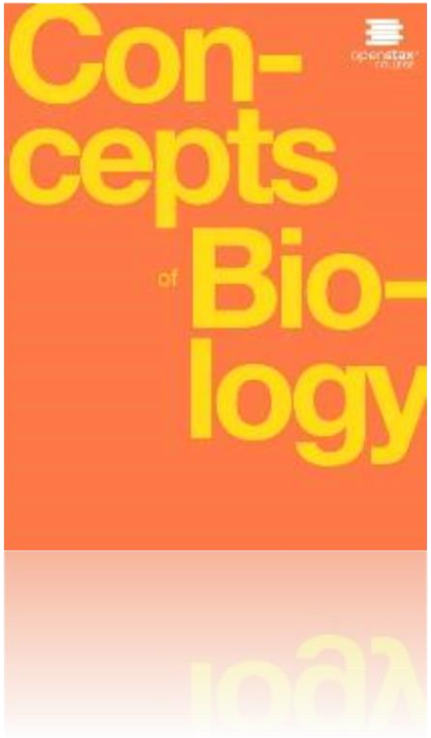
CONCEPTS OF BIOLOGY

Chapter 3 CELL STRUCTURE AND FUNCTION

PowerPoint Image Slideshow



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CELL STRUCTURE AND FUNCTION (1 OF 2)

Vision a brick wall…

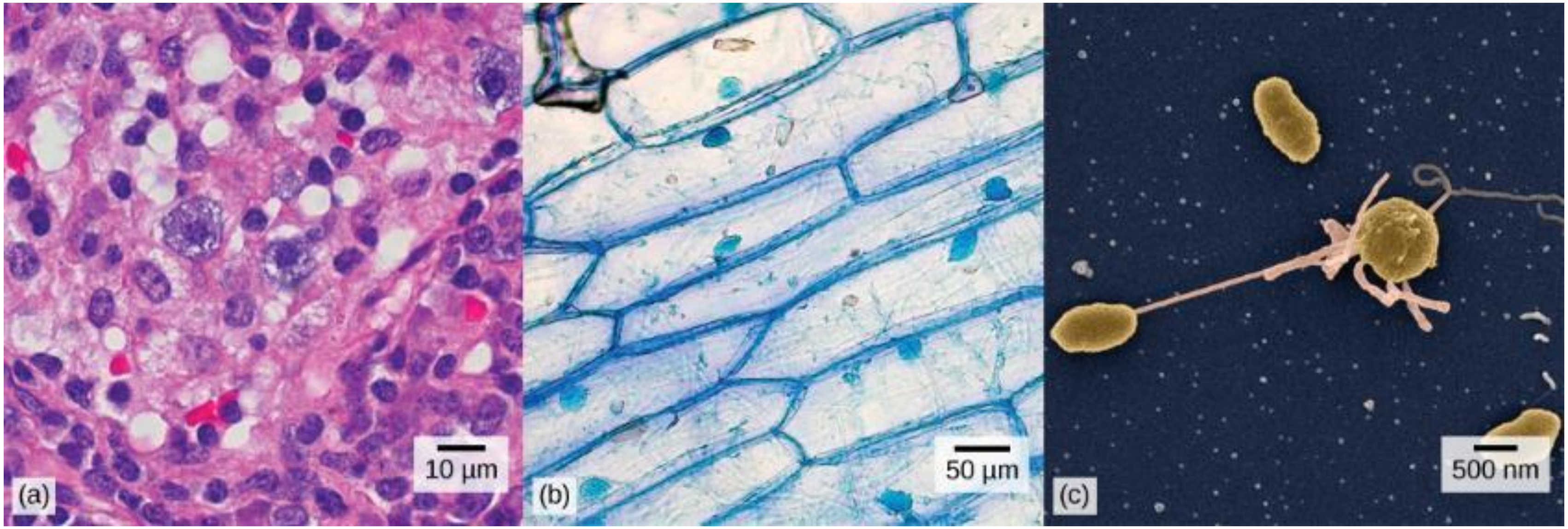
What is the basic building block of that wall?

- It’s a brick, of course
- Like a brick wall, your body is composed of basic building blocks, and the building blocks of your body are **CELLS**.

CELL STRUCTURE AND FUNCTION (2 OF 2)

- Just as a home is made from a variety of building materials, the human body is made of many different types of cells
- For example, our skin, bones, blood, brain and muscles are all made of cells that function differently

FIGURE 3.1



(a) Nasal sinus cells (viewed with a light microscope), (b) onion cells (viewed with a light microscope), and (c) *Vibrio tasmaniensis* bacterial cells (viewed using a scanning electron microscope) are from very different organism, yet all share certain characteristics of basic cell structure. (credit a: modification of work by Ed Uthman, MD; credit b: modification of work by Umberto Salvagnin; credit c: modification of work by Anthony D'Onofrio; scale-bar data from Matt Russell)

3.1 HOW CELLS ARE STUDIED (1 OF 2)

- **Cell** - the smallest unit of a living thing; they are the building blocks of all organisms
- Cells that interconnect and perform shared functions form **tissues**
- Tissues combine to form **organs,** for example your stomach is an organ made up of epithelial, muscle, and nervous tissues
- Organs come together to make **organ systems**, for example your digestive system, circulatory system, etc
- Organ systems come together to make **organisms**, for example, an elephant or you!

3.1 HOW CELLS ARE STUDIED (2 OF 2)

Cells are divided into two broad categories:

- **Eukaryotic** – includes animal cells, plant cells, fungal cells and protist cells.
- **Prokaryotic** – includes bacteria cells and archea cells

Microscopy

- **Microscope** - an instrument that magnifies an object
- An image taken from a microscope is called a **micrograph**

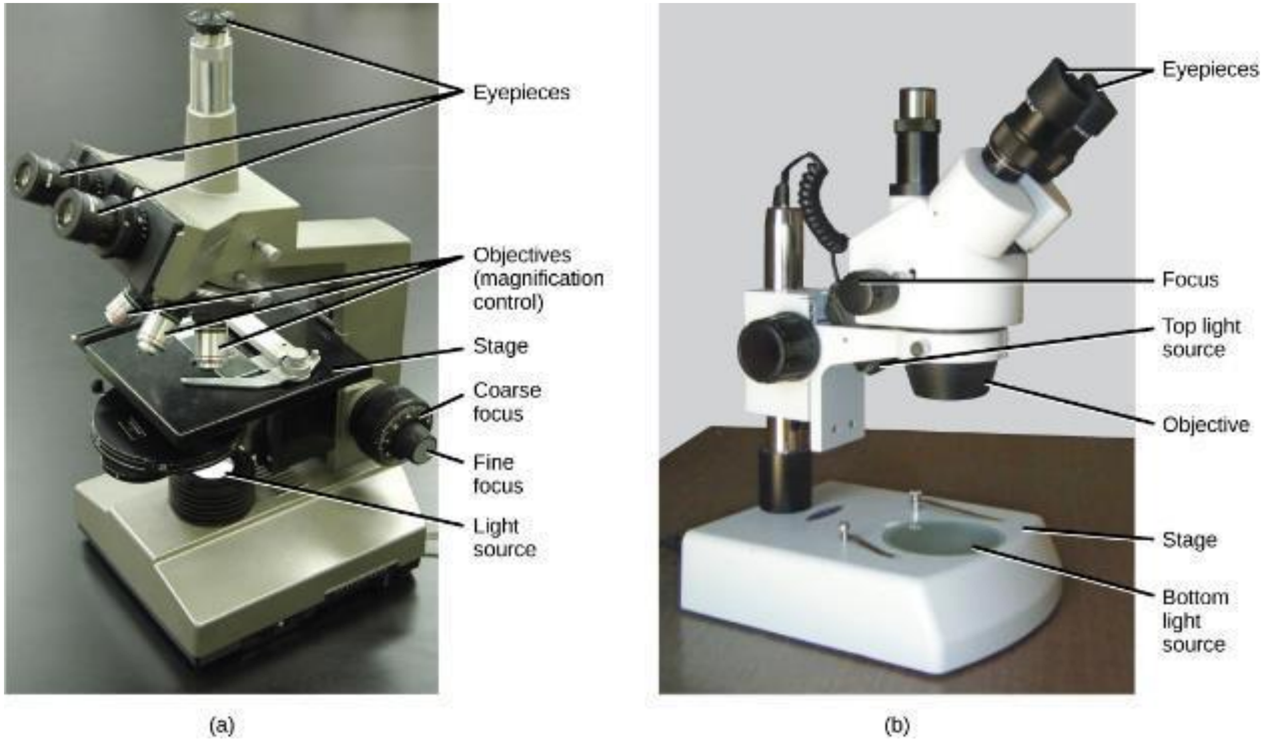
Light Microscopes

- Approximately 250 red blood cells can fit on the tip of a pin. To view them, we must magnify them
- Light passes through slides of the specimen and lens to create a magnified view of the cells
- Stains are used to create better images of the cells and their components
- Can magnify cells 40 to 1000 times the object size

Dissecting Microscopes

- Magnify only 20 to 80 times the object size
- Provides a three-dimensional view of the specimen

FIGURE 3.2



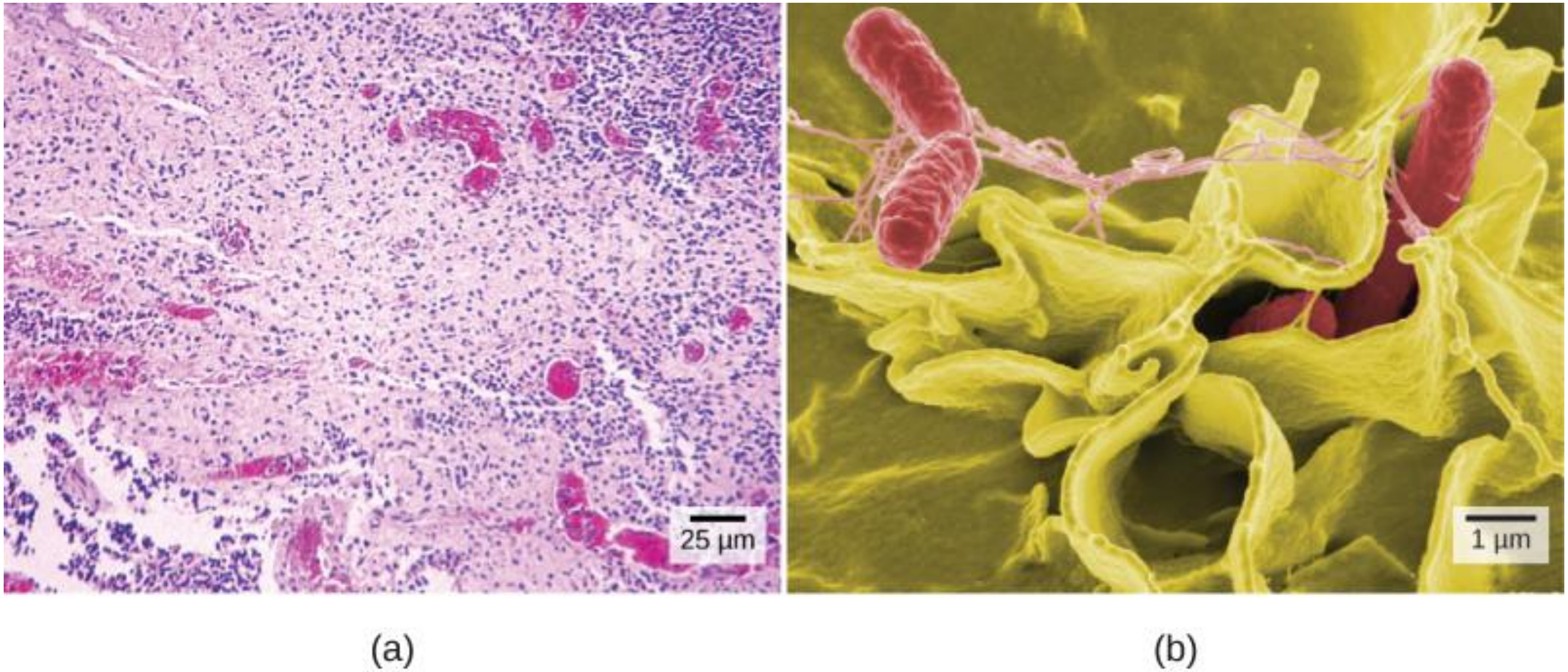
(a) Most light microscopes used in a college biology lab can magnify cells up to approximately 400 times.

(b) Dissecting microscopes have a lower magnification than light microscopes and are used to examine larger objects, such as tissues.

Electron Microscopes

- Use a beam of electrons instead of a beam of light
- Cells are coated with a metal
- Only dead cells can be viewed with electron microscopes

FIGURE 3.3



(a) *Salmonella* bacteria are viewed with a light microscope.

(b) This scanning electron micrograph shows *Salmonella* bacteria (in red) invading human cells. (credit a: modification of work by CDC, Armed Forces Institute of Pathology, Charles N. Farmer; credit b: modification of work by Rocky Mountain Laboratories, NIAID, NIH; scale-bar data from Matt Russell)

CELL THEORY

- In the 1600s, Antony van Leeuwenhoek, a dutch shopkeeper observed moving protists and sperm, which he termed "animalcules"
- In 1665, Robert Hooke viewed cork tissue and coined the term "cell" (from latin *cella*, meaning "small room")
- By the late 1830s, botanist Matthias Schleiden and zoologist Theodor Schwann proposed the **unified cell theory** which states:
  - ✓ All living things are composed of one or more cells
  - ✓ The cell is the basic unit of life
  - ✓ All new cells arise from existing cells

3.2 COMPARING PROKARYOTIC AND EUKARYOTIC CELLS (1 OF 3)

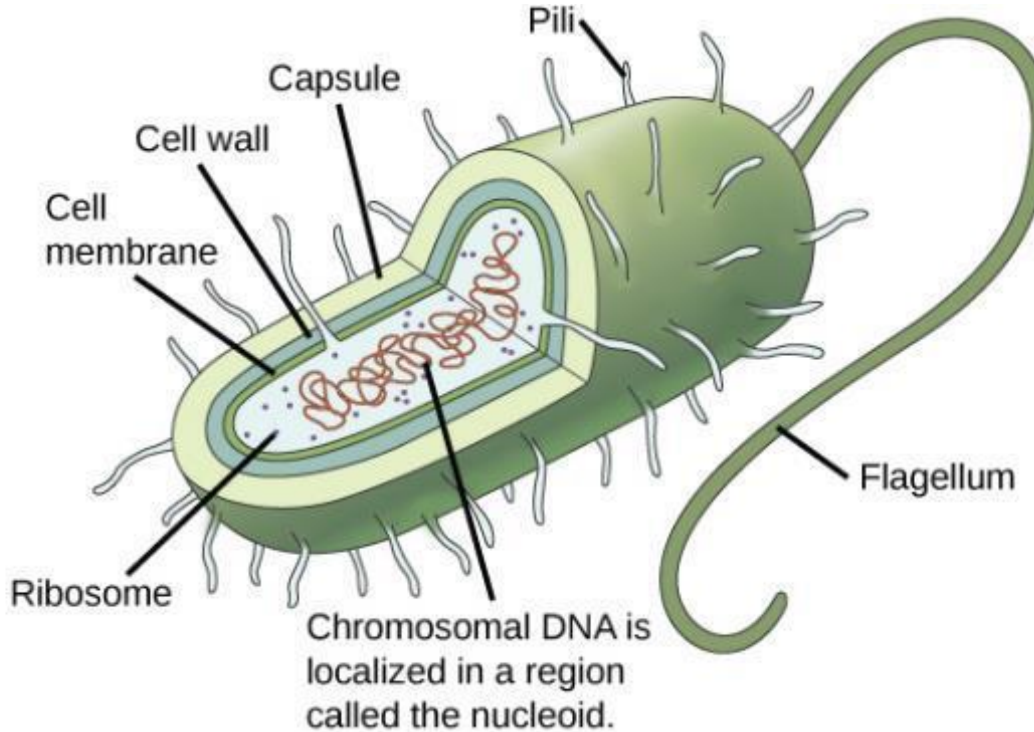
All cells share four common components:

- ✓ Plasma membrane – an outer covering that separates the cell’s interior from the surrounding environment
- ✓ Cytoplasm – jelly-like region of the cell where all the organelles are found
- ✓ DNA – the genetic material
- ✓ Ribosomes – particles that synthesize proteins

3.2 COMPARING PROKARYOTIC AND EUKARYOTIC CELLS (2 OF 3)

- **Prokaryotic cell** - a simple, single-celled organism that lacks a nucleus, or any other membrane-bound organelles
- Prokaryotic DNA is found in the central part of the cell, a darkened region called the **nucleoid**
- Bacteria have a cell wall made up of peptidoglycan (amino acids and sugars)
- Archaea lack this peptidoglycan cell wall
- Some prokaryotes have flagella, pili or fimbriae

FIGURE 3.5



This figure shows the generalized structure of a prokaryotic cell.

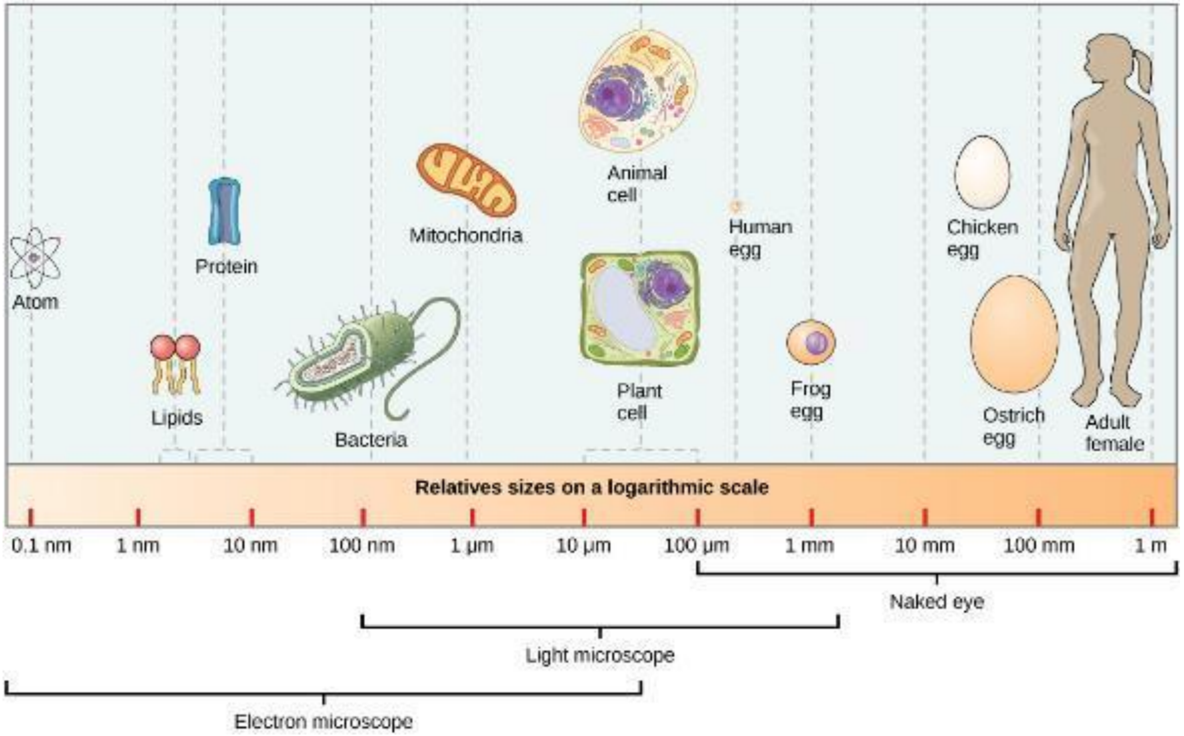
3.2 COMPARING PROKARYOTIC AND EUKARYOTIC CELLS (3 OF 3)

- **Eukaryotic cell** - a cell that has a membrane-bound nucleus and other membrane-bound organelles
- **Organelles** – membrane-bound compartments or sacs inside the cell that have specialized functions

Cell Size

- Prokaryotic cells range 0.1 – 5.0 μm
- Eukaryotic cells range 10 – 100 μm
- Cell size is limited because volume increases much more quickly than does cell surface area; as a cell becomes larger, it becomes more and more difficult for the cell to acquire sufficient materials to support the processes inside the cell

FIGURE 3.6

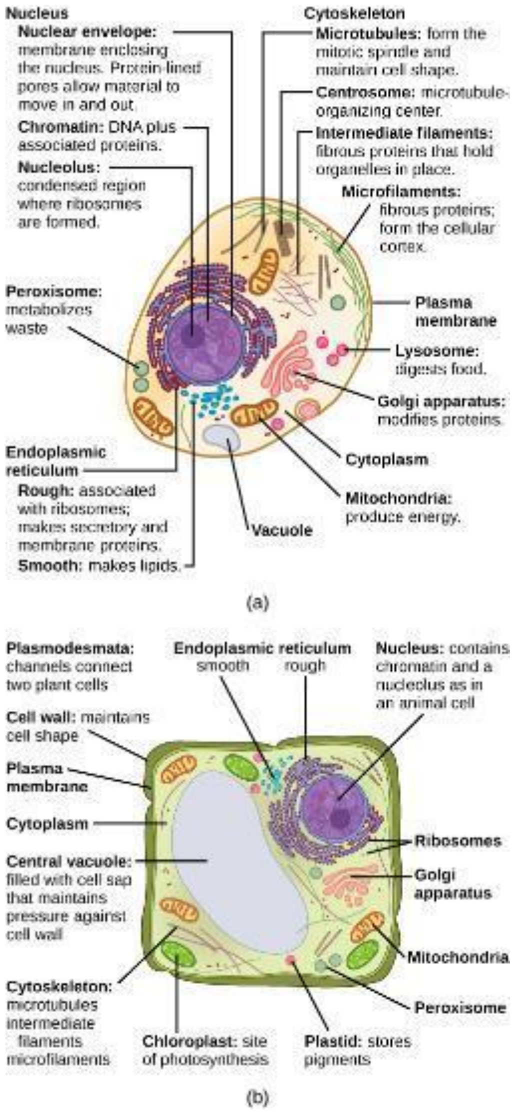


This figure shows the relative sizes of different kinds of cells and cellular components. An adult human is shown for comparison.

3.3 EUKARYOTIC CELLS

- Eukaryotic cells are more complex than prokaryotic cells
- Organelles allow for various functions to occur in the cell at the same time
- Two important components of the cells are the plasma membrane and the cytoplasm

FIGURE 3.7

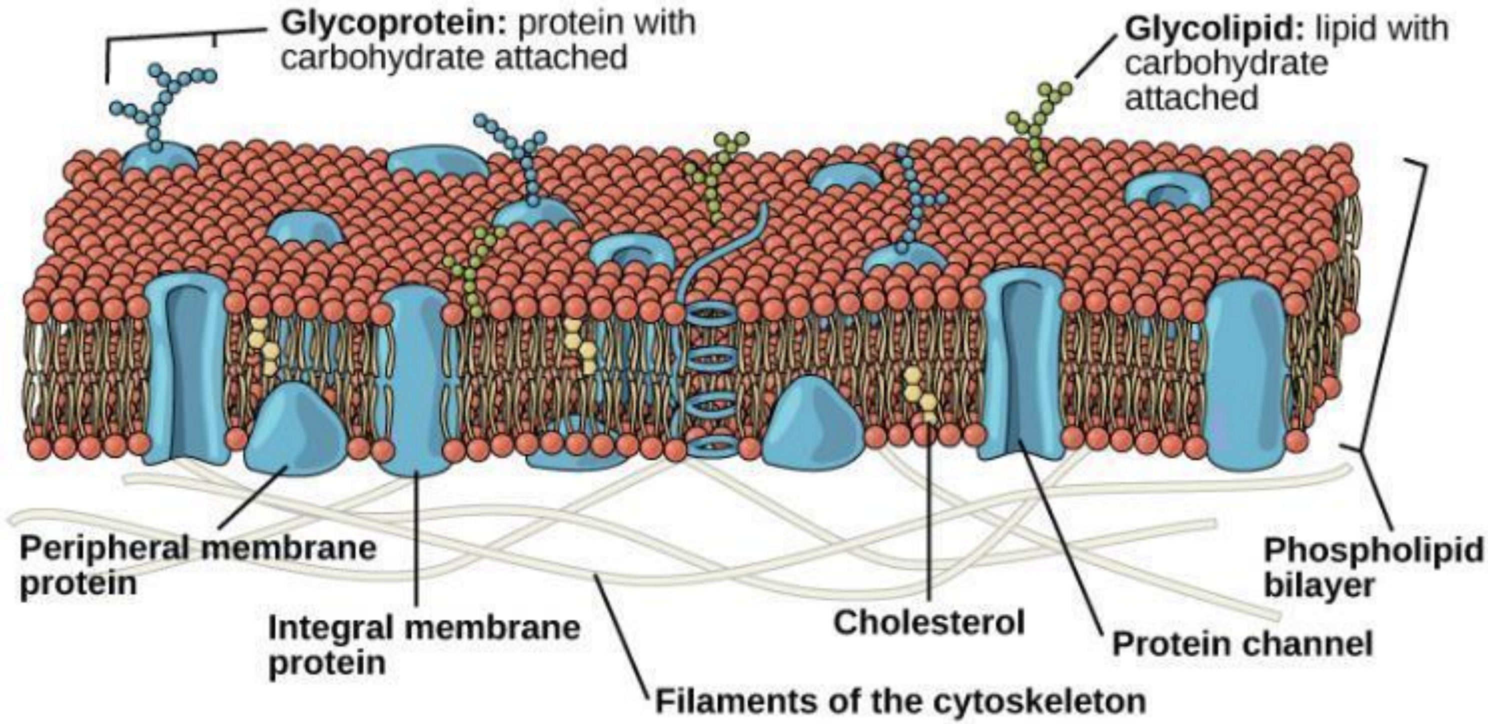


This figure shows (a) a typical animal cell and (b) a typical plant cell.

The Plasma Membrane

- **Plasma membrane** - made up of a phospholipid bilayer with embedded proteins that separates the internal contents of the cell from its surrounding environment
- The plasma membrane regulates the passage of some substances
- Some plasma membranes are folded into fingerlike projections called **microvilli** which increases the surface area of the plasma membrane for increasing absorption

FIGURE 3.8



The plasma membrane is a phospholipid bilayer with embedded proteins. There are other components, such as cholesterol and carbohydrates, which can be found in the membrane in addition to phospholipids and protein.

The Cytoplasm

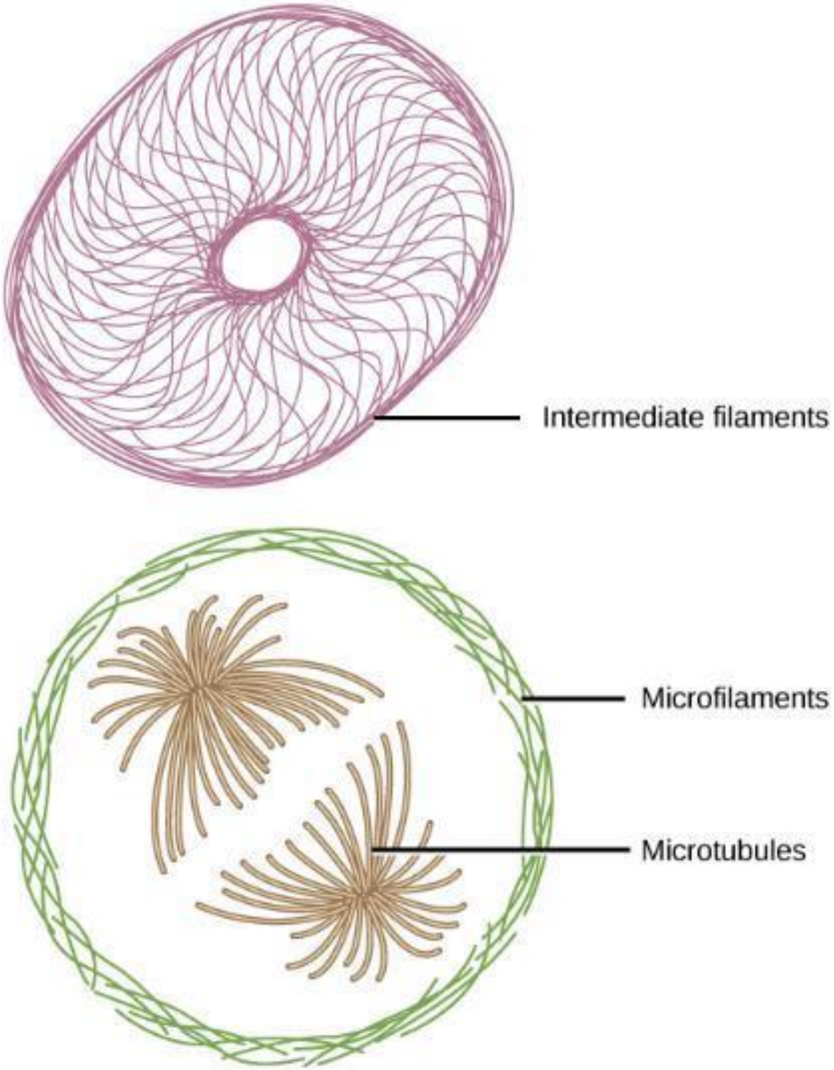
- **Cytoplasm** comprises the contents of a cell between the plasma membrane and the nuclear envelope
- It is made up of organelles suspended in the gel-like cytosol, the cytoskeleton, and various chemicals

The Cytoskeleton

- **Cytoskeleton** - a network of proteins fibers that helps to maintain the shape of the cell, secures certain organelles in specific positions, allows cytoplasm and vesicles to move within the cell and enables unicellular organisms to move independently
- There are three types of fibers within the cytoskeleton:
  - ✓ Microfilaments (or actin filaments)
  - ✓ Intermediate filaments
  - ✓ Microtubules

FIGURE 3.9

Microfilaments, intermediate filaments, and microtubules compose a cell's cytoskeleton.



Flagella and Cilia

- **Flagella** are long, hair-like structures that extend from the plasma membrane and are used to move the entire cell
- When present the cell has just one flagellum or a few flagella
- **Cilia** are short, hair-like structure that are used to move entire cells or move substances along the outer surface of the cell
- When cilia are present they are many in number and extend along the entire membrane surface

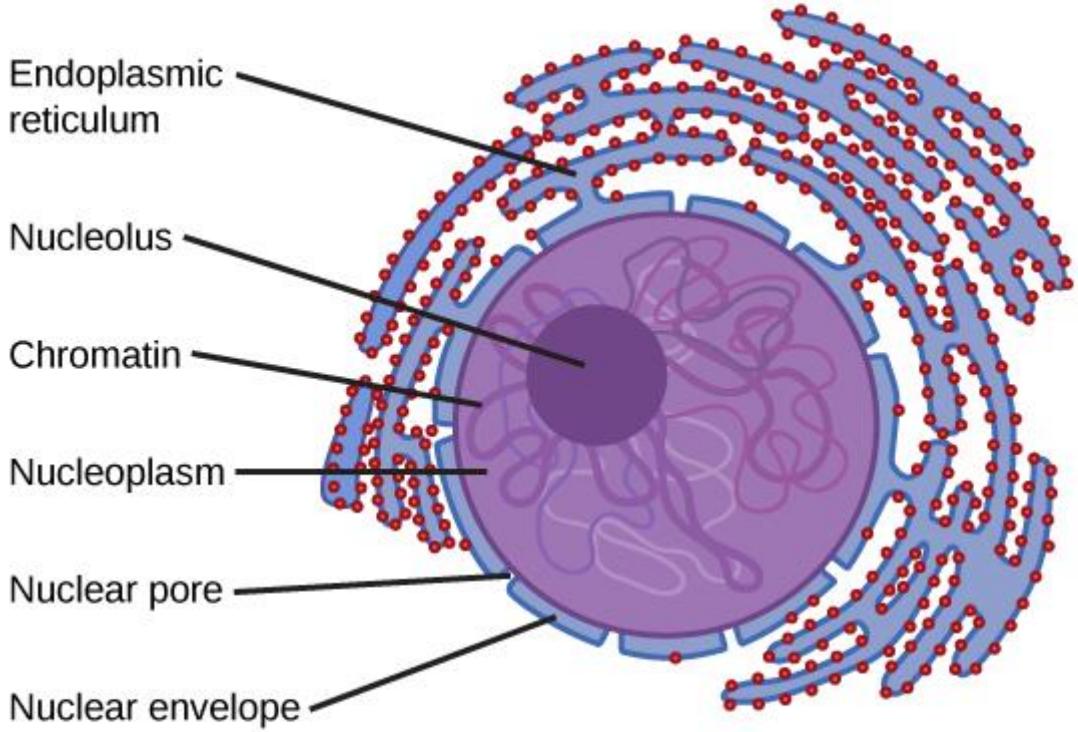
The Endomembrane System

- The endomembrane system is a group of membranes and organelles in eukaryotic cells that work together to modify, package, and transport lipids and proteins.
- Includes:
  - ✓ The nuclear envelope
  - ✓ Lysosomes and vesicles
  - ✓ The endoplasmic reticulum
  - ✓ Golgi apparatus

The Nucleus

- **Nucleus** - houses the cell's DNA in the form of chromatin and directs the synthesis of ribosomes and proteins
- **Nuclear envelope** - a double-membrane structure that constitutes the outermost portion of the nucleus
- The nuclear envelope is punctuated with pores that control the passage of ions, molecules, and RNA
- **Nucleolus** - the darkly stained area that aggregates the ribosomal RNA

FIGURE 3.10



The outermost boundary of the nucleus is the nuclear envelope. Notice that the nuclear envelope consists of two phospholipid bilayers (membranes)—an outer membrane and an inner membrane—in contrast to the plasma membrane (Figure 3.8), which consists of only one phospholipid bilayer. (credit: modification of work by NIGMS, NIH)

The Endoplasmic Reticulum

- **Endoplasmic reticulum (ER)** - a series of interconnected membranous tubules that collectively modify proteins and synthesize lipids
- These two functions are performed in separate areas: the rough endoplasmic reticulum and the smooth endoplasmic reticulum
- The membrane of the ER is continuous with the nuclear envelope

The Rough Endoplasmic Reticulum

- **Rough endoplasmic reticulum (RER)** - so named because the ribosomes attached to its cytoplasmic surface gives it a rough appearance when viewed through an electron microscope
- The attached ribosomes synthesize proteins into the lumen of the RER, where they undergo modifications such as folding or addition of sugars
- The RER also makes phospholipids for the cell membrane

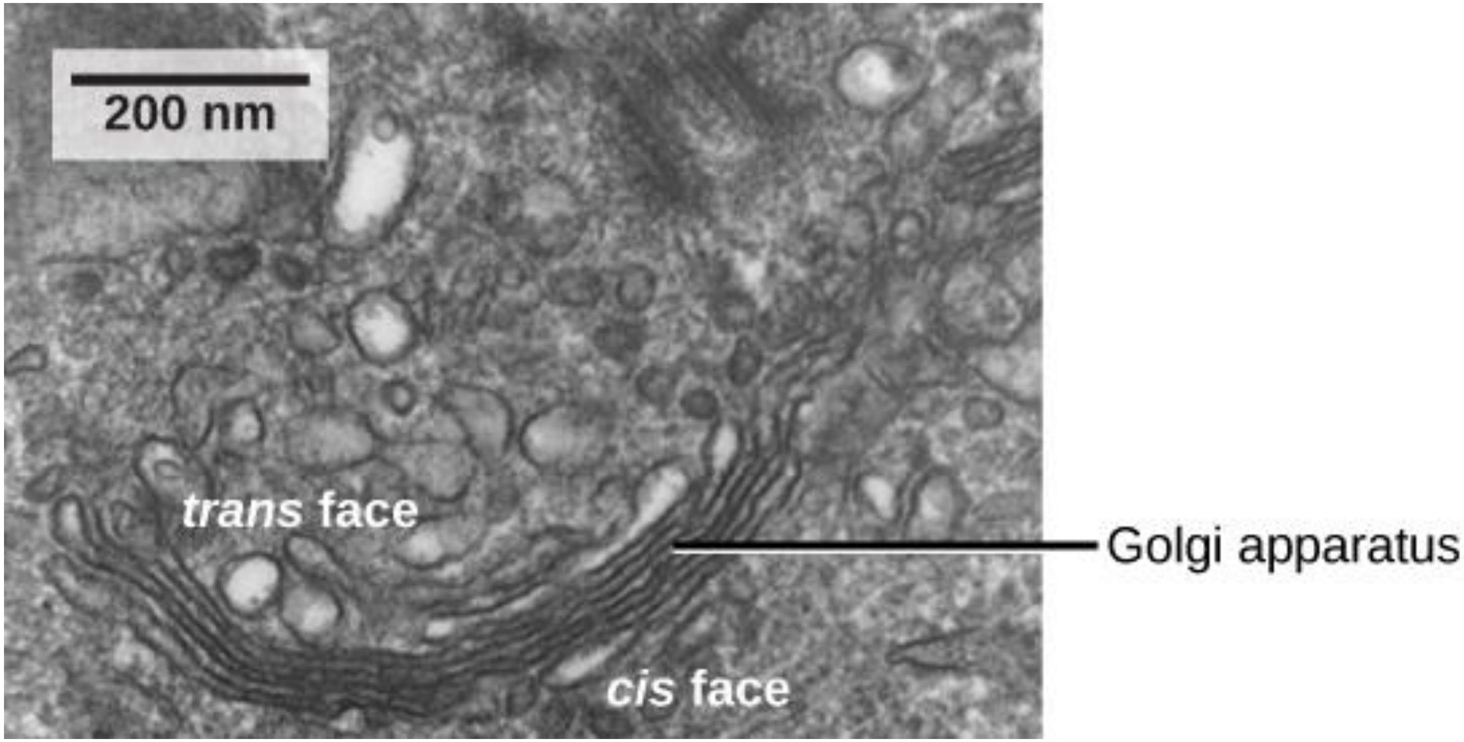
The Smooth Endoplasmic Reticulum

- **Smooth endoplasmic reticulum (SER) -** has few or no ribosomes attached, thus having a smooth appearance under the microscope
- It is continuous with the RER
- Functions include synthesis of carbohydrates, lipids and steroid hormones; detoxification of medications and poisons; alcohol metabolism, and storage of calcium ions

The Golgi Apparatus

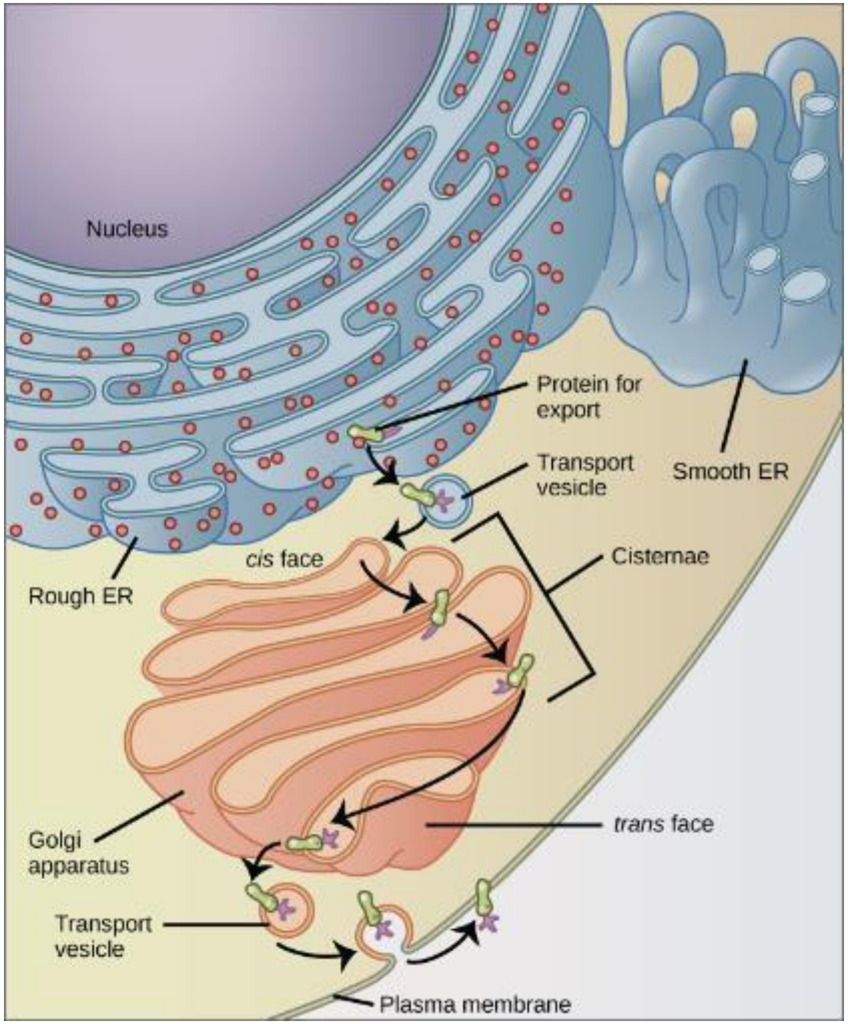
- **Golgi apparatus** - a series of flattened sacs that function to sort, tag, package and distribute lipids and proteins

FIGURE 3.11



The Golgi apparatus in this transmission electron micrograph of a white blood cell is visible as a stack of semicircular flattened rings in the lower portion of this image. Several vesicles can be seen near the Golgi apparatus. (credit: modification of work by Louisa Howard; scale-bar data from Matt Russell)

FIGURE 3.13

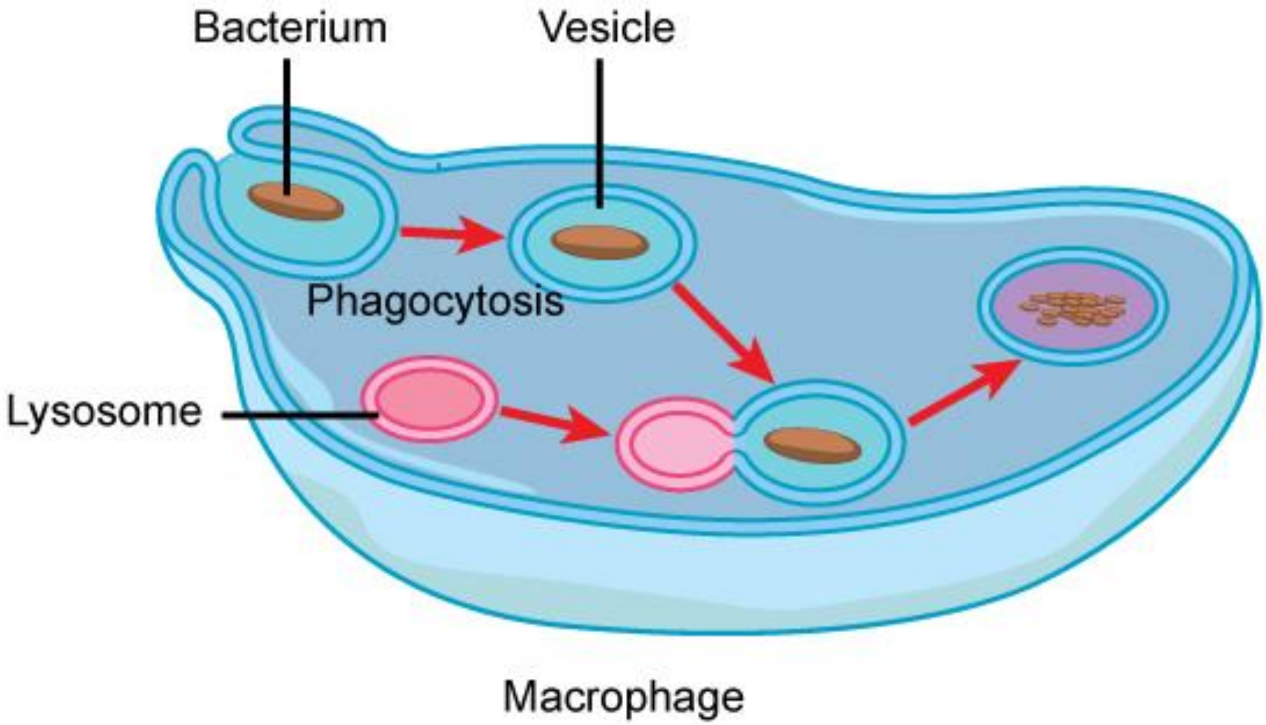


The endomembrane system works to modify, package, and transport lipids and proteins. (credit: modification of work by Magnus Manske)

Lysosomes

- **Lysosomes** - membrane-bound vesicles that contain digestive enzymes that aid the breakdown of proteins, polysaccharides, lipids, nucleic acids, and even worn-out organelles

FIGURE 3.12



A macrophage has phagocytized a potentially pathogenic bacterium into a vesicle, which then fuses with a lysosome within the cell so that the pathogen can be destroyed. Other organelles are present in the cell, but for simplicity, are not shown.

Vesicles and Vacuoles

- **Vesicles** and **vacuoles** - membrane-bound sacs that function in storage and transport
- Vesicles can fuse with other membrane-bound organelles
- Vacuoles are somewhat larger than vesicles and do not fuse with other organelles

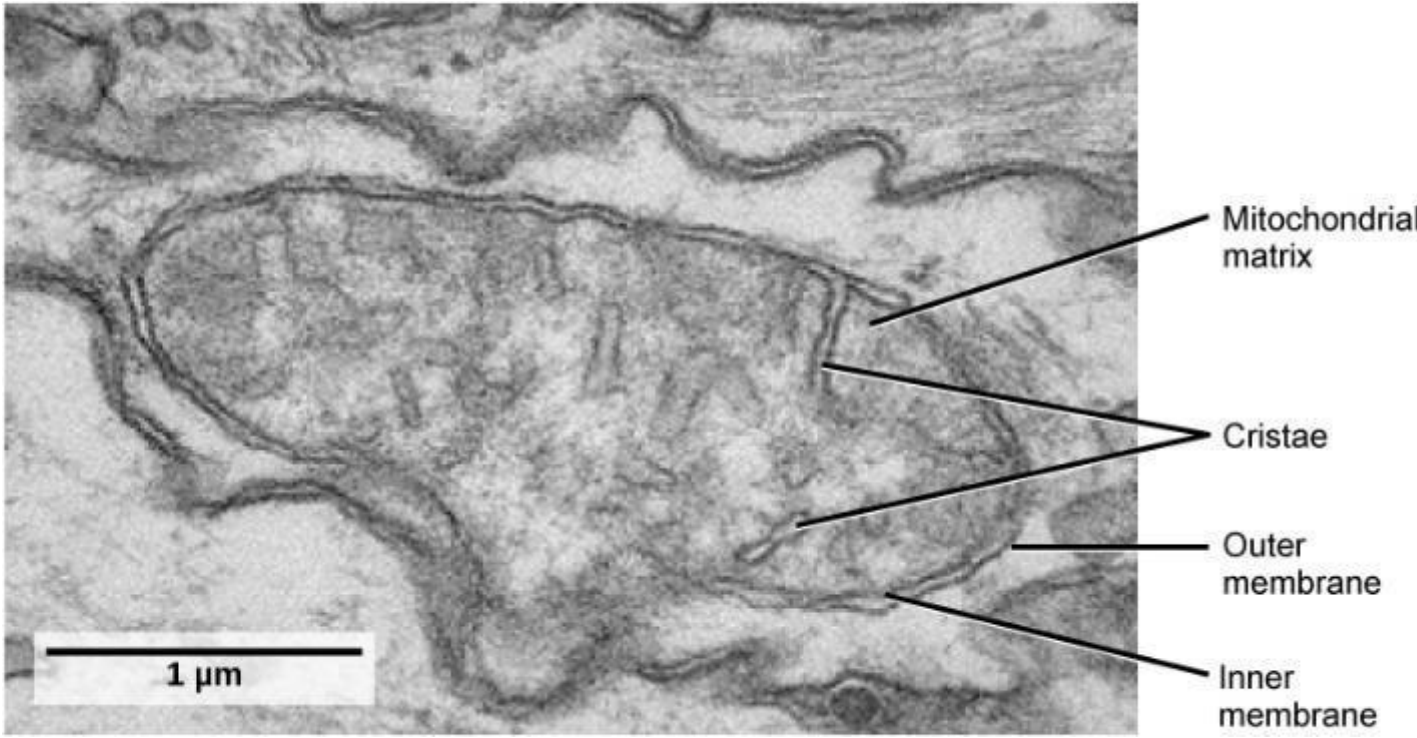
Ribosomes

- **Ribosomes** - the cellular structures that are responsible for protein synthesis
- Ribosomes can be free floating in the cytoplasm, attached to the cytoplasmic side of the endoplasmic reticulum or plasma membrane

Mitochondria

- **Mitochondria** - nicknamed the "powerhouses" of the cell because they produce adenosine triphosphate (ATP), the cell's main energy-carrying molecule
- Contain their own DNA

FIGURE 3.14



This transmission electron micrograph shows a mitochondrion as viewed with an electron microscope. Notice the inner and outer membranes, the cristae, and the mitochondrial matrix. (credit: modification of work by Matthew Britton; scale-bar data from Matt Russell)

Peroxisomes

- **Peroxisomes** - small, round organelles, enclosed by single membranes that carry out oxidation reactions that break down fatty acids and amino acids
- The byproduct of these oxidation reactions is hydrogen peroxide (H_2O_2)

Animal Cells Vs. Plant Cells

- Animal and plant cells having many things in common, but there are a few differences
- Animal cells have centrioles, centrosomes, and lysosomes, whereas plant cell do not
- Plant cells have a cell wall, chloroplasts, plasmodesmata, plastids, and a large central vacuole, whereas animal cells do not

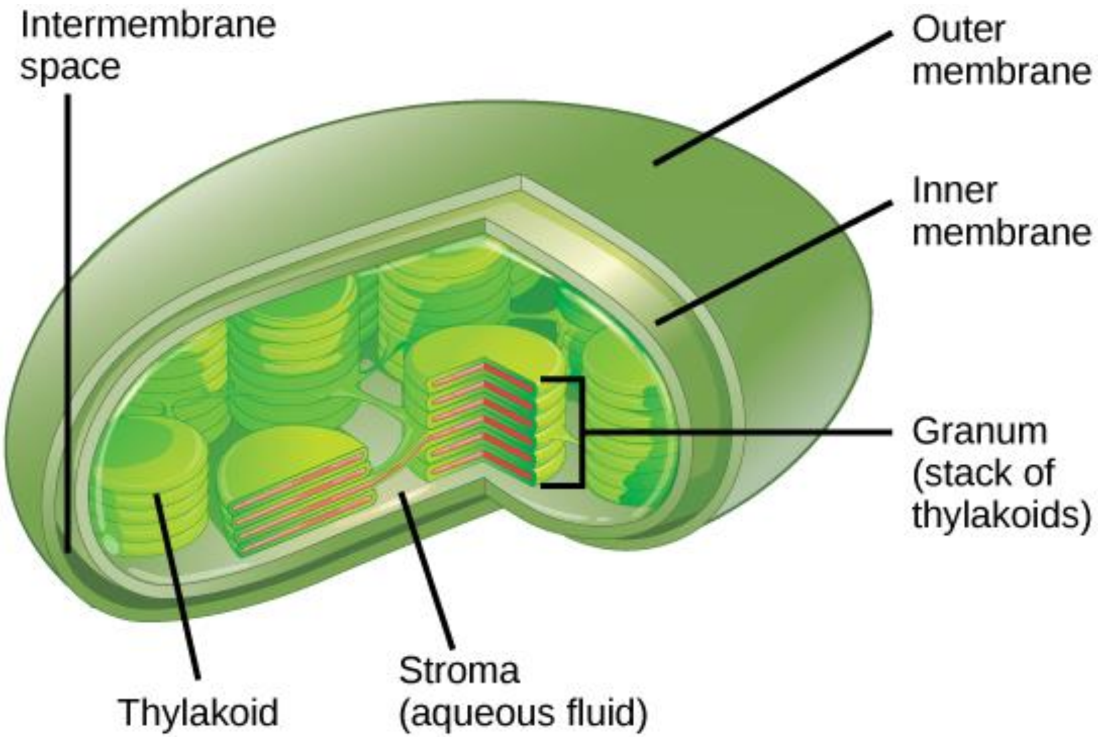
The Cell Wall

- **Cell wall** - a rigid covering external to the plasma membrane that protects the cell, provides structural support, and gives shape to the cell
- Fungal and some protist cells also have cell walls
- The cell wall is composed mainly of cellulose

Chloroplasts

- **Chloroplasts** - function in photosynthesis, a process that uses carbon dioxide, water and light energy to make glucose and oxygen
- They have their own DNA
- Plants are **autotrophs** because they are able to make their own food (glucose), whereas animals are **heterotrophs** because they must rely on other organisms for the food source

FIGURE 3.15



This simplified diagram of a chloroplast shows the outer membrane, inner membrane, thylakoids, grana, and stroma.

The Central Vacuole

- **Central vacuole** - plays a key role in regulating the cell’s concentration of water in changing environmental conditions
- The liquid inside the central vacuole creates **turgor pressure**, which is the outward pressure caused by the fluid inside the cell
- Turgor pressure is what makes the plant stiff, firm and erect; when water leaves the cell, turgor pressure is reduced and the plant wilts

Endosymbiosis

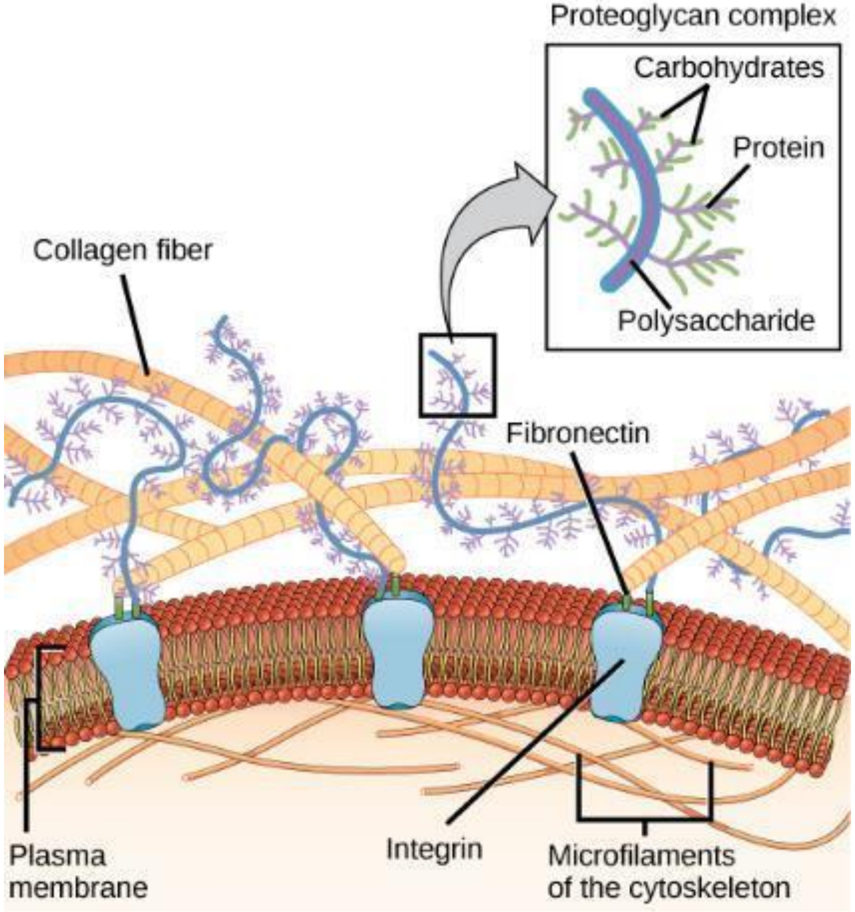
- The idea that mitochondria and chloroplast were bacteria cells that were engulfed by a larger cell and they began living symbiotically
- Supporting evidence: mitochondria and chloroplast:
  - ✓ have their own DNA
  - ✓ have two membranes, the original one and the one acquired when they were engulfed
  - ✓ are about the size of bacteria cells
  - ✓ reproduce in a process similar to bacteria reproduction

Extracellular Matrix of Animal Cells

- **Extracellular matrix** - what holds the cells together to form a tissue and allows cells to communicate with one another
- It is made up of glycoproteins and protein collagen

FIGURE 3.16

The extracellular matrix consists of a network of substances secreted by cells.



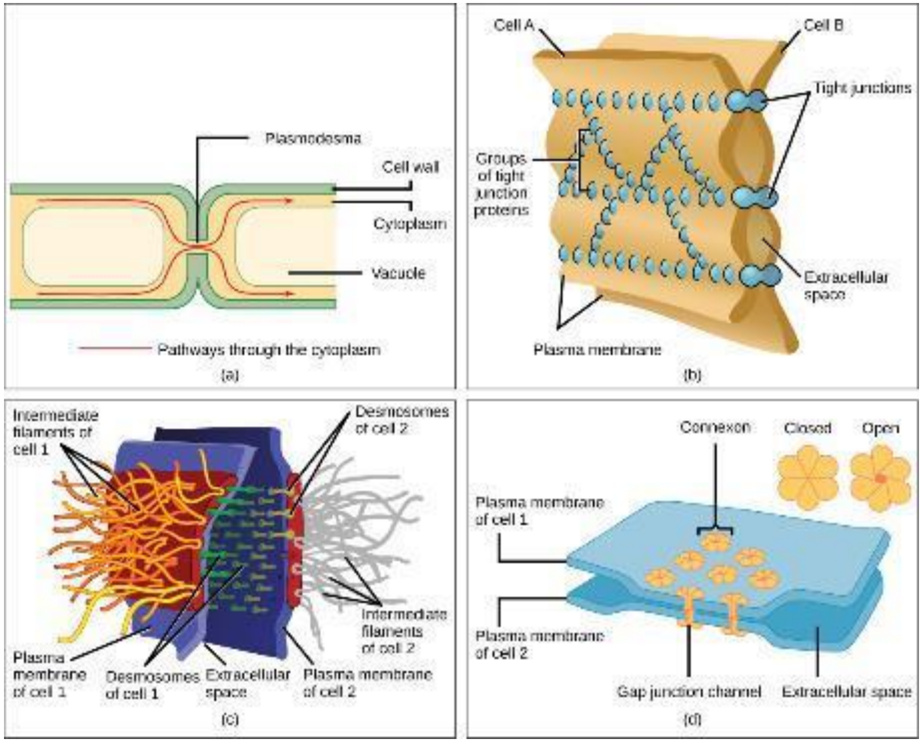
Intercellular Junctions (1 of 2)

- Cells can also communicate with each other by direct contact, referred to as intercellular junctions
- Plasmodesmata are junctions between plant cells
- Tight junctions, gap junctions and desmosomes are all junctions between animal cells

Intercellular Junctions (2 of 2)

- **Plasmodesmata** are numerous channels that pass between the cell walls of adjacent plant cells, connects their cytoplasm and enables signaling and transporting
- **Tight junctions** form a watertight seal between two adjacent animal cells
- **Desmosomes** act like spot welds between adjacent epithelial cells
- **Gap junctions** are channels between adjacent animal cells which enables communication and transport

FIGURE 3.17



There are four kinds of connections between cells. (a) A plasmodesma is a channel between the cell walls of two adjacent plant cells. (b) Tight junctions join adjacent animal cells. (c) Desmosomes join two animal cells together. (d) Gap junctions act as channels between animal cells. (credit b, c, d: modification of work by Mariana Ruiz Villareal)

3.4 THE CELL MEMBRANE

- A cell’s plasma membrane defines its boundaries
- It is dynamic and constantly in flux
- It is flexible
- It carries recognition markers
- It carries receptors

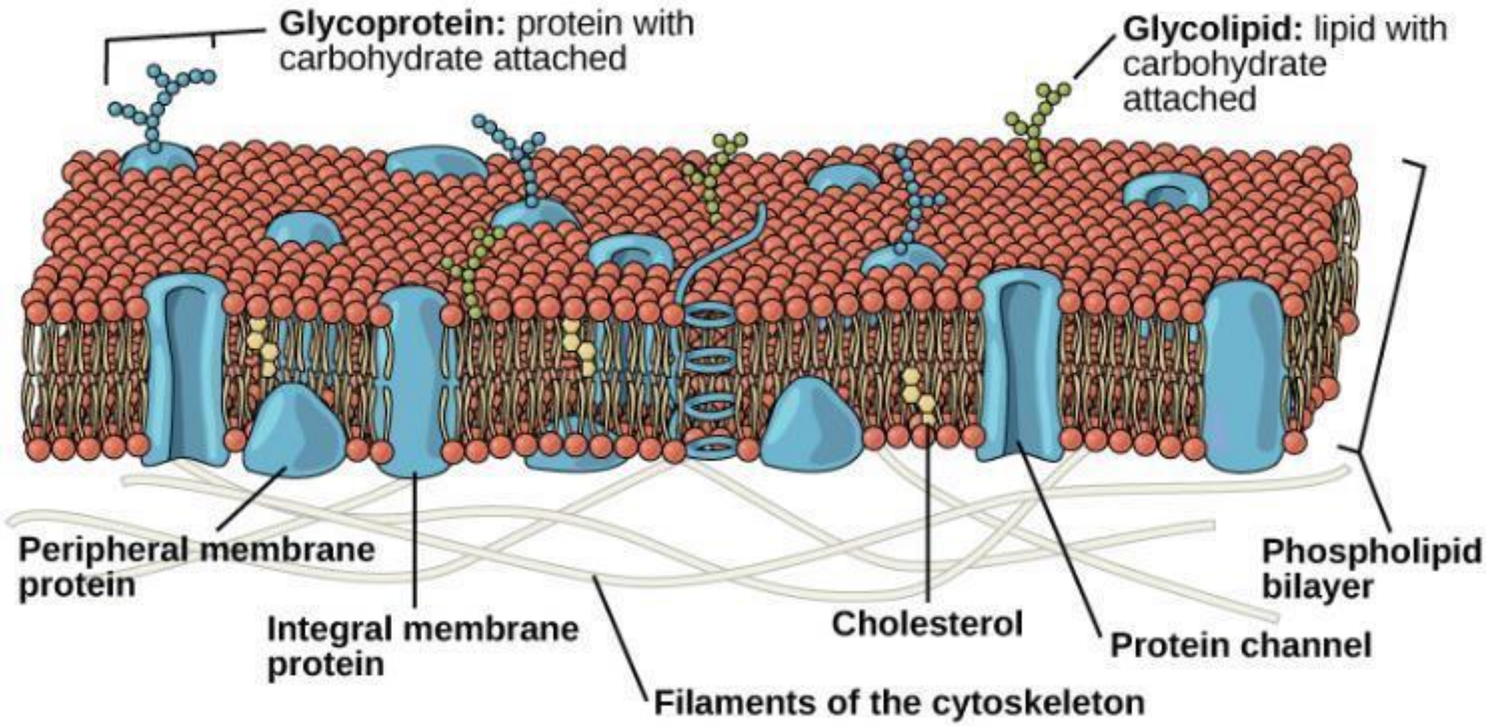
The Fluid Mosaic Model (1 of 4)

- **Fluid mosaic model** -describes the plasma membrane as a mosaic of components, including phospholipids, cholesterol, proteins and carbohydrates in which the components are able to flow and change position

The Fluid Mosaic Model (2 of 4)

- The plasma membrane is made up primarily of a bilayer of phospholipids with embedded proteins, carbohydrates, glycolipids, glycoproteins, and in animal cells, cholesterol
- The main fabric of the membrane is composed of two layers of phospholipids molecules
- The hydrophilic (polar) ends of the phospholipids are in contact with the aqueous fluids inside and outside the cell
- The interior part of the membrane is composed of the hydrophobic (nonpolar) fatty acid tails

FIGURE 3.18

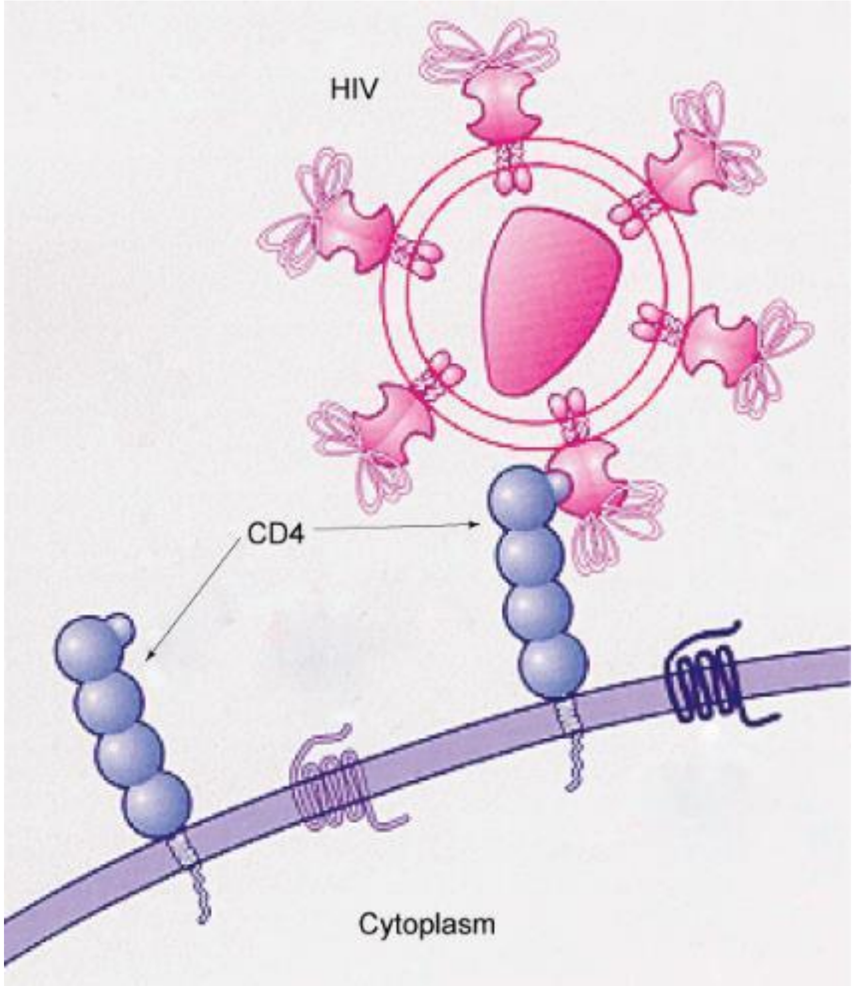


The fluid mosaic model of the plasma membrane structure describes the plasma membrane as a fluid combination of phospholipids, cholesterol, proteins, and carbohydrates.

The Fluid Mosaic Model (3 of 4)

- The second major component of the plasma membrane is proteins
- Proteins serves as channels, pumps, enzymes, structural attachments, or as part of the cell’s recognition sites

FIGURE 3.19



HIV docks at and binds to the CD4 receptor, a glycoprotein on the surface of T cells, before entering, or infecting, the cell. (credit: modification of work by US National Institutes of Health/National Institute of Allergy and Infectious Diseases)

The Fluid Mosaic Model (4 of 4)

- The third major component of the plasma membrane is carbohydrates
- They are always found on the exterior surface of cells and are bound to either proteins (forming glycoproteins) or to lipids (forming glycolipids)
- The carbohydrate chains may consist of 2-60 monosaccharide unit and may be either straight or branched
- Carbohydrates form specialized sites on the cell surface that allow cells to recognize each other

3.5 Passive Transport (1 of 3)

- Plasma membranes are **selectively permeable** – they allow some substances through but not others
- Selective permeability is important for cell function

3.5 Passive Transport (2 of 3)

- **Passive transport** - a naturally occurring phenomenon which substances move from an area of higher concentration to an area of lower concentration in a process called **diffusion**
- the most direct form of membrane transport
- does not require energy

3.5 Passive Transport (3 of 3)

- **Concentration gradient** - the difference in concentrations between two solutions
- A molecule is said to move "down" its concentration gradient when it moves from high concentration to low concentration

Selective Permeability (1 of 2)

- Plasma membranes are asymmetric, meaning the interior of the membrane is not identical to the exterior of the membrane
- Integral proteins act as channels or pumps and work in one direction
- The hydrophobic/hydrophilic regions of the phospholipids allow some materials to move through while others are hindered
- Fat-soluble substances, and such as molecules of oxygen and carbon dioxide (having no charge) can pass through by simple diffusion

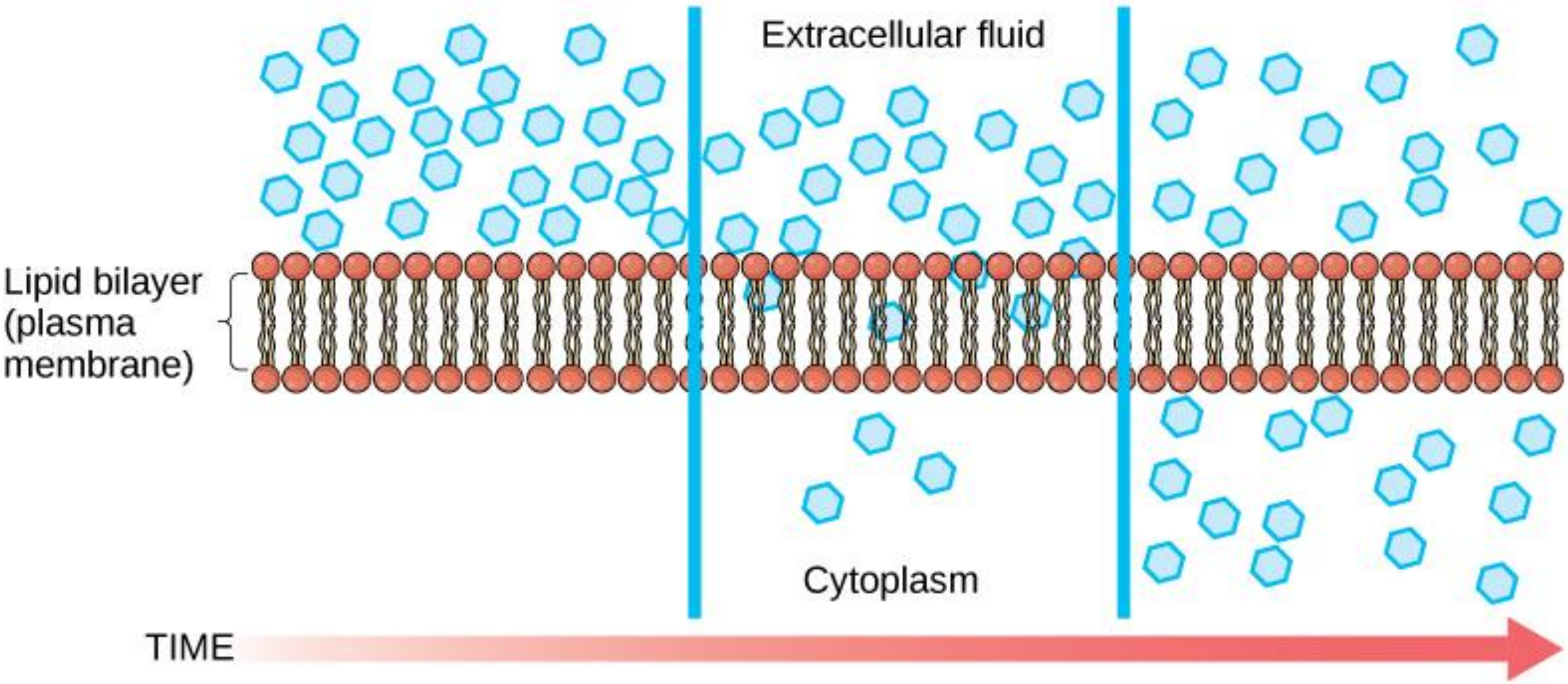
Selective Permeability (2 of 2)

- Polar substances (with the exception of water) can not readily pass through the membrane
- Ions, even though they are small, can not easily pass through the membrane because they are charged
- Ions such as sodium, potassium, calcium, and chloride have special means of penetrating plasma membranes

Diffusion (1 of 2)

- **Diffusion** - the movement of a substance from an area of high concentration to an area of low concentration until the concentration is equal across the space
- diffusion is passive, it expends no energy

FIGURE 3.20



Diffusion through a permeable membrane follows the concentration gradient of a substance, moving the substance from an area of high concentration to one of low concentration. (credit: modification of work by Mariana Ruiz Villarreal)

Diffusion (2 of 2)

- Several factors affect the rate of diffusion:
  - ✓ **Concentration gradient** – the greater the difference in concentration, the more rapid the diffusion
  - ✓ **Mass of the molecules diffusing** – the more massive a molecule is the slower it will diffuse
  - ✓ **Temperature** – higher temperatures increase the rate of diffusion
  - ✓ **Solvent density** – as the density of the solvent increases, the rate of diffusion decreases

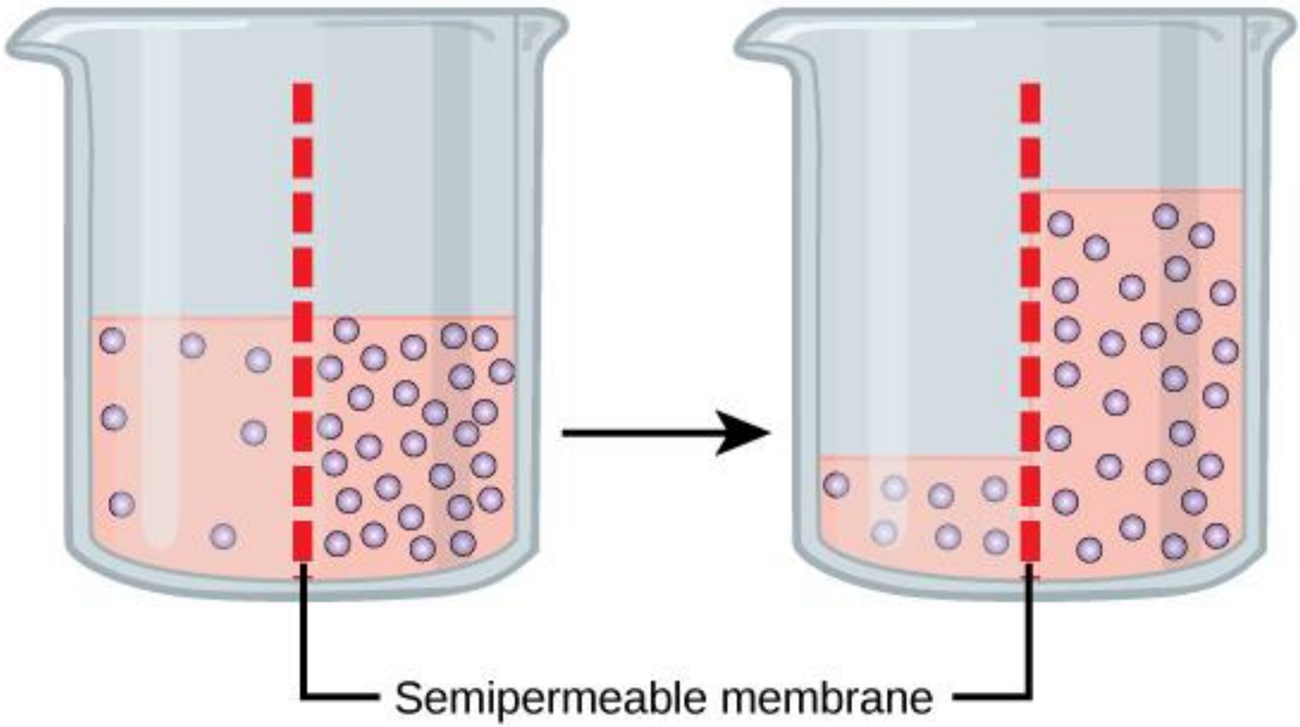
Facilitated Transport

- **Facilitated transport** (or facilitated diffusion) moves materials across the plasma membrane with the assistance of transmembrane proteins, down the concentration gradient (from high to low concentration) without the expenditure of cellular energy

Osmosis

- **Osmosis** - the diffusion of water through a semipermeable membrane
- It is the movement of water from an area of high WATER concentration to an area of low WATER concentration
- Water is the **solvent** (what does the dissolving), the dissolved substance is called the **solute**
- If the solute can not cross the membrane, the solvent (water) will

FIGURE 3.21



In osmosis, water always moves from an area of higher concentration (of water) to one of lower concentration (of water). In this system, the solute cannot pass through the selectively permeable membrane.

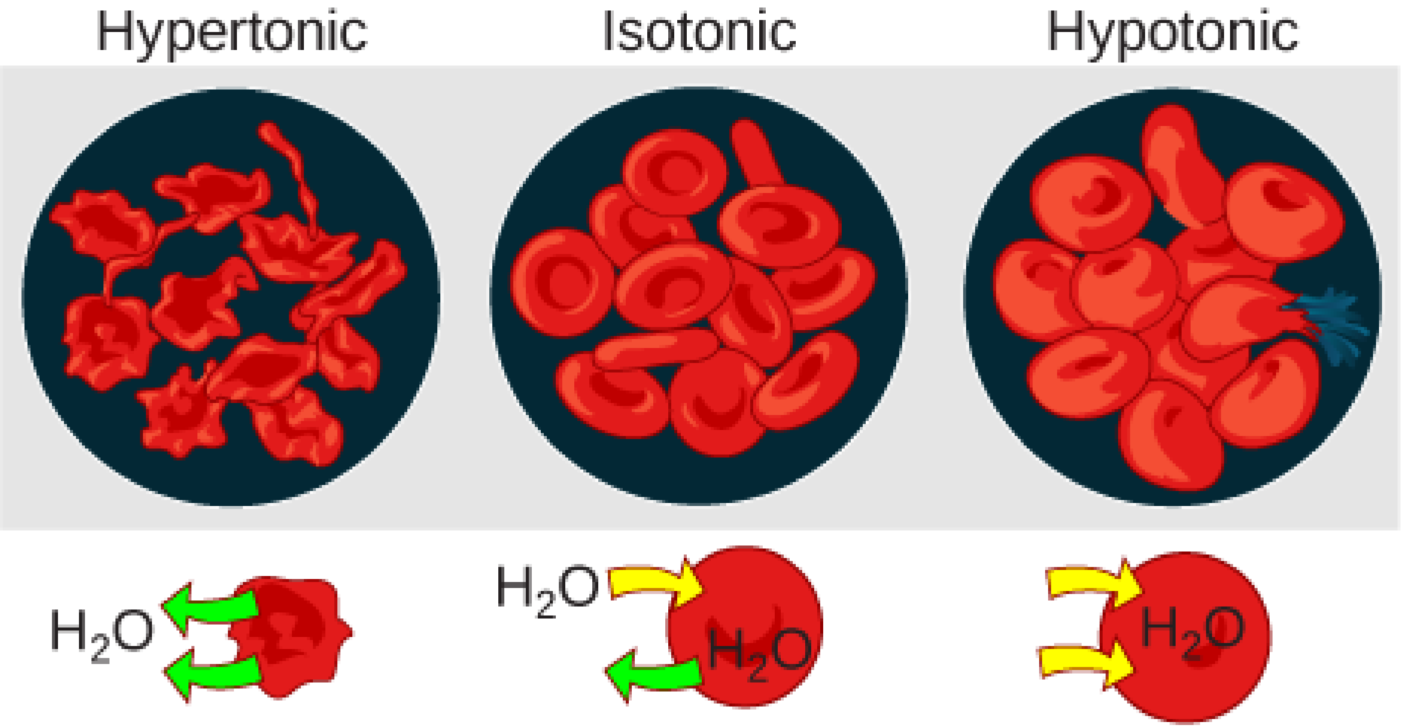
Tonicity (1 of 3)

- **Tonicity** describes the amount of solute in a solution
- **Osmolarity** – the total amount of solutes dissolved in a specific amount of solution

Tonicity (2 of 3)

- Three terms are used to relate osmolarity of a cell to the osmolarity of the extracellular fluid:
    - ✓ **Hypotonic** – the extracellular fluid has a lower concentration of solute than the fluid inside the cell. This situation causes water to enter the cells and animal cells may burst, or **lyse**
    - ✓ **Hypertonic** – the extracellular fluid has a higher concentration of solute than the fluid inside the cell. This situation causes water to leave the cells. This may cause animal cells to shrivel or **crenate**
    - ✓ **Isotonic** – the extracellular and intracellular fluid have equal concentrations of solute, water moves into and out of the cell at the same rate, so the cell remains normal

FIGURE 3.22

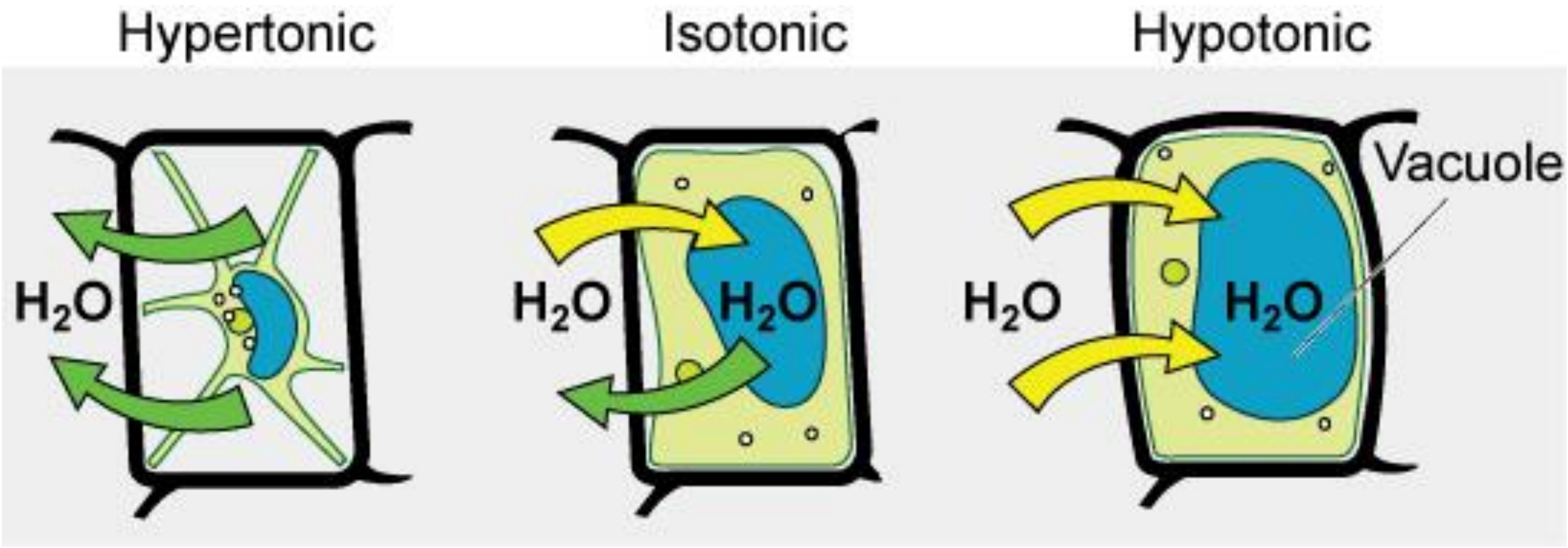


Osmotic pressure changes the shape of red blood cells in hypertonic, isotonic, and hypotonic solutions. (credit: modification of work by Mariana Ruiz Villarreal)

Tonicity (3 of 3)

- Some cells have a cell walls, such as plants, fungi, bacteria, and some protist
  - ✓ In a hypotonic solution, the plasma membrane can only expand to the limit of the cell wall, it won’t lyse
  - ✓ In a hypertonic solution, water will leave the cell, the plant will lose turgor pressure and wilt

FIGURE 3.23



The turgor pressure within a plant cell depends on the tonicity of the solution that it is bathed in. (credit: modification of work by Mariana Ruiz Villarreal)

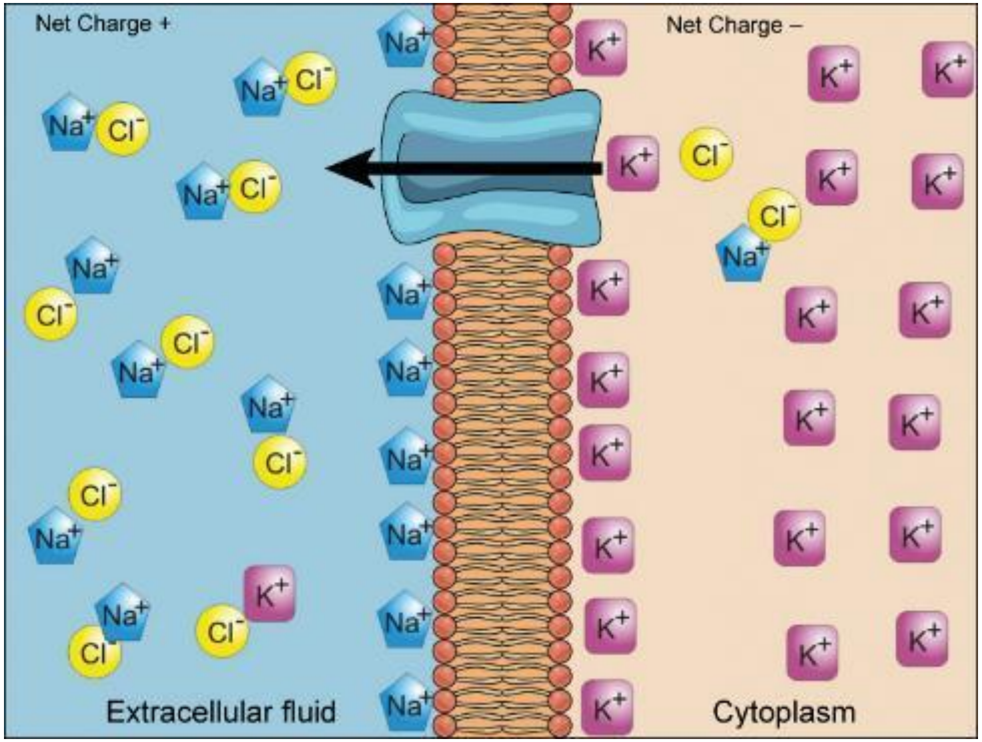
3.6 ACTIVE TRANSPORT

- **Active transport** mechanisms require the use of the cell's energy, usually in the form of ATP
- Energy is required to move substances against the concentration gradient (from areas of low concentration to area of high concentration)
- Also moved ions, charged molecules and large molecules

Electrochemical Gradient

- **Electrochemical gradient** - the difference in the net charge on the inside and outside of the plasma membrane
- The inside of living cells is electrically negative with respect to the outside of the cell
- The electrochemical gradient is very important to the functioning of muscle and nerve cells

FIGURE 3.24



Electrochemical gradients arise from the combined effects of concentration gradients and electrical gradients. (credit: modification of work by “Synaptitude”/Wikimedia Commons)

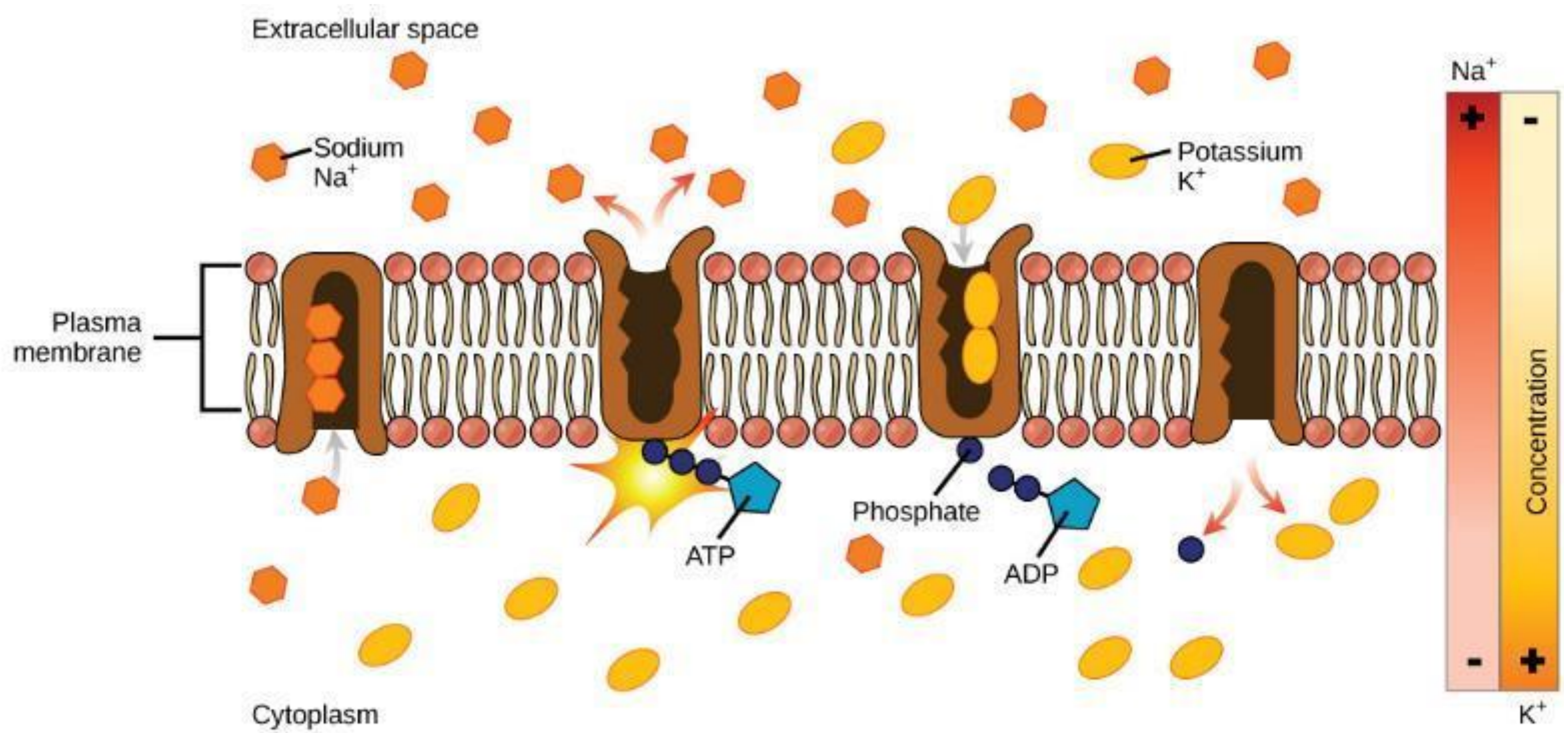
Moving Against A Gradient (1 of 2)

- To move substances against their concentration or electrochemical gradient, the cell must use energy
- This energy is harvested from ATP generated through cellular metabolism by the mitochondria
- Active transport mechanisms, collectively called **pumps** or **carrier proteins**, work against electrochemical gradients

Moving Against A Gradient (2 of 2)

- Two mechanisms exist for the transport:
  - ✓ **Primary active transport** – moves ions across a membrane and creates a difference in charge across that membrane. Ex: sodium-potassium pump
  - ✓ **Secondary active transport** – uses the energy of the electrochemical gradient created by the primary active transport system to bring in other substances such as amino acids and glucose

FIGURE 3.25



The sodium-potassium pump move potassium and sodium ions across the plasma membrane. (credit: modification of work by Mariana Ruiz Villarreal)

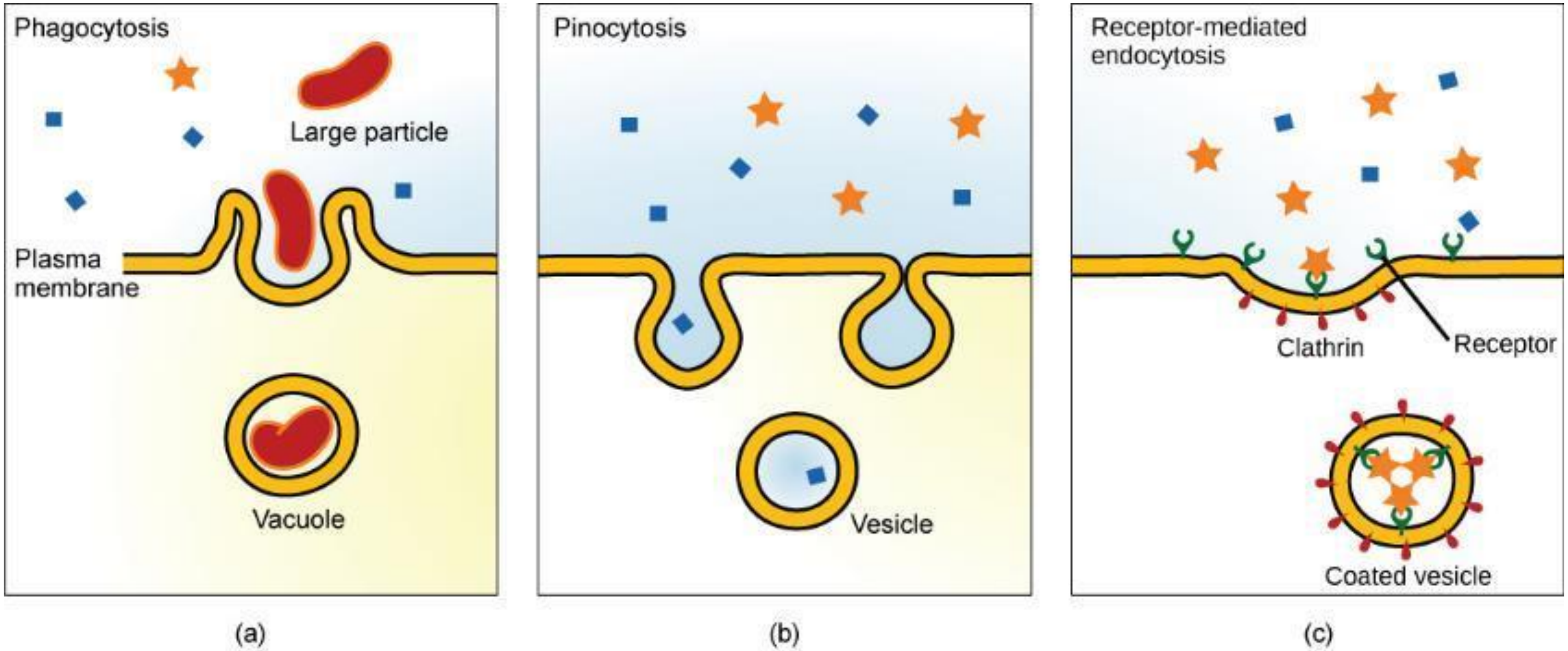
Endocytosis (1 of 2)

- **Endocytosis** - a type of active transport that moves particles, such as large molecules, parts of cells, and even whole cells into a cell
- The plasma membrane invaginates, forming a pocket around the target particle
- The pocket pinches off, resulting in the particle being contained in a newly created vacuole that is formed from the plasma membrane

Endocytosis (2 of 2)

- There are three variations of endocytosis:
  - ✓ **Phagocytosis** – the process by which large particles, such as cells, are taken in by a cell
  - ✓ **Pinocytosis** – the process by which fluids are taken in by a cell
  - ✓ **Receptor-mediated endocytosis** – the process by which particles bind to the receptor proteins, causing the plasma membrane to invaginate, bringing the particle and the proteins into the cell

FIGURE 3.26



Three variations of endocytosis are shown.

(a) In one form of endocytosis, phagocytosis, the cell membrane surrounds the particle and pinches off to form an intracellular vacuole.

(b) In another type of endocytosis, pinocytosis, the cell membrane surrounds a small volume of fluid and pinches off, forming a vesicle.

(c) In receptor-mediated endocytosis, uptake of substances by the cell is targeted to a single type of substance that binds at the receptor on the external cell membrane. (credit: modification of work by Mariana Ruiz Villarreal)

Exocytosis

- **Exocytosis** - the process of expelling a particle from a cell when its vesicle membrane fuses with the plasma membrane

FIGURE 3.27

In exocytosis, a vesicle migrates to the plasma membrane, binds, and releases its contents to the outside of the cell. (credit: modification of work by Mariana Ruiz Villarreal)