Prokaryotic and Eukaryotic Cells

Learning Objective

4-1 Compare and contrast the overall cell structure of prokaryotes and eukaryotes.

Prokaryotic and Eukaryotic Cells

- **Prokaryote** comes from the Greek words for prenucleus.
- **Eukaryote** comes from the Greek words for true nucleus.

Prokaryote

- One circular chromosome, not in a membrane
- No histones
- No organelles
- Bacteria: peptidoglycan cell walls
- Archaea: pseudomurein cell walls
- Binary fission

Eukaryote

- Paired chromosomes, in nuclear membrane
- Histones
- Organelles
- Polysaccharide cell walls
- Mitotic spindle

Check Your Understanding

- ✓ What is the main feature that distinguishes prokaryotes from eukaryotes? 4-1

The Prokaryotic Cell

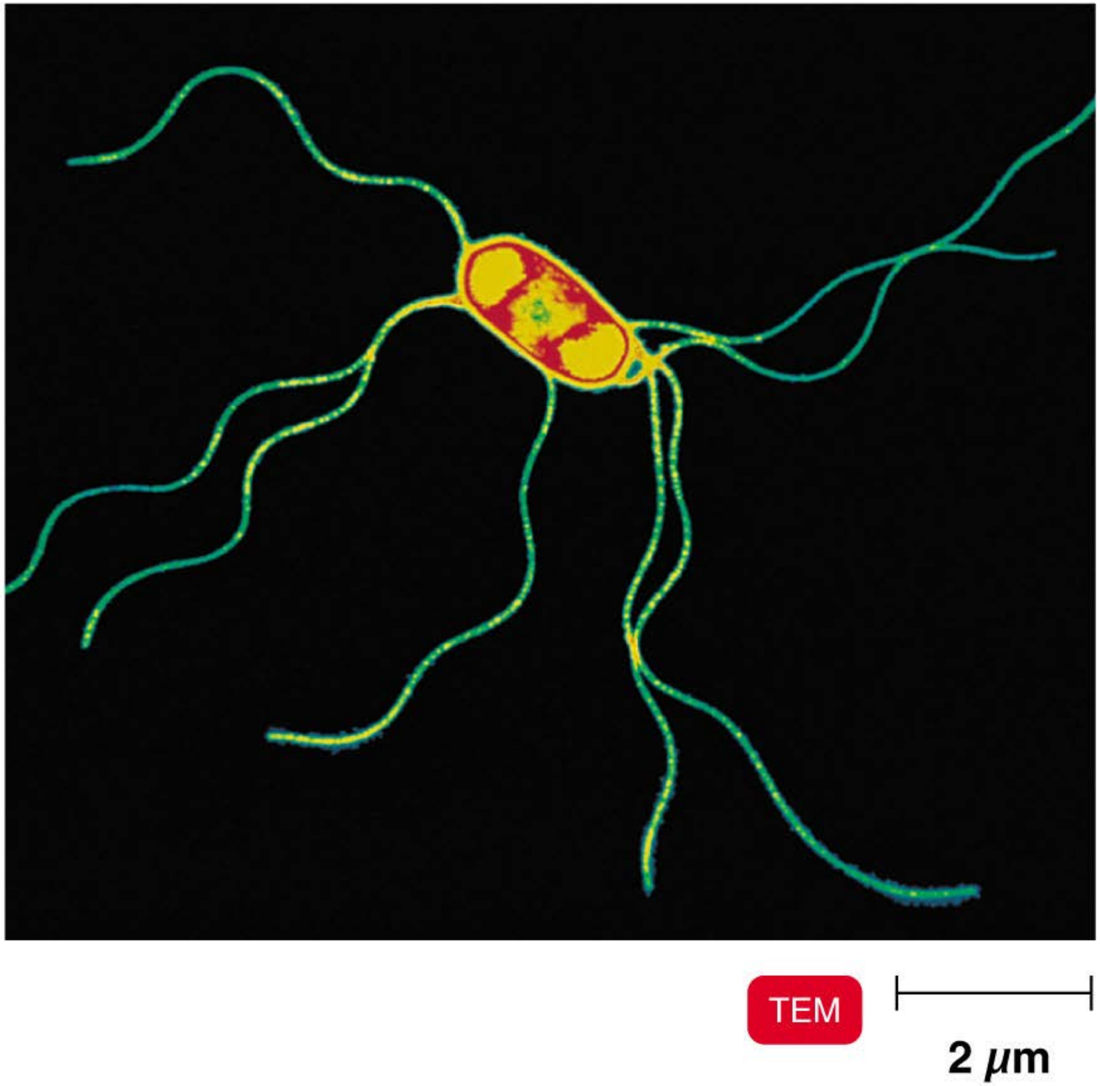
Learning Objective

4-2 Identify the three basic shapes of bacteria.

Prokaryotic Cells: Shapes

- Average size: 0.2–1.0 µm × 2–8 µm
- Most bacteria are monomorphic
- A few are pleomorphic

Figure 4.9b Flagella and bacterial motility.



(b) A *Proteus* cell in the swarming stage may have more than 1000 peritrichous flagella.

Basic Shapes

- Bacillus (rod-shaped)
- Coccus (spherical)
- Spiral
  - Spirillum
  - Vibrio
  - Spirochete

Figure 4.1a Arrangements of cocci.

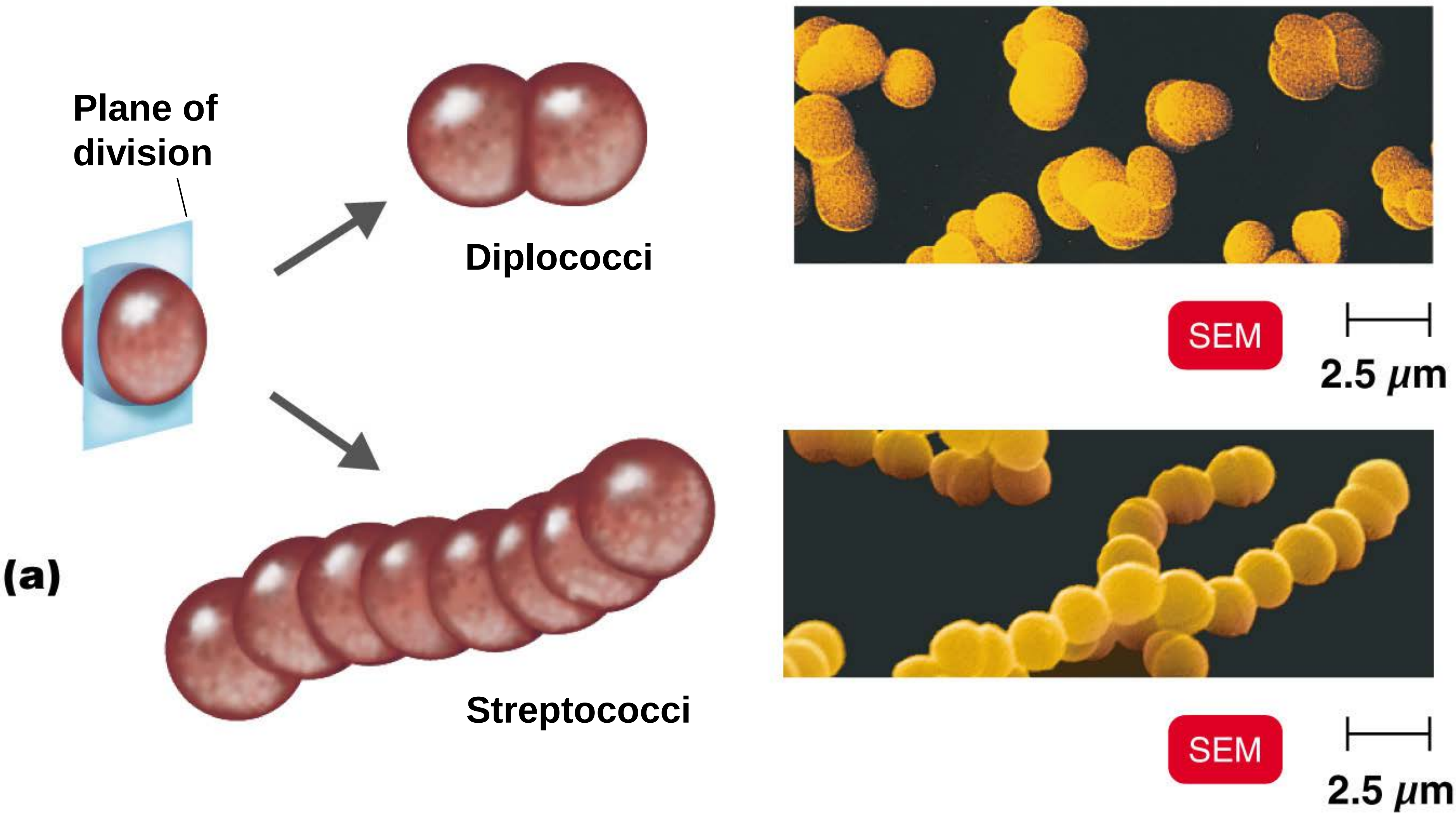
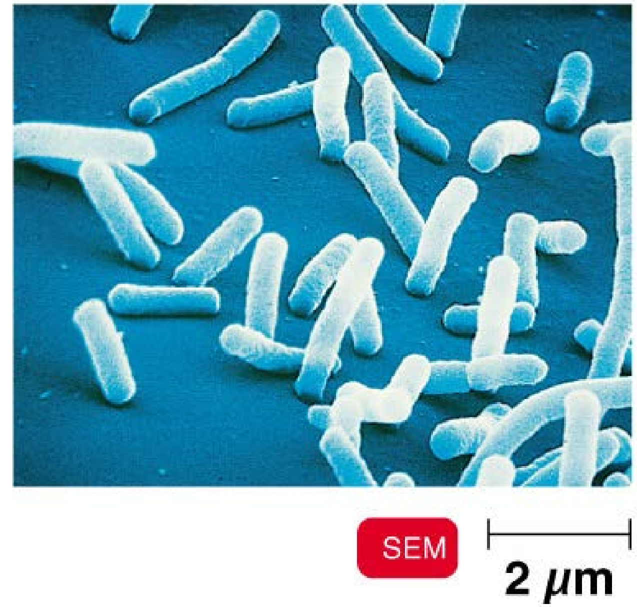


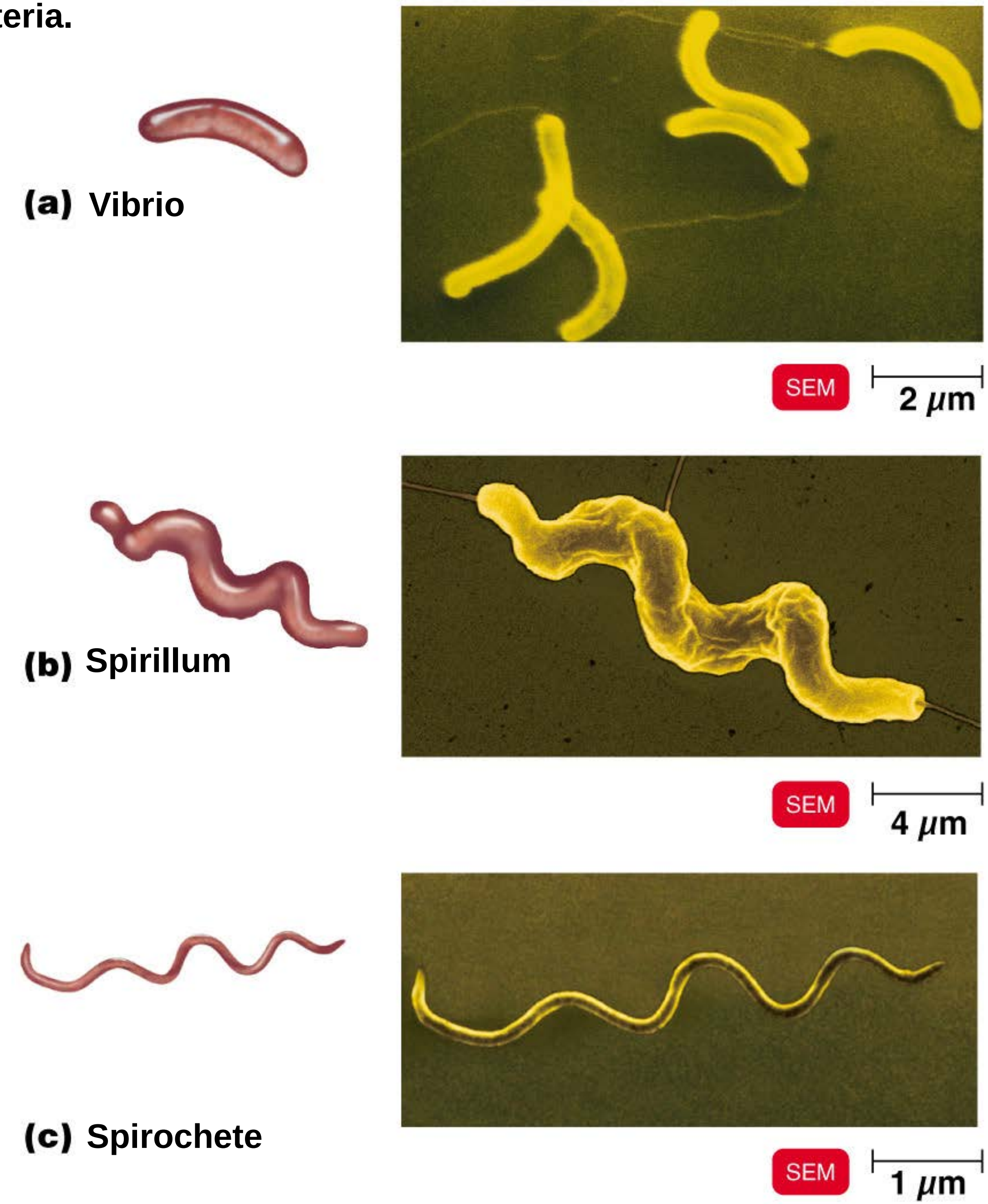
Figure 4.2ad Bacilli.

(a) Single bacillus



(d) Coccobacillus

Figure 4.4 Spiral bacteria.



***Bacillus* or Bacillus**

- Scientific name: *Bacillus*
- Shape: bacillus

Figure 4.3 A double-stranded helix formed by *Bacillus subtilis*.

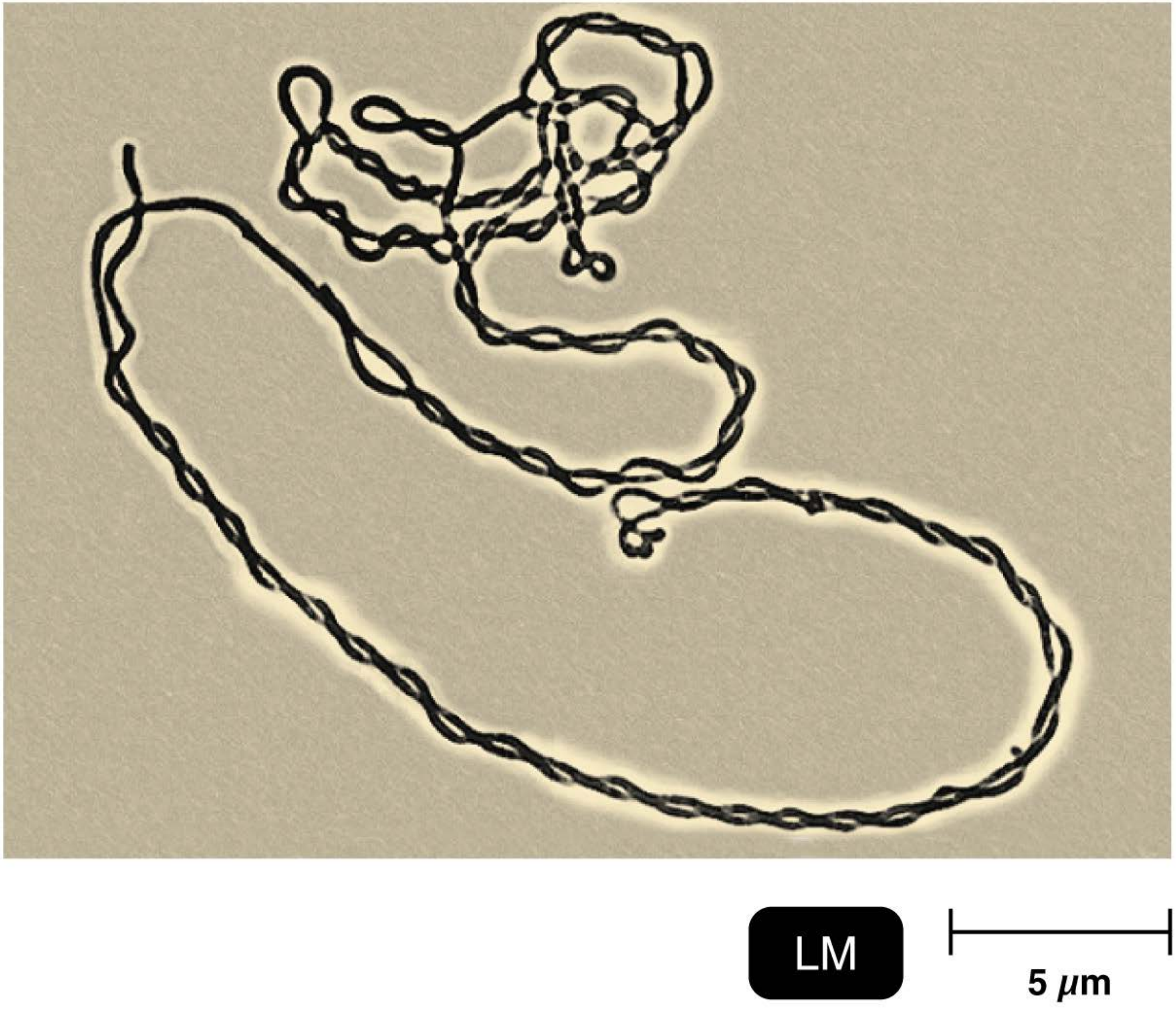
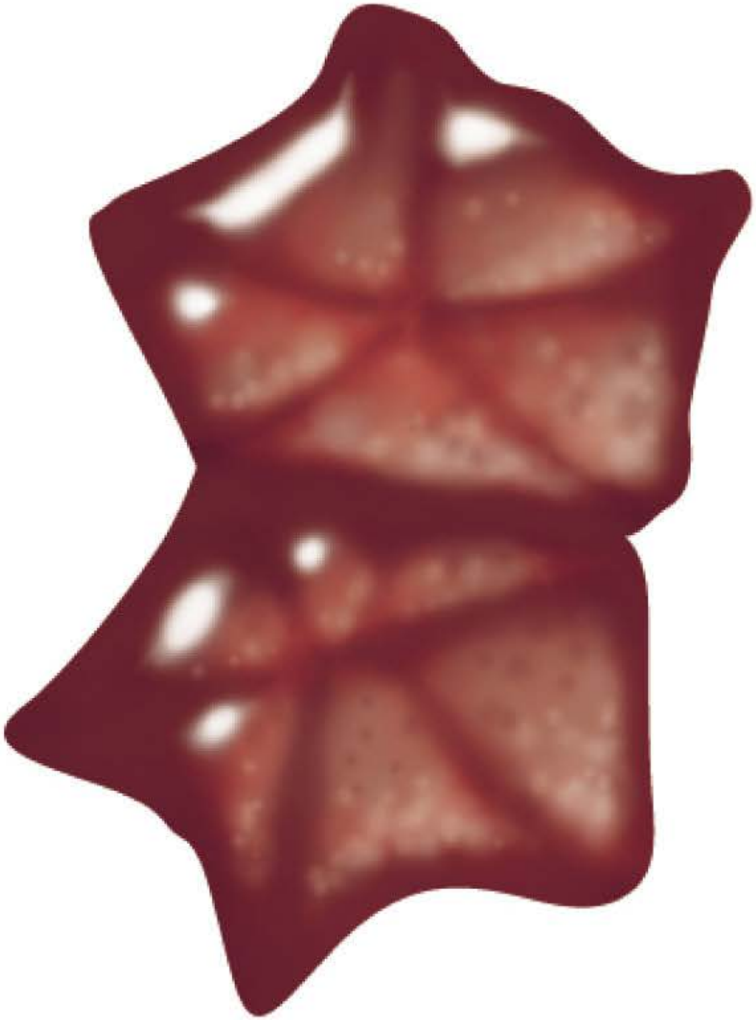
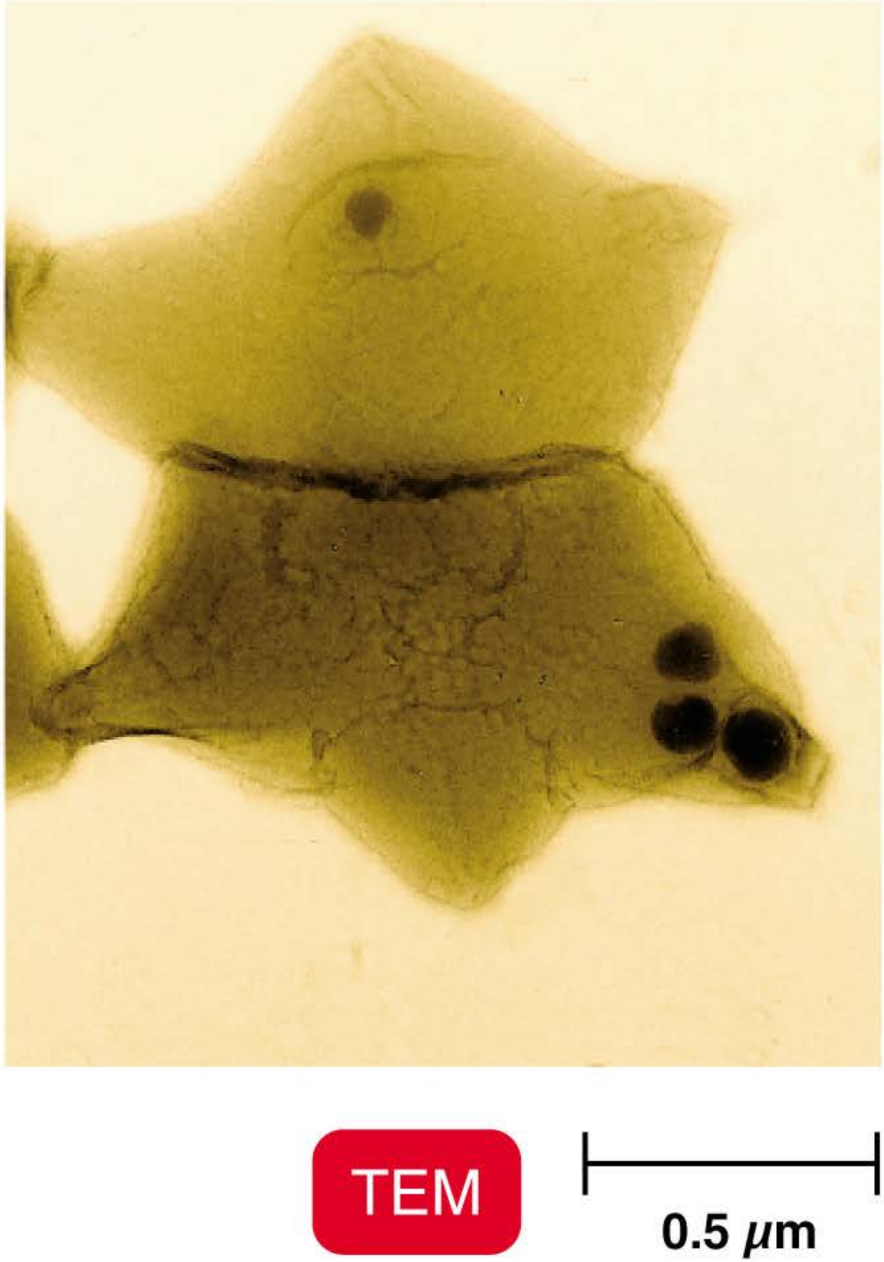


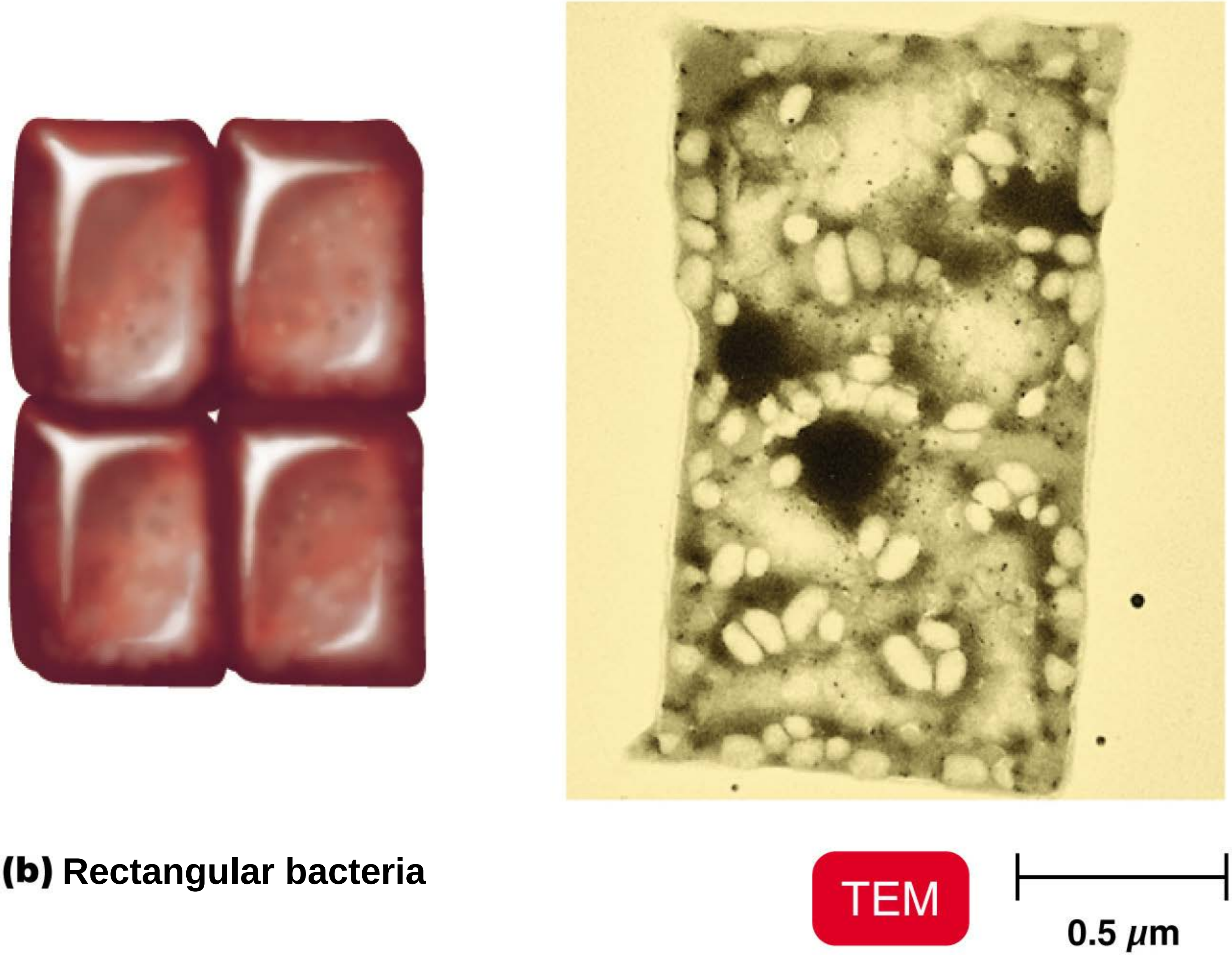
Figure 4.5a Star-shaped and rectangular prokaryotes.





(a) Star-shaped bacteria

Figure 4.5b Star-shaped and rectangular prokaryotes.



(b) Rectangular bacteria

Arrangements

- Pairs: diplococci, diplobacilli
- Clusters: staphylococci
- Chains: streptococci, streptobacilli

Figure 4.1ad Arrangements of cocci.

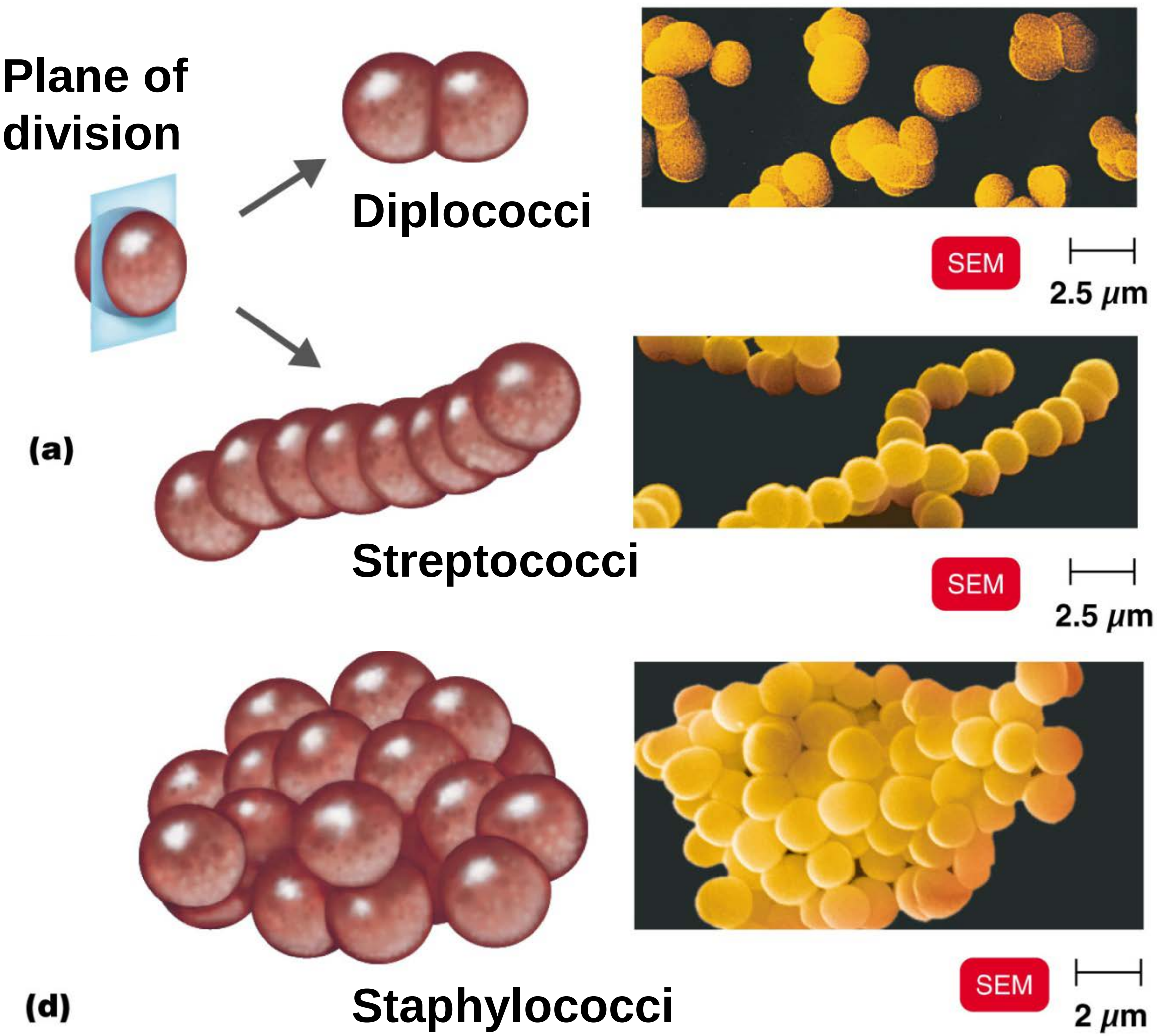
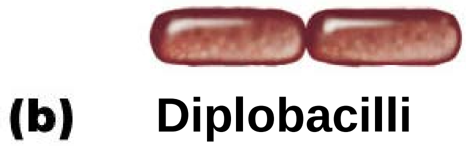
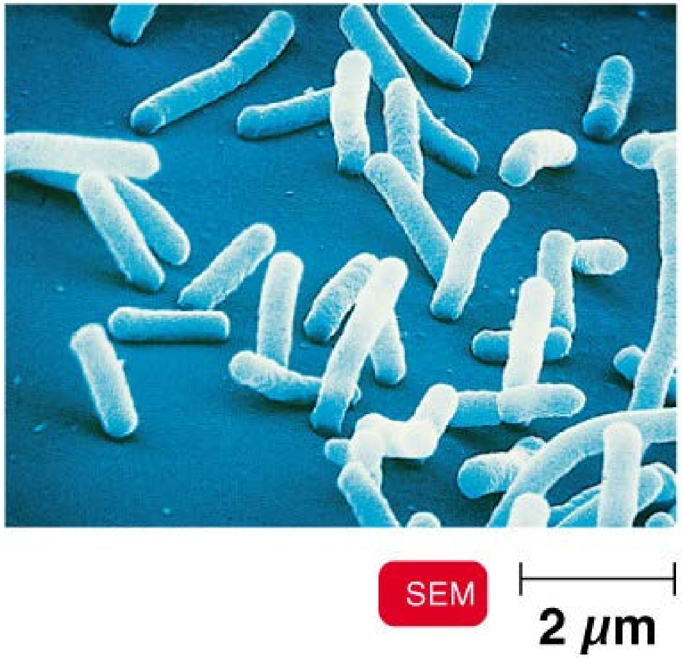
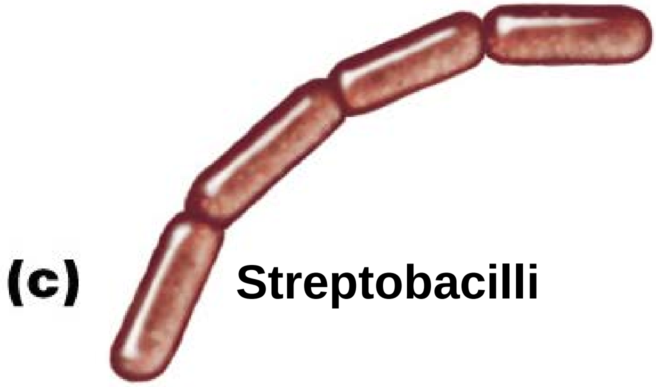


Figure 4.2b-c Bacilli.



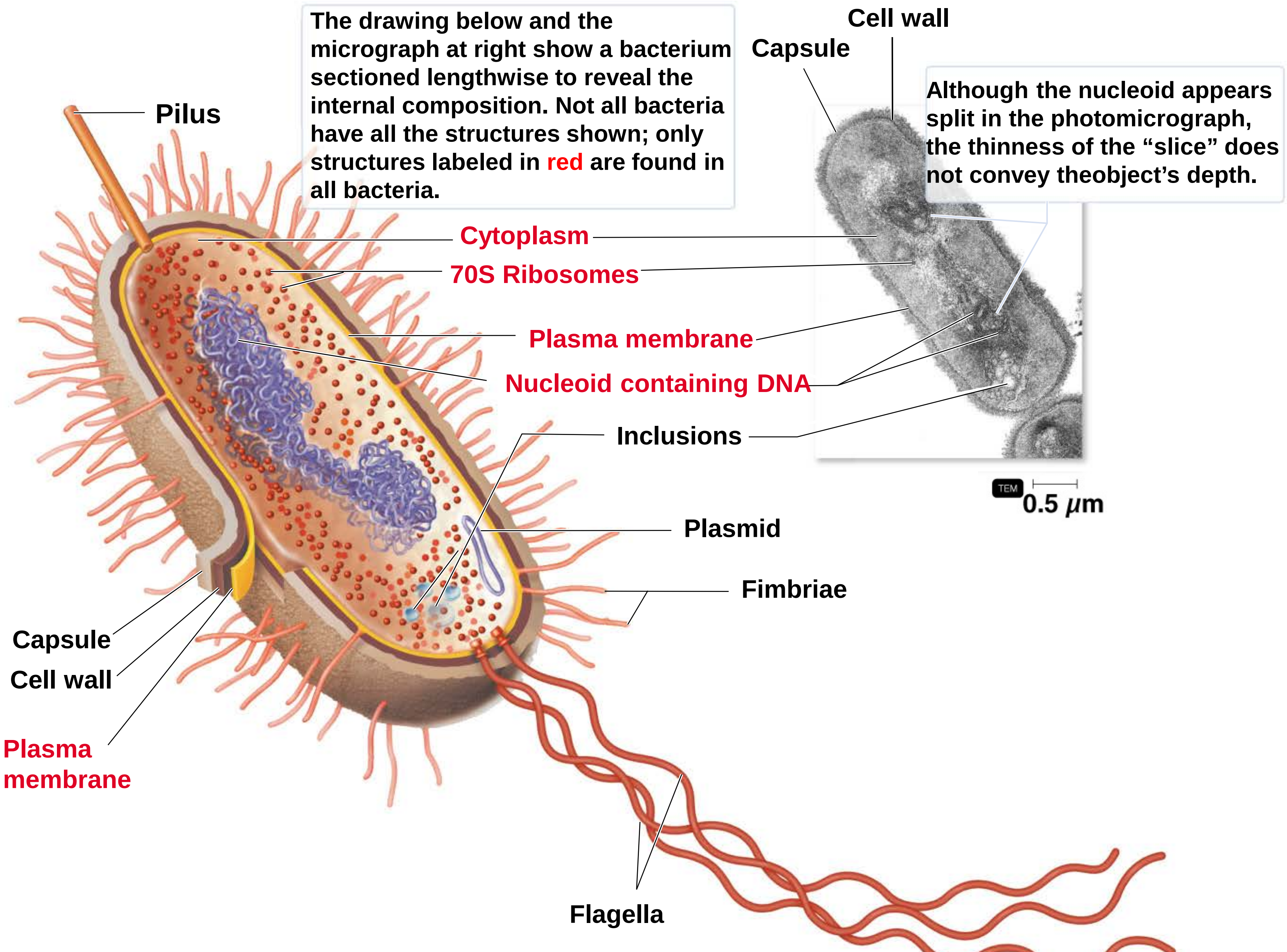




Check Your Understanding

- ✓ How would you be able to identify streptococci through a microscope? 4-2

Figure 4.6 The Structure of a Prokaryotic Cell.



Structures External to the Cell Wall

Learning Objectives

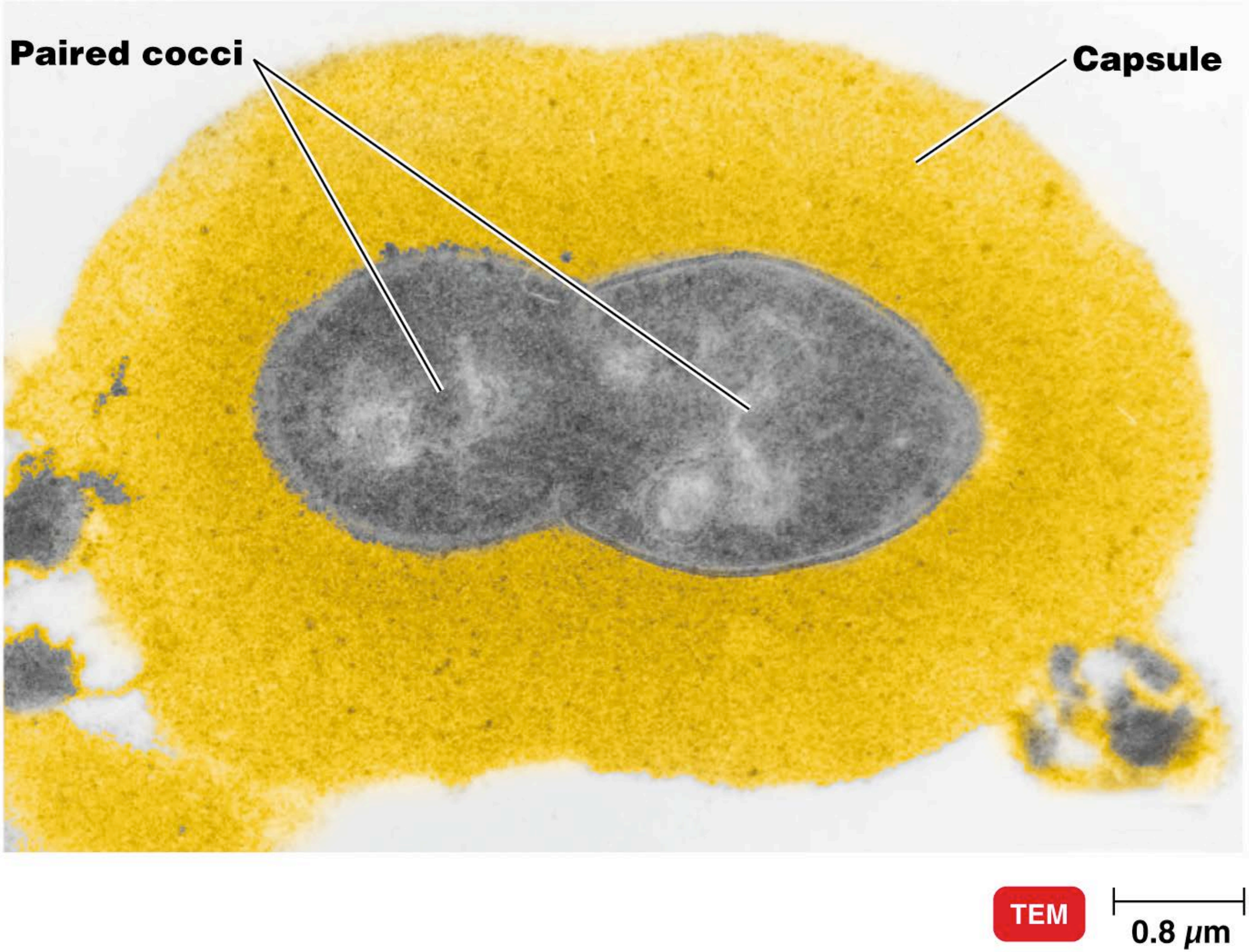
4-3 Describe the structure and function of the glycocalyx.

4-4 Differentiate flagella, axial filaments, fimbriae, and pili.

Glycocalyx

- Outside cell wall
- Usually sticky
- Capsule: neatly organized
- Slime layer: unorganized and loose
- Extracellular polysaccharide allows cell to attach
- Capsules prevent phagocytosis

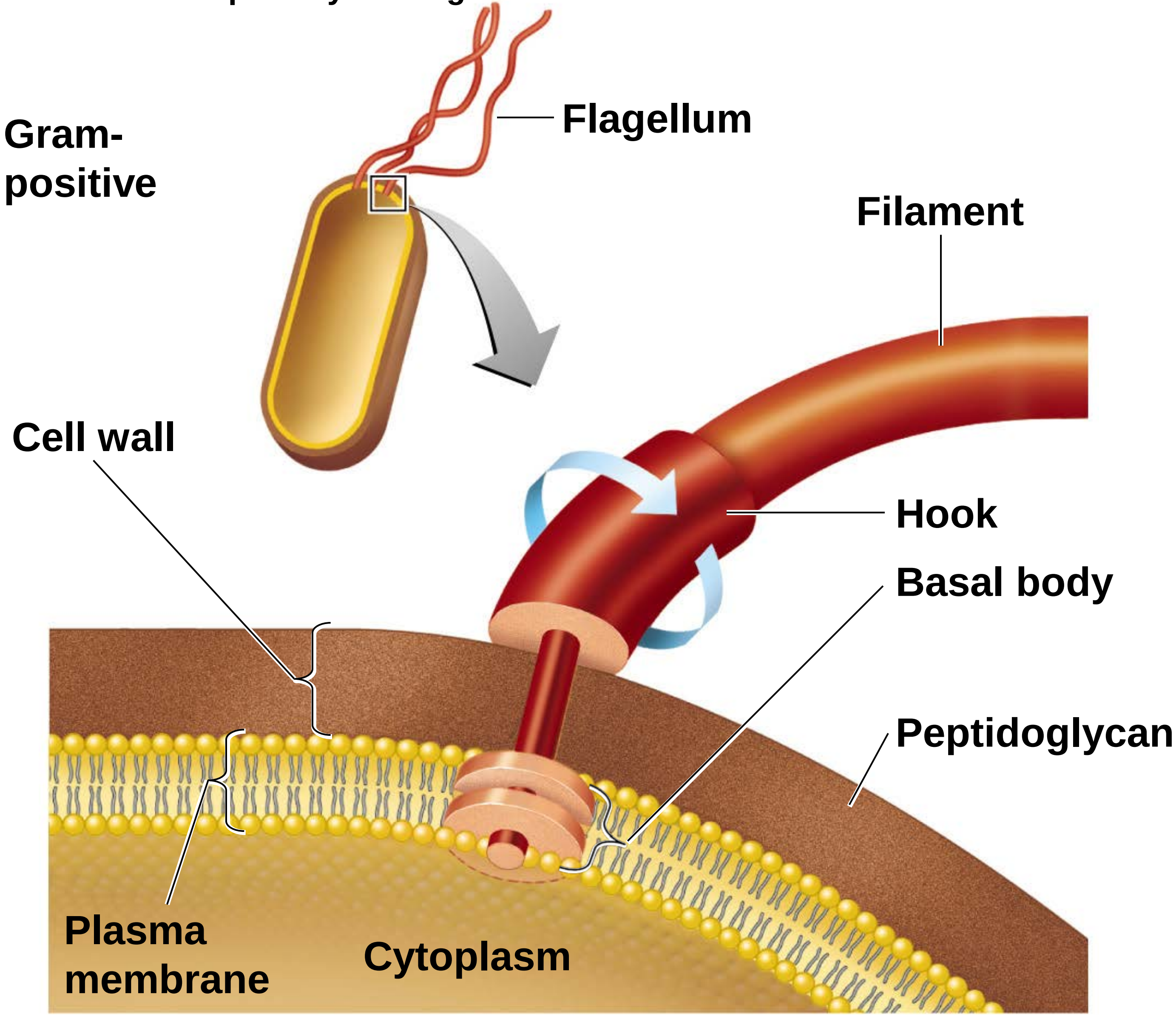
Figure 24.12 ***Streptococcus pneumoniae*****, the cause of pneumococcal pneumonia.**



Flagella

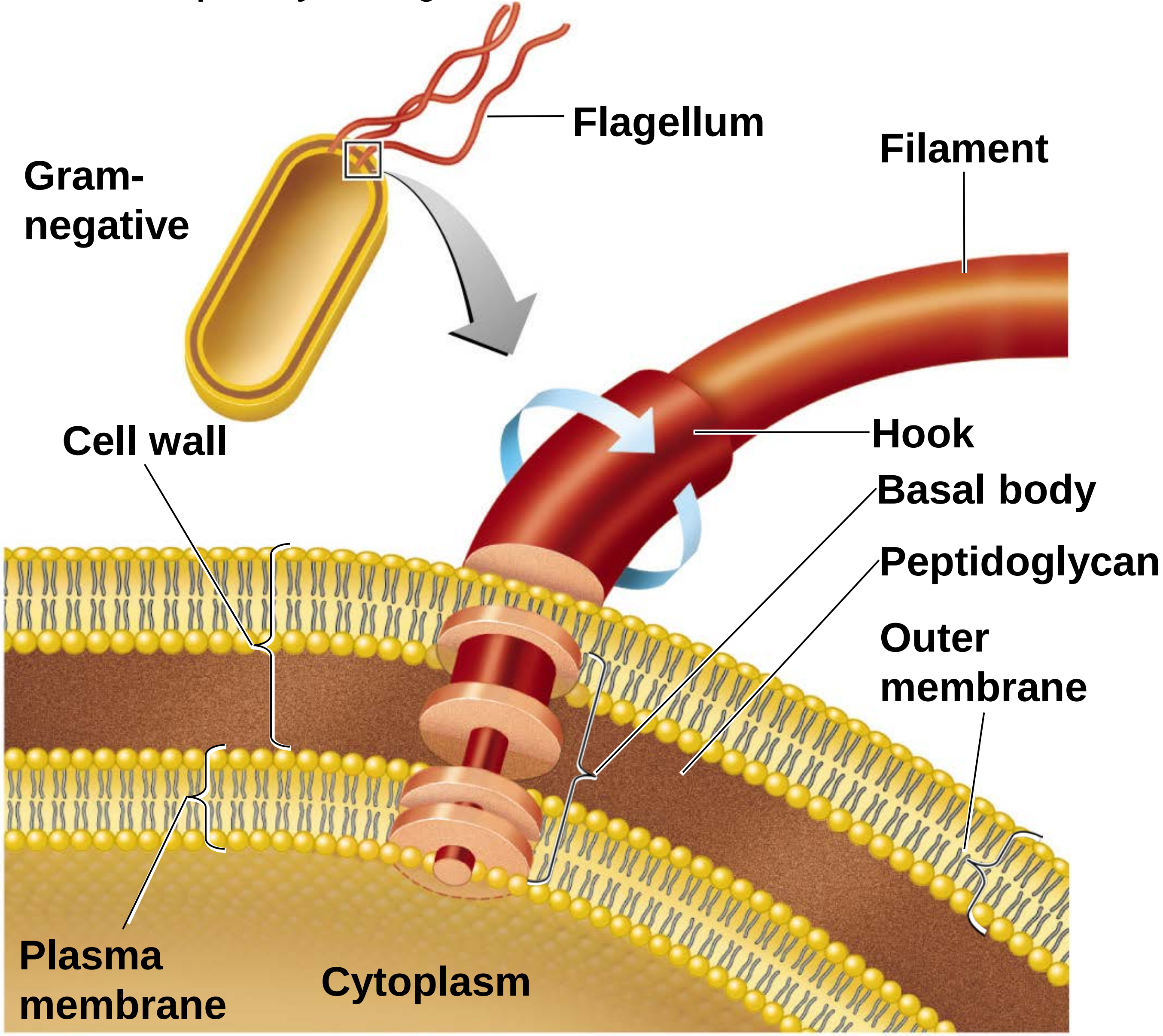
- Outside cell wall
- Made of chains of flagellin
- Attached to a protein hook
- Anchored to the wall and membrane by the basal body

Figure 4.8b The structure of a prokaryotic flagellum.



(b) Parts and attachment of a flagellum of a gram-positive bacterium

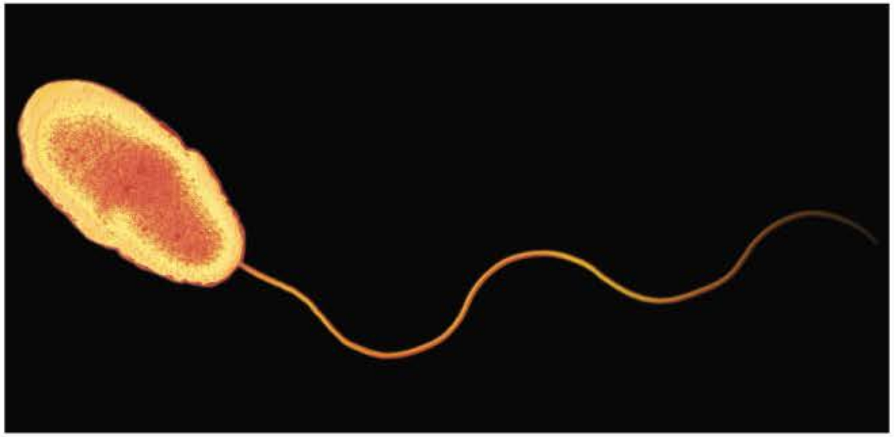
Figure 4.8a The structure of a prokaryotic flagellum.



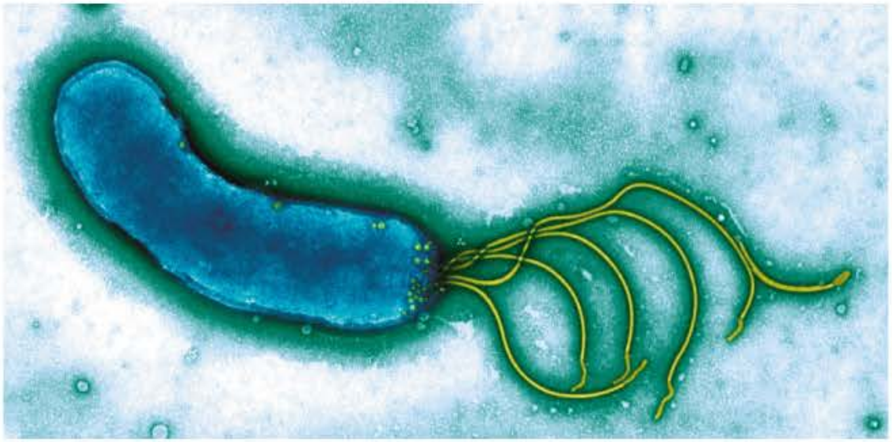
(a) Parts and attachment of a flagellum of a gram-negative bacterium

Figure 4.7 Arrangements of bacterial flagella.

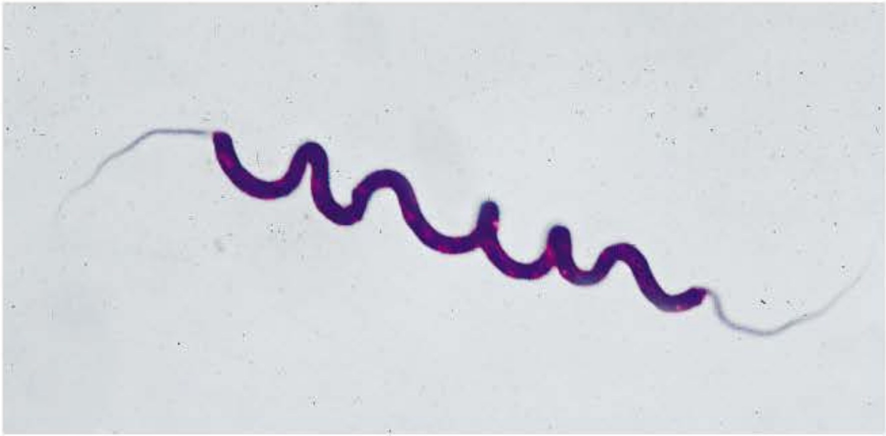
(a) Peritrichous



(b) Monotrichous and polar



(c) Lophotrichous and polar



(d) Amphitrichous and polar

Motile Cells

- Rotate flagella to run or tumble
- Move toward or away from stimuli (**taxis**)
- Flagella proteins are H antigens
  (e.g., *E. coli* O157:H7)

Motile Cells

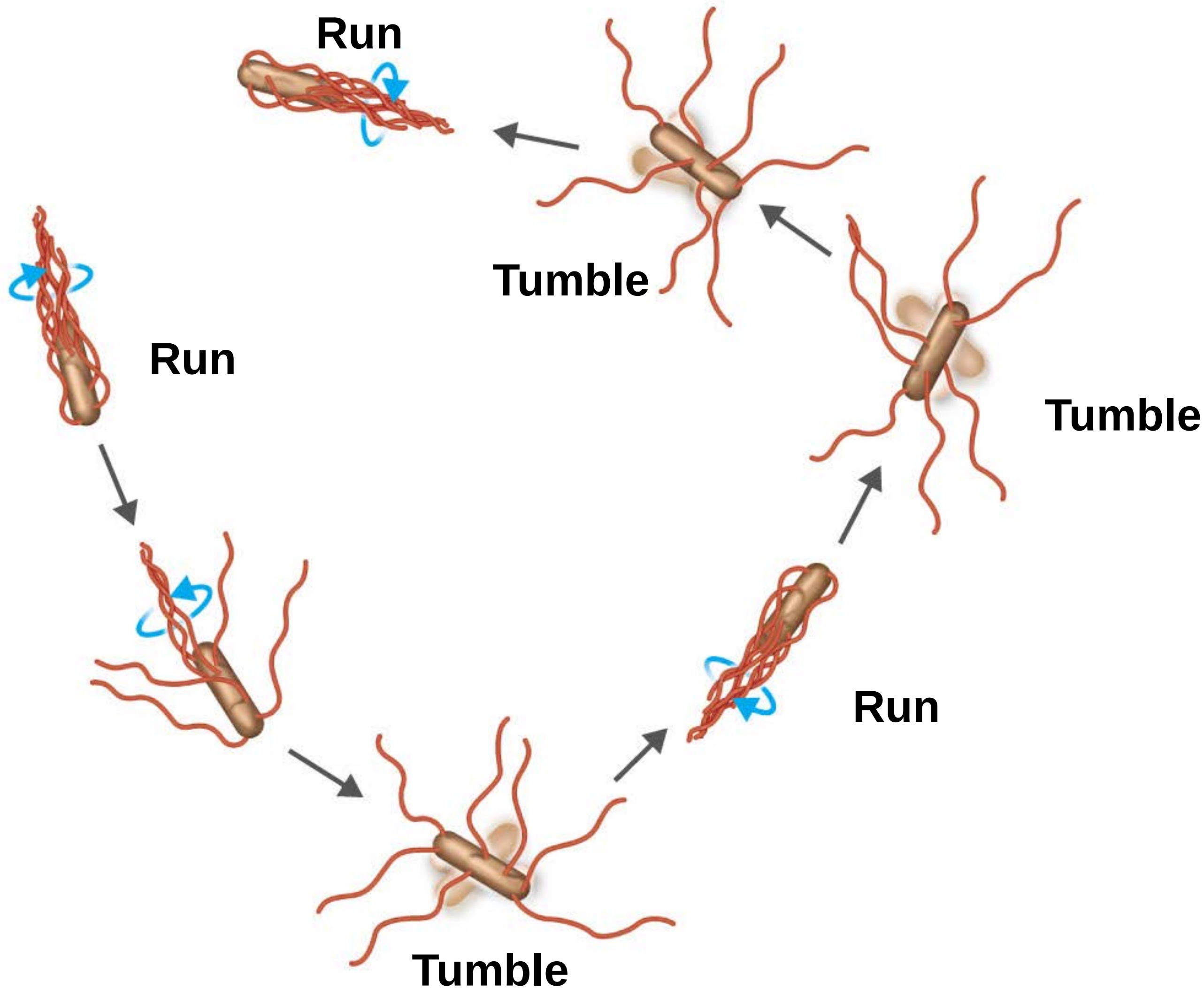
PLAY ANIMATION Motility

PLAY ANIMATION Flagella: Structure

PLAY ANIMATION Flagella: Movement

PLAY ANIMATION Flagella: Arrangement

Figure 4.9a Flagella and bacterial motility.

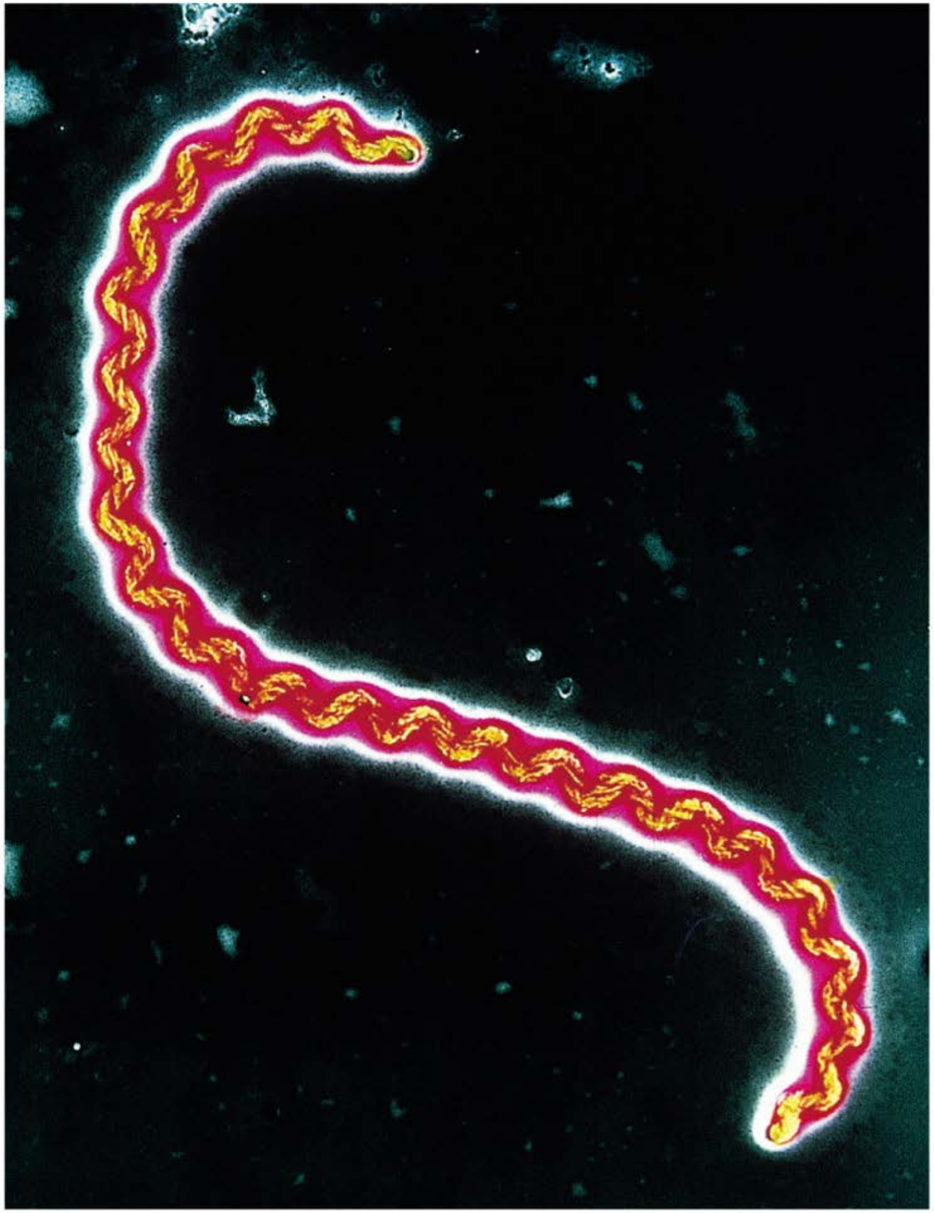


(a) A bacterium running and tumbling. Notice that the direction of flagellar rotation (blue arrows) determines which of these movements occurs. Gray arrows indicate direction of movement of the microbe.

Axial Filaments

- Also called **endoflagella**
- In spirochetes
- Anchored at one end of a cell
- Rotation causes cell to move

Figure 4.10a Axial filaments.

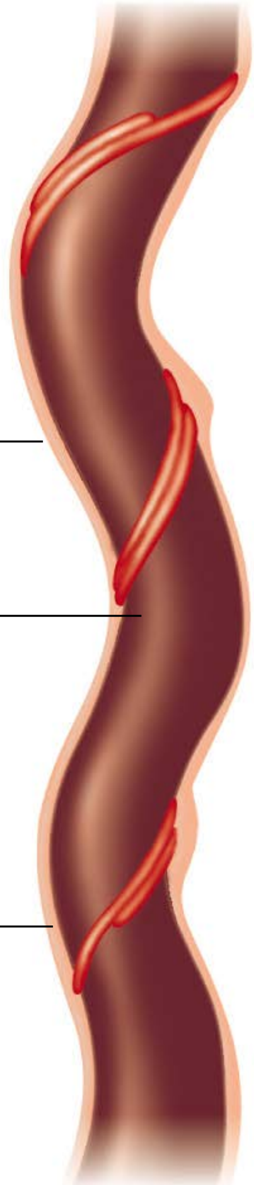


(a) A photomicrograph of the spirochete *Leptospira*, showing an axial filament

Axial Filaments

PLAY ANIMATION Spirochetes

Figure 4.10b Axial filaments.



(b) A diagram of axial filaments wrapping around part of a spirochete (see Figure 11.26a for a cross section of axial filaments)

Fimbriae and Pili

- Fimbriae allow attachment

Figure 4.11 Fimbriae.

Fimbriae and Pili

- Pili
  - Facilitate transfer of DNA from one cell to another
  - **Gliding** motility
  - **Twitching** motility

Check Your Understanding

- ✓ Why are bacterial capsules medically important? 4-3
- ✓ How do bacteria move? 4-4

The Cell Wall

Learning Objectives

4-5 Compare and contrast the cell walls of gram-positive bacteria, gram-negative bacteria, acid-fast bacteria, archaea, and mycoplasmas.

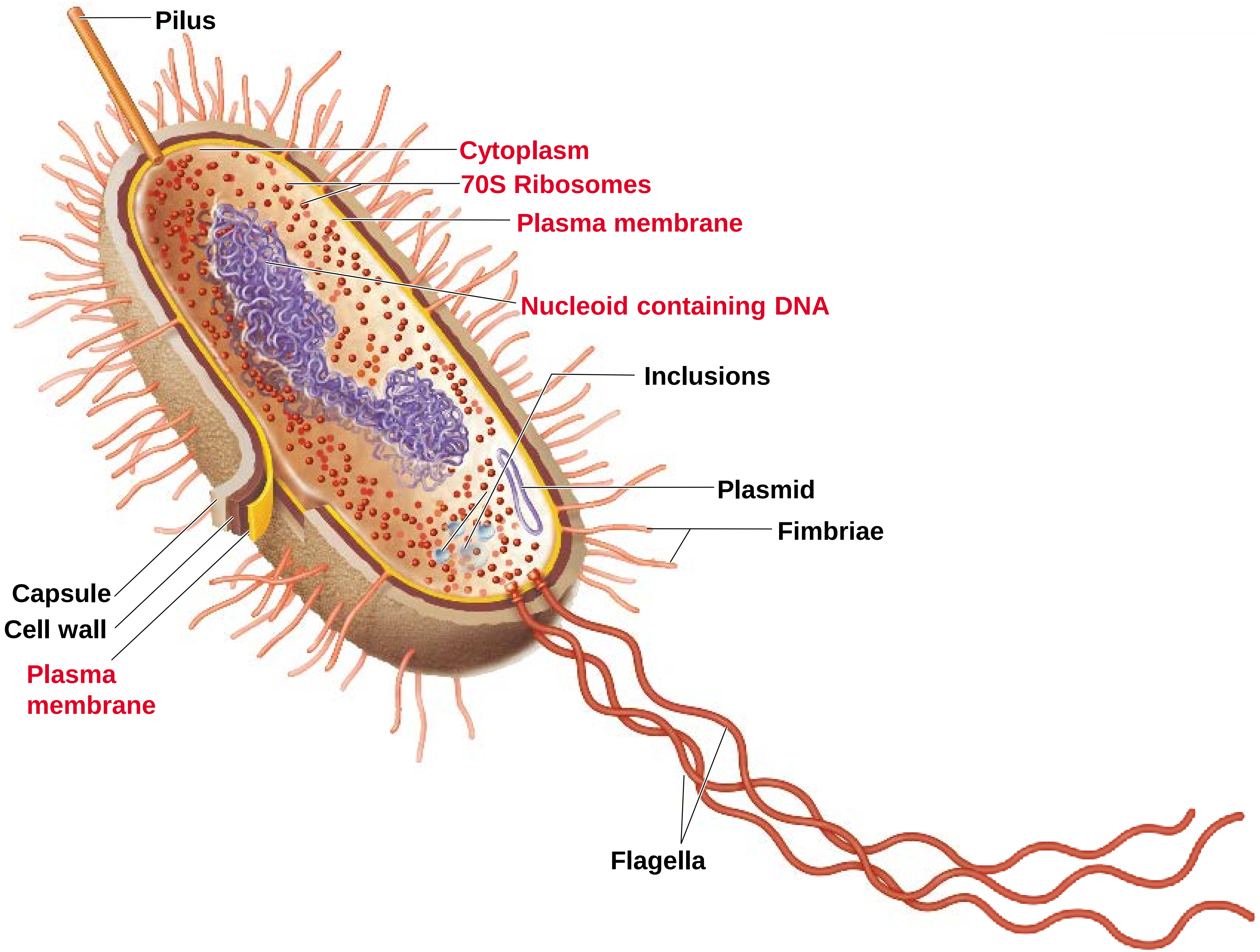
4-6 Compare and contrast archaea and mycoplasmas.

4-7 Differentiate *protoplast*, *spheroplast*, and *L form*.

The Cell Wall

- Prevents osmotic lysis
- Made of **peptidoglycan** (in bacteria)

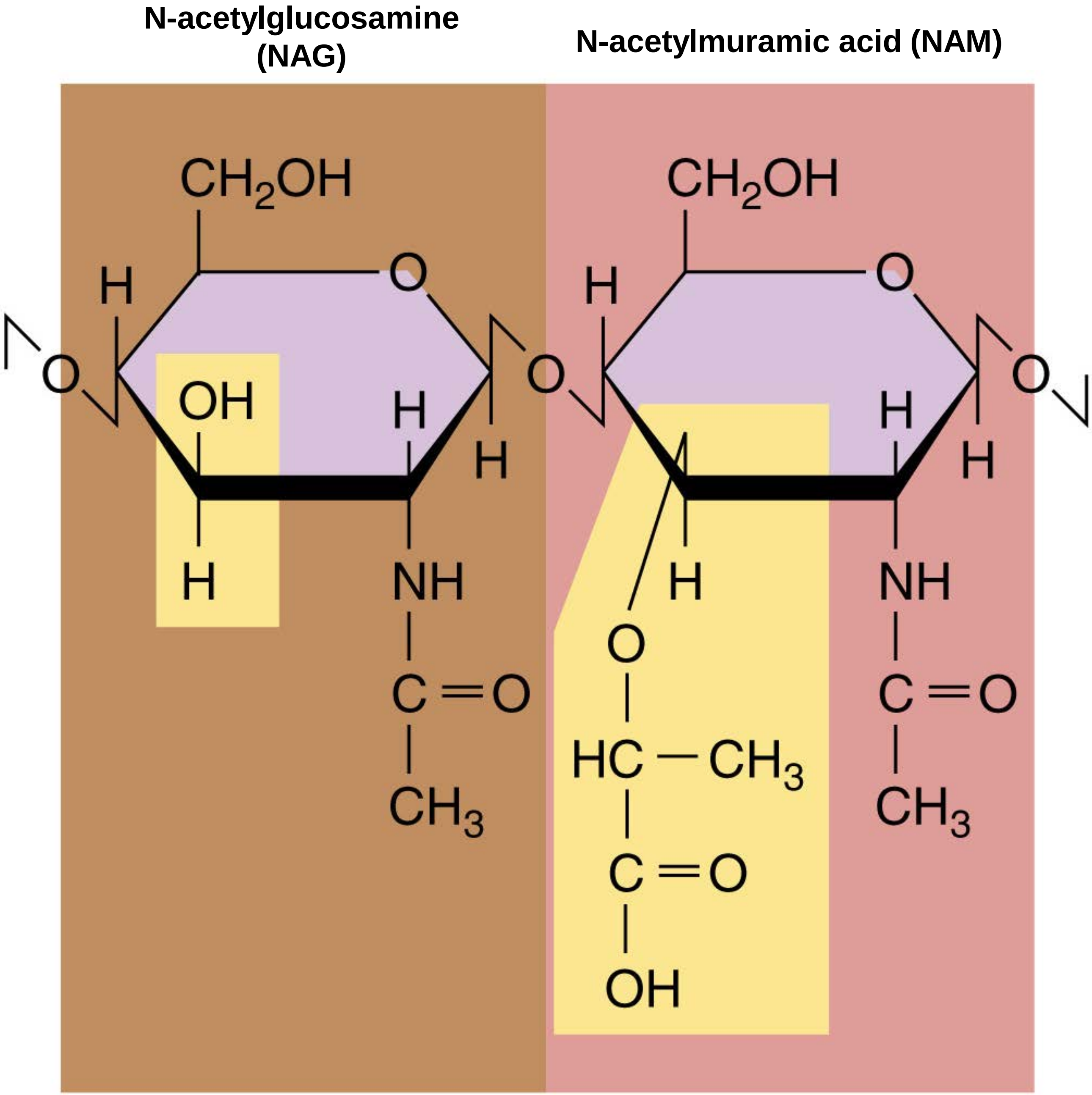
Figure 4.6 The Structure of a Prokaryotic Cell (Part 1 of 2).



Peptidoglycan

- Polymer of disaccharide:
  - N-acetylglucosamine (NAG)
  - N-acetylmuramic acid (NAM)

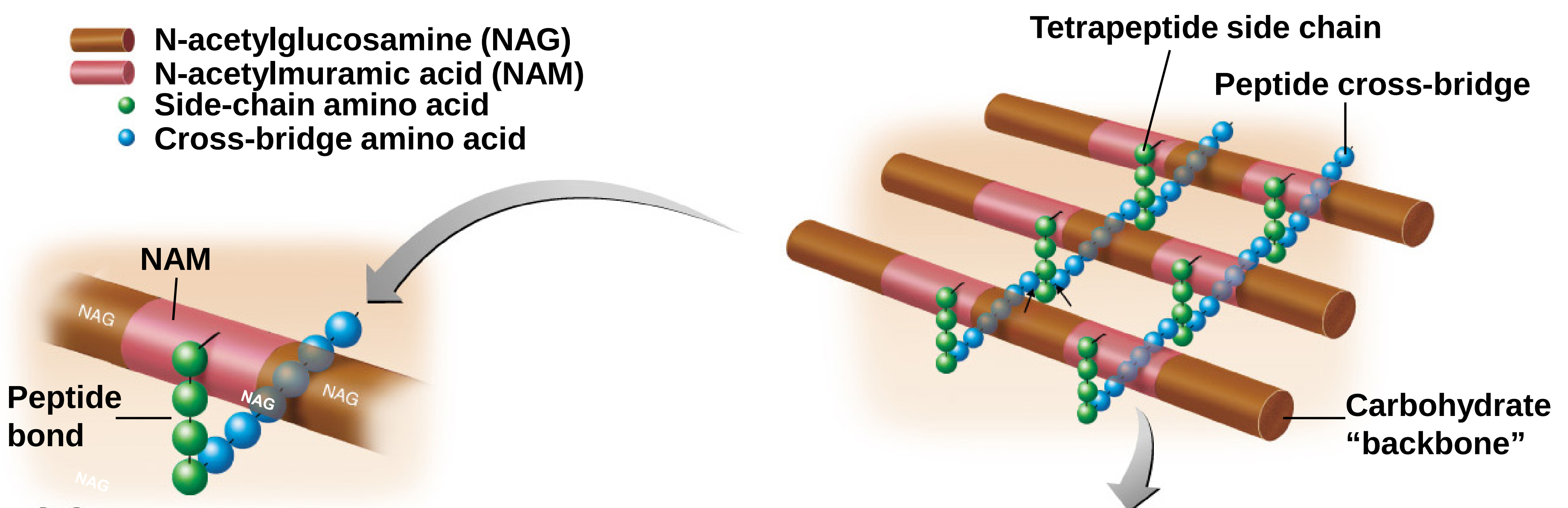
Figure 4.12 N-acetylglucosamine (NAG) and N-acetylmuramic acid (NAM) joined as in a peptidoglycan.



Peptidoglycan in Gram-Positive Bacteria

- Linked by **polypeptides**

Figure 4.13a Bacterial cell walls.



(a) Structure of peptidoglycan in gram-positive bacteria

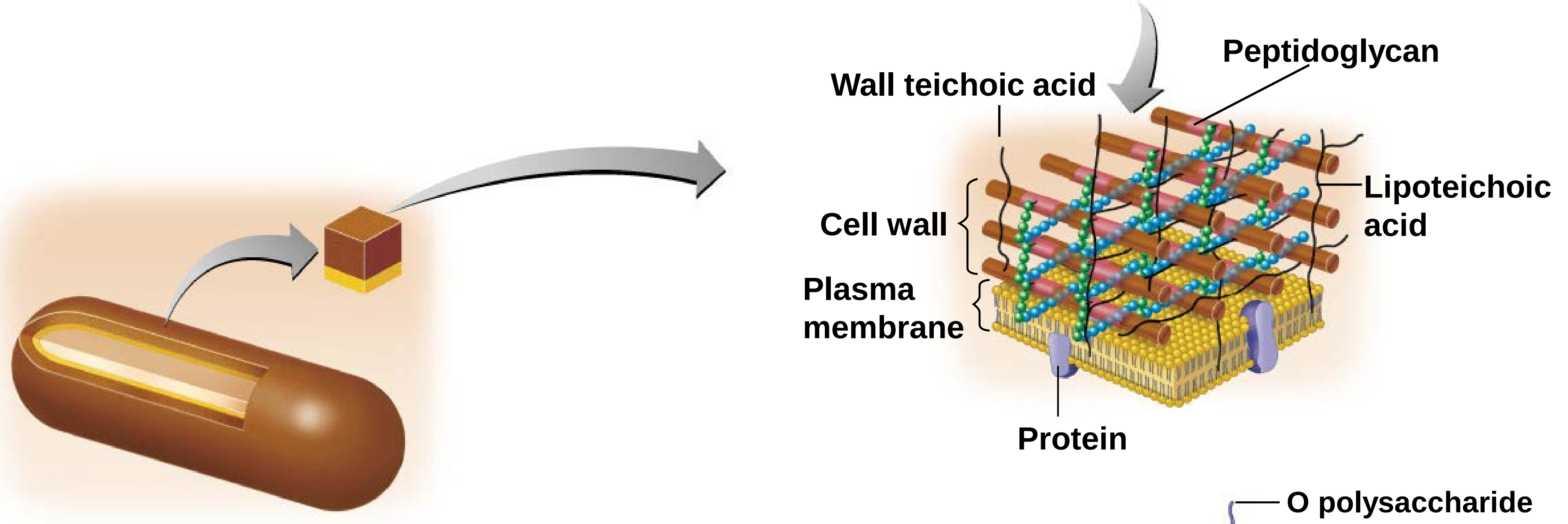
Gram-Positive Cell Wall

- Thick peptidoglycan
- Teichoic acids

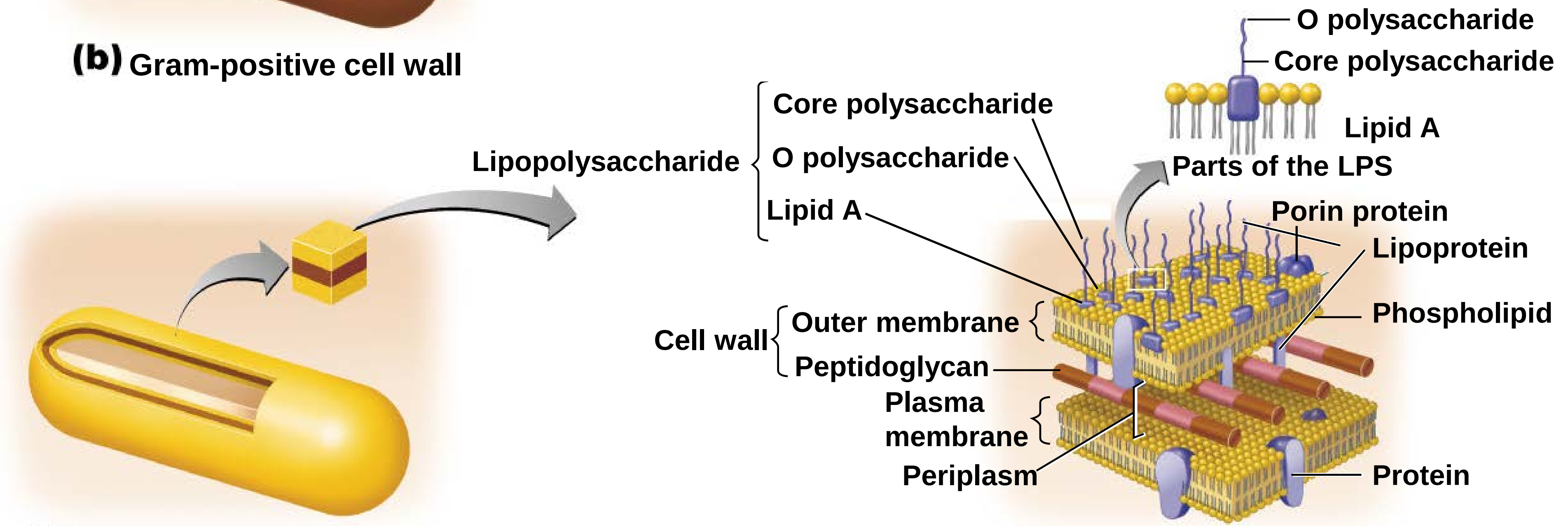
Gram-Negative Cell Wall

- Thin peptidoglycan
- Outer membrane
- Periplasmic space

Figure 4.13b-c Bacterial cell walls.



(b) Gram-positive cell wall

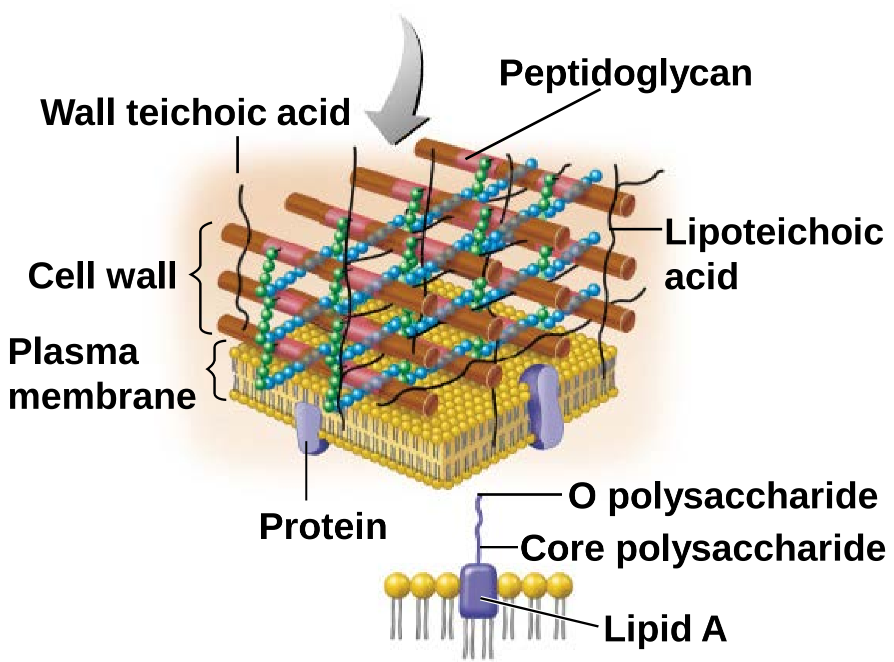


(c) Gram-negative cell wall

Gram-Positive Cell Walls

- Teichoic acids
  - Lipoteichoic acid links to plasma membrane
  - Wall teichoic acid links to peptidoglycan
- May regulate movement of cations
- Polysaccharides provide antigenic variation

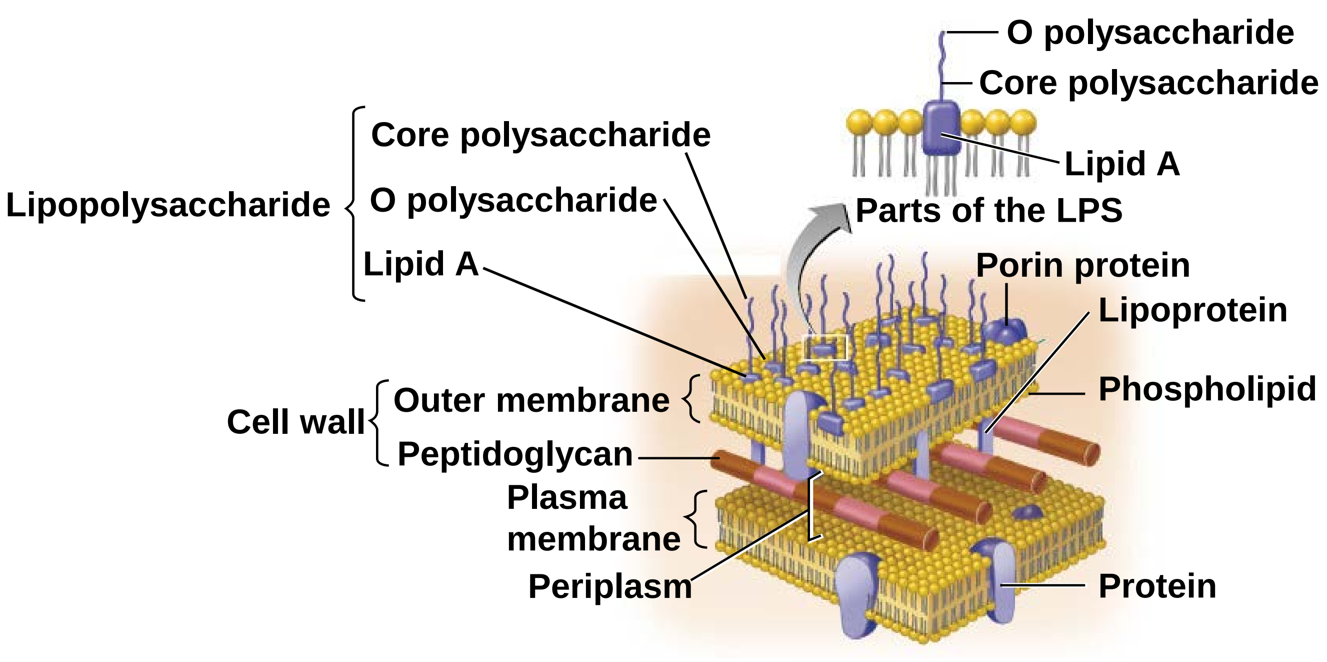
Figure 4.13b Bacterial cell walls.



Gram-Negative Outer Membrane

- Lipopolysaccharides, lipoproteins, phospholipids
- Forms the periplasm between the outer membrane and the plasma membrane

Figure 4.13c Bacterial cell walls.



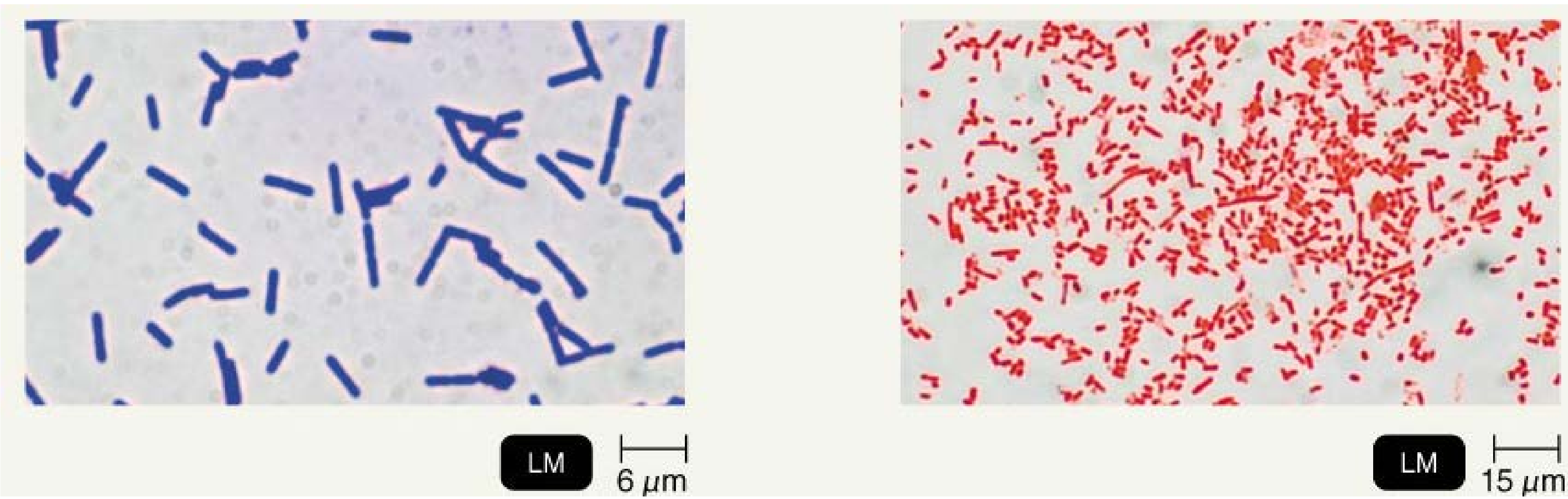
Gram-Negative Outer Membrane

- Protection from phagocytes, complement, and antibiotics
- **O polysaccharide** antigen, e.g., *E. coli* O157:H7
- **Lipid A** is an endotoxin
- **Porins** (proteins) form channels through membrane

The Gram Stain Mechanism

- Crystal violet-iodine crystals form in cell
- Gram-positive
  - Alcohol dehydrates peptidoglycan
  - CV-I crystals do not leave
- Gram-negative
  - Alcohol dissolves outer membrane and leaves holes in peptidoglycan
  - CV-I washes out

Table 4.1 Some Comparative Characteristics of Gram-Positive and Gram-Negative Bacteria



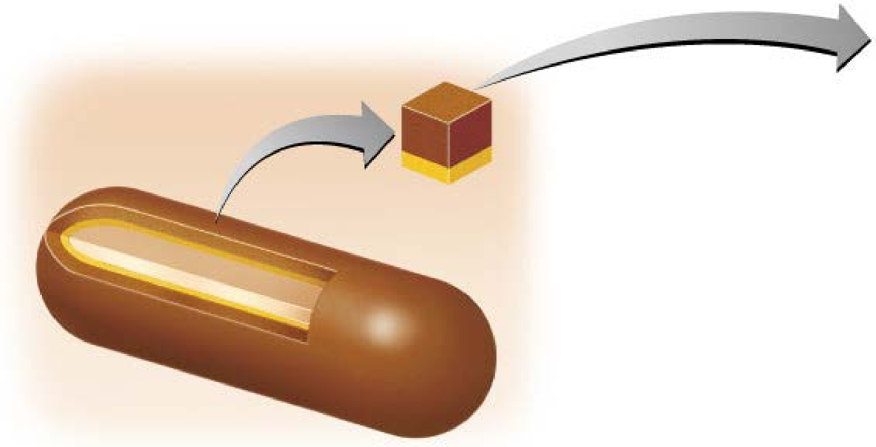
Gram-Positive Cell Wall

- 2-ring basal body
- Disrupted by lysozyme
- Penicillin sensitive

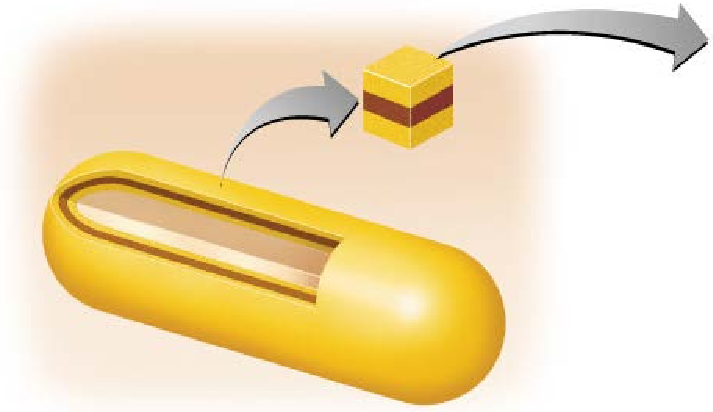
Gram-Negative Cell Wall

- 4-ring basal body
- Endotoxin (LPS)
- Tetracycline sensitive

Figure 4.13b-c Bacterial cell walls.



(b) Gram-positive cell wall

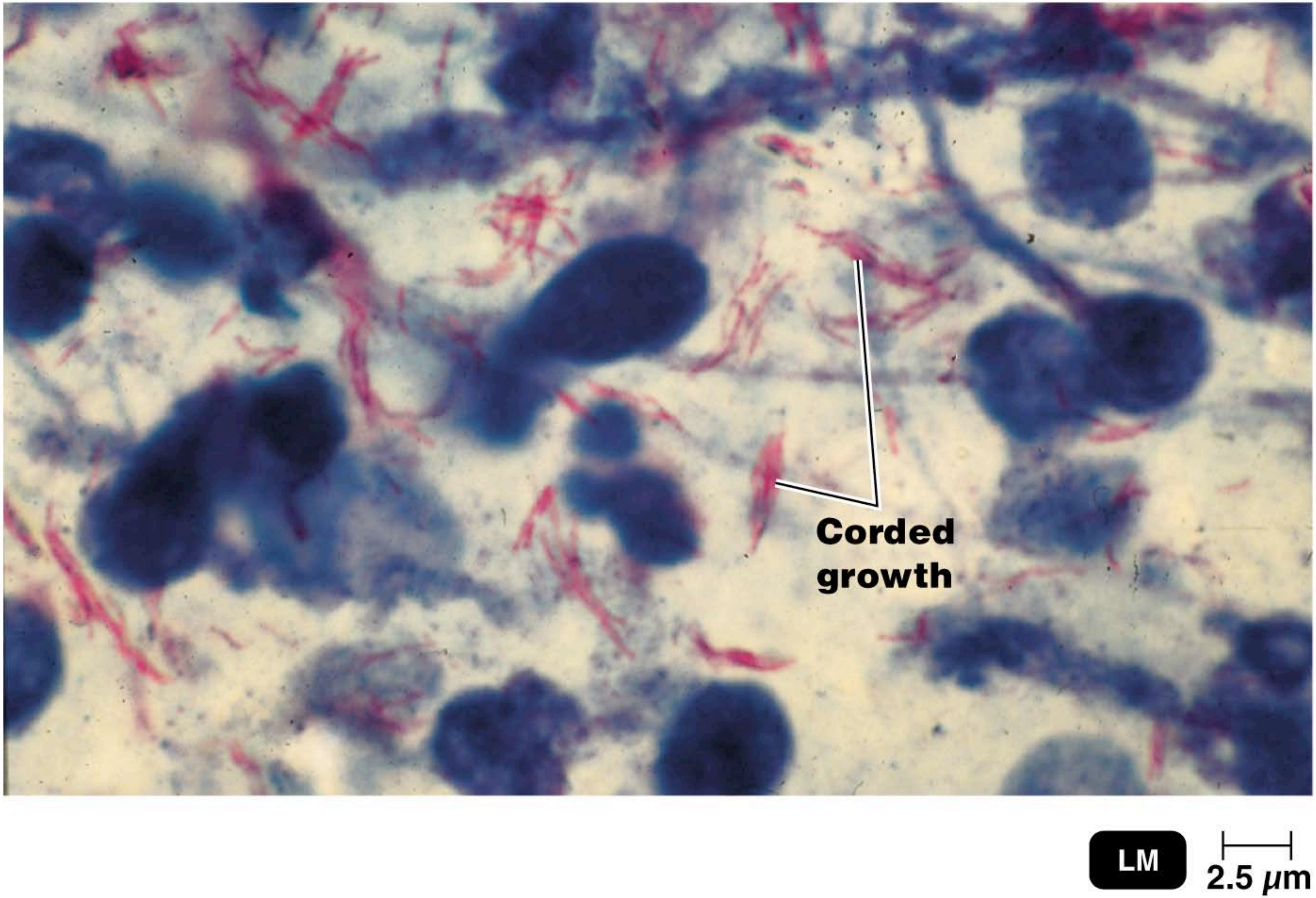


(c) Gram-negative cell wall

Atypical Cell Walls

- Acid-fast cell walls
  - Like gram-positive cell walls
  - Waxy lipid (**mycolic acid**) bound to peptidoglycan
  - *Mycobacterium*
  - *Nocardia*

Figure 24.8 *Mycobacterium tuberculosis*.



Atypical Cell Walls

- Mycoplasmas
  - Lack cell walls
  - Sterols in plasma membrane
- Archaea
  - Wall-less, or
  - Walls of pseudomurein (lack NAM and D-amino acids)

Damage to the Cell Wall

- Lysozyme digests disaccharide in peptidoglycan
- Penicillin inhibits peptide bridges in peptidoglycan
- **Protoplast** is a wall-less cell
- **Spheroplast** is a wall-less gram-positive cell
  - Protoplasts and spheroplasts are susceptible to osmotic lysis
- **L forms** are wall-less cells that swell into irregular shapes

Check Your Understanding

- ✓ Why are drugs that target cell wall synthesis useful? 4-5
- ✓ Why are mycoplasmas resistant to antibiotics that interfere with cell wall synthesis? 4-6
- ✓ How do protoplasts differ from L forms? 4-7

Structures Internal to the Cell Wall

Learning Objectives

4-8 Describe the structure, chemistry, and functions of the prokaryotic plasma membrane.

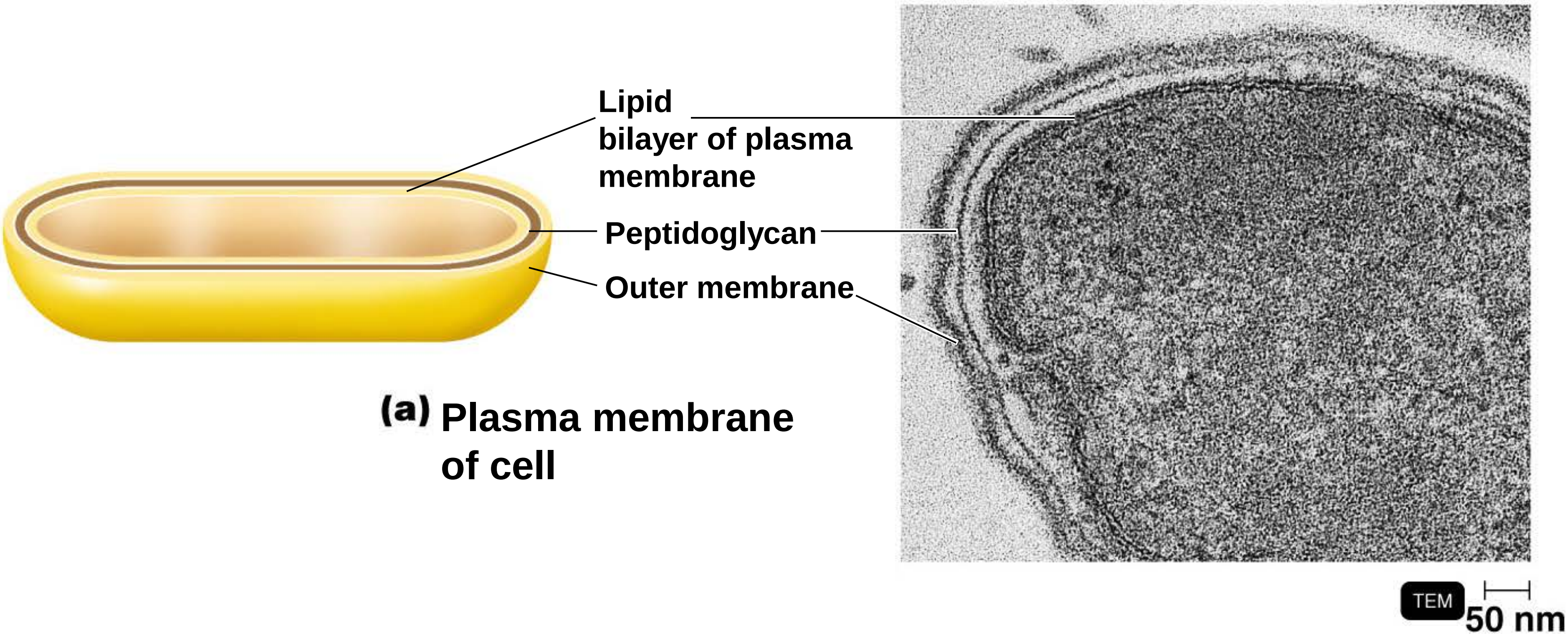
4-9 Define *simple diffusion*, *facilitated diffusion*, *osmosis*, *active transport*, and *group translocation*.

4-10 Identify the functions of the nucleoid and ribosomes.

4-11 Identify the functions of four inclusions.

4-12 Describe the functions of endospores, sporulation, and endospore germination.

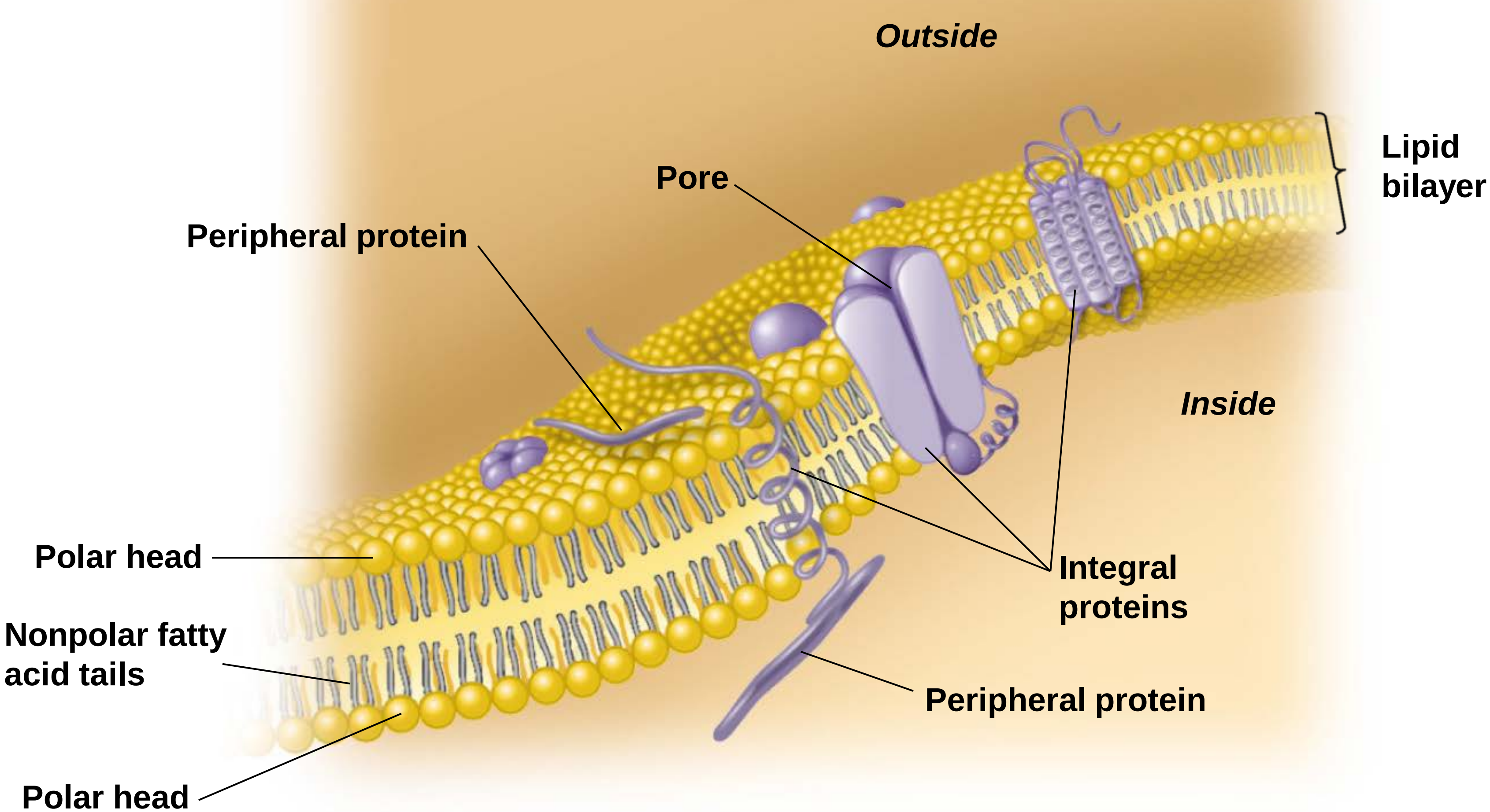
Figure 4.14a Plasma membrane.



The Plasma Membrane

- Phospholipid bilayer
- Peripheral proteins
- Integral proteins
- Transmembrane
- Proteins

Figure 4.14b Plasma membrane.



(b) Lipid bilayer of plasma membrane

Fluid Mosaic Model

- Membrane is as viscous as olive oil
- Proteins move to function
- Phospholipids rotate and move laterally

The Plasma Membrane

- **Selective permeability** allows passage of some molecules
- Enzymes for ATP production
- Photosynthetic pigments on foldings called **chromatophores** or **thylakoids**

The Plasma Membrane

- Damage to the membrane by alcohols, quaternary ammonium (detergents), and polymyxin antibiotics causes leakage of cell contents

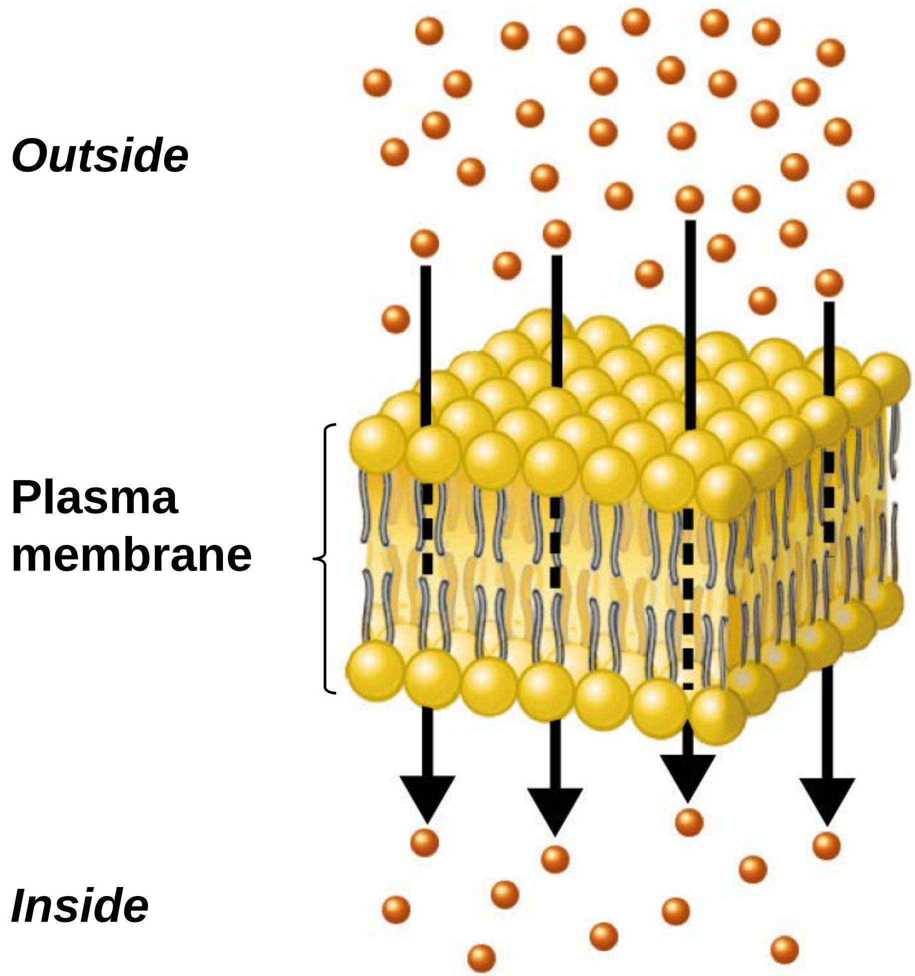
PLAY ANIMATION Membrane Structure

PLAY ANIMATION Membrane Permeability

Movement of Materials across Membranes

- **Simple diffusion**: movement of a solute from an area of high concentration to an area of low concentration

Figure 4.17a Passive processes.

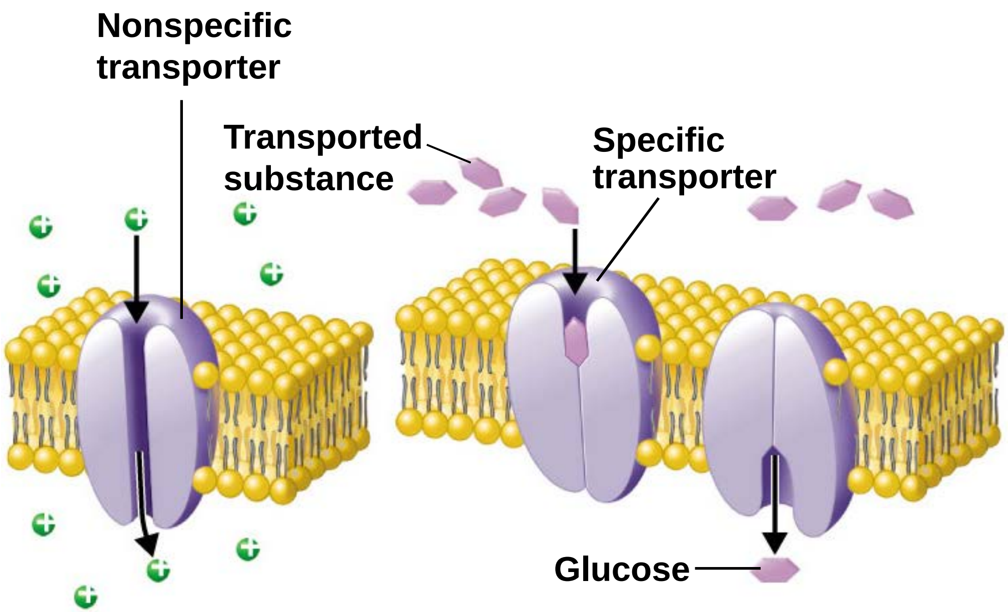


(a) **Simple diffusion through the lipid bilayer**

Movement of Materials across Membranes

- **Facilitated diffusion**: solute combines with a transporter protein in the membrane

Figure 4.17b-c Passive processes.



(b) Facilitated diffusion through a nonspecific transporter

(c) Facilitated diffusion through a specific transporter

Movement of Materials across Membranes

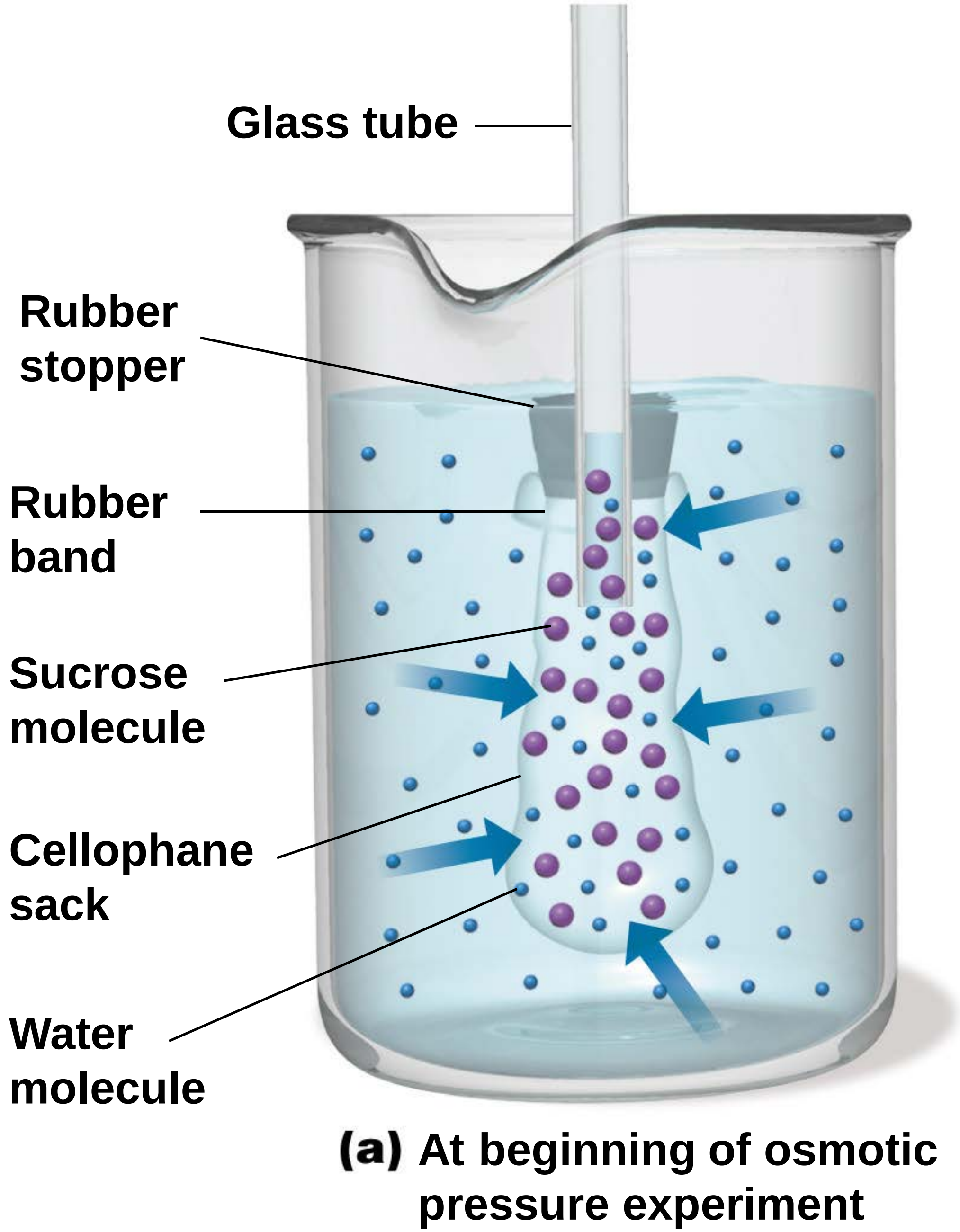
PLAY ANIMATION Passive Transport: Special Types of Diffusion

PLAY ANIMATION Passive Transport: Principles of Diffusion

Movement of Materials across Membranes

- **Osmosis**: the movement of water across a selectively permeable membrane from an area of high water to an area of lower water concentration
- **Osmotic pressure**: the pressure needed to stop the movement of water across the membrane

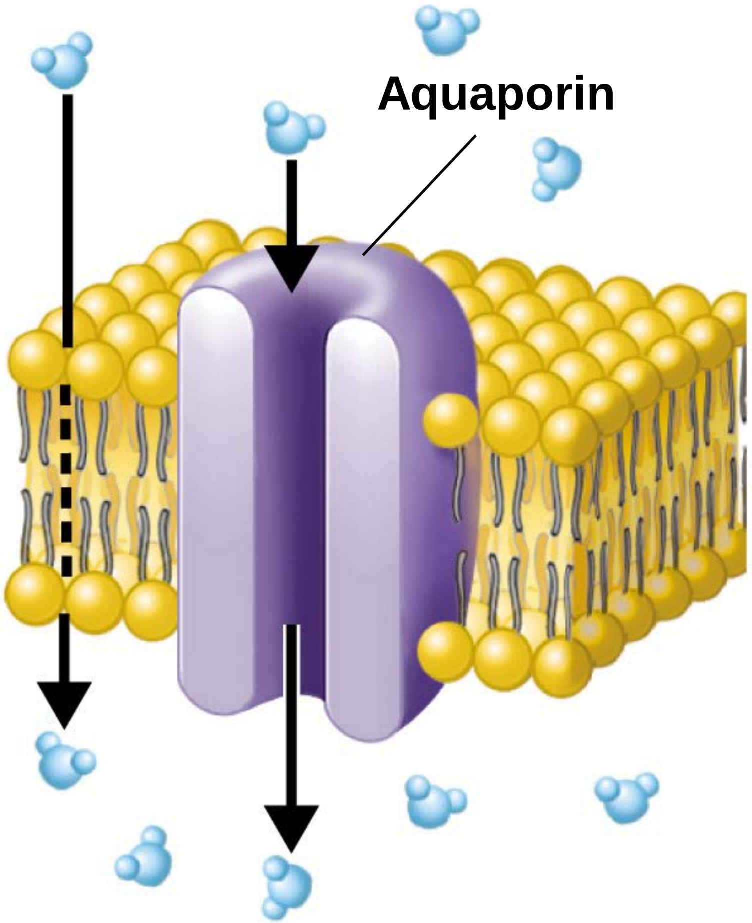
Figure 4.18a The principle of osmosis.



Movement of Materials across Membranes

- Through lipid layer
- Aquaporins (water channels)

Figure 4.17d Passive processes.



(d) Osmosis through the lipid bilayer (left) and an aquaporin (right)

Figure 4.18a-b The principle of osmosis.

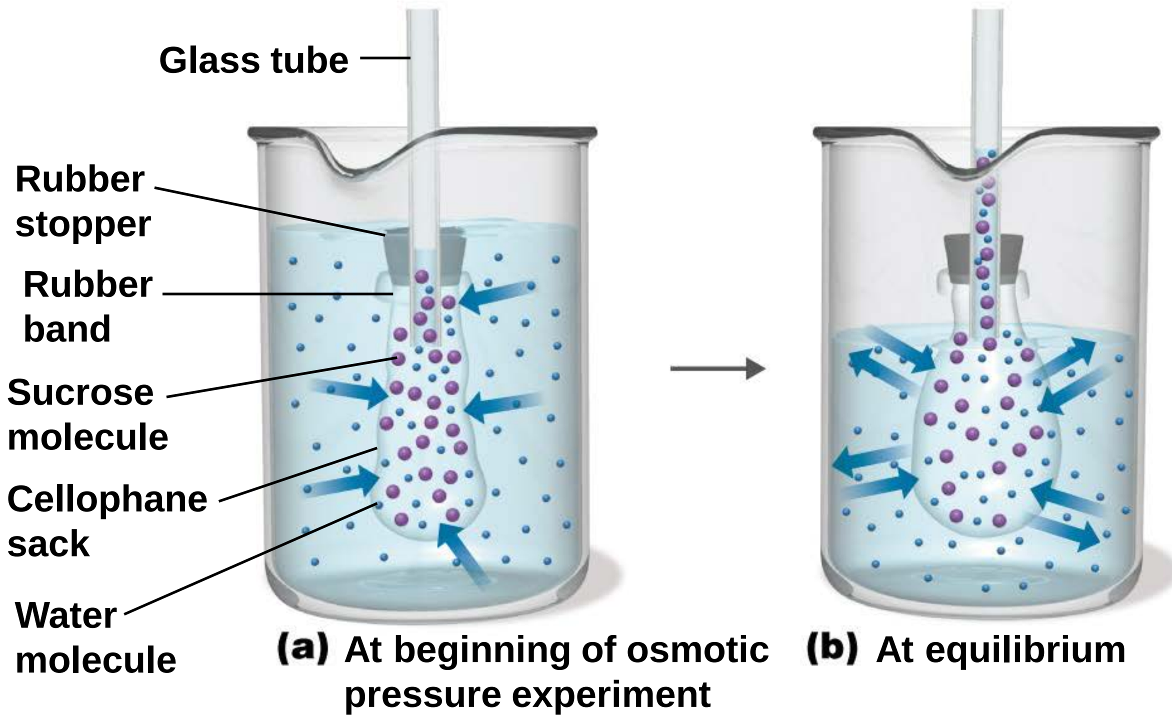
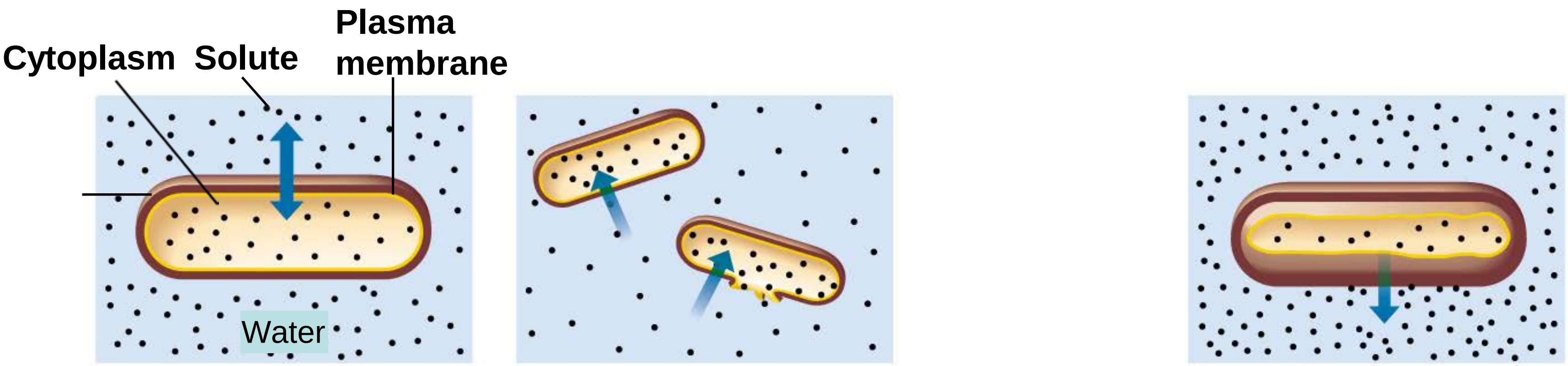


Figure 4.18c-e The principle of osmosis.



(c) Isotonic solution. No net movement of water occurs.

(d) Hypotonic solution. Water moves into the cell. If the cell wall is strong, it contains the swelling. If the cell wall is weak or damaged, the cell bursts (osmotic lysis).

(e) Hypertonic solution. Water moves out of the cell, causing its cytoplasm to shrink (plasmolysis).

Movement of Materials across Membranes

- **Active transport**: requires a transporter protein and ATP
- **Group translocation**: requires a transporter protein and PEP

PLAY ANIMATION Active Transport: Types

PLAY ANIMATION Active Transport: Overview

Check Your Understanding

- ✓ Which agents can cause injury to the bacterial plasma membrane? 4-8
- ✓ How are simple diffusion and facilitated diffusion similar? How are they different? 4-9

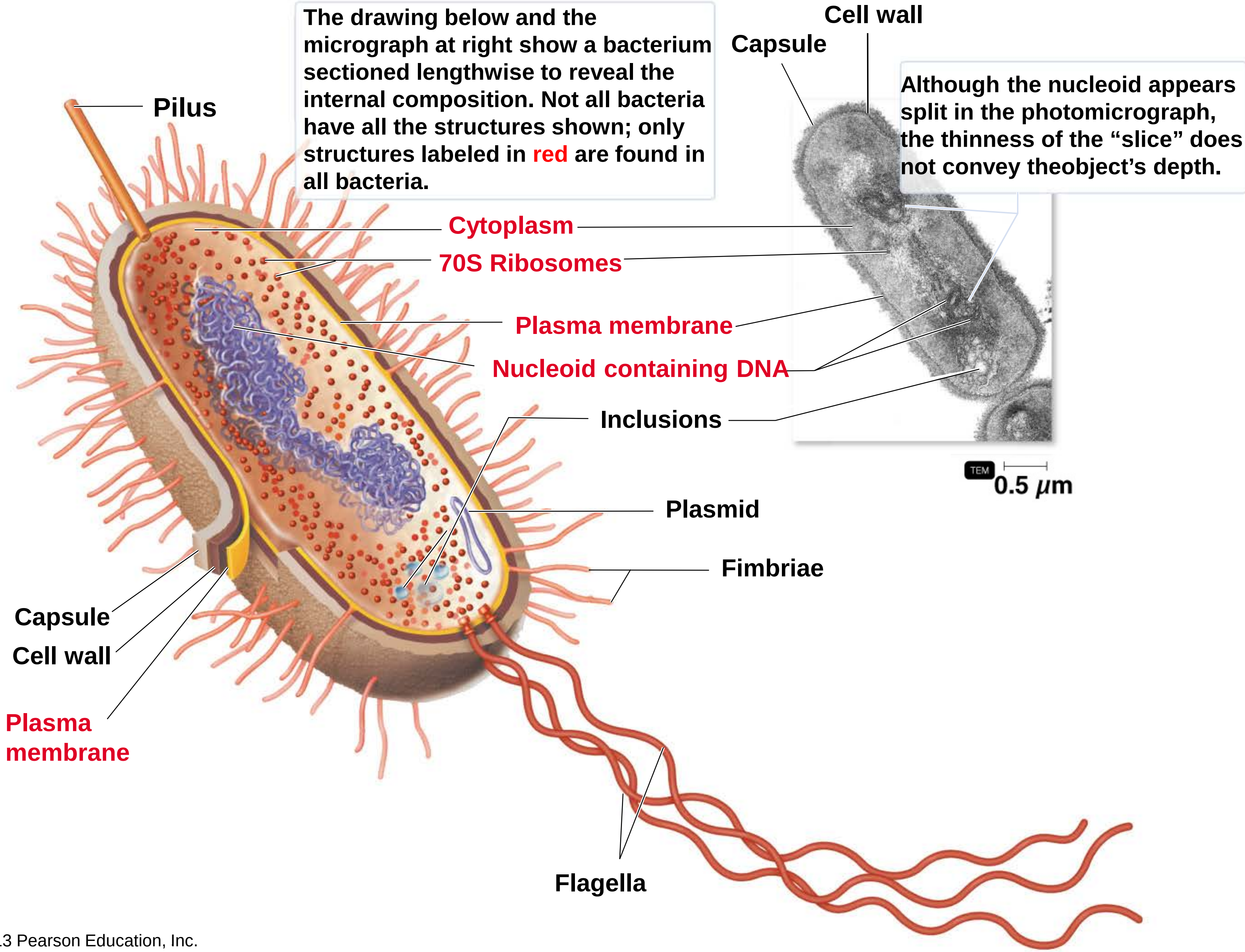
Cytoplasm

- The substance inside the plasma membrane

The Nucleoid

- **Bacterial chromosome**

Figure 4.6 The Structure of a Prokaryotic Cell.



The Prokaryotic Ribosome

- Protein synthesis
- 70S
  - 50S + 30S subunits

Figure 4.19 The prokaryotic ribosome.

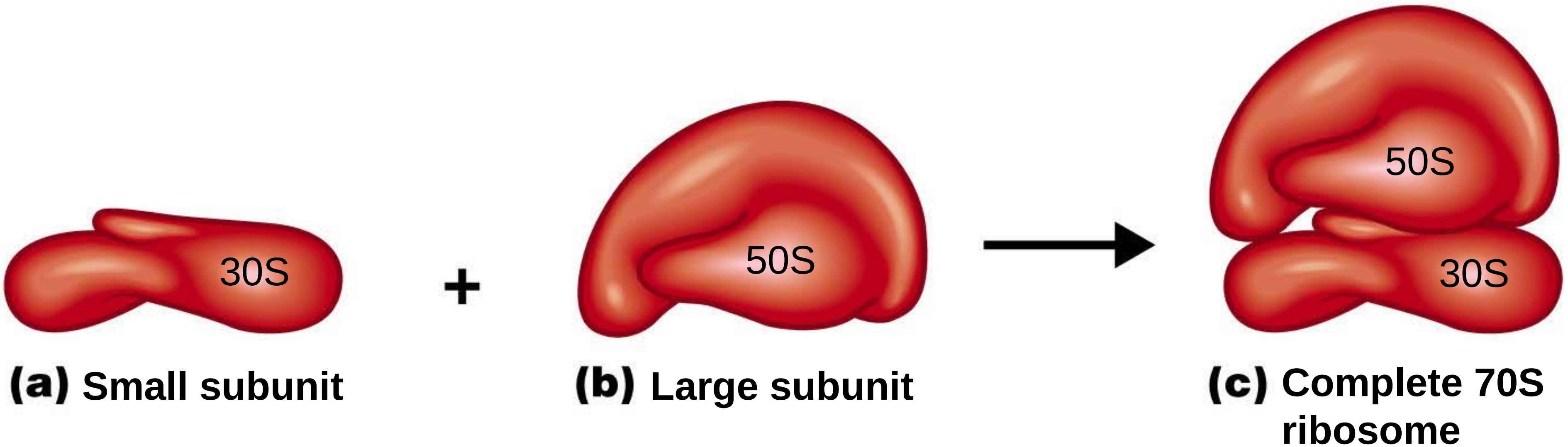
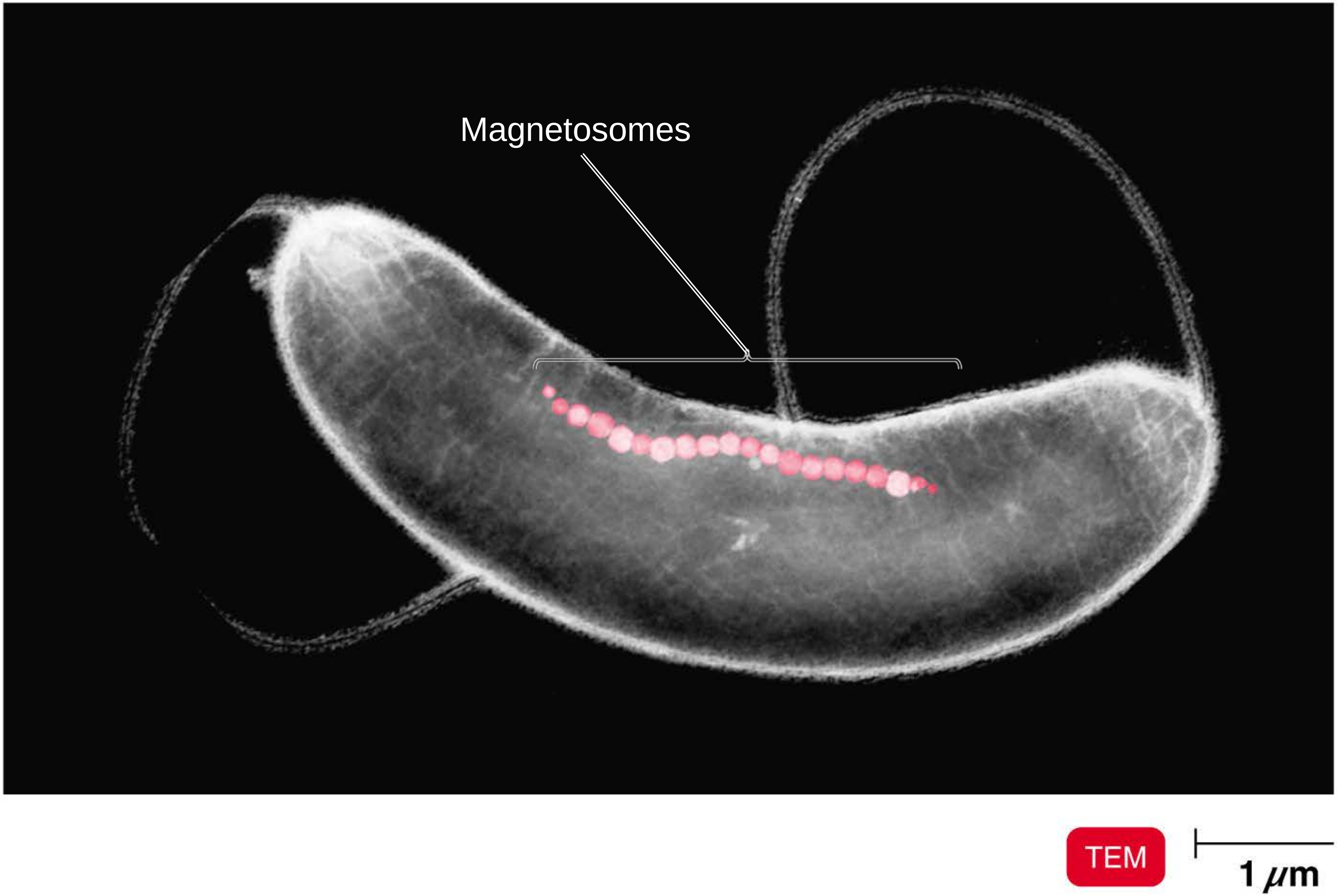


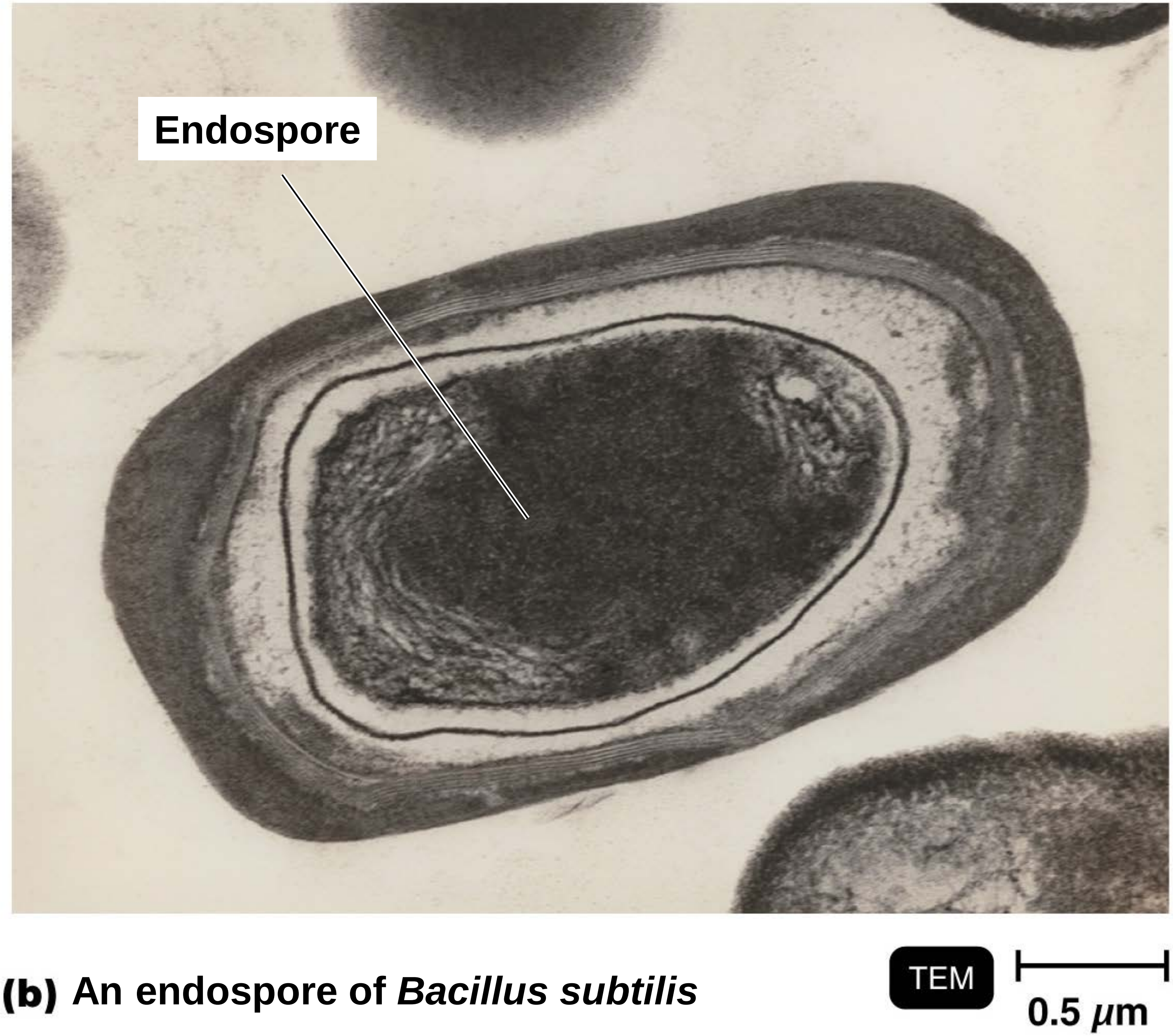
Figure 4.20 Magnetosomes.



Endospores

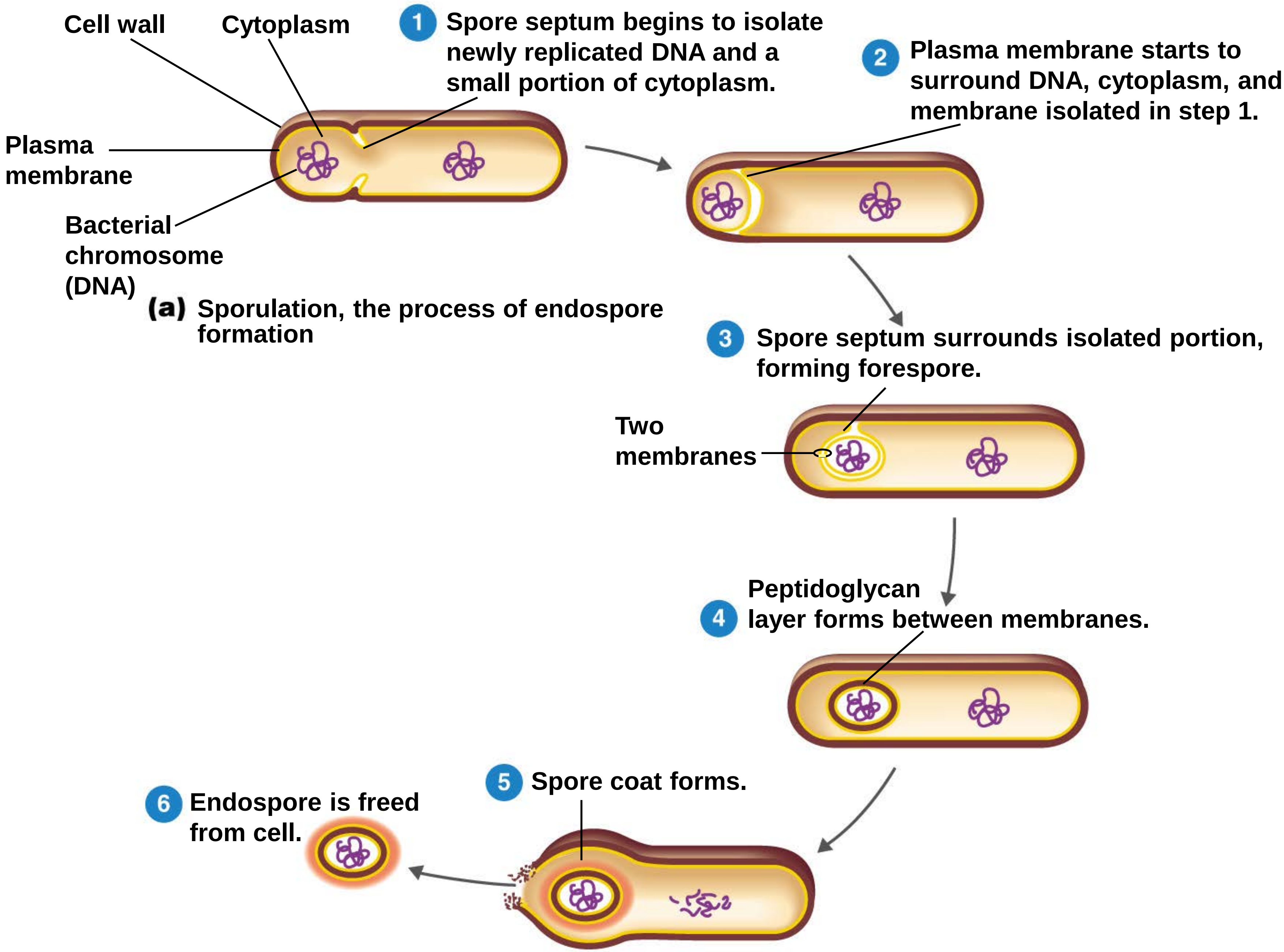
- Resting cells
- Resistant to desiccation, heat, chemicals
- *Bacillus, Clostridium*
- **Sporulation**: endospore formation
- **Germination**: return to vegetative state

Figure 4.21b Formation of endospores by sporulation.



(b) An endospore of *Bacillus subtilis*

Figure 4.21a Formation of endospores by sporulation.

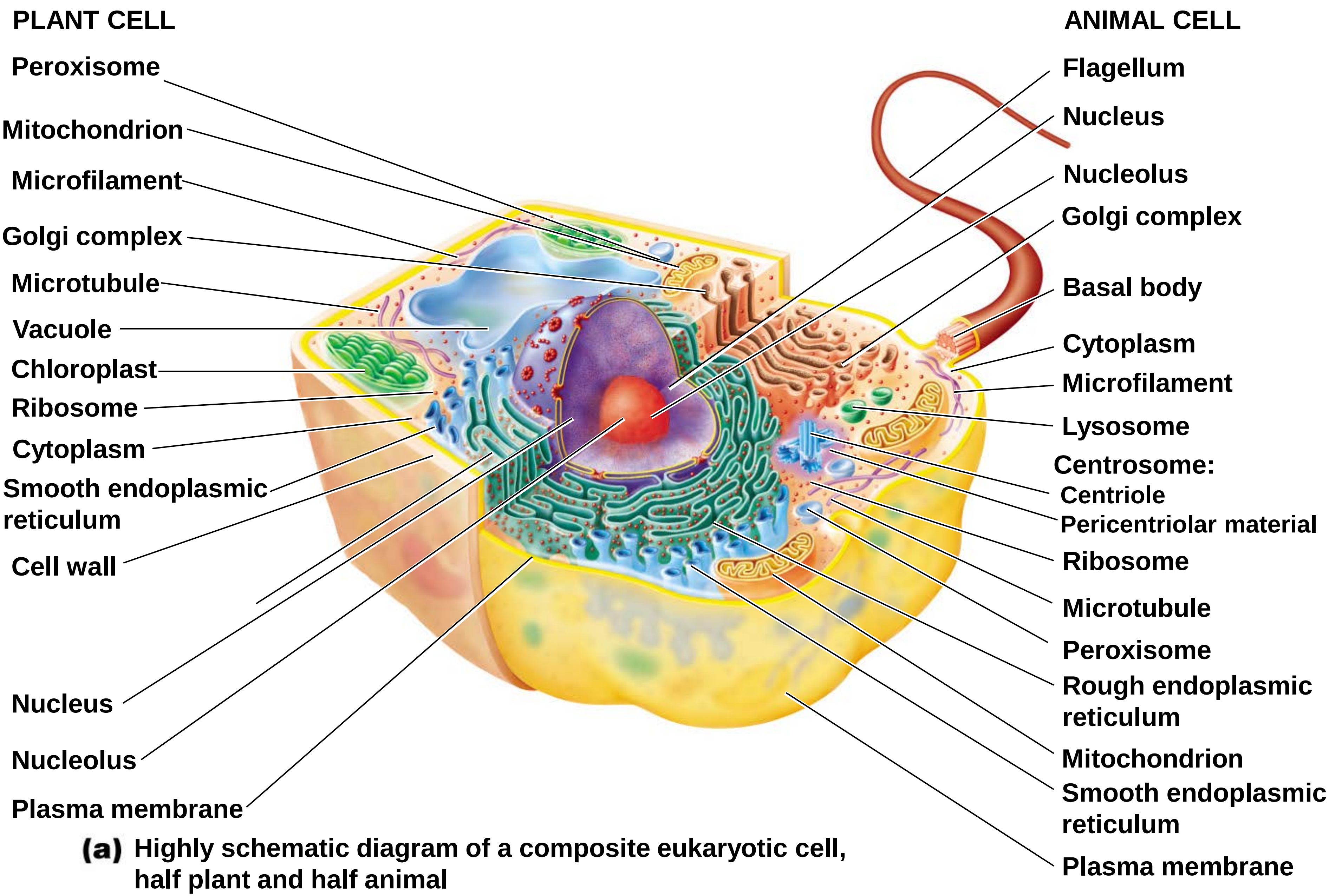


(a) Sporulation, the process of endospore formation

Check Your Understanding

- ✓ Where is the DNA located in a prokaryotic cell? 4-10
- ✓ What is the general function of inclusions? 4-11
- ✓ Under what conditions do endospores form? 4-12

Figure 4.22a Eukaryotic cells showing typical structures.



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

The Cell Wall and Glycocalyx

Learning Objective

4-14 Compare and contrast prokaryotic and eukaryotic cell walls and glycocalyxes.

The Cell Wall and Glycocalyx

- Cell wall
  - Plants, algae, fungi
  - Carbohydrates
- Cellulose, chitin, glucan, mannan
- **Glycocalyx**
  - Carbohydrates extending from animal plasma membrane
  - Bonded to proteins and lipids in membrane

The Plasma Membrane

Learning Objective

4-15 Compare and contrast prokaryotic and eukaryotic plasma membranes.

The Plasma Membrane

- Phospholipid bilayer
- Peripheral proteins
- Integral proteins
- Transmembrane proteins
- Sterols
- Glycocalyx carbohydrates

The Plasma Membrane

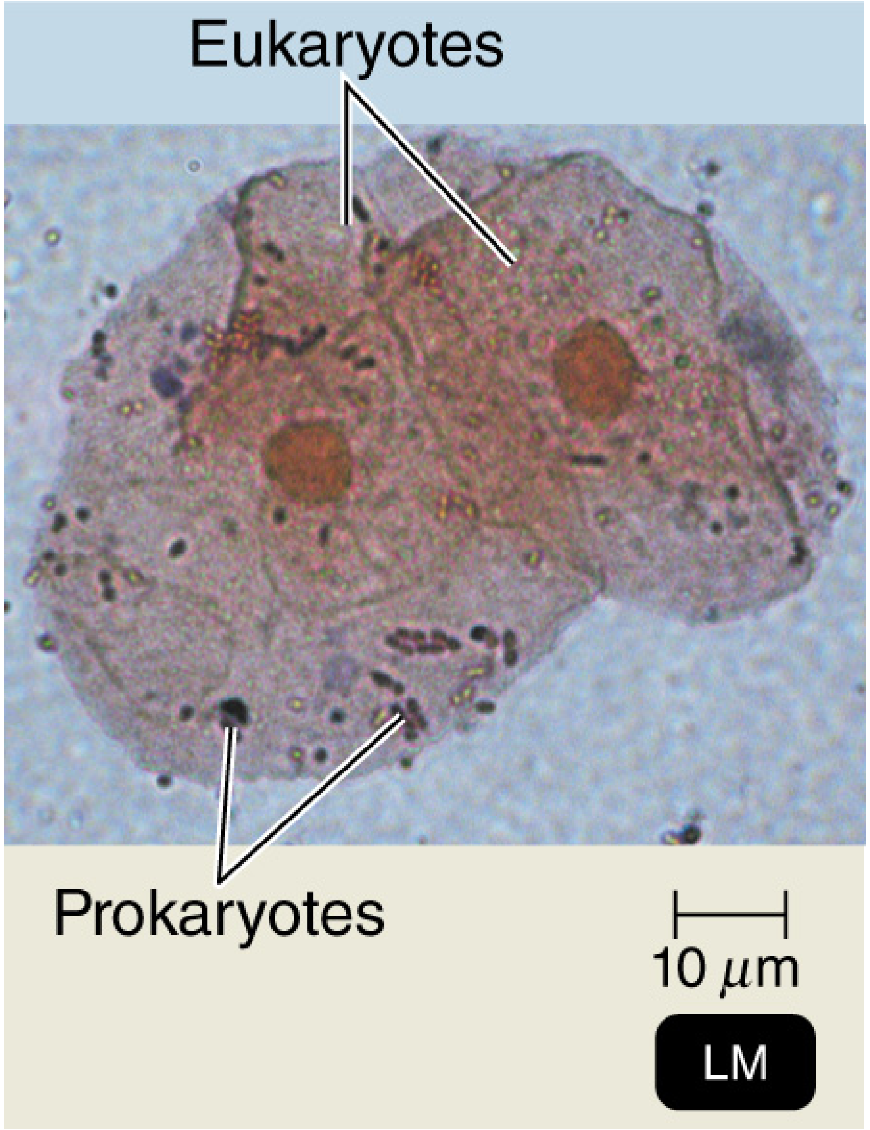
- Selective permeability allows passage of some molecules
- Simple diffusion
- Facilitative diffusion
- Osmosis
- Active transport
- **Endocytosis**
  - Phagocytosis: pseudopods extend and engulf particles
  - Pinocytosis: membrane folds inward, bringing in fluid and dissolved substances

Cytoplasm

Learning Objective

4-16 Compare and contrast prokaryotic and eukaryotic cytoplasms.

Table 4.2 Principal Differences between Prokaryotic and Eukaryotic Cells



Cytoplasm

- **Cytoplasm membrane**: substance inside plasma and outside nucleus
- **Cytosol**: fluid portion of cytoplasm
- **Cytoskeleton**: microfilaments, intermediate filaments, microtubules
- **Cytoplasmic streaming**: movement of cytoplasm throughout cells

Ribosomes

Learning Objective

4-17 Compare the structure and function of eukaryotic and prokaryotic ribosomes.

Ribosomes

- Protein synthesis
- 80S
  - Membrane-bound: attached to ER
  - Free: in cytoplasm
- 70S
  - In chloroplasts and mitochondria

Check Your Understanding

- ✓ Identify at least one significant difference between eukaryotic and prokaryotic flagella and cilia, cell walls, plasma membranes, and cytoplasm.

  4-13–4-16

- ✓ The antibiotic erythromycin binds with the 50S portion of a ribosome. What effect does this have on a prokaryotic cell? On a eukaryotic cell? 4-17

Organelles

Learning Objectives

4-18 Define *organelle*.

4-19 Describe the functions of the nucleus, endoplasmic reticulum, Golgi complex, lysosomes, vacuoles, mitochondria, chloroplasts, peroxisomes, and centrosomes.

Organelles

- **Nucleus**: contains chromosomes
- **ER**: transport network
- **Golgi complex**: membrane formation and secretion
- **Lysosome**: digestive enzymes
- **Vacuole**: brings food into cells and provides support

Organelles

- **Mitochondrion**: cellular respiration
- **Chloroplast**: photosynthesis
- **Peroxisome**: oxidation of fatty acids; destroys H_2O_2
- **Centrosome**: consists of protein fibers and centrioles

Figure 4.24c The eukaryotic nucleus.

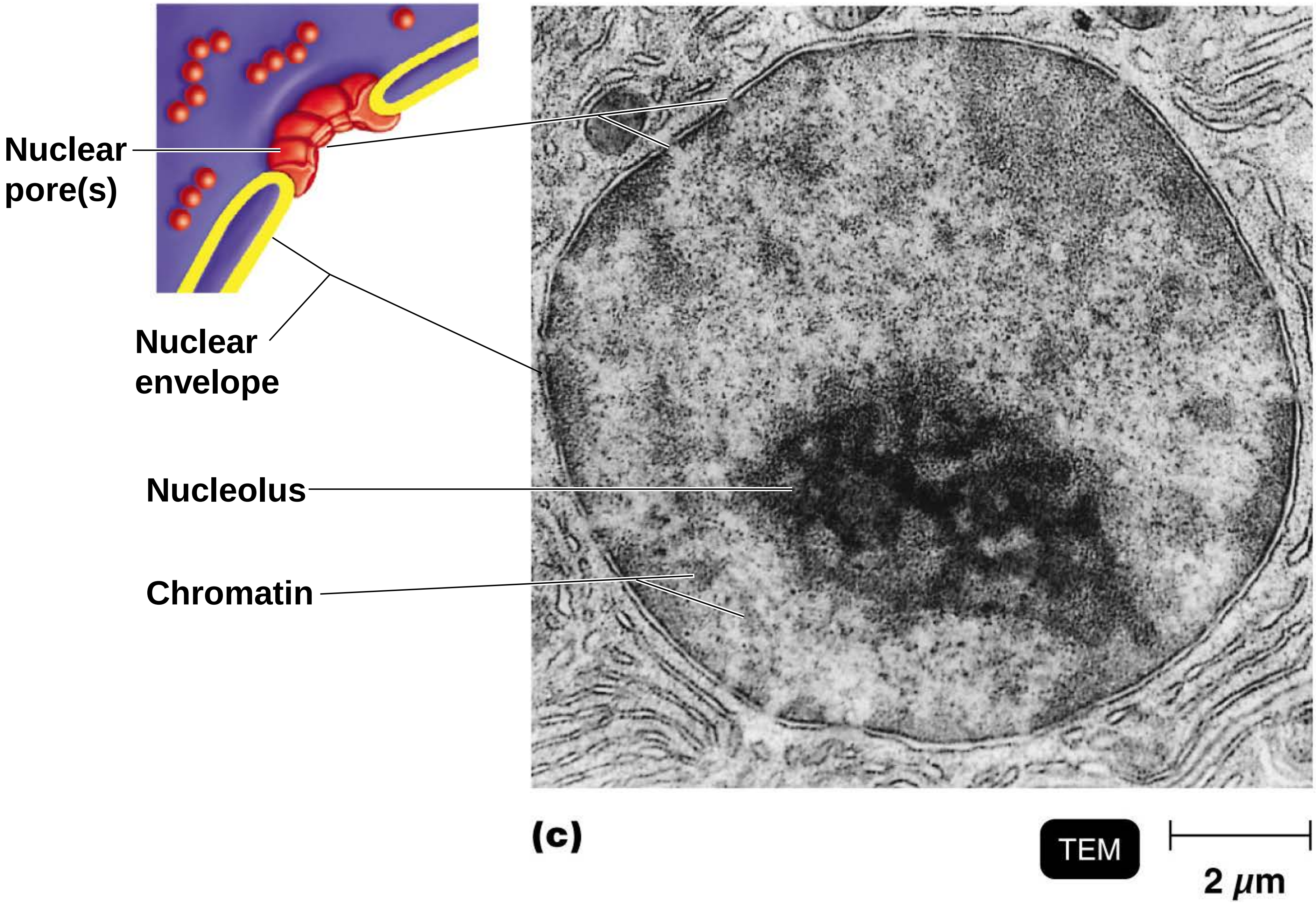


Figure 4.24a-b The eukaryotic nucleus.

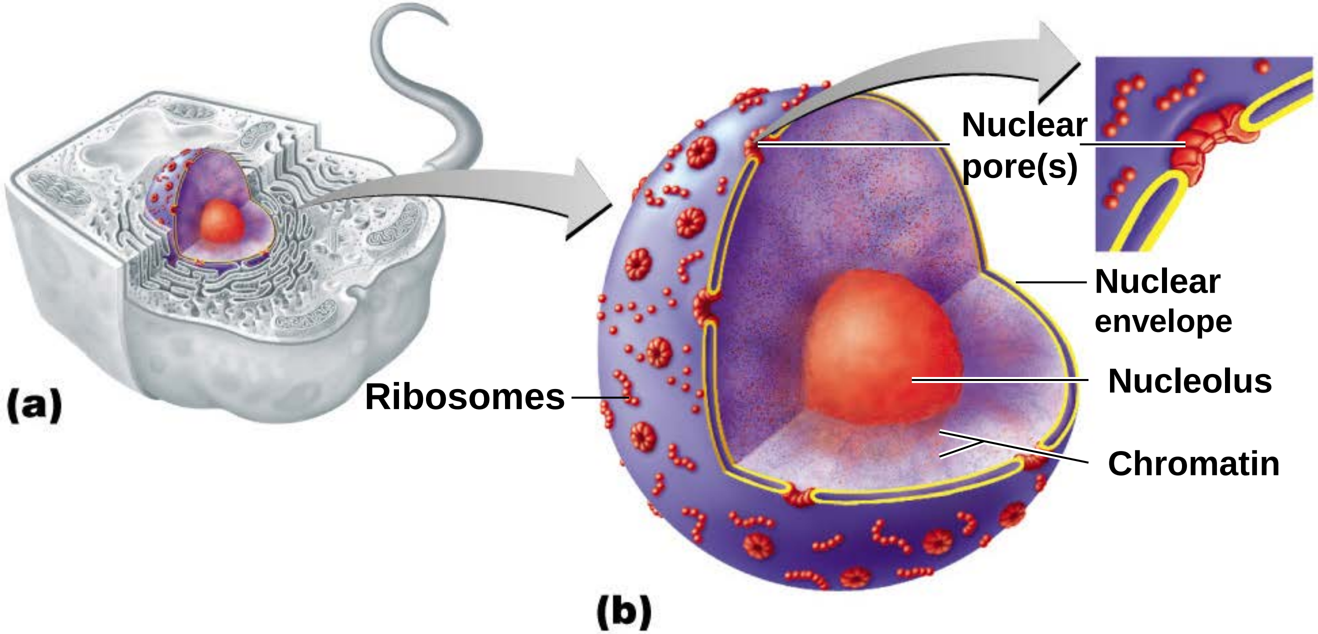


Figure 4.25 Rough endoplasmic reticulum and ribosomes.

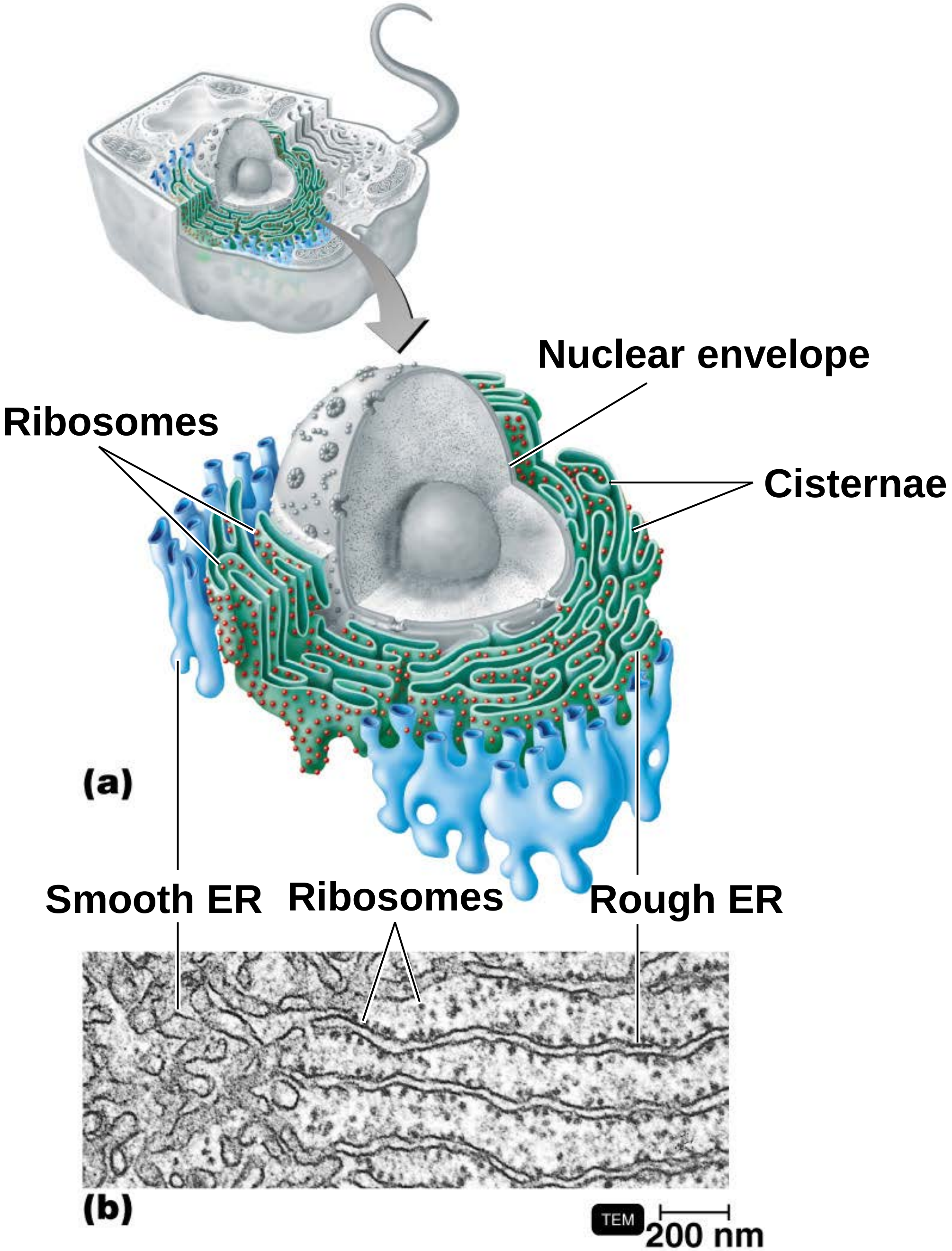


Figure 4.25a Rough endoplasmic reticulum and ribosomes.

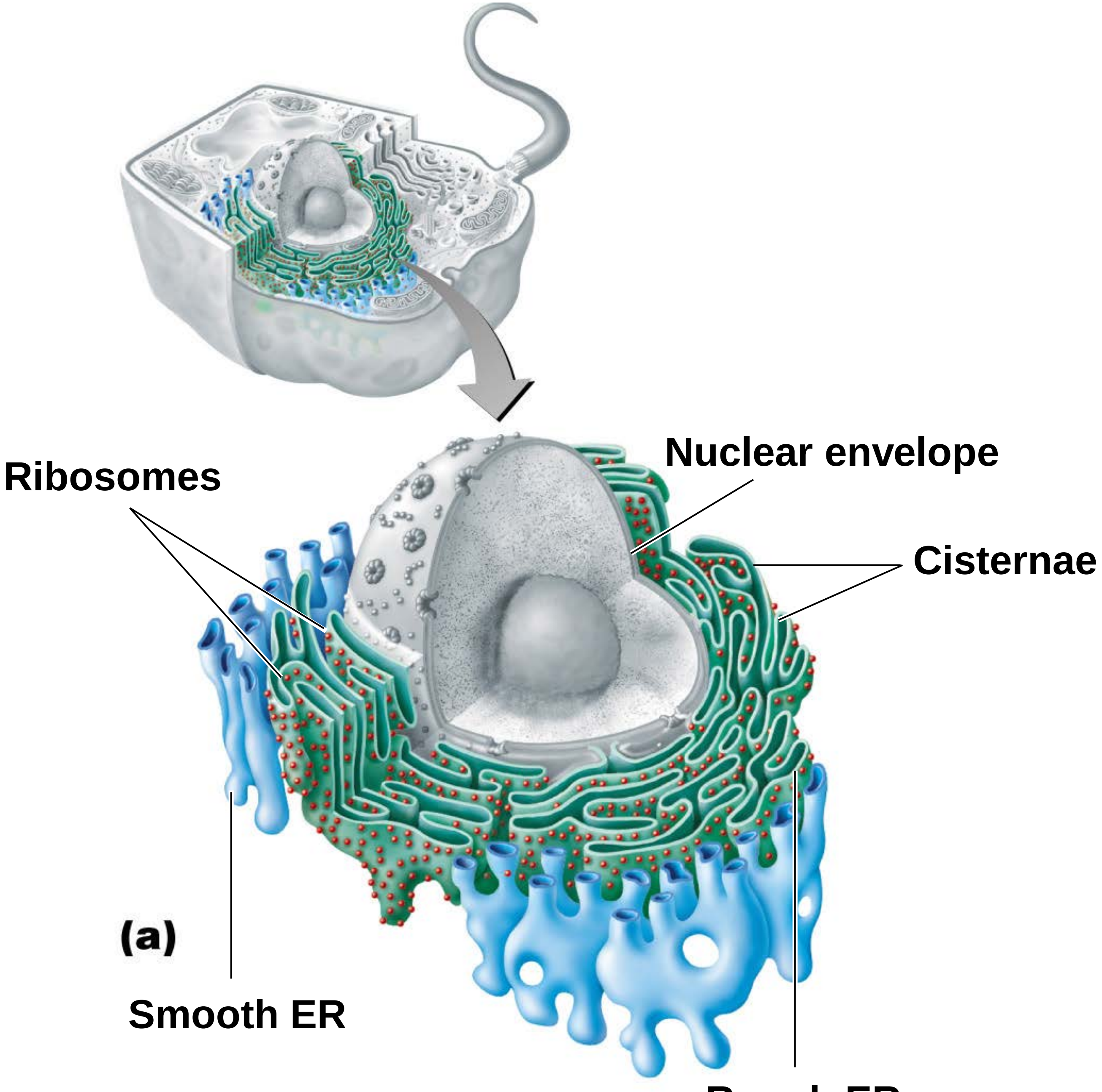


Figure 4.25b Rough endoplasmic reticulum and ribosomes.

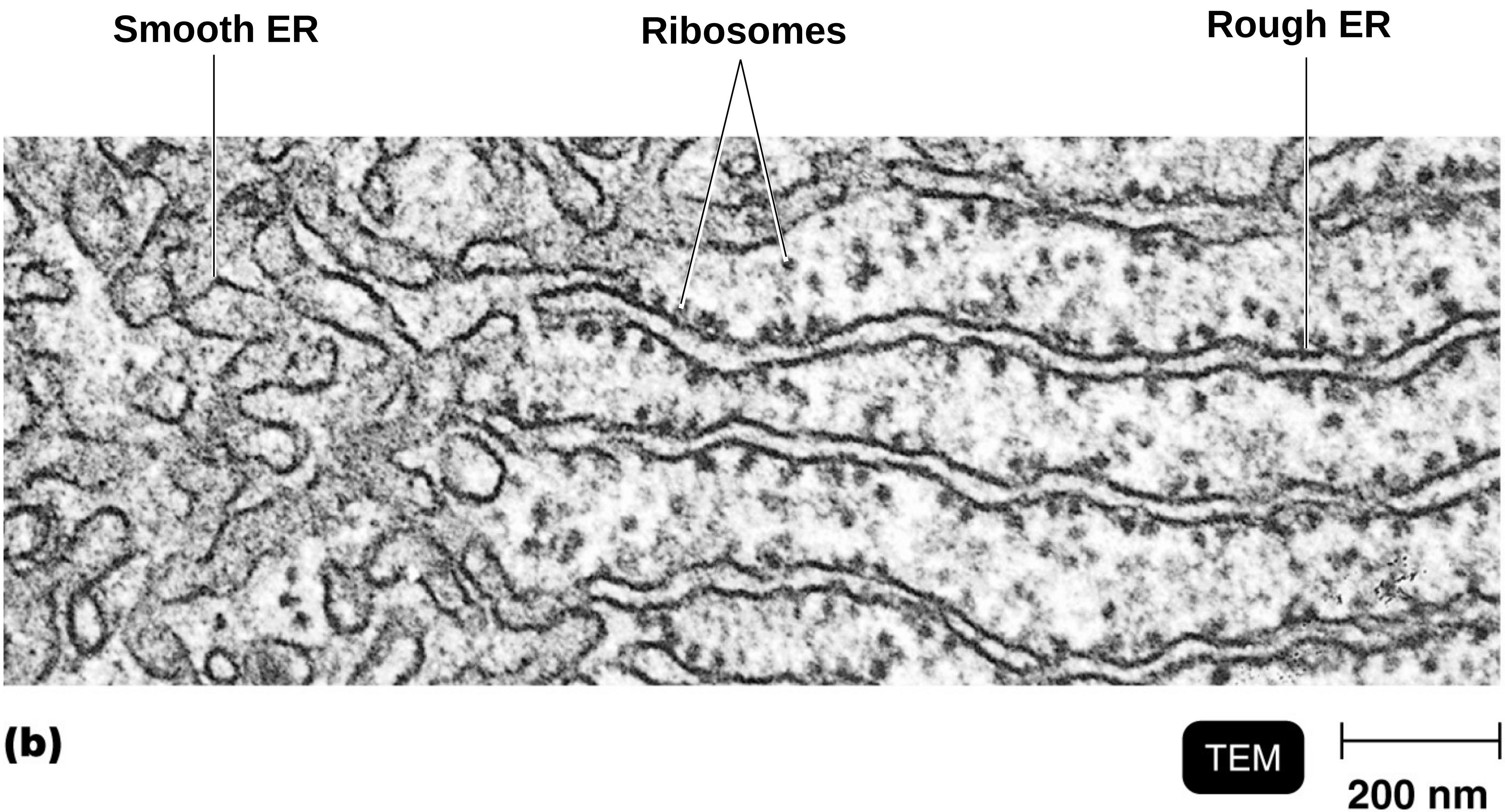


Figure 4.26 Golgi complex.

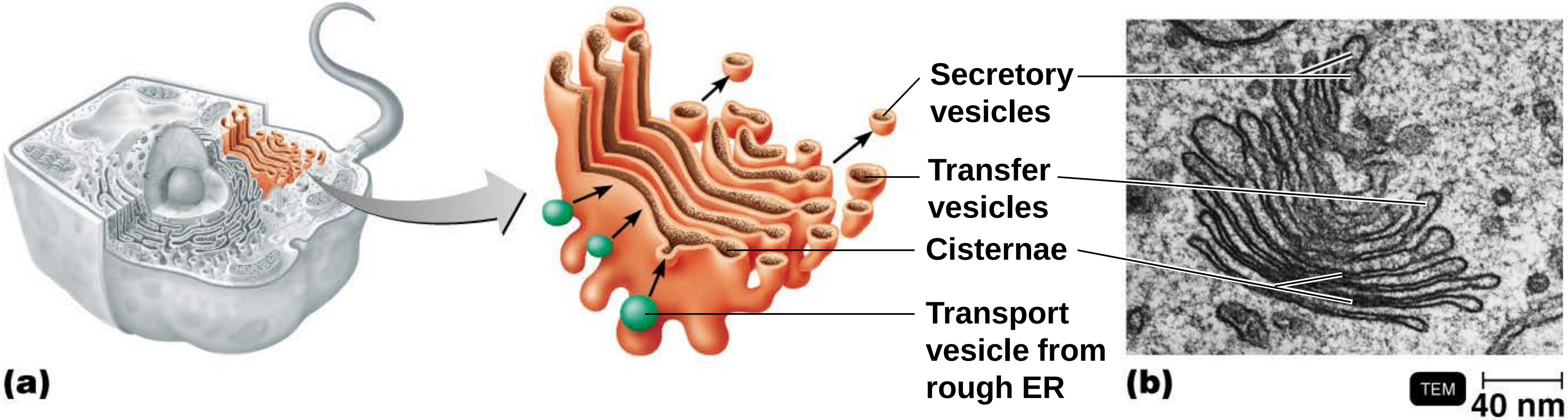
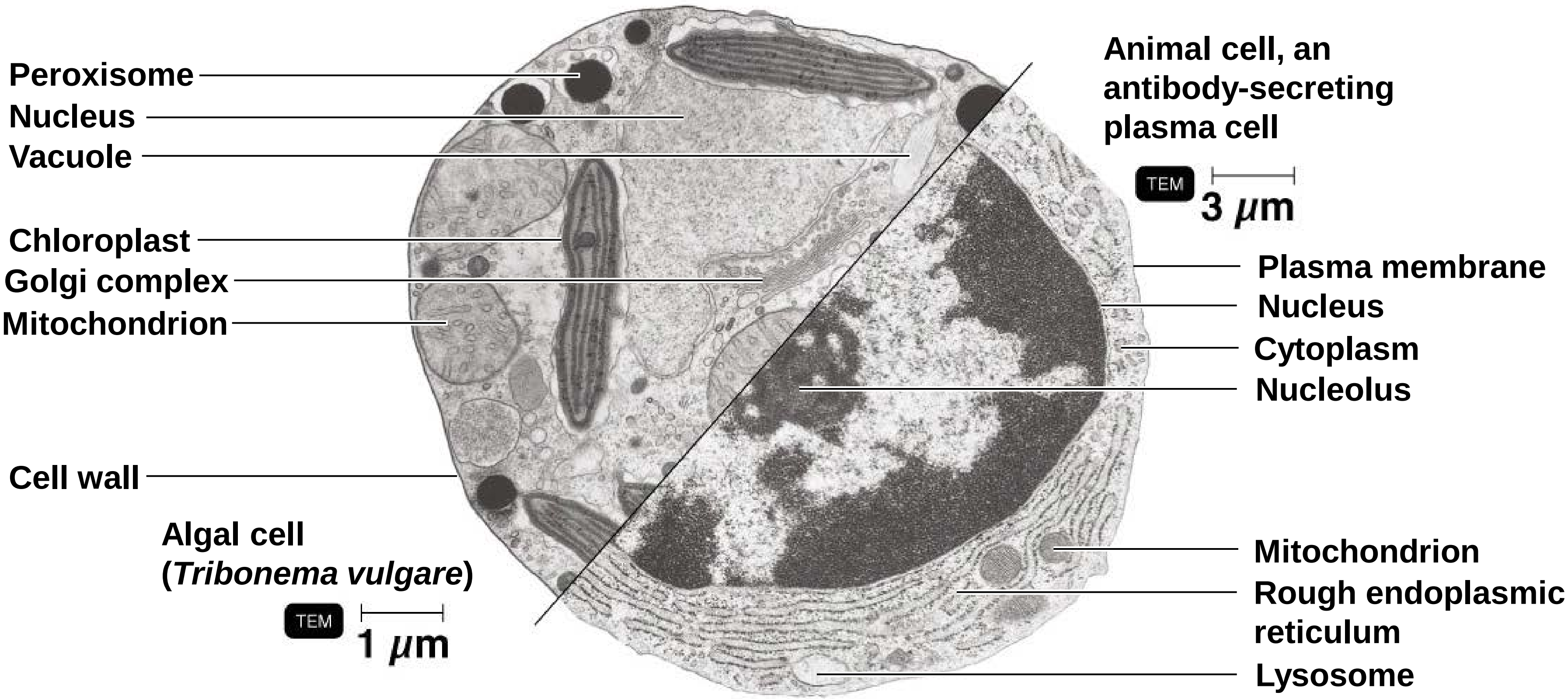
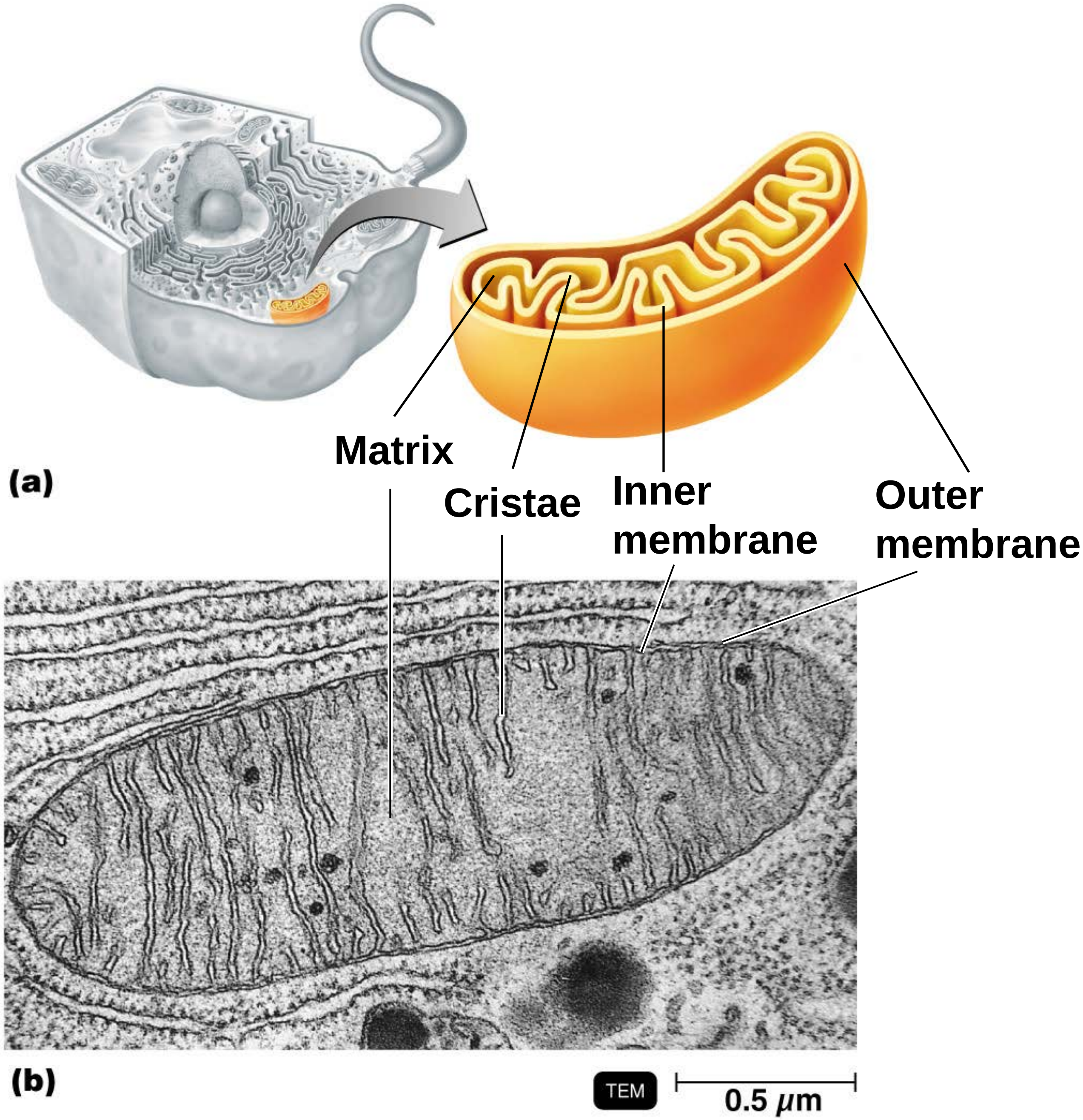


Figure 4.22b Eukaryotic cells showing typical structures.



(b) Transmission electron micrographs of plant and animal cells.

Figure 4.27 Mitochondria.



Check Your Understanding

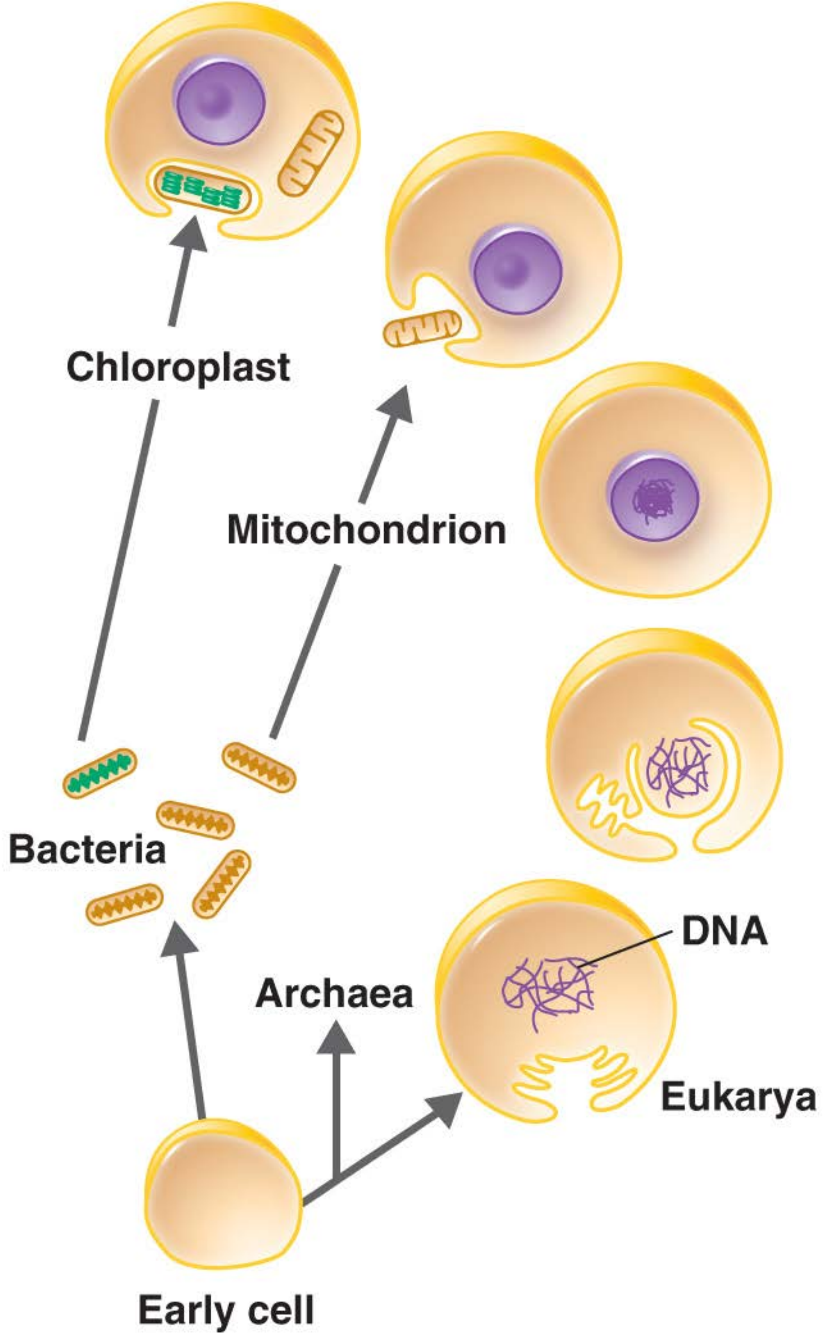
- ✓ Compare the structure of the nucleus of a eukaryote and the nucleoid of a prokaryote. 4-18
- ✓ How do rough and smooth ER compare structurally and functionally? 4-19

The Evolution of Eukaryotes

Learning Objective

4-20 Discuss evidence that supports the endosymbiotic theory of eukaryotic evolution.

Figure 10.2 A model of the origin of eukaryotes.



Endosymbiotic Theory

- What are the fine extensions on the protozoan shown on the following slide?