CELL STRUCTURE & FUNCTION

Chapter 3—Week 1

1

PROCESSES OF LIFE

1) Growth—increase in size

2) Reproduction—increase in number

3) Responsiveness—react to environmental stimuli

4) Metabolism—take in nutrients, perform chemical reactions

2

MICROBES CONTRASTED

TABLE 3.1 Characteristics of Life and Their Distribution in Microbes

Characteristic	Bacteria, Archaea, Eukaryotes	Viruses
Growth: increase in size	Occurs in all	Growth does not occur
Reproduction: increase in number	Occurs in all	Host cell replicates the virus
Responsiveness: ability to react to environmental stimuli	Occurs in all	Reaction to host cells seen in some viruses
Metabolism: controlled chemical reactions of organisms	Occurs in all	Viruses use host cell's metabolism
Cellular structure: membrane-bound structure capable of all of the above functions	Present in all	Viruses lack cytoplasmic membrane or cellular structure

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CELLS: PROKARYOTES OR EUKARYOTES

Prokaryotes:
- Include both bacterial and archaea
- Lack nucleus
- Lack membrane-bound organelles
- Typically smaller in size, simple in structure

Eukaryotes:
- Include algae, protozoa, fungi, animals, and plants
- Have a nucleus (membrane bound, contains the cell's DNA)
- "true nucleus"
- Have membrane-bound organelles
- Typically larger in size, more complex in structure

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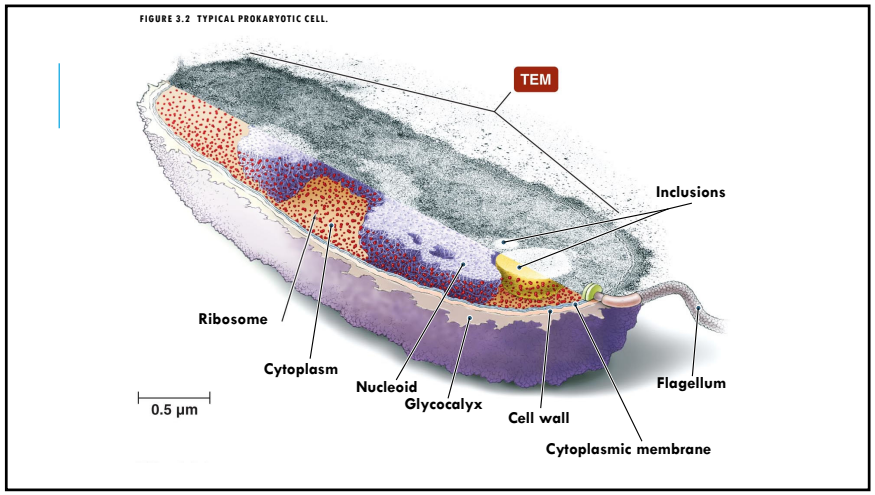

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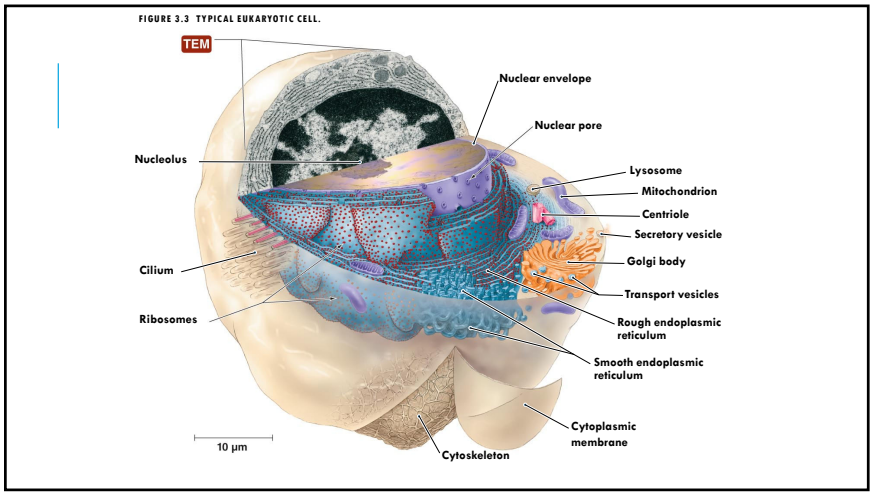

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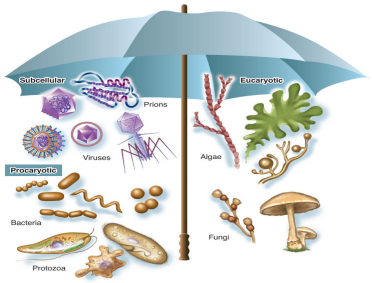
INTRODUCING THE MICROBES

Measured in very small units of the metric system called micrometers (µm) and nanometers (nm)



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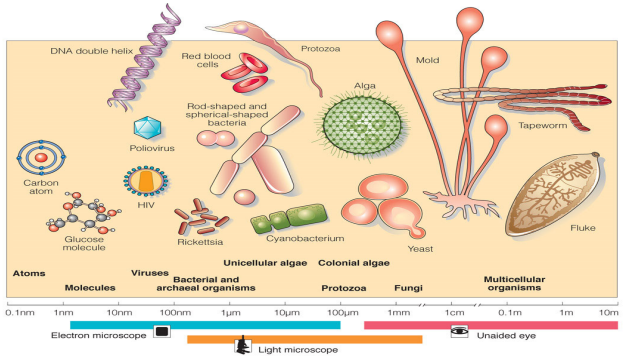
MICROORGANISM SIZE RANGE



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EXTERNAL STRUCTURES OF BACTERIAL CELLS

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GLYCOCALYX: BACTERIAL CAPSULE OR SLIME LAYER

Not always present

Not always integral to the life of the cell

Easily removed by treating a culture with enzymes or manipulating the culture nutrients available

VIRULENCE FACTOR when present—enhances the organism's ability to produce disease

Special notes:

Glycocalyx = gelatinous, sticky substance that surrounds the outside of the cell (may be made of polysaccharides, polypeptides, or both. These are produced inside the cell and are extruded onto the cell's surface

Classification of this layer is dependent on composition of the layer:

Capsule—when the glycocalyx is made of repeating organic chemical units firmly attached to the cell surface

OR

Slime Layer—a loose, water-soluble glycocalyx

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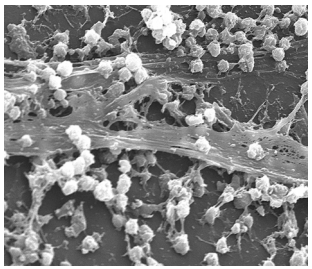
FUNCTION OF THE GLYCOCALYX OR CAPSULE

Prevent phagocytosis of the cell by our immune cells

Prevent bacterial cells from drying out

Slime layers are often sticky and provide the means for bacteria to attach to surfaces as **biofilms,** which are aggregates of bacteria living together on a surface



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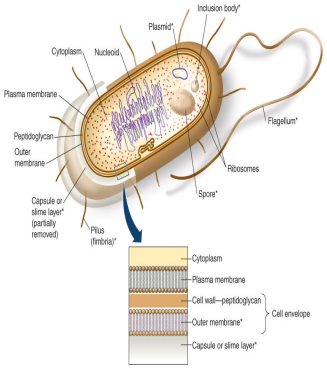
FLAGELLA

= long structures that extend beyond the surface of a cell and its glycocalyx and propel the cell through its environment

Not all bacteria have flagella but for those that do, it assists with mobility and survival of the cell

Movement is similar to a boat propeller



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FLAGELLA

Used for motility
- Rotates like propeller
- **Responsible for Chemotaxis**
  - Move toward **attractant**
  - Move away from **repellant**
- Long, hollow, filament made of subunits of **flagellin**
- Many arrangements (single, polar, bipolar, dispersed, etc.)
- Cells with flagella are *motile*

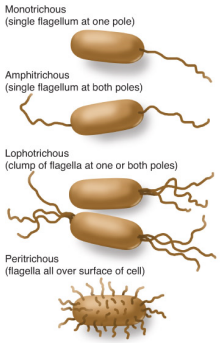

Figure 04.09: Structure and arrangement of flagella.

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FIMBRIAE AND PILI

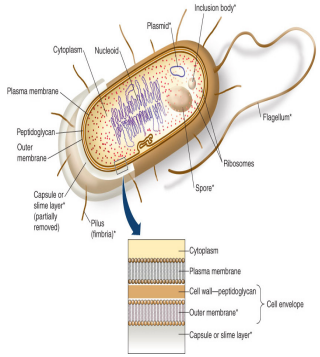
Fimbriae—rodlike, proteinaceous extensions

Sticky projections adhere to one another and to substances in the environment

Crucial to the pathogenicity of gonorrhea—non-fimbriated cells of this type don't cause disease

Pili—longer versions of fimbriae but shorter than flagella

Cells use pili to transfer DNA from one cell to another = conjugation



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BACTERIAL CELL WALLS

- Provide structure and shape and protect cell from osmotic forces
- Assist some cells in attaching to other cells or in resisting antimicrobial drugs
- Can target cell wall of bacteria with antibiotics
- Give bacterial cells characteristic shapes
- Composed of peptidoglycan
- Scientists describe two basic types of bacterial cell walls
  - Gram-positive and Gram-negative

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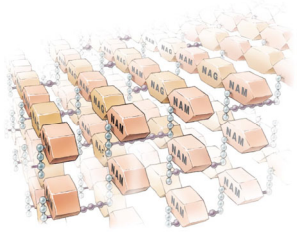
BACTERIAL CELL WALLS



- Composed of **peptidoglycan,** a meshlike complex polysaccharide (sugar)
- Made of either NAG or NAM, which are structurally similar to glucose
- Cell walls gives bacterial cells their characteristic shapes

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GRAM POSITIVE VS. GRAM NEGATIVE

Cell wall

- G+: thick layer of rigid polymer, peptidoglycan (lab note: holds crystal violet stain in gram stain procedure)
- G−: thin layer of peptidoglycan
  Prevents osmotic rupture of cell membrane

Outer membrane (in gram negatives only)

- Contains fever inducing **endotoxin**

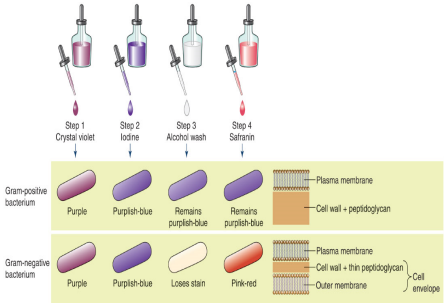

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FIGURE 3.15A COMPARISON OF CELL WALLS OF GRAM-POSITIVE AND GRAM-NEGATIVE BACTERIA.

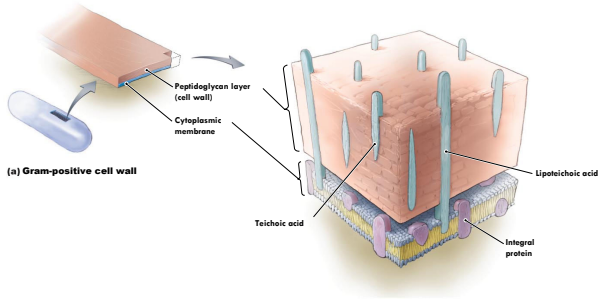

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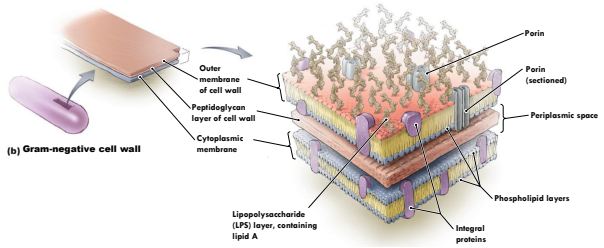
FIGURE 3.15B COMPARISON OF CELL WALLS OF GRAM-POSITIVE AND GRAM-NEGATIVE BACTERIA.



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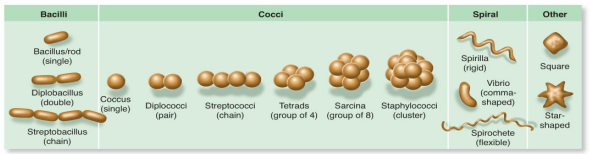
CELL SHAPES AND PATTERNS

Morphology: bacteria are found in several common shapes (and arrangements), which are useful in species identification

- **Bacillus,** (bacilli, pl.) rod shaped
- **Coccus,** (cocci, pl.) spherical
- **Curved or spiral,** (vibrio= curved or comma-shaped; spirilla= rigid or stiff helix; & spirochete= loose or flexible helix)
- **Other unique shapes (pleomorphic = vary in size and shape)**



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BACTERIAL WITHOUT CELL WALLS

- *Mycoplasma pneumoniae* is one of a few bacterial lacking in a cell wall
- The Mycoplasma bacteria are considered "atypical" bacteria as they lack cells walls and are extremely small in size, which initially led to their mistaken classification as "viruses"

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BACTERIAL CYTOPLASMIC MEMBRANE

Structure

- Referred to as phospholipid bilayer
  - Composed of lipids and associated proteins
    - Integral proteins
    - Peripheral proteins
- Fluid mosaic model describes current understanding of membrane structure

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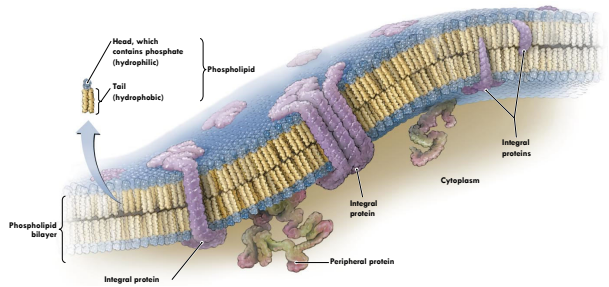
FIGURE 3.16 THE STRUCTURE OF A PROKARYOTIC CYTOPLASMIC MEMBRANE: A PHOSPHOLIPID BILAYER.



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BACTERIAL CYTOPLASMIC MEMBRANES

Function

- Control passage of substances into and out of the cell
- Energy storage
- Harvest light energy in photosynthetic bacteria
- Selectively permeable
- Naturally impermeable to most substances
- Proteins allow substances to cross membrane
- Maintain concentration and electrical gradient

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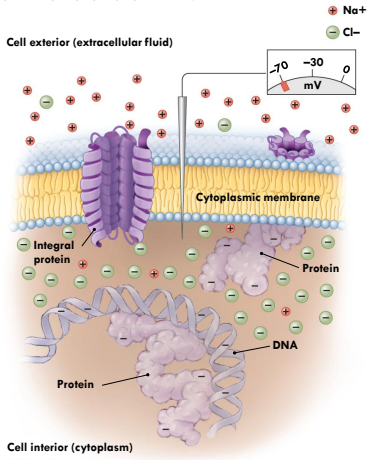
FIGURE 3.17 ELECTRICAL POTENTIAL OF A CYTOPLASMIC MEMBRANE.



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BACTERIAL CELL MEMBRANE FUNCTION—PASSIVE

Function

Passive processes

- Diffusion
- Facilitated diffusion
- Osmosis

- DON'T REQUIRE ATP

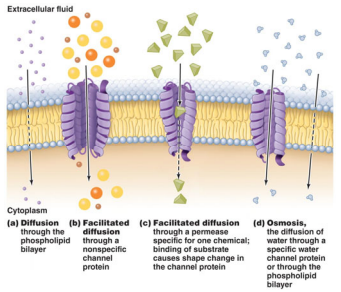

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FIGURE 3.19 OSMOSIS, THE DIFFUSION OF WATER ACROSS A SEMIPERMEABLE MEMBRANE.

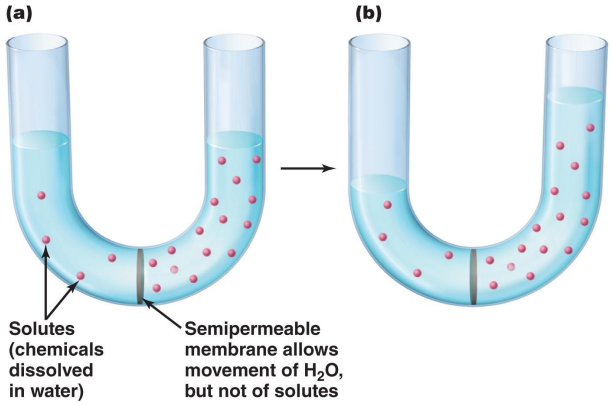

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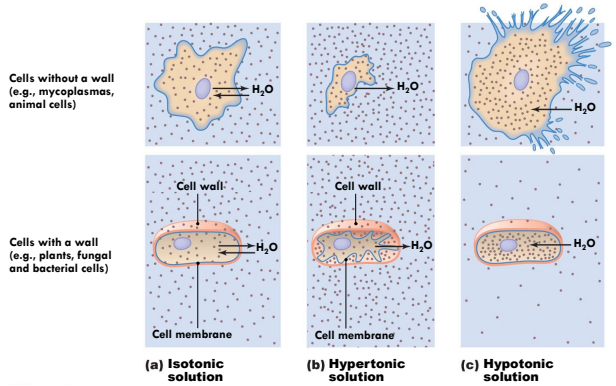
FIGURE 3.20 EFFECTS OF ISOTONIC, HYPERTONIC, AND HYPOTONIC SOLUTIONS ON CELLS.



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BACTERIAL CELL MEMBRANE

Function
- Active processes
  - Active transport
  - Group translocation
    - Substance is chemically modified during transport

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BACTERIAL CELL MEMBRANE FUNCTION—ACTIVE

Function
- Active processes
  - Active transport
  - Group translocation
    - Substance is chemically modified during transport
  - REQUIRE ATP

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FIGURE 3.21 MECHANISMS OF ACTIVE TRANSPORT.

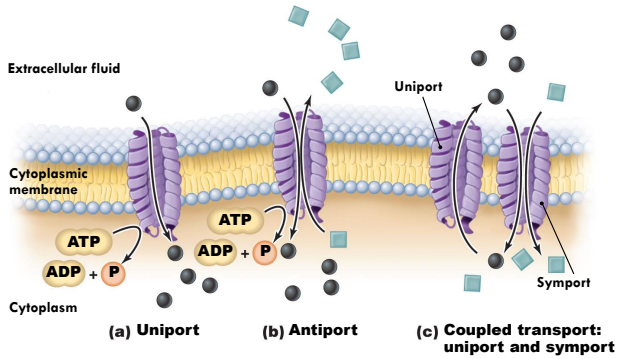

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TABLE 3.2 Transport Processes Across Bacterial Cytoplasmic Membranes

	Description	Examples of Transported Substances
Passive Transport Processes	Processes require no use of energy by the cell; the electrochemical gradient provides energy.	
Diffusion	Molecules move down their electrochemical gradient through the phospholipid bilayer of the membrane.	Oxygen, carbon dioxide, lipid-soluble chemicals
Facilitated diffusion	Molecules move down their electrochemical gradient through channels or carrier proteins.	Glucose, fructose, urea, some vitamins
Osmosis	Water molecules move down their concentration gradient across a selectively permeable membrane.	Water
Active Transport Processes	Cell expends energy in the form of ATP to move a substance against its electrochemical gradient.	
Active transport	ATP-dependent carrier proteins bring substances into cell.	Na^+, K^+, Ca^{2+}, H^+, Cl^-
Group translocation	The substance is chemically altered during transport; found only in some bacteria.	Glucose, mannose, fructose

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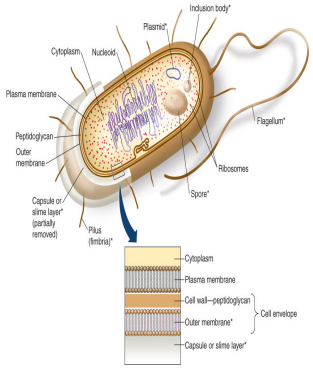
CYTOPLASM

= the area of the cell enclosed by the cell membrane containing organelles that function in cell metabolism and multiplication



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CYTOPLASM OF BACTERIA

Cytosol
- Liquid portion of cytoplasm
- Mostly water
- Contains cell's DNA in region called the *nucleoid*

Inclusions
- May include reserve deposits of chemicals

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CYTOPLASM OF BACTERIA

Endospores
- Unique structures produced by some bacteria
- Defensive strategy against unfavorable conditions
- Vegetative cells transform into endospores when nutrients are limited
- Resistant to extreme conditions such as heat, radiation, chemicals

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SPORES (ENDOSPORES) AND SPORULATION

=endospores, formed within the cell during "hard times"

Transformation from vegetative cell to endospore only when nutrients are in limited supply
- viable for long periods (perhaps centuries or longer)
- resistant to:
  - Heat
  - Boiling
  - Dehydration
  - Radiation
  - Various chemical compounds (ie alcohol)

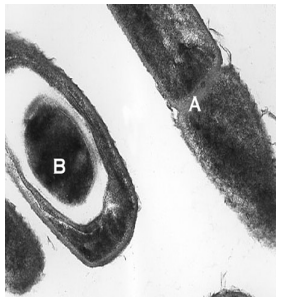

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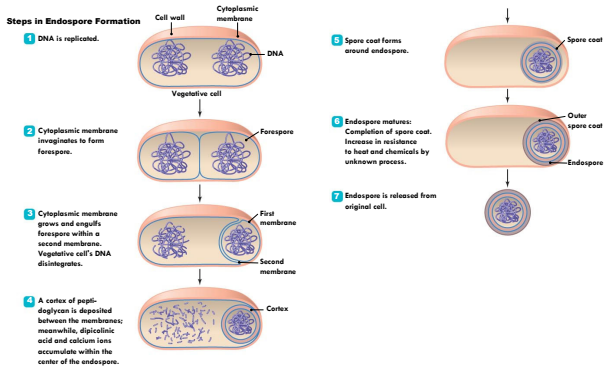
FIGURE 3.24 THE FORMATION OF AN ENDOSPORE.



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SPORULATION

Important spore forming pathogens:

- *Bacillus anthracis*, anthrax,
- *Clostridium* spp., tetanus, botulism, gas gangrene

Sporulation is essential to the survival for these organisms in adverse conditions

- On a practical level, sporulation in a major concern re: microbe safety

Video: Spore video: http://highered.mcgraw-hill.com/sites/007352543x/student_view0/chapter20/bacterial_endospore_formation.html

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CYTOPLASM OF PROKARYOTES

Nonmembranous Organelles

- Ribosomes
  - Sites of protein synthesis
  - Composed of polypeptides and ribosomal RNA
  - 70S ribosome composed of smaller 30S and 50S subunits
  - Many antibacterial drugs act on bacterial ribosomes without affecting larger eukaryotic ribosomes

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CYTOPLASM OF PROKARYOTES

Nonmembranous Organelles

- Cytoskeleton
  - Composed of three or four types of protein fibers
  - Can play different roles in the cell
    - Cell division
    - Cell shape
    - Segregation of DNA molecules
    - Movement through the environment

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EXTERNAL STRUCTURE OF EUKARYOTIC CELLS

Glycocalyces

- Not as organized as prokaryotic capsules
- Help anchor animal cells to each other
- Strengthen cell surface
- Provide protection against dehydration
- Function in cell-to-cell recognition and communication

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EUKARYOTIC CELL WALLS AND CYTOPLASMIC MEMBRANES

Fungi, algae, plants, and some protozoa have cell walls

Composed of various polysaccharides

- Cellulose is found in plant cell walls
- Fungal cell walls are composed of cellulose, chitin, and/or glucomannan
- Algal cell walls are composed of a variety of polysaccharides

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EUKARYOTIC CELL WALLS AND CYTOPLASMIC MEMBRANES

- All eukaryotic cells have cytoplasmic membrane
- Are a fluid mosaic of phospholipids and proteins
- Contain steroid lipids to help maintain fluidity
- Localize signaling, protein sorting, and movement
- Control movement into and out of cell

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TABLE 3.4 Active Transport Processes Found Only in Eukaryotes: Endocytosis and Exocytosis

	Description	Examples of Transported Substances
Endocytosis: phagocytosis and pinocytosis	Substances are surrounded by pseudopods and brought into the cell. Phagocytosis involves solid substances; pinocytosis involves liquids.	Bacteria, viruses, aged and dead cells; liquid nutrients in extracellular solutions
Exocytosis	Vesicles containing substances are fused with cytoplasmic membrane, dumping their contents to the outside.	Wastes, secretions

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CYTOPLASM OF EUKARYOTES

Flagella

- Structure and arrangement
  - Differ structurally and functionally from prokaryotic flagella
    - Within the cytoplasmic membrane
    - Shaft composed of tubulin arranged to form microtubules
  - Filaments anchored to cell by basal body; no hook
  - May be single or multiple; generally found at one pole of cell
- Function
  - Do not rotate but undulate rhythmically

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FIGURE 3.31A-B EUKARYOTIC FLAGELLA AND CILIA.

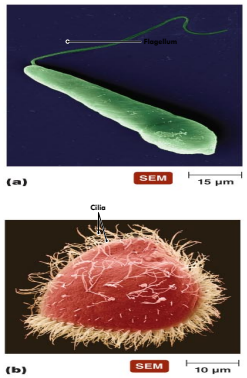

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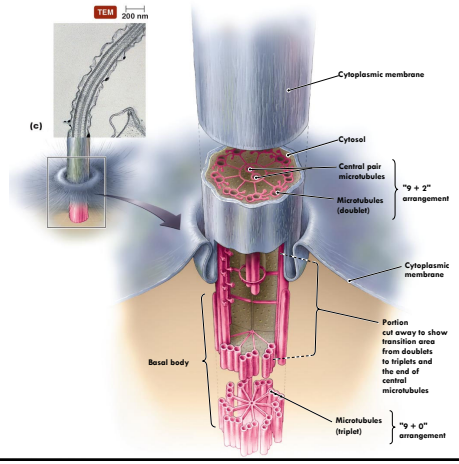
FIGURE 3.31C EUKARYOTIC FLAGELLA AND CILIA.



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CYTOPLASM OF EUKARYOTES

Cilia

- Shorter and more numerous than flagella
- Coordinated beating propels cells through their environment
- Also used to move substances past the surface of the cell

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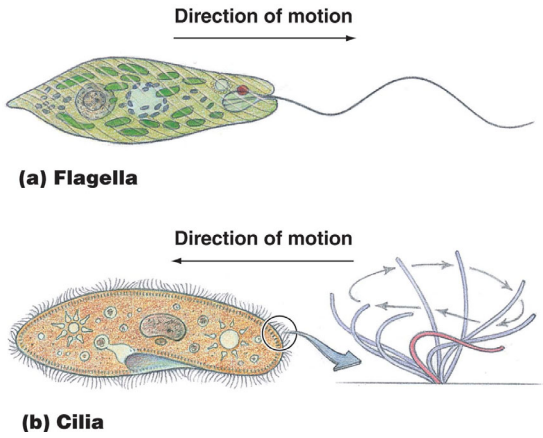
FIGURE 3.32 MOVEMENT OF EUKARYOTIC FLAGELLA AND CILIA.



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CYTOPLASM OF EUKARYOTES

Other Nonmembranous Organelles

- Ribosomes
  - Larger than prokaryotic ribosomes (80S versus 70S)
  - Composed of 60S and 40S subunits
- Cytoskeleton
  - Extensive network of fibers and tubules
  - Anchors organelles
  - Produces basic shape of the cell
  - Made up of tubulin microtubules, actin microfilaments, and intermediate filaments

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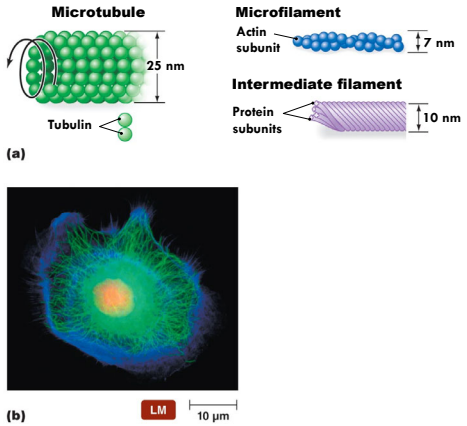
FIGURE 3.33 EUKARYOTIC CYTOSKELETON.



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CYTOPLASM OF EUKARYOTES

Other Nonmembranous Organelles

- Centrioles and centrosome
  - Centrioles are composed of nine triplets of microtubules
    - Located in region of cytoplasm called *centrosome*
    - Not found in all eukaryotic cells
  - Centrosomes play a role in mitosis, cytokinesis, and formation of flagella and cilia

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FIGURE 3.34 CENTROSOME.

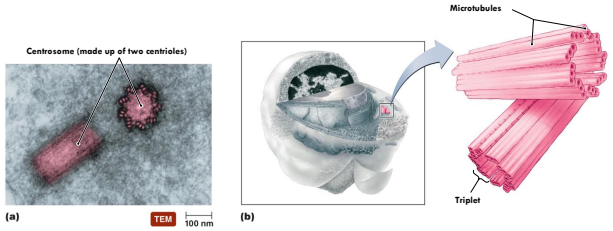

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TABLE 3.5 Nonmembranous and Membranous Organelles of Cells

	General Function	Prokaryotes	Eukaryotes
Nonmembranous Organelles			
Ribosomes	Protein synthesis	Present in all	Present in all
Cytoskeleton	Shape in prokaryotes; support, cytoplasmic streaming, and endocytosis in eukaryotes	Present in some	Present in all
Centrosome	Appears to play a role in mitosis, cytokinesis, and flagella and cilia formation in animal cells	Absent in all	Present in animals
Membranous Organelles	Sequester chemical reactions within the cell		
Nucleus	"Control center" of the cell	Absent in all	Present in all
Endoplasmic reticulum	Transport within the cell, lipid synthesis	Absent in all	Present in all
Golgi bodies	Exocytosis, secretion	Absent in all	Present in some
Lysosomes	Breakdown of nutrients, self-destruction of damaged or aged cells	Absent in all	Present in some
Peroxisomes	Neutralization of toxins	Absent in all	Present in some
Vacuoles	Storage	Absent in all	Present in some
Vesicles	Storage, digestion, transport	Absent in all	Present in all
Mitochondria	Aerobic ATP production	Absent in all	Present in most
Chloroplasts	Photosynthesis	Absent in all, though infoldings of cytoplasmic membrane called photosynthetic lamellae have same function in photosynthetic prokaryotes	Present in plants and algae

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CYTOPLASM OF EUKARYOTES

Membranous Organelles

- Nucleus
  - Often largest organelle in cell
  - Contains most of the cell's DNA
  - Semiliquid portion is called *nucleoplasm*
    - Contains chromatin
  - RNA synthesized in nucleoli present in nucleoplasm
  - Surrounded by nuclear envelope
    - Contains nuclear pores

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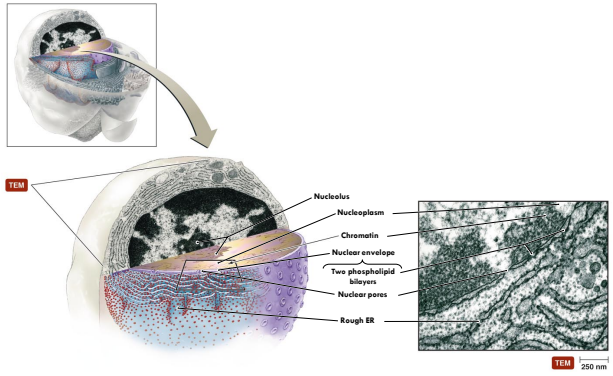
FIGURE 3.35 EUKARYOTIC NUCLEUS.



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CYTOPLASM OF EUKARYOTES

Membranous Organelles

- Endoplasmic reticulum
  - Netlike arrangement of flattened, hollow tubules continuous with nuclear envelope
  - Functions as transport system
  - Two forms
    - Smooth endoplasmic reticulum (SER)
    - Rough endoplasmic reticulum (RER)

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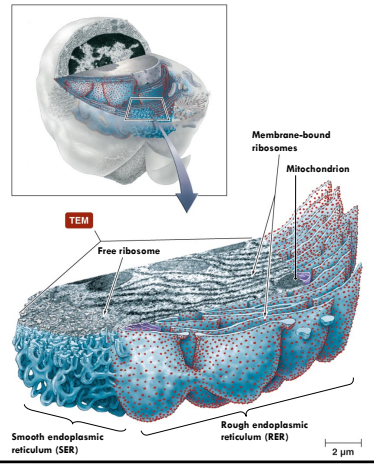
FIGURE 3.36 ENDOPLASMIC RETICULUM.



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CYTOPLASM OF EUKARYOTES

Membranous Organelles

- Golgi body
  - Receives, processes, and packages large molecules for export from cell
  - Packages molecules in secretory vesicles that fuse with cytoplasmic membrane
  - Composed of flattened hollow sacs surrounded by phospholipid bilayer
  - Not in all eukaryotic cells

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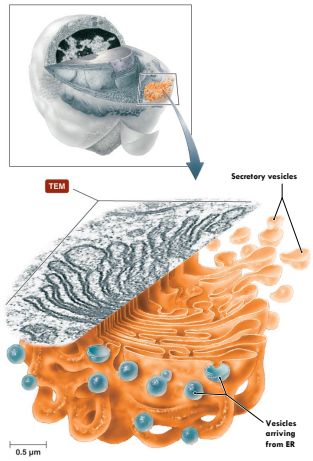
FIGURE 3.37 GOLGI BODY.



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CYTOPLASM OF EUKARYOTES

Membranous Organelles

- Lysosomes, peroxisomes, vacuoles, and vesicles
  - Store and transfer chemicals within cells
  - May store nutrients in cell
  - Lysosomes contain catabolic enzymes
  - Peroxisomes contain enzymes that degrade poisonous wastes

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FIGURE 3.38 VACUOLE.

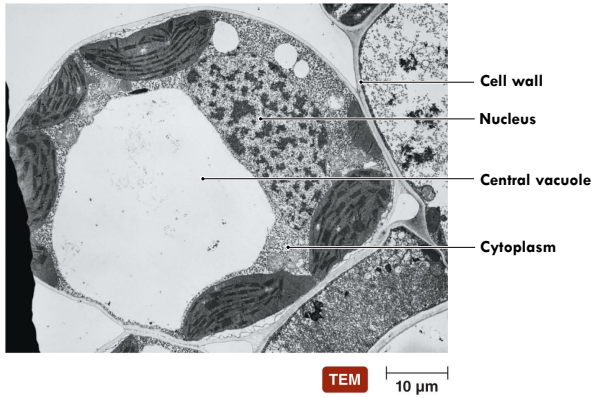

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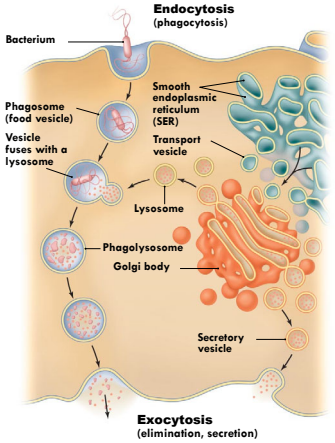
FIGURE 3.39 THE ROLES OF VESICLES IN ENDOCYTOSIS AND EXOCYTOSIS.



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CYTOPLASM OF EUKARYOTES

Membranous Organelles

- Mitochondria
  - Have two membranes composed of phospholipid bilayer
  - Produce most of cell's ATP
  - Interior matrix contains 70S ribosomes and circular molecule of DNA

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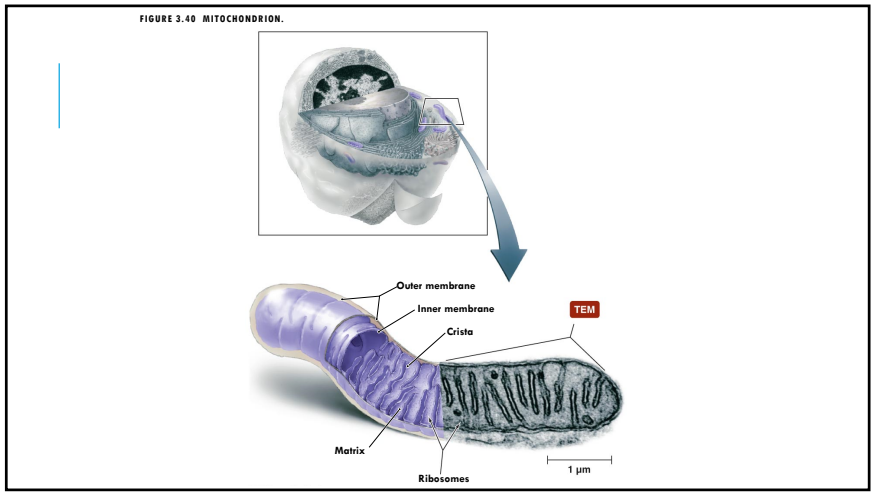
FIGURE 3.40 MITOCHONDRION.
Outer membrane
Inner membrane
Crista
TEM
Matrix
Ribosomes
1 µm

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