbiotic Theory

- **Ancestors** of **eukaryotic cells** were large prokaryotic cells with smaller prokaryotic cells living inside of them.
- **Chloroplasts** and **mitochondria** originated from independent cells that entered and stayed inside a larger cell.
  - Both organelles contain their own DNA.
  - Have 70S ribosomes and make their own proteins.
  - Replicate independently from the cell, by binary fission.
- **Symbiotic relationship**
  - Larger cell obtains energy or nutrients.
  - Smaller cell is protected by larger cell.

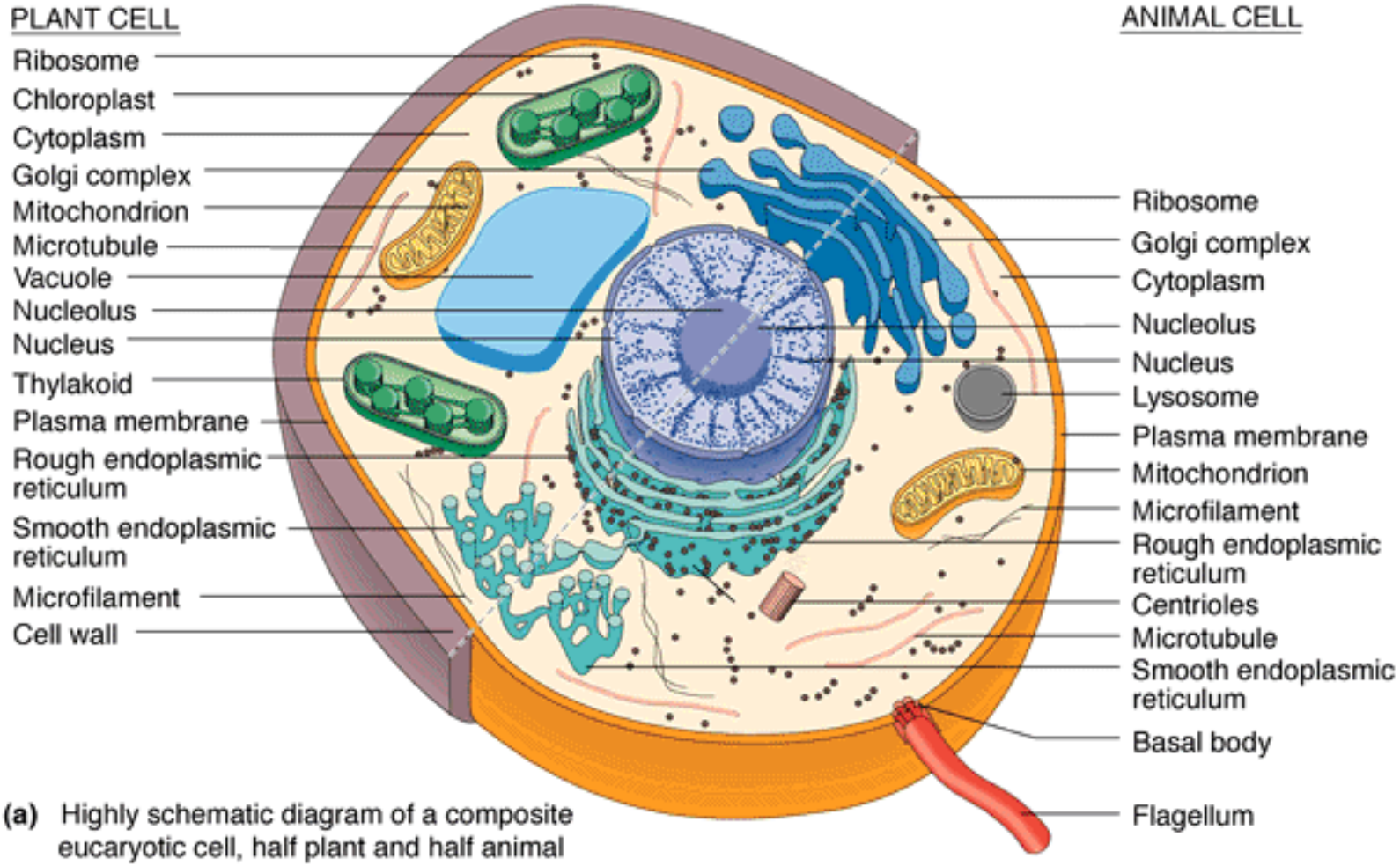
Eukaryotic Cell Structure: Organelles Centrioles

- Found in animal cells, not plant cells.
- Pair of cylindrical structures located near the nucleus.
- Made up of microtubules (9 + 2 pattern).
- **Important functions:**
  - Movement of chromosomes during cell division.
  - Formation of cilia and flagella (as basal bodies).

Important Differences Between Plant and Animal Cells

Plant cells	Animal cells
Cell wall	No cell wall
Chloroplasts	No chloroplasts
Large central vacuole	No central vacuole
Flagella rare	Flagella more usual
No Centrioles	Centrioles present
No Lysosome	Lysosomes present

Animal versus Plant Cell Structure



(a) Highly schematic diagram of a composite eucaryotic cell, half plant and half animal

Important Differences Between Eukaryotic and Prokaryotic Cells

	Procaryotes	Eucaryotes
Cell size	0.2-2 um in diameter	10-100 um in diameter
Nucleus	Absent	Present
Membranous Organelles	Absent	Present
Cell Wall	Chemically complex	When present, simple
Ribosomes	Smaller (70S)	Larger (80S) in cell 70S in organelles
DNA	Single circular chromosome	Multiple linear chromosomes (histones)
Cell Division	Binary fission	Mitosis
Cytoskeleton	Absent	Present