

Chapter 3: Cells



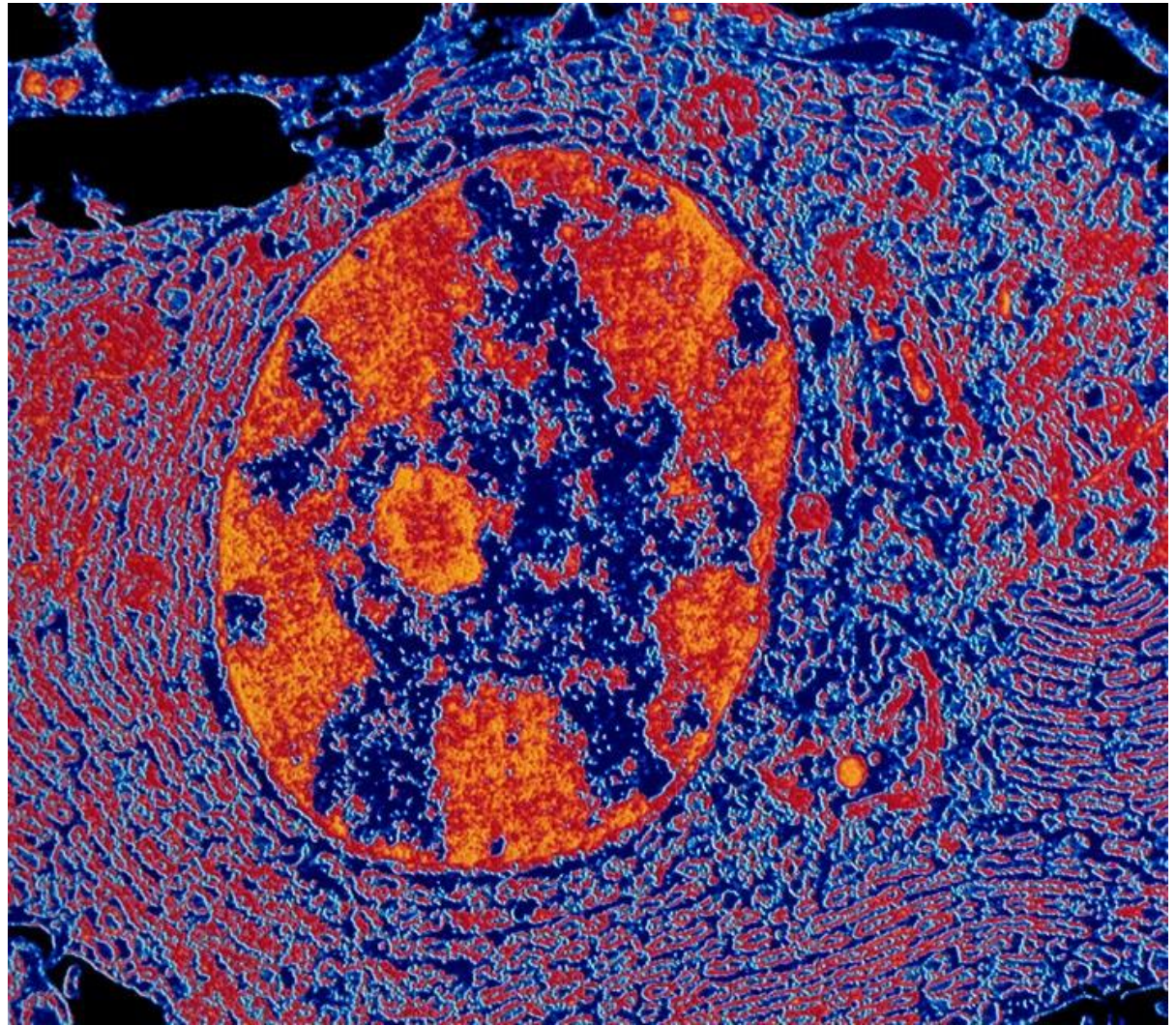
The smallest part of you

Learning Objectives

- ❑ Describe what a cell is and the two general types of cells.
- ❑ Describe the structure and functions of cell membranes.
- ❑ Describe several ways in which molecules move across membranes.
- ❑ Describe how cells are connected and how they communicate with each other.

3.1–3.3

What is a cell?



3.1 All organisms are made of cells.

The **cell**: The smallest unit of life that can function independently and perform all the necessary functions of life, including reproducing itself.



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Figure 3-1b
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Cell Theory

1. All living organisms are made up of one or more cells.
2. All cells arise from other pre-existing cells.

Take-home message 3.1

- The most basic unit of any organism is the cell, the smallest unit of life that can function independently and perform all of the necessary functions of life, including reproducing itself.
- All living organisms are made up of one or more cells and all cells arise from other pre-existing cells.

3.2 Prokaryotic cells are structurally simple, but there are many types of them.

Every cell on earth falls into one of two basic categories:

1. A eukaryotic cell

- has a central control structure called a nucleus, which contains the cell's DNA.
- **eukaryotes**

2. A prokaryotic cell

- does not have a nucleus; its DNA simply resides in the middle of the cell.
- **prokaryotes**

THE PROKARYOTE: BASIC STRUCTURE

FOUR STRUCTURES IN ALL PROKARYOTES

PLASMA MEMBRANE

Encloses cell contents:
DNA, ribosomes, and cytoplasm

CYTOPLASM

Jelly-like fluid inside cell

RIBOSOMES

Granular bodies in the cytoplasm
that convert genetic information
into protein structure

DNA

One or more circular loops
containing genetic information

ADDITIONAL STRUCTURES

CELL WALL

Protects and gives shape
to the cell

PILI

Hair-like projections that help
cells attach to other surfaces

FLAGELLUM

Whip-like projection(s) that
aids in cellular movement

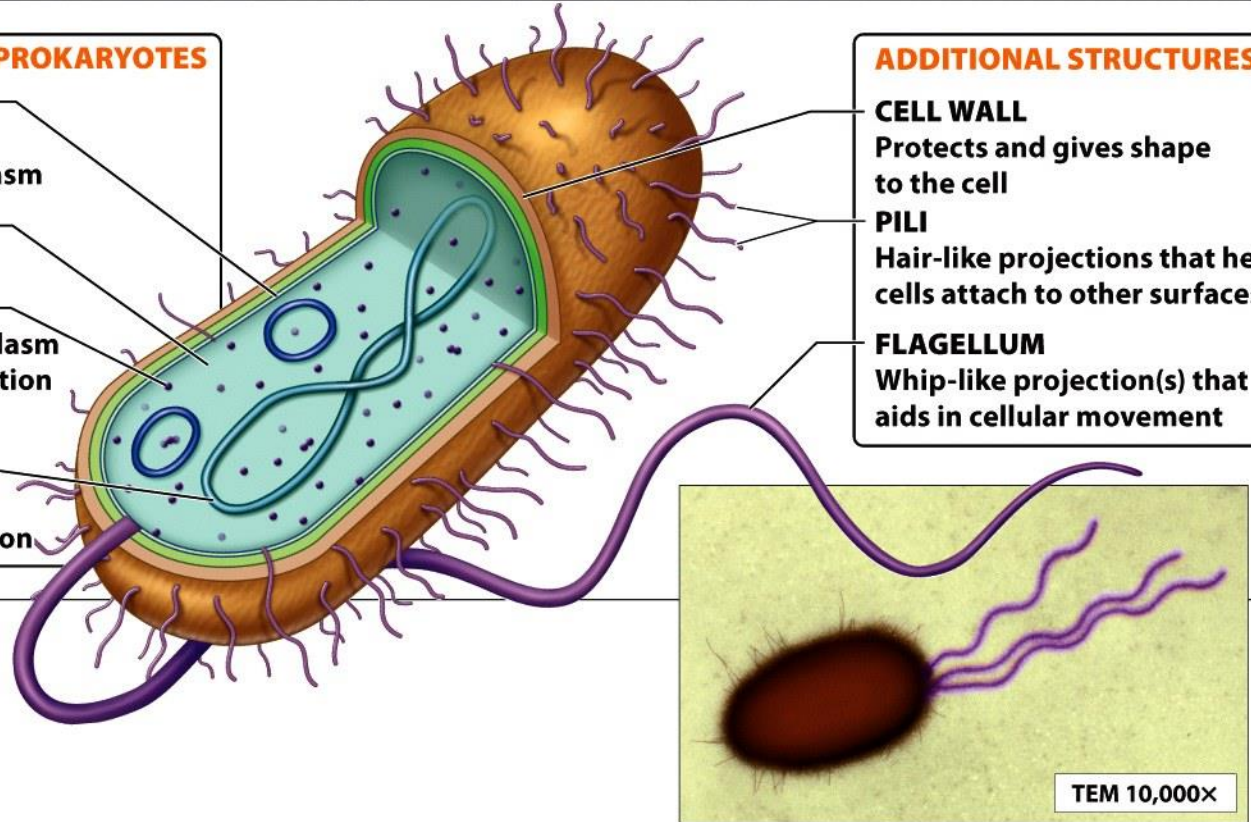


Figure 3-3

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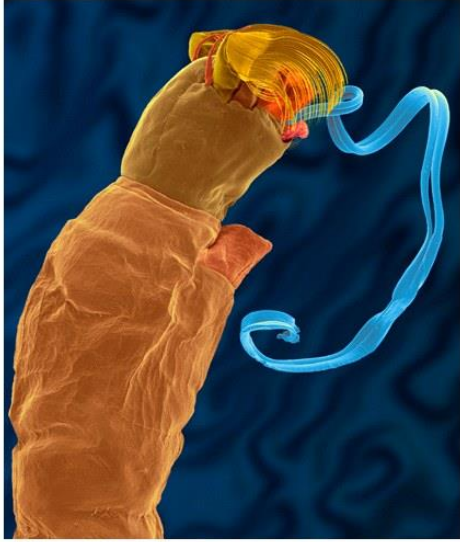
Take-home message 3.2

- Every cell on earth is either a eukaryote or a prokaryote.
- Prokaryotes, which have no nucleus, were the first cells on earth.

Take-home message 3.2

- They are all single-celled organisms.
- Prokaryotes include the bacteria and archaea and, as a group, are characterized by tremendous metabolic diversity.

3.3 Eukaryotic cells have compartments with specialized functions.

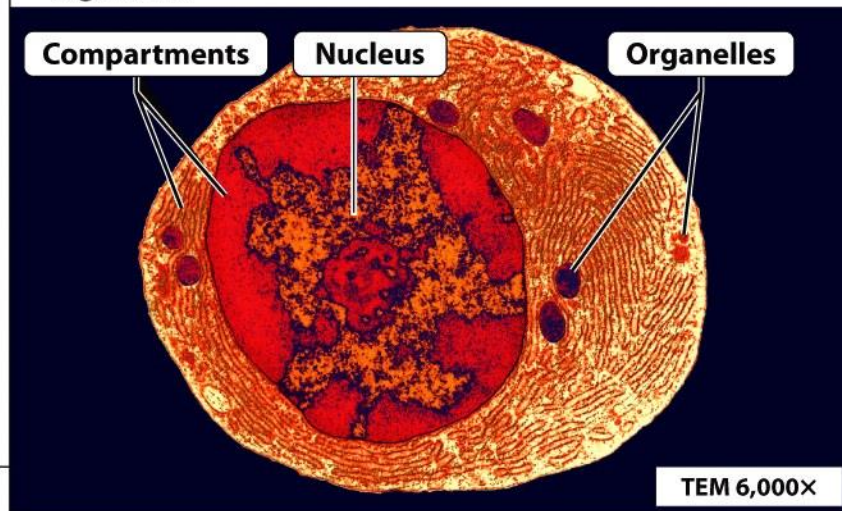


Eukaryotic cells have organelles.

EUKARYOTES vs. PROKARYOTES

TYPICAL EUKARYOTIC CELL FEATURES

- DNA contained in nucleus
- Internal structures organized into compartments
- Larger than prokaryotes—usually 10 times bigger
- Cytoplasm contains specialized structures called organelles



TYPICAL PROKARYOTIC CELL FEATURES

- No nucleus—DNA is in the cytoplasm
- Internal structures not organized into compartments
- Much smaller than eukaryotes

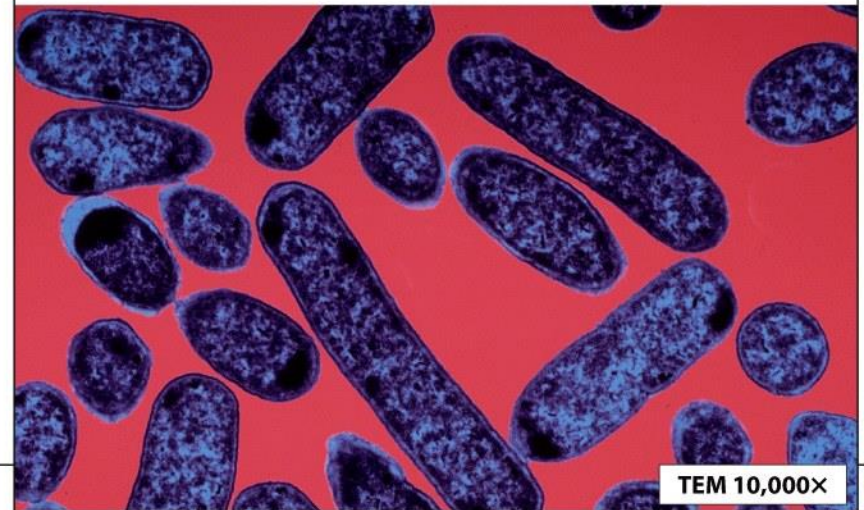


Figure 3-5

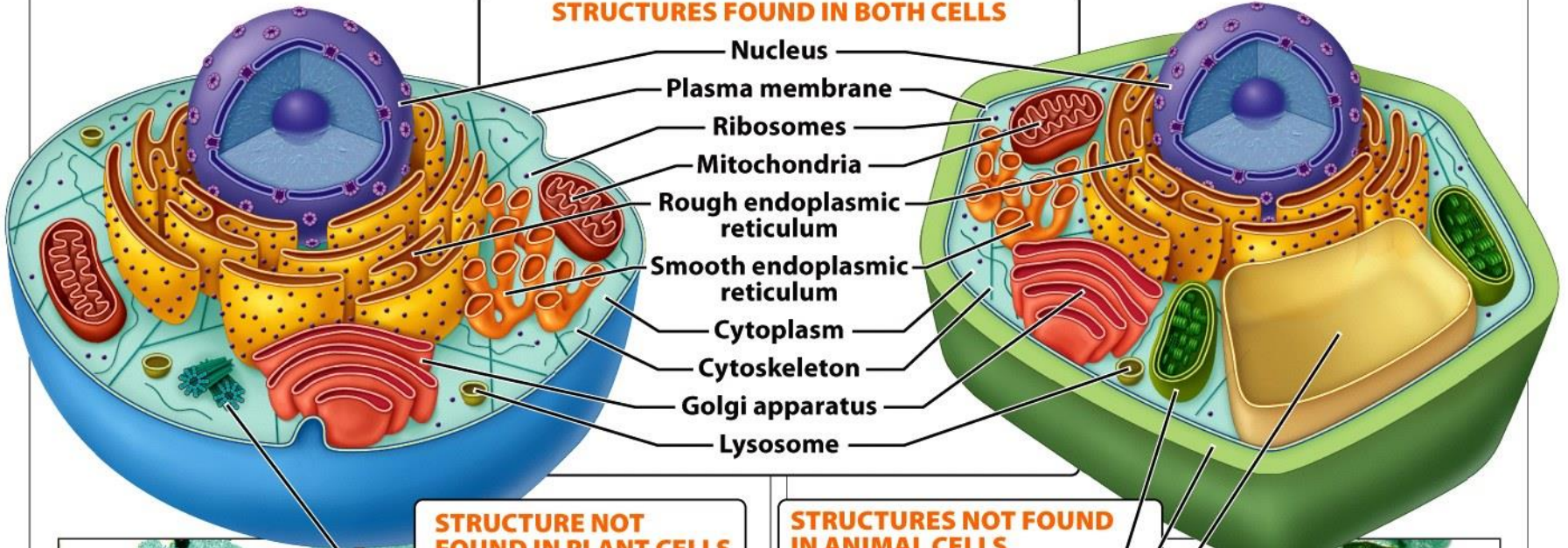
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THE ANIMAL CELL: BASIC STRUCTURE

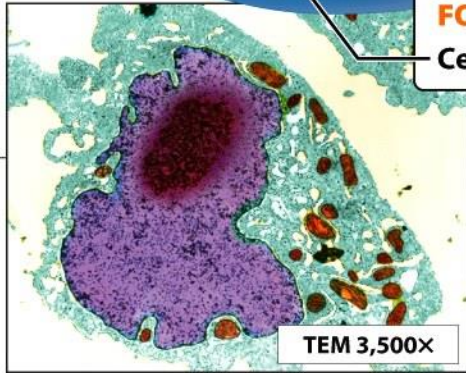
THE PLANT CELL: BASIC STRUCTURE

STRUCTURES FOUND IN BOTH CELLS



STRUCTURE NOT FOUND IN PLANT CELLS

Centriole



STRUCTURES NOT FOUND IN ANIMAL CELLS

- Chloroplast
- Cell wall
- Vacuole (occasionally found in animal cells)

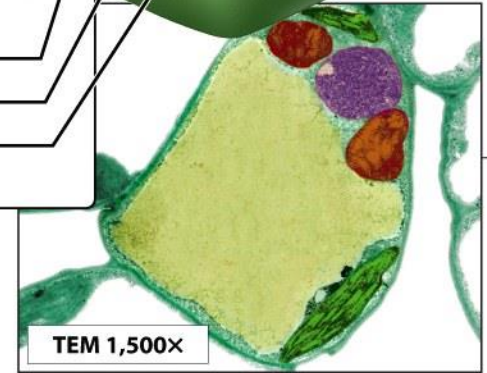


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3.4–3.7
Cell membranes
are gatekeepers.



3-4. Every cell is bordered by a plasma membrane.

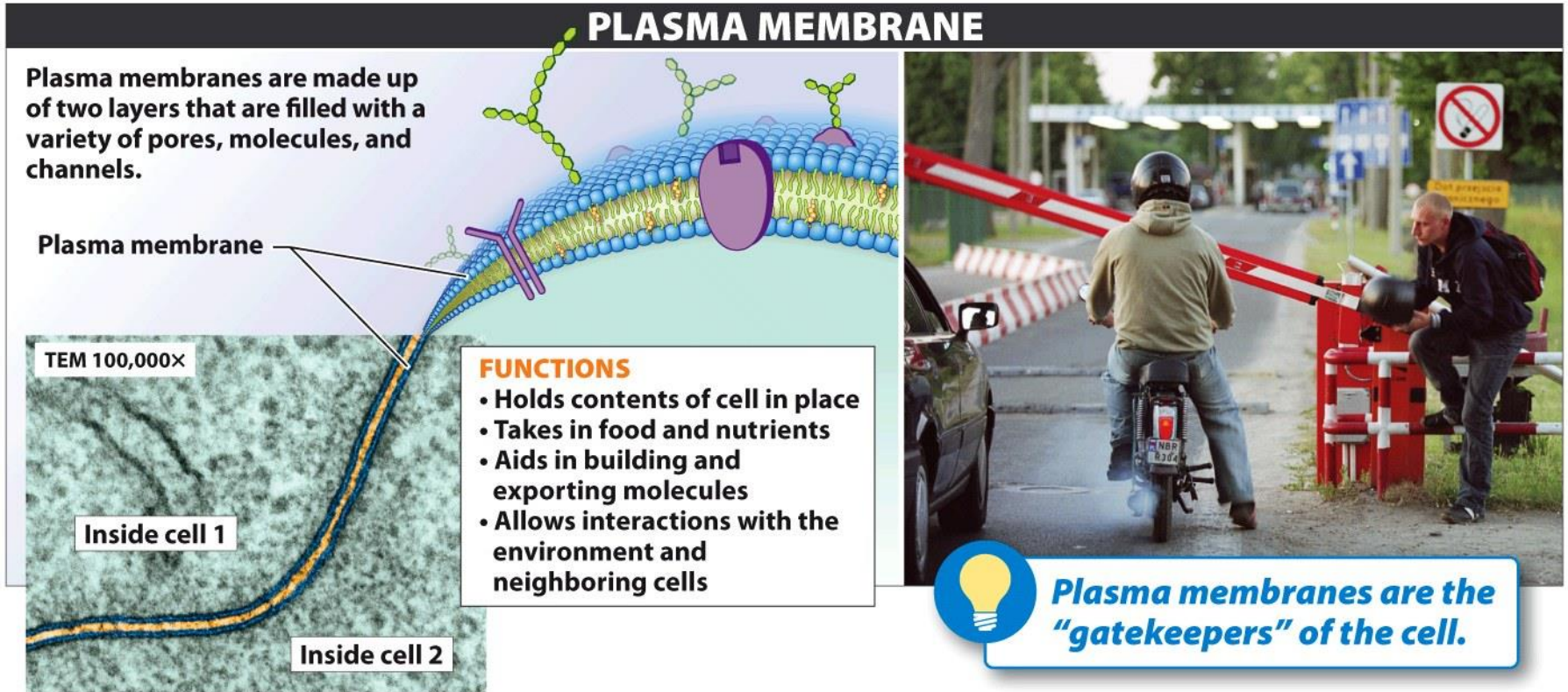


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Why are plasma membranes such complex structures?

They perform several critical functions.

- Take in food and nutrients
- Dispose of waste products
- Build and export molecules
- Regulate heat exchange
- Regulate flow of materials in and out of cell

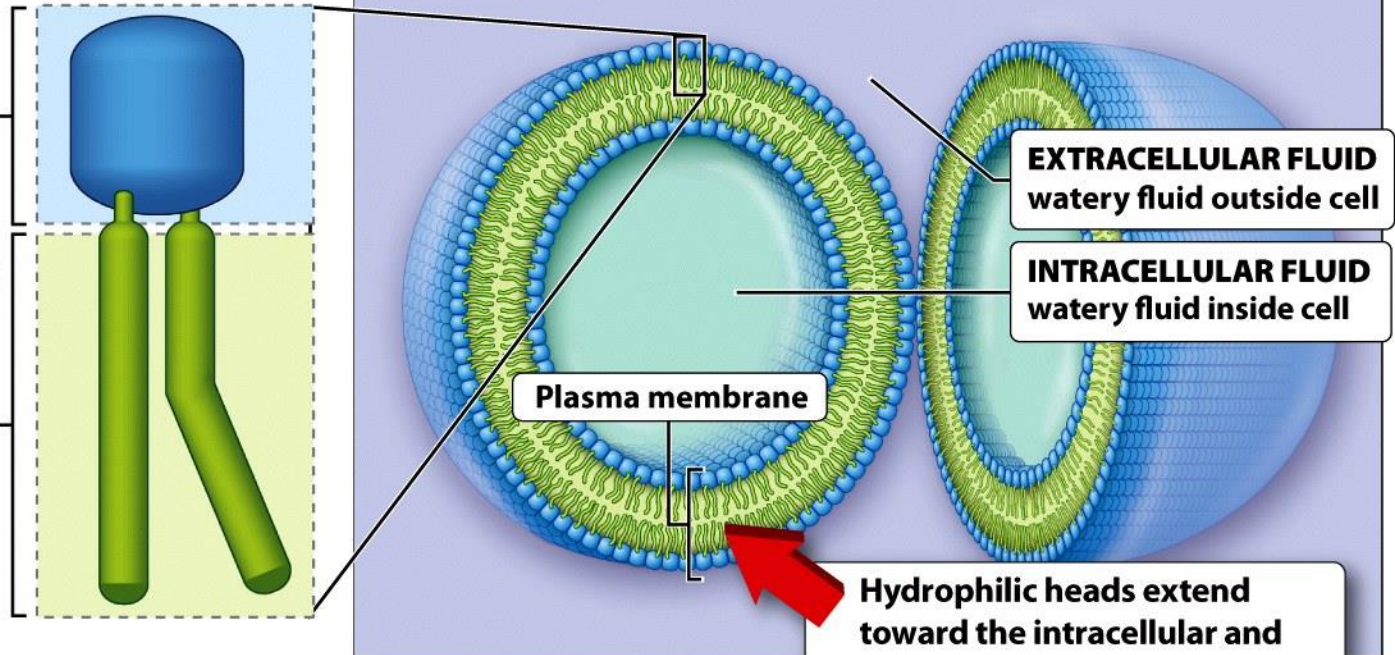
PHOSPHOLIPID BILAYER: STRUCTURE

HYDROPHILIC HEAD

- Attracted to water
- Composed of a glycerol linked to phosphorus-containing molecule

HYDROPHOBIC TAILS

- Not attracted to water
- Composed of carbon-hydrogen chains



Hydrophilic heads extend toward the intracellular and extracellular fluid, and hydrophobic tails are directed away from these watery fluids.

Figure 3-9

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Take-home message 3.4

- Every cell of every living organism is enclosed by a plasma membrane, a two-layered membrane that holds the contents of a cell in place and regulates what enters and leaves the cell.

3.5 Molecules embedded within the plasma membrane help it perform its functions.

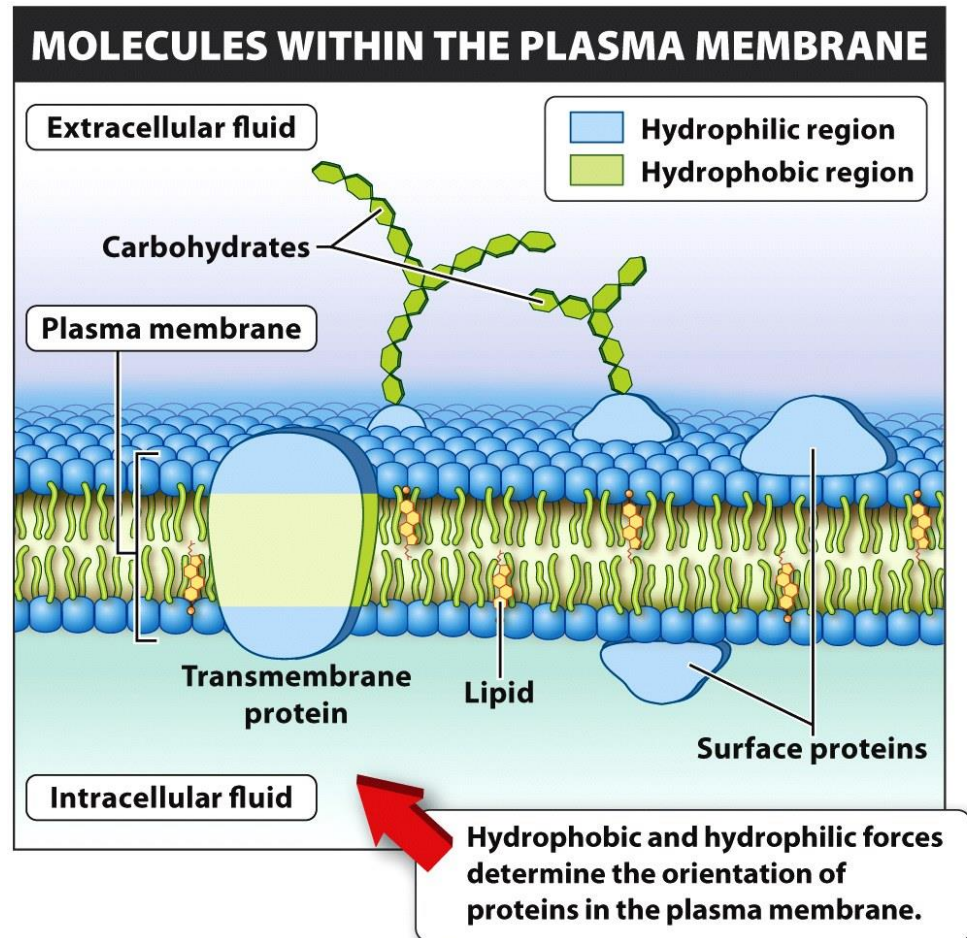


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What determines whether a protein resides on the surface or extends through the bilayer?

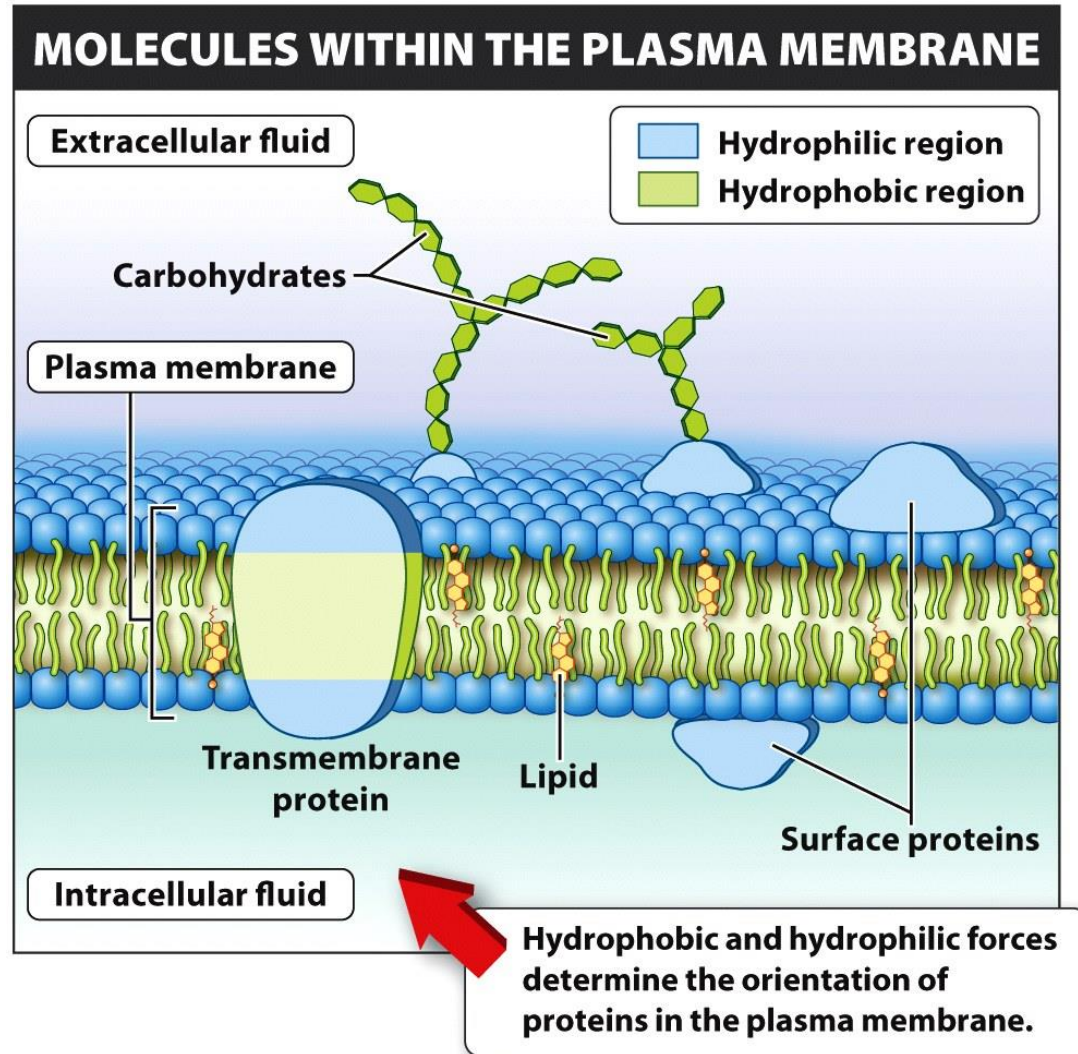


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There are four primary types of membrane proteins, each of which performs a different function.

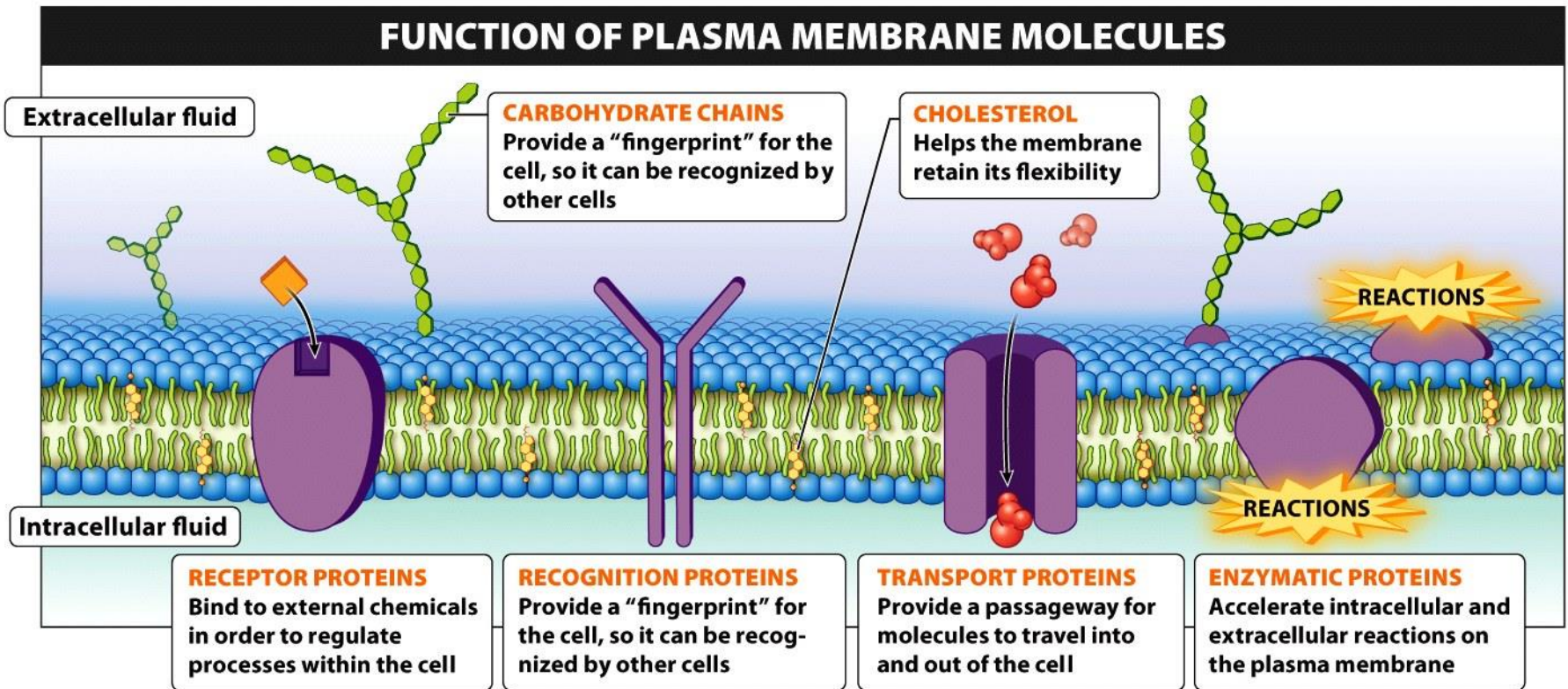


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The Plasma Membrane

“Fluid Mosaic”

In addition to proteins, two other molecules are found in the plasma membrane:

1. Short, branched carbohydrate chains
2. Cholesterol

Take-home message 3.5

- The plasma membrane is a fluid mosaic of proteins, lipids, and carbohydrates.

Take-home message 3.5

- Proteins found in the plasma membrane enable it to carry out most of its gatekeeping functions.
- The proteins function as receptors, help molecules gain entry into and out of the cell, and catalyze reactions on the inner and outer cell surfaces.

Take-home message 3.5

- Carbohydrates and plasma proteins identify the cell to other cells.
- Phospholipids make up the majority of plasma membranes, while cholesterol influences membrane fluidity.

3.7 Membrane surfaces have a “fingerprint” that identifies the cell.

- Cells with an improper fingerprint are recognized as foreign and are attacked by your body’s defenses.

LIVER TRANSPLANT

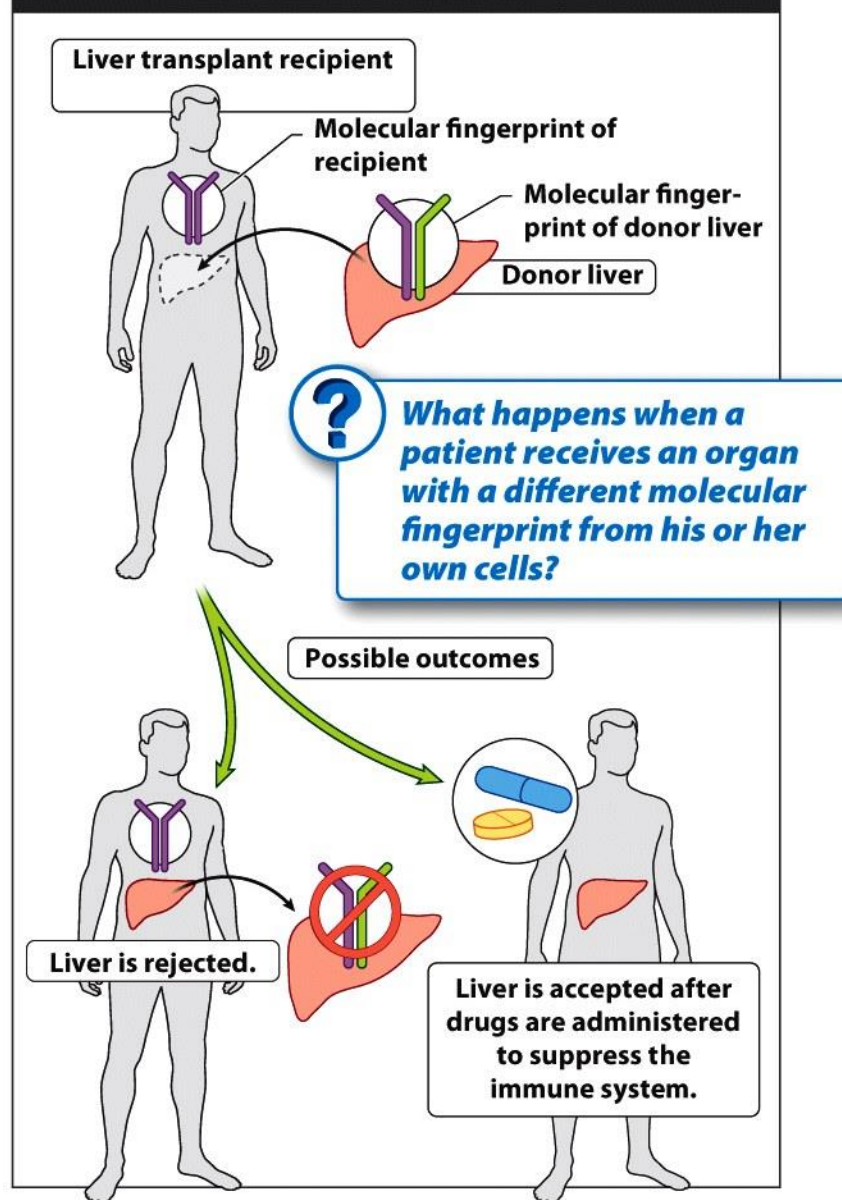


Figure 3-14

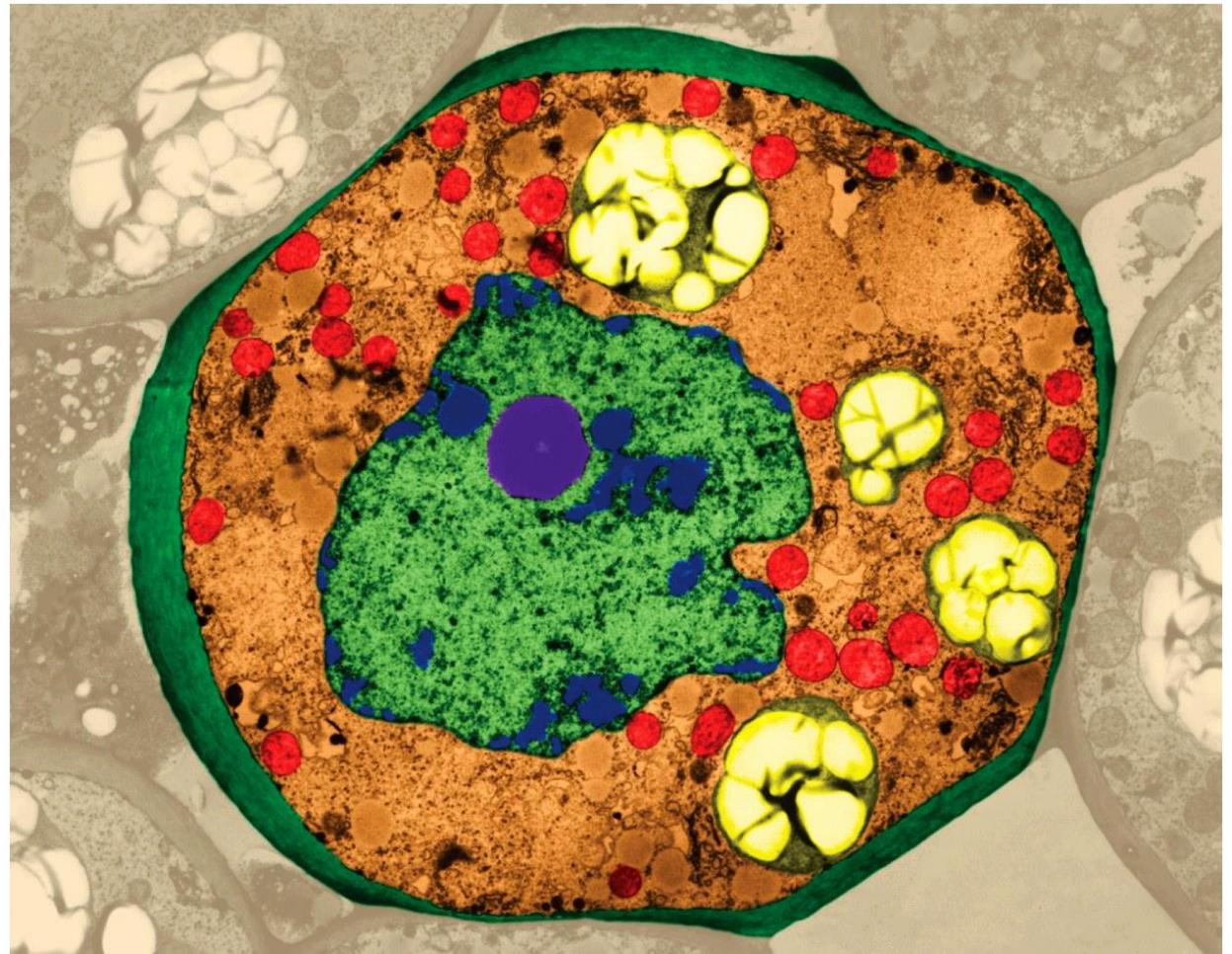
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Take-home message 3.7

- Every cell in your body has a “fingerprint” made from a variety of molecules on the outside-facing surface of the cell membrane.
- This molecular fingerprint is key to the function of your immune system.

3.13–3.21
Nine important
landmarks
distinguish
eukaryotic cells.



3.13 The nucleus is the cell's genetic control center.

- The nucleus—the largest and most prominent organelle in most eukaryotic cells.
- The nucleus has two primary functions:
 - genetic control center
 - storehouse for hereditary information

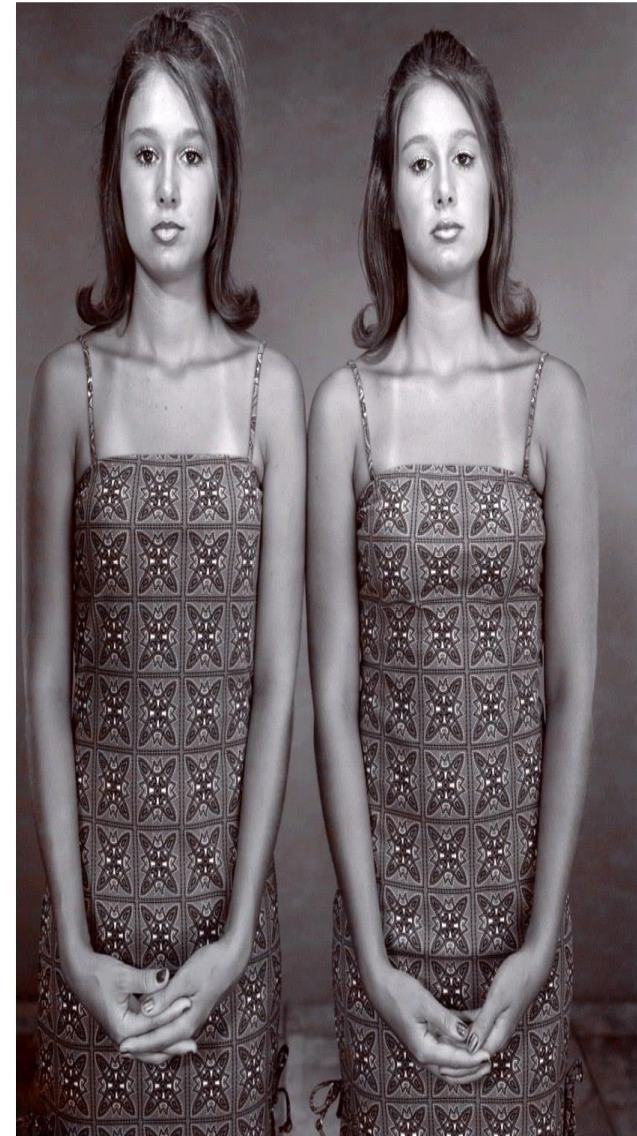


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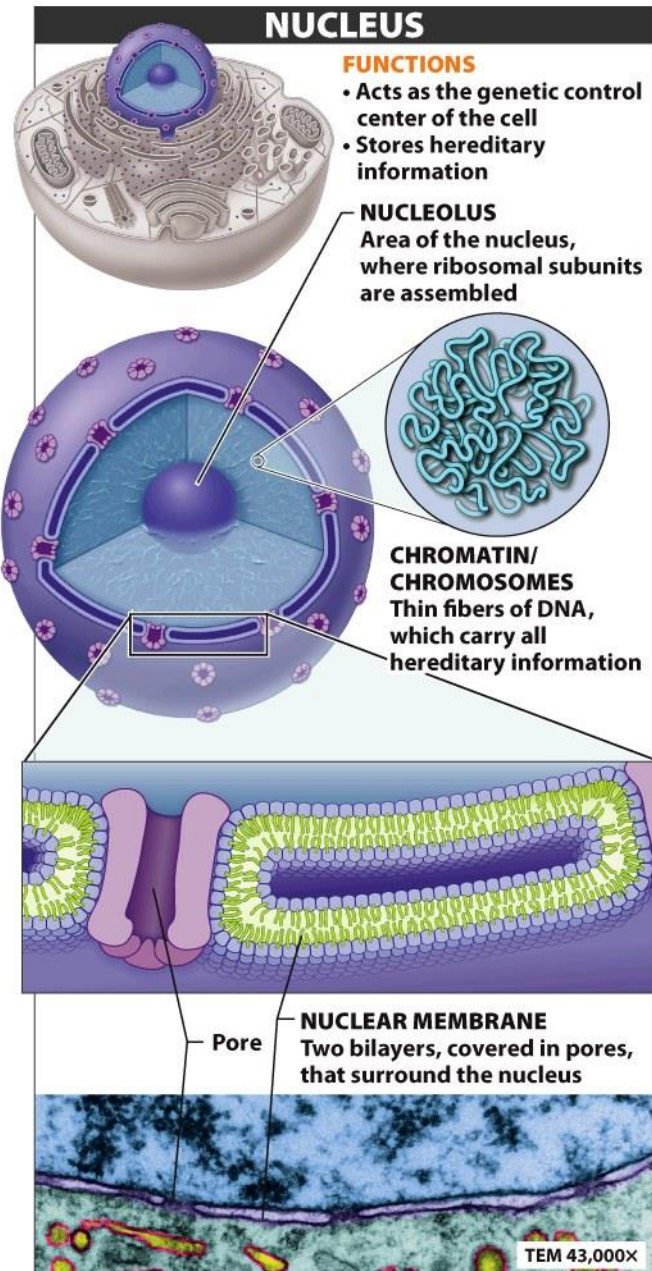


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Chromatin

- a mass of long, thin fibers consisting of DNA with some proteins attached

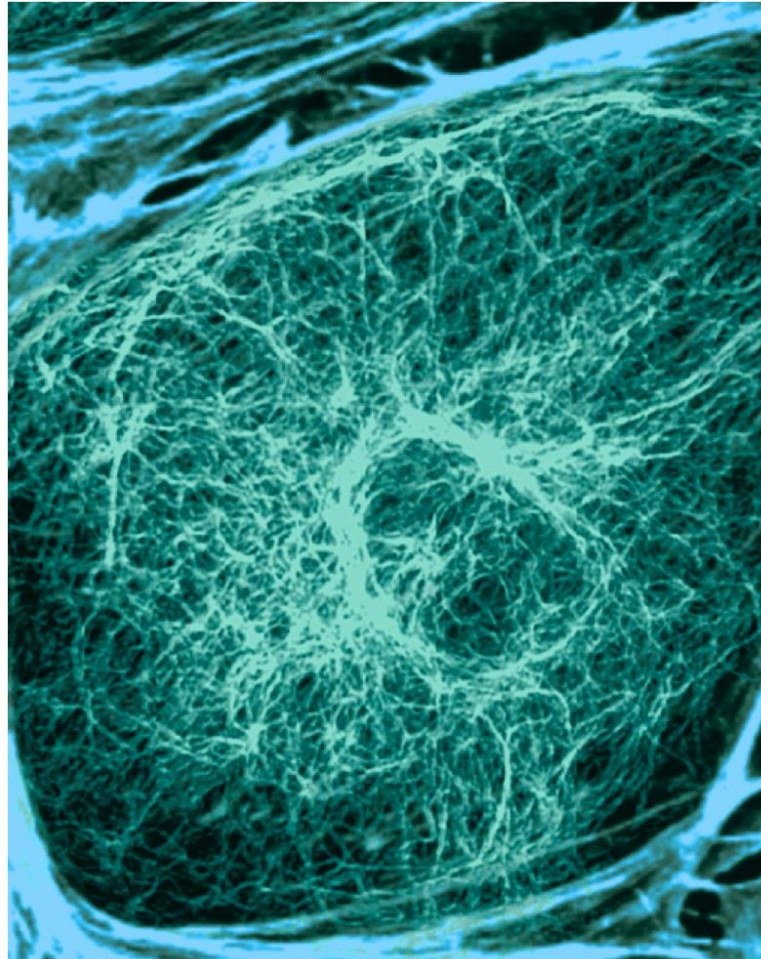
Nucleolus

- an area near the center of the nucleus where subunits of the **ribosomes** are assembled
- Ribosomes are like little factories.

Take-home message 3.13

- The nucleus is usually the largest and most prominent organelle in the eukaryotic cell.
- It directs most cellular activities by controlling which molecules are produced and in what quantity they are produced.
- The nucleus is also the storehouse for all hereditary information.

3.14 Cytoplasm and cytoskeleton: the cell's internal environment, physical support, and movement



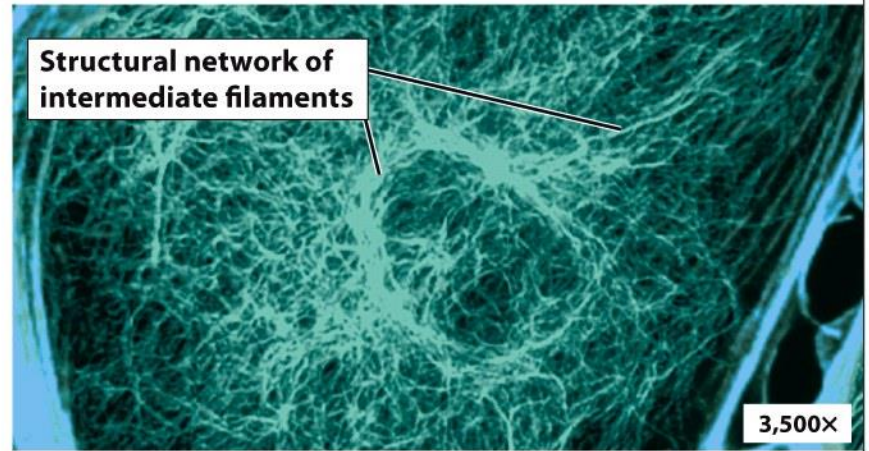
Cytoskeleton: Three Chief Purposes

CYTOSKELETON



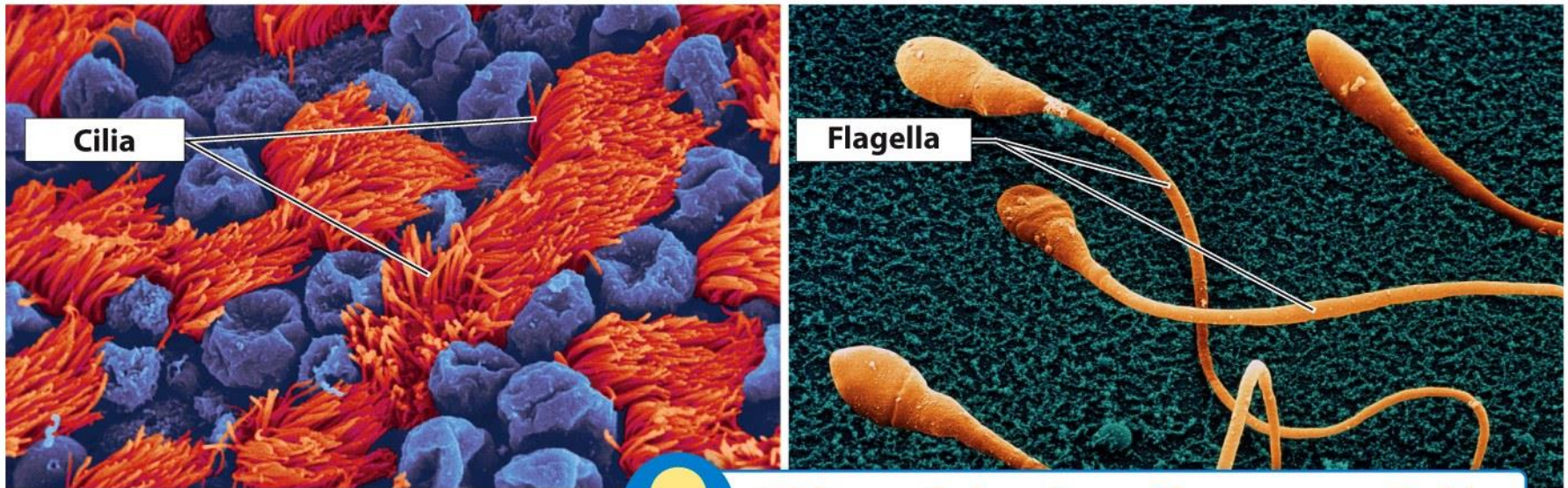
FUNCTIONS

- Acts as the inner scaffolding of the cell
- Provides shape and support
- Controls intracellular traffic flow
- Enables movement



Cilia and Flagellum

CELLULAR MOVEMENT



With gentle beating, cilia can move fluid past cells, whereas flagella, with whip-like motions, can move the cells themselves.

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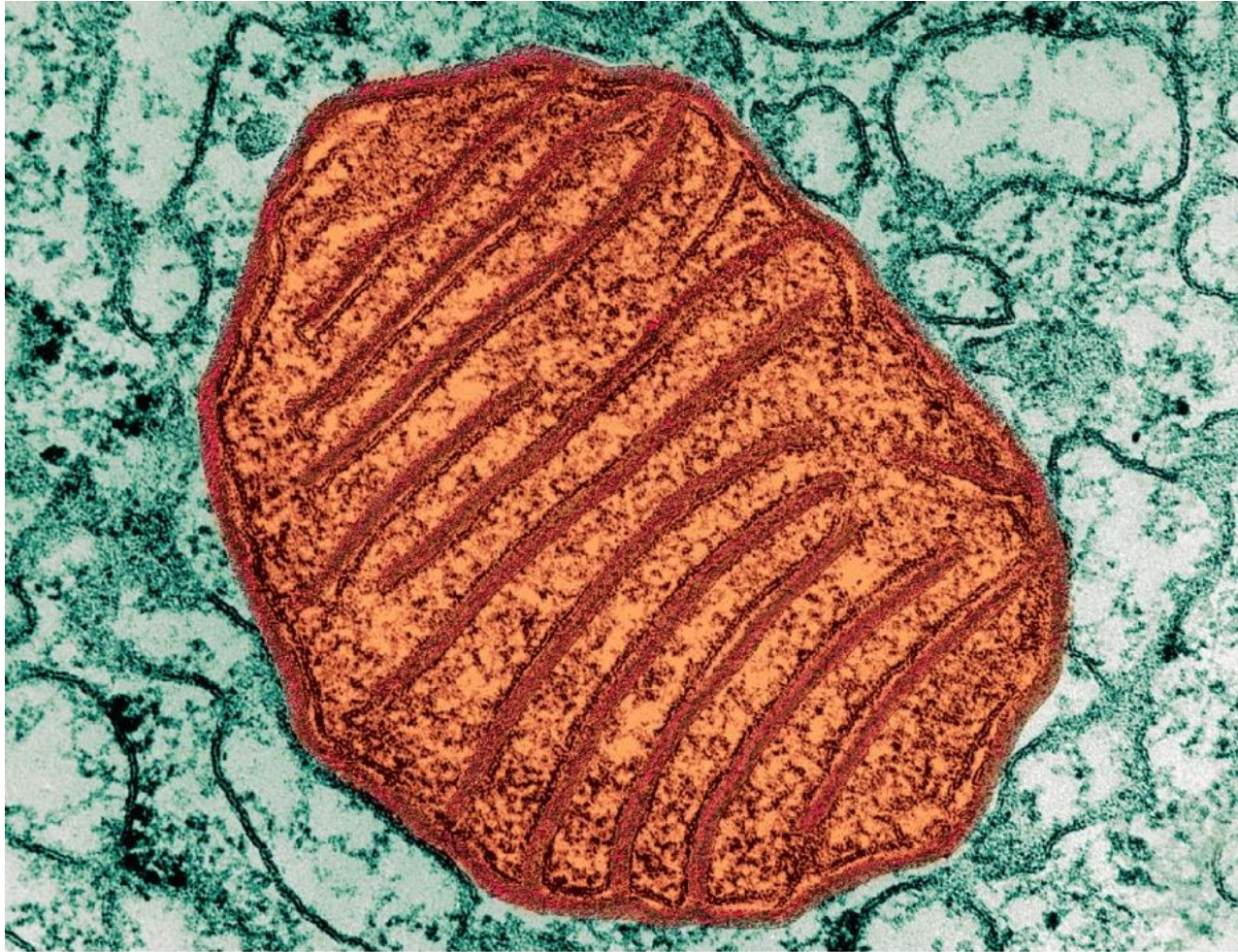
Take-home message 3.14

- The inner scaffolding of the cell, which is made from proteins, is the cytoskeleton.

Take-home message 3.14

- It gives animal cells shape and support.
- It gives cells some ability to control their movement.
- It serves as a series of tracks on which organelles and molecules are guided across and around the inside of the cell.

3.15 Mitochondria: the cell's energy converters

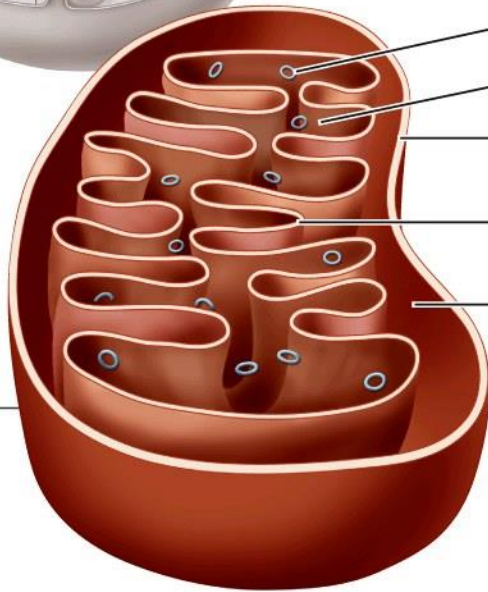


Bag-within-a-Bag Structure: *the intermembrane space and the matrix*

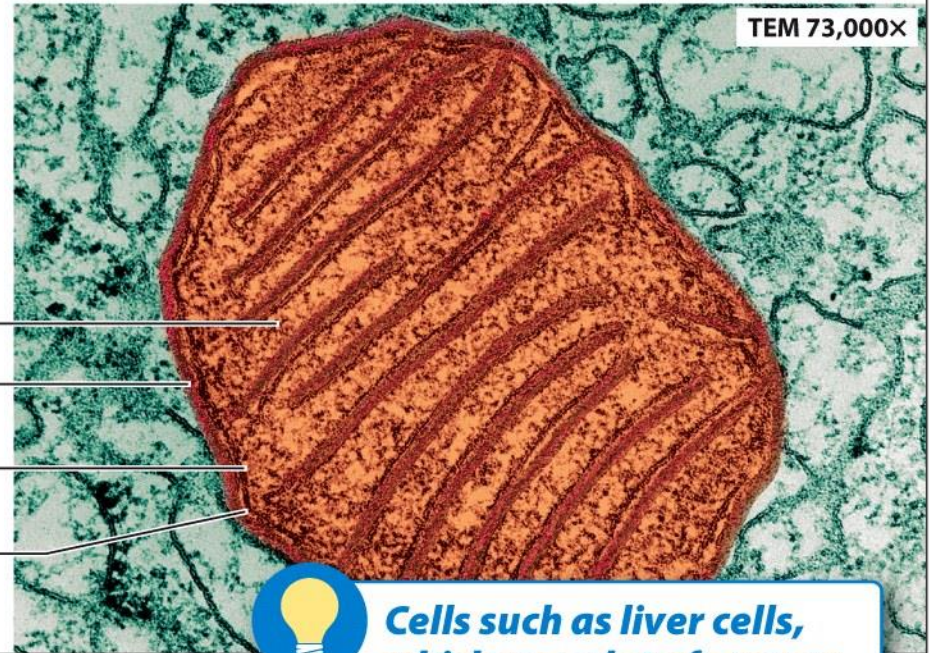
MITOCHONDRIA

FUNCTIONS

- Act as all-purpose energy converters
- Harvest energy to be used for cellular functions



DNA
Matrix
Outer membrane
Inner membrane
Intermembrane space



Cells such as liver cells, which use a lot of energy, can have up to 2,500 mitochondria!

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**We all have more DNA
from one parent than
the other.**

*Who is the bigger contributor:
mom or dad?*

Why?

Which statement about mitochondria is false?

1. Mitochondria are surrounded by two membranes.
2. Mitochondria make energy of the cell (ATP).
3. You inherited half of your mitochondria from your mother.
4. The characteristics of mitochondria can be explained by endosymbiosis.

Which cell type contains the most mitochondria per cell?

1. Liver
2. Muscle
3. White blood cell
4. Dermal cell
5. White adipose cell
6. Red blood cell

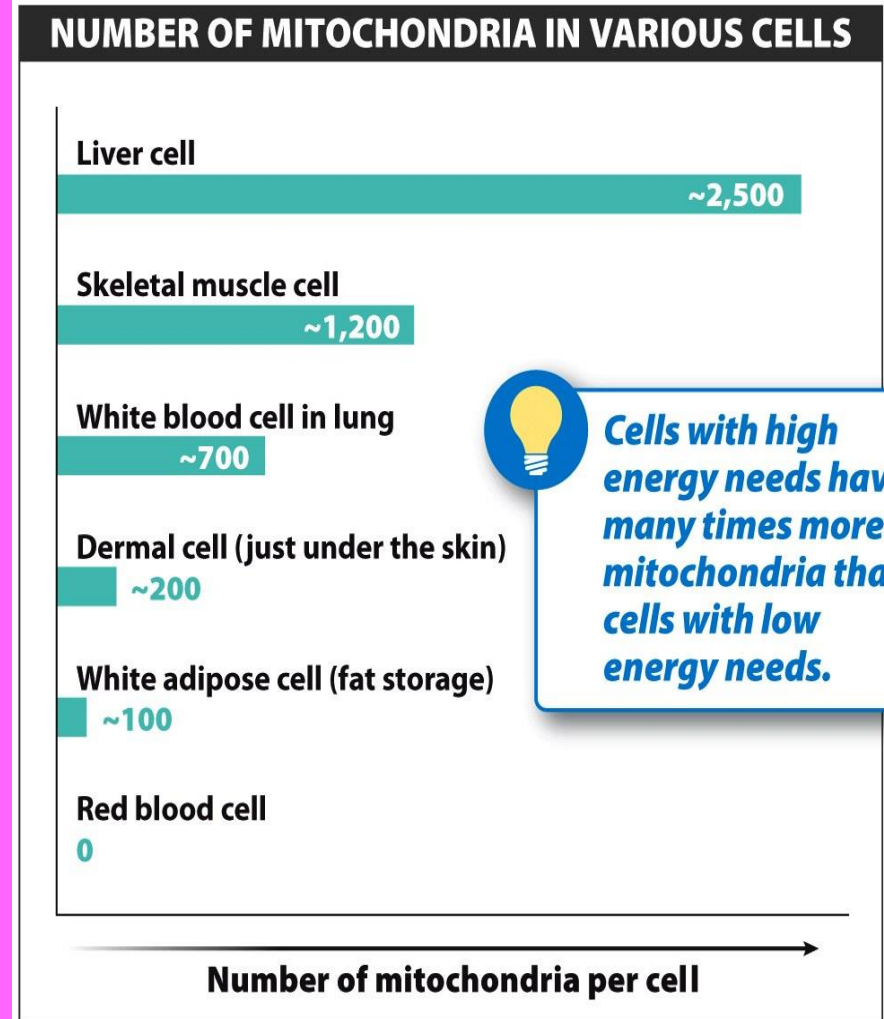


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Which cell type in the graph might require the most energy?

1. Liver
2. Muscle
3. White blood cell
4. Dermal cell
5. White adipose cell
6. Red blood cell

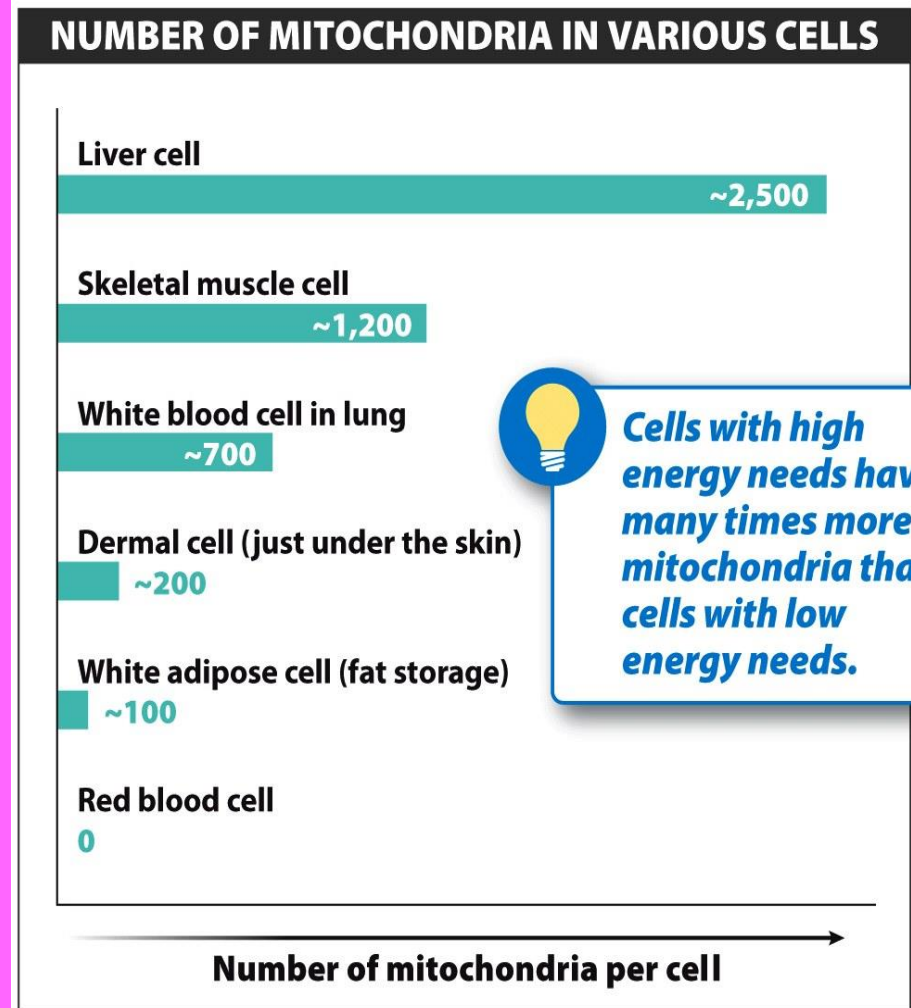


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Take-home message 3.15

- ❑ In mitochondria, the energy contained within the chemical bonds of carbohydrate, fat, and protein molecules is converted into carbon dioxide, water, and ATP—the energy source for all cellular functions and activities.
- ❑ Mitochondria may have their evolutionary origins as symbiotic bacteria living within other cells.

3.16 Lysosomes are the cell's garbage disposals.

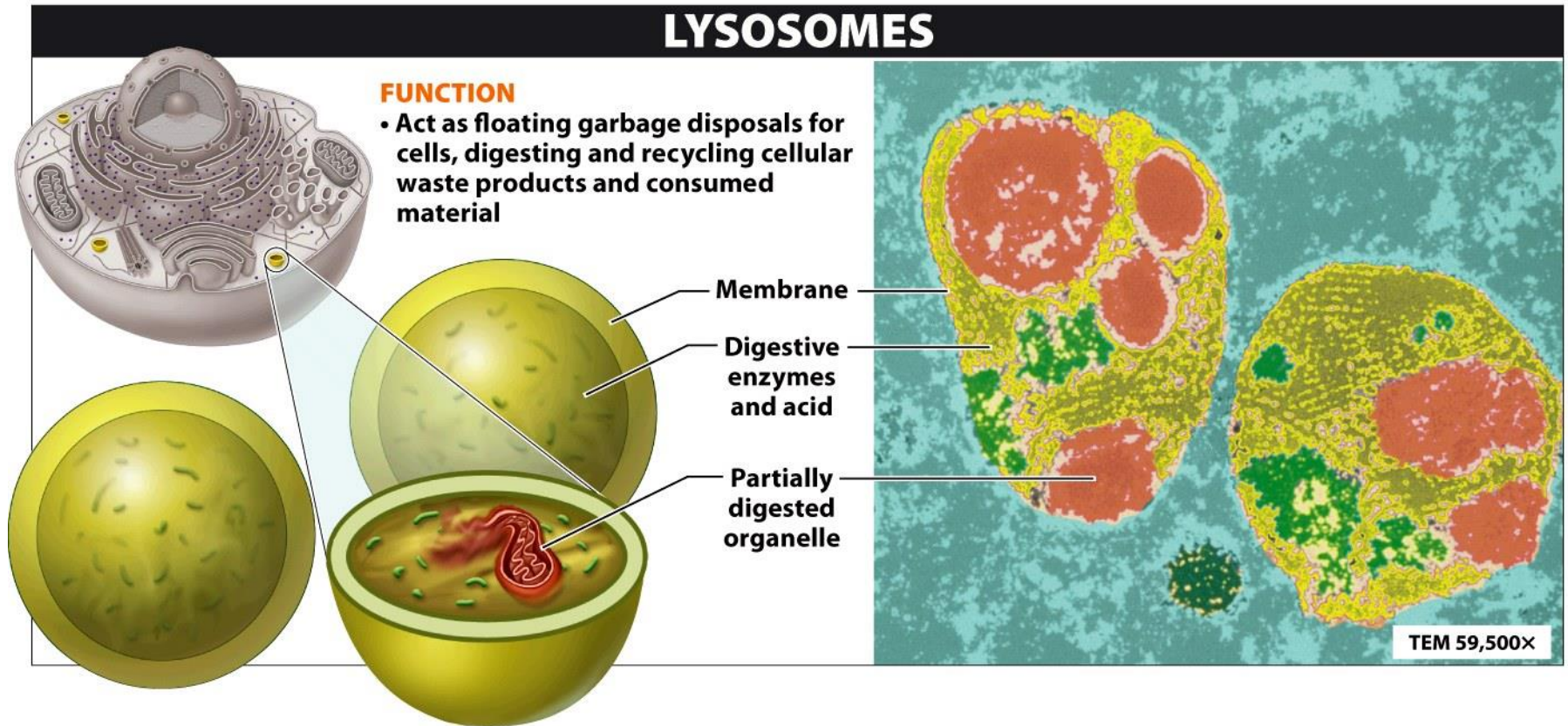


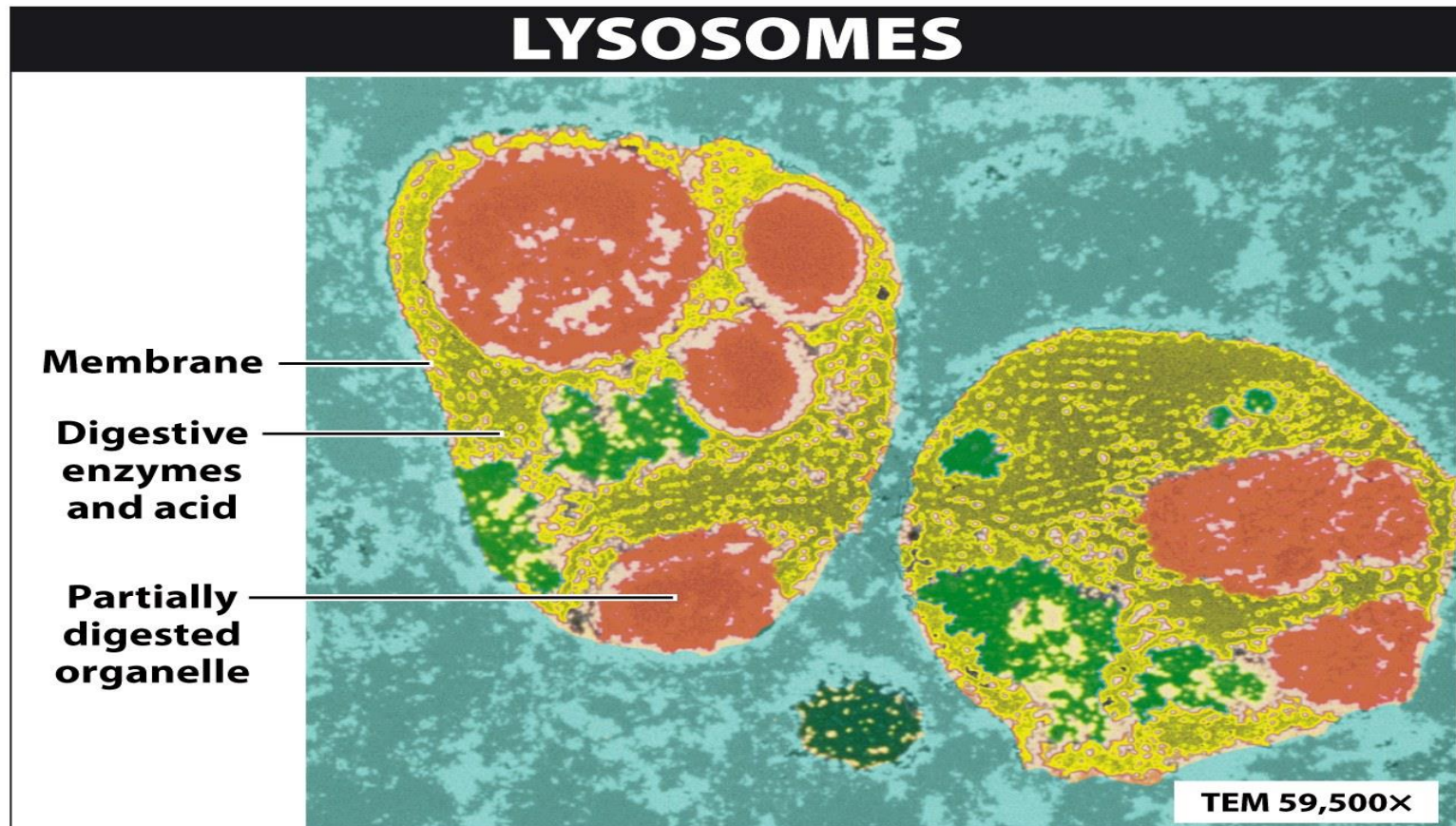
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Lysosomes

round, membrane-enclosed, acid-filled vesicles that function as garbage disposals



Take-home message 3.16

- Lysosomes are round, membrane-enclosed, acid-filled vesicles that function as a cell's garbage disposal.
- They are filled with about 50 different digestive enzymes and enable a cell to dismantle macromolecules, including disease-causing bacteria.

The Endomembrane System

Rough E.R. Smooth E.R. and Golgi

OVERVIEW OF THE ENDOMEMBRANE SYSTEM

FUNCTIONS

- Produces and modifies molecules to be exported to other parts of the organism
- Breaks down toxic chemicals and cellular by-products

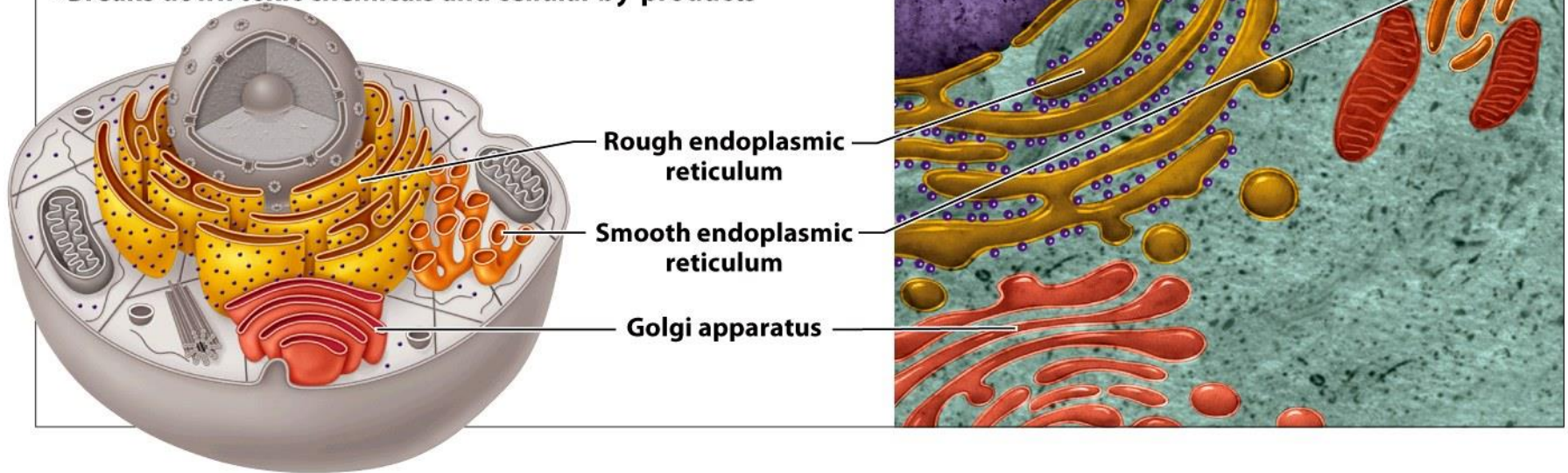
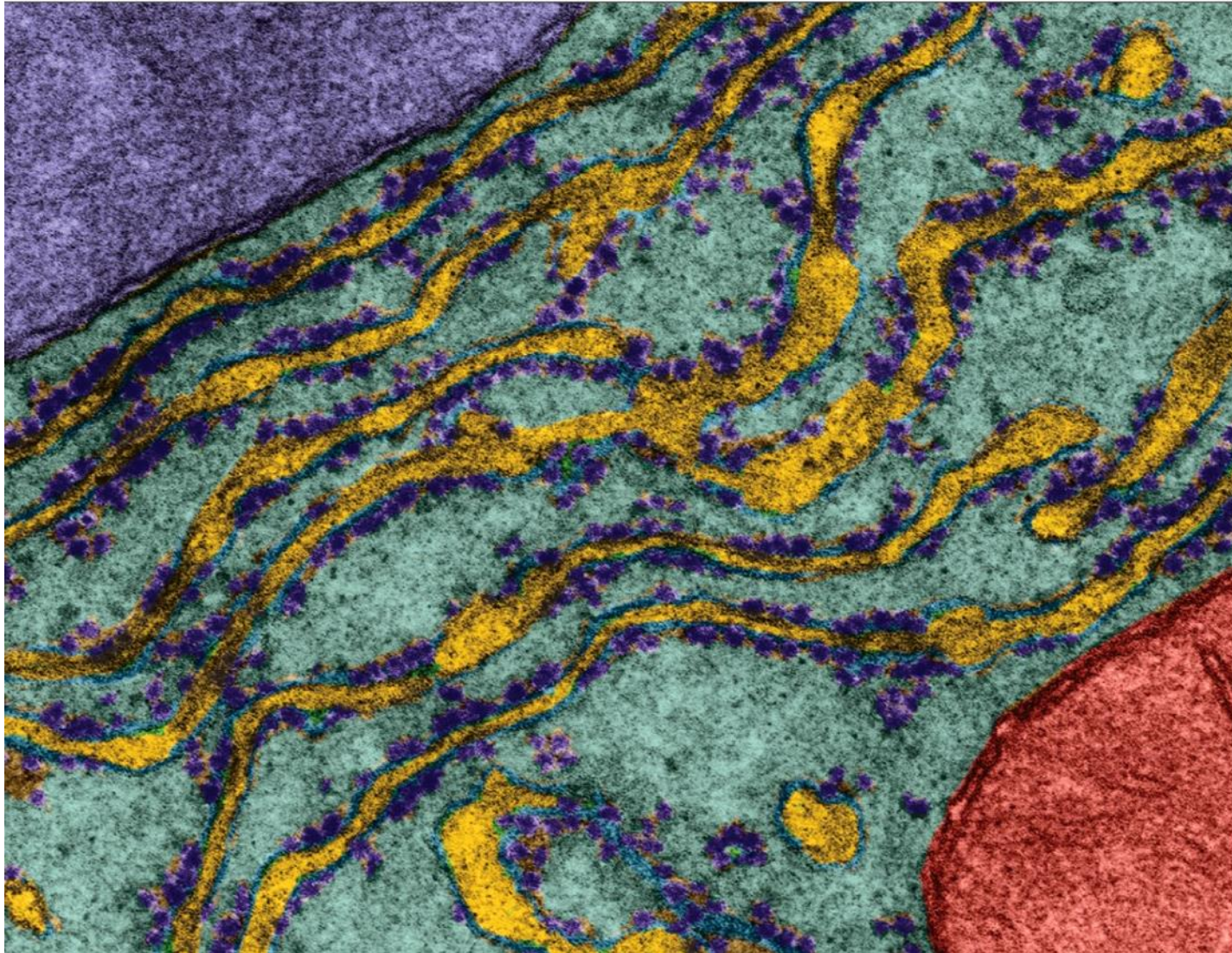


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3.17 Endoplasmic reticulum: where cells build proteins and disarm toxins



Rough Endoplasmic Reticulum

ROUGH ENDOPLASMIC RETICULUM

FUNCTION

- Modifies proteins that will be shipped to other locations in the endomembrane system, the cell surface, or outside the cell

Ribosomes

Rough ER is covered in ribosomes. Ribosomes are protein-making machines.

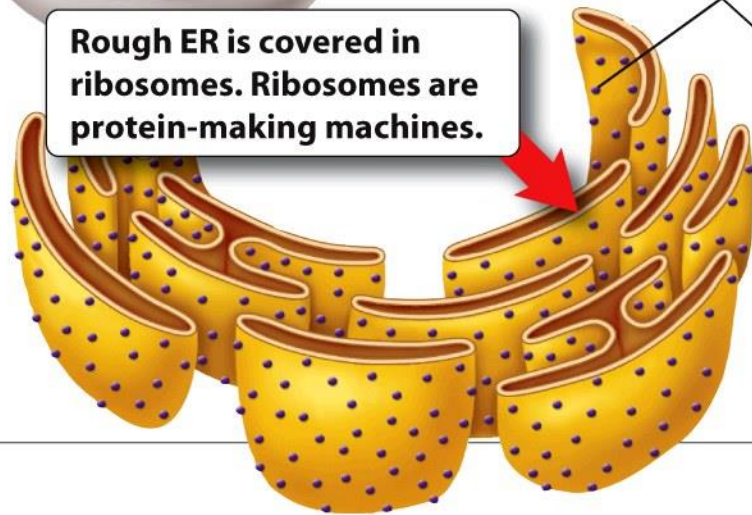
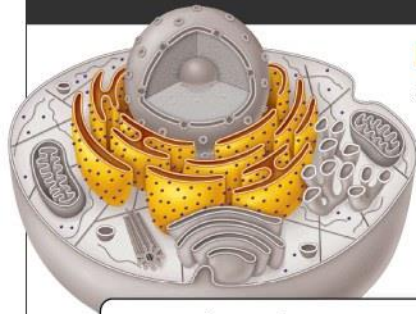
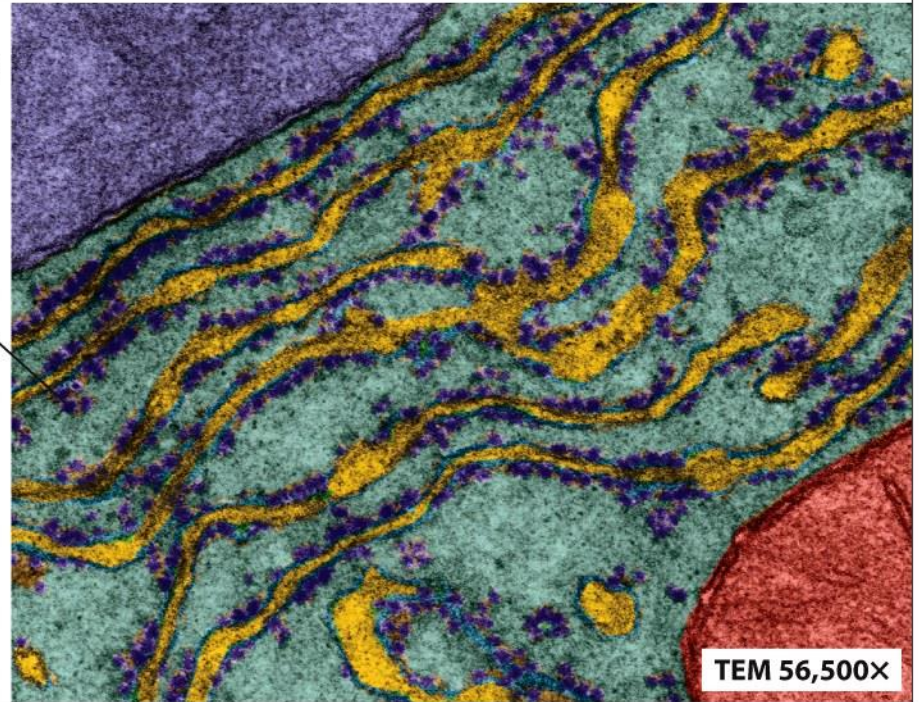


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The Smooth Endoplasmic Reticulum

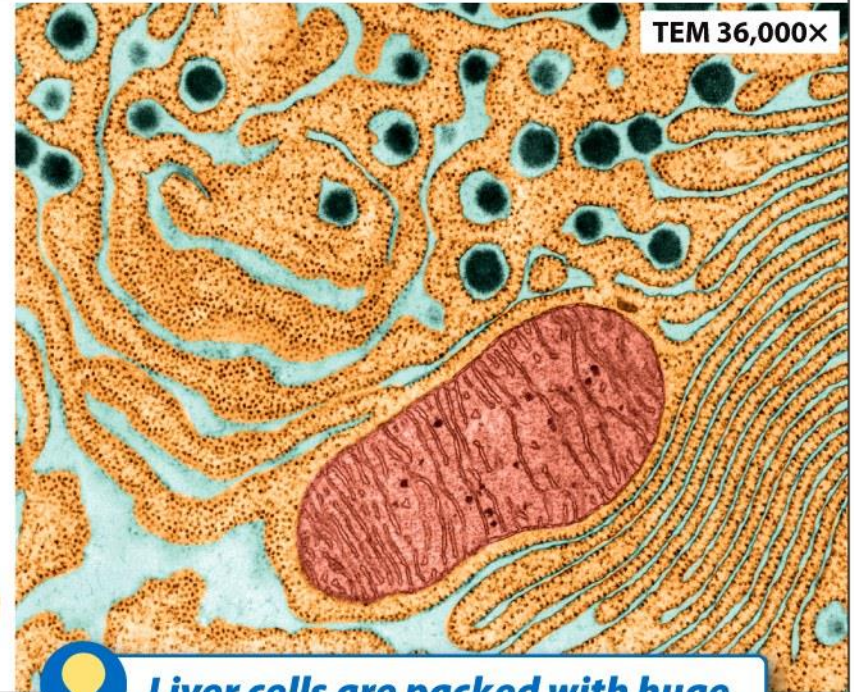
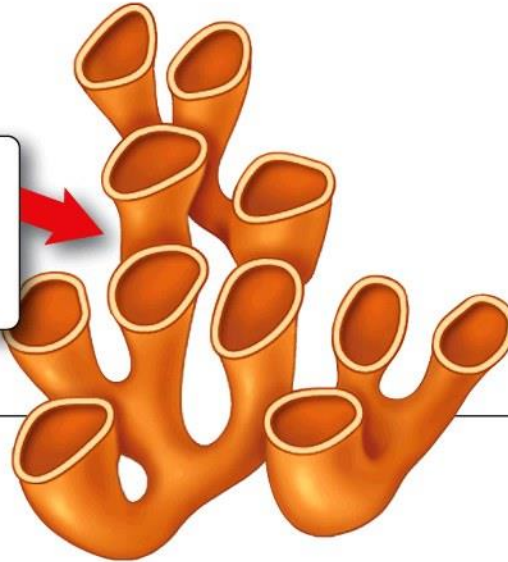
SMOOTH ENDOPLASMIC RETICULUM



FUNCTIONS

- Synthesizes lipids such as fatty acids, phospholipids, and steroids
- Detoxifies molecules such as alcohol, drugs, and metabolic waste products

Smooth ER is called "smooth" because it has no ribosomes on its surface.



Liver cells are packed with huge amounts of smooth ER, because the liver is the primary site for detoxifying harmful molecules.

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Take-home message 3.17

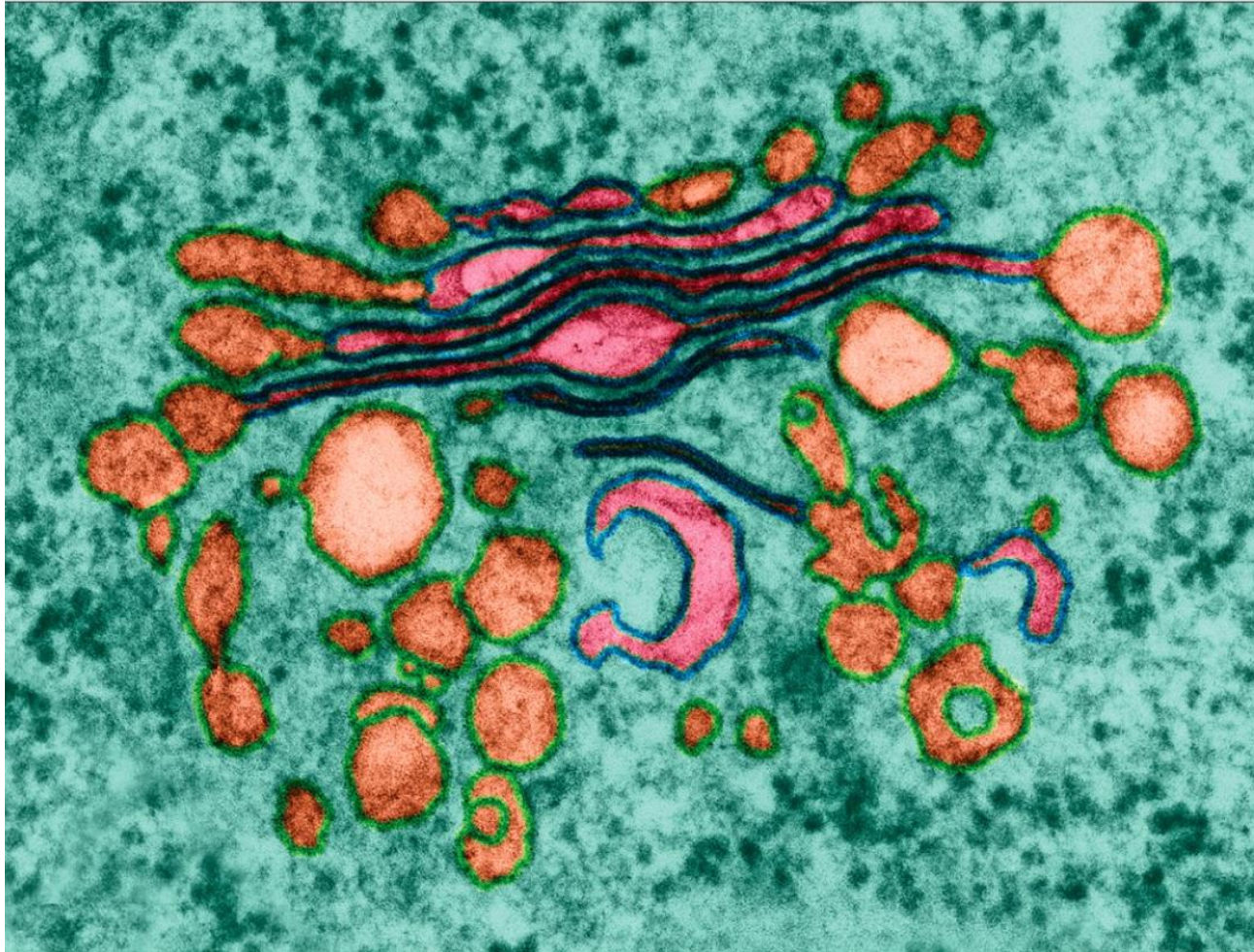
- The production and modification of biological molecules within eukaryotic cells occurs in a system of organelles called the endomembrane system, which includes the rough and smooth endoplasmic reticulum.

Take-home message 3.17

- In rough ER, proteins that will be shipped elsewhere in the body are folded and packaged.
- In the smooth ER, lipids are synthesized and alcohol, antibiotics, and other drugs are detoxified.

3.18 The Golgi apparatus processes products for delivery throughout the body.

3.18 Golgi apparatus: Where the cell processes products for delivery throughout the body



GOLGI APPARATUS

FUNCTION

- Processes and packages proteins, lipids, and other molecules for export to other locations in or outside of the cell

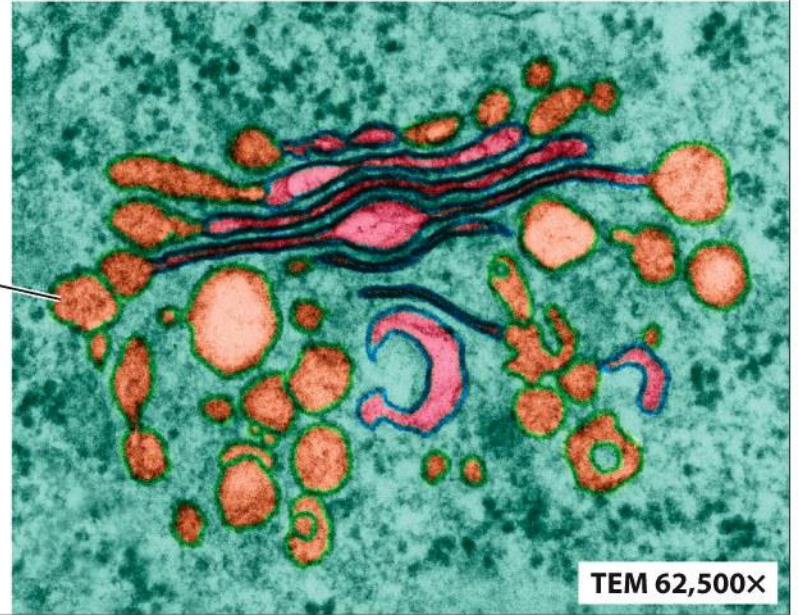
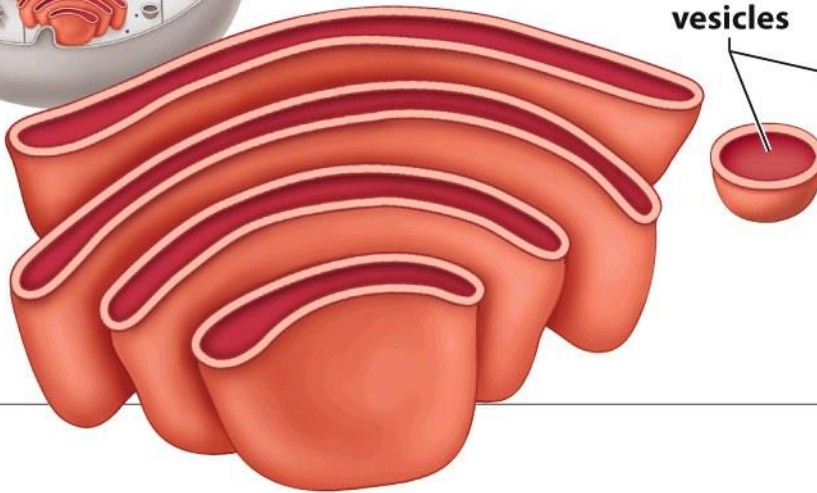


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THE ENDOMEMBRANE SYSTEM AT WORK

- 1** Transport vesicle buds from the smooth or rough ER.
- 2** Transport vesicle fuses with Golgi apparatus, dumping contents inside.
- 3** Golgi apparatus modifies the molecules as they move through its successive chambers.
- 4** Modified molecules bud off from the Golgi apparatus as a transport vesicle.
- 5** Vesicle may fuse with the plasma membrane, dumping contents outside the cell for delivery elsewhere in the organism.

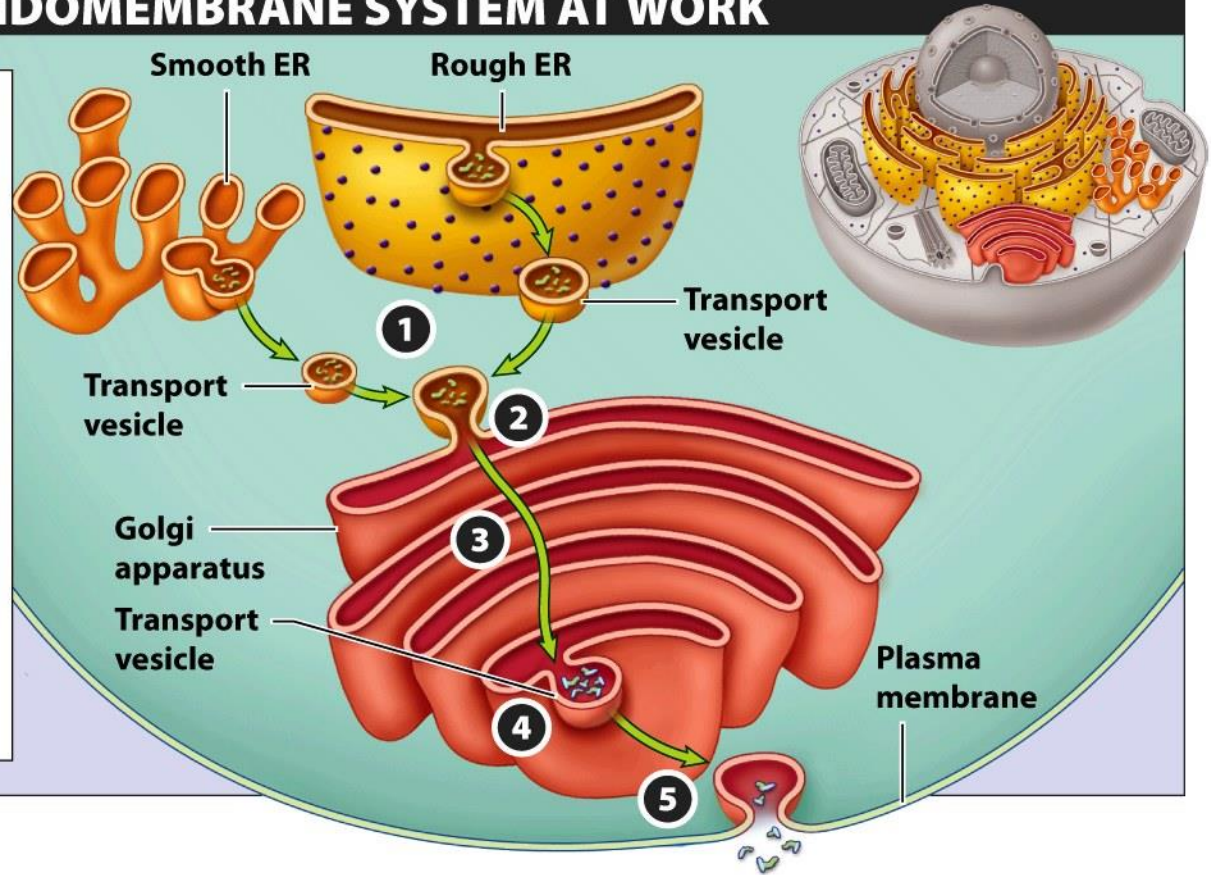


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You can think of a cell as a car factory. The control center holds the directions for making the car. There are assembly lines for constructing the engine and frame of the car. After the main structure of the car is built, the finishing touches are added (paint, leather seats, chrome bumpers). Lastly, the car is shipped to different car dealers. Which organelle would be responsible for putting the finishing touches on the car (protein)?

1. Nucleus
2. Ribosome
3. Rough endoplasmic reticulum
4. Smooth endoplasmic reticulum
5. Golgi apparatus

Take-home message 3.18

- The Golgi apparatus—another organelle within the endomembrane system—processes molecules synthesized within a cell and packages those that are destined for use elsewhere in the body.

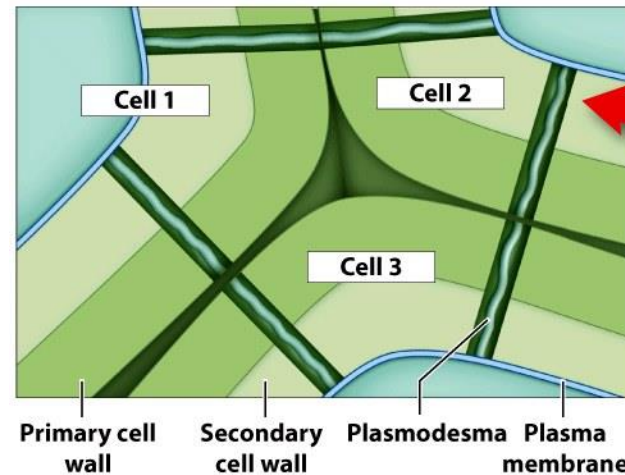
3.19 The cell wall provides additional protection and support for plant cells.

PLANT CELL WALL



FUNCTIONS

- Provides the cell with structural strength
- Gives the cell increased water resistance
- Provides some protection from insects and other animals that might eat plant parts



Plasmodesmata allow water and other molecules to pass between adjacent cells.

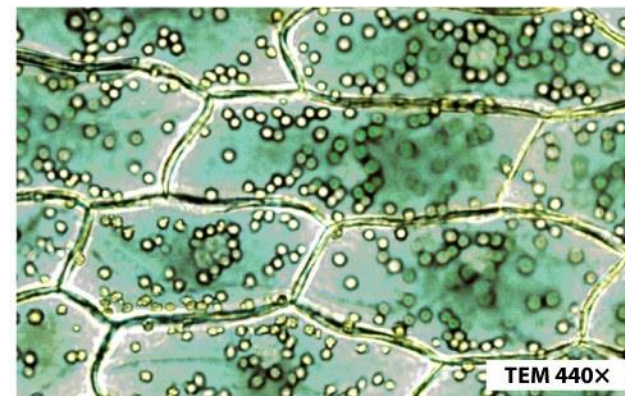


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Take-home message 3.19

- ❑ The cell wall is an organelle found in plants (and some other non-animal organisms).
- ❑ It is made primarily from the carbohydrate cellulose and it surrounds the plasma membrane of a plant cell.

Take-home message 3.19

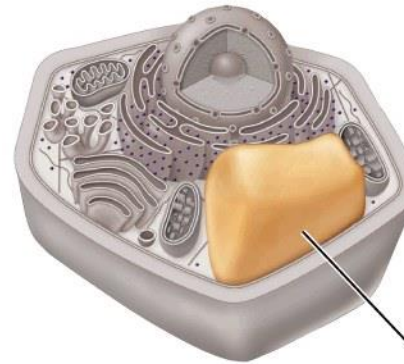
- The cell wall confers tremendous structural strength on plant cells, gives plants increased water resistance, and provides some protection from insects and other animals that might eat them.
- In plants, plasmodesmata connect cells and enable communication and transport between them.

3.20 Vacuoles: multipurpose storage sacs for cells

VACUOLE

FUNCTIONS

- Stores nutrients
- Retains and degrades waste products
- Accumulates poisonous materials
- Contains pigments, enabling plants to attract birds and insects that help the plant reproduce
- Provides physical support



Vacuole



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The central vacuole can play an important role in five different areas of plant life:

1. Nutrient storage
2. Waste management
3. Predator deterrence
4. Sexual reproduction
5. Physical support

Take-home message 3.20

- ❑ In plants, vacuoles can occupy most of the interior space of the cell.
- ❑ Vacuoles also appear in some other eukaryotic species.
- ❑ They function as storage space and play a role in nutrition, waste management, predator deterrence, reproduction, and physical support.

3.21 Chloroplasts: the plant cell's power plant

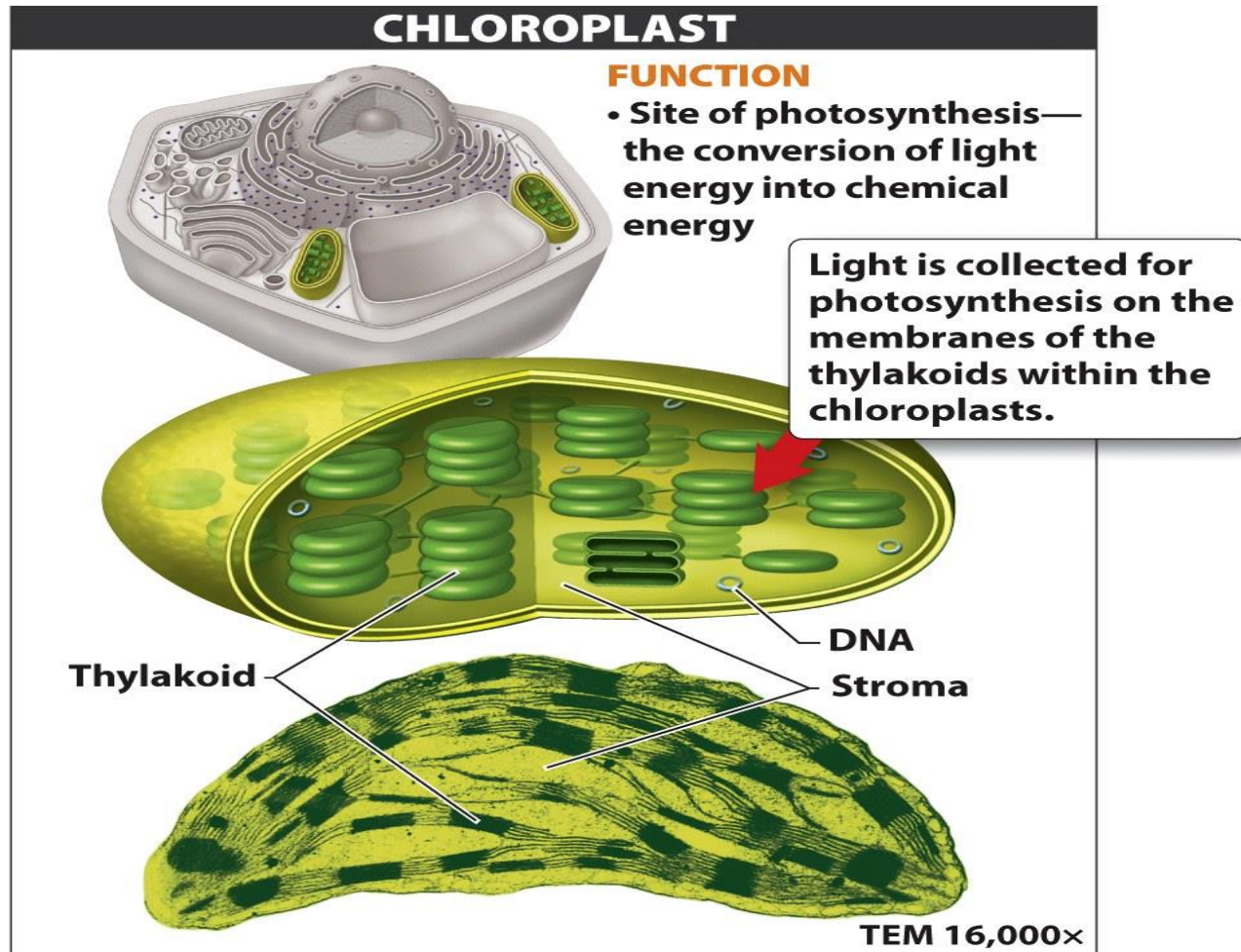


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CHLOROPLAST

FUNCTION

- Site of photosynthesis—the conversion of light energy into chemical energy

Light is collected for photosynthesis on the membranes of the thylakoids within the chloroplasts.

The **stroma** and interconnected little flattened sacs called **thylakoids**

Thylakoid

DNA

Stroma

TEM 16,000x











REVIEW OF CELL STRUCTURES			
STRUCTURE	ANIMALS	PLANTS	FUNCTION
 Nucleus	✓	✓	Directs cellular activity and stores hereditary information
 Cytoskeleton	✓	✓	Provides structural shape and support and enables cellular movement
 Mitochondrion	✓	✓	Harvests energy for cellular functions
 Lysosome	✓	✓	Digests and recycles cellular waste products and consumed material
 Rough ER	✓	✓	Modifies proteins that will be shipped elsewhere in the organism
 Smooth ER	✓	✓	Synthesizes lipids and detoxifies molecules
 Golgi apparatus	✓	✓	Processes and packages proteins, lipids, and other molecules
 Cell wall	✗	✓	Provides structural strength, protection, and increased resistance to water loss
 Vacuole	Sometimes	✓	Stores nutrients, degrades waste products, provides pigments and structural support
 Chloroplast	✗	✓	Performs photosynthesis

Figure 3-41

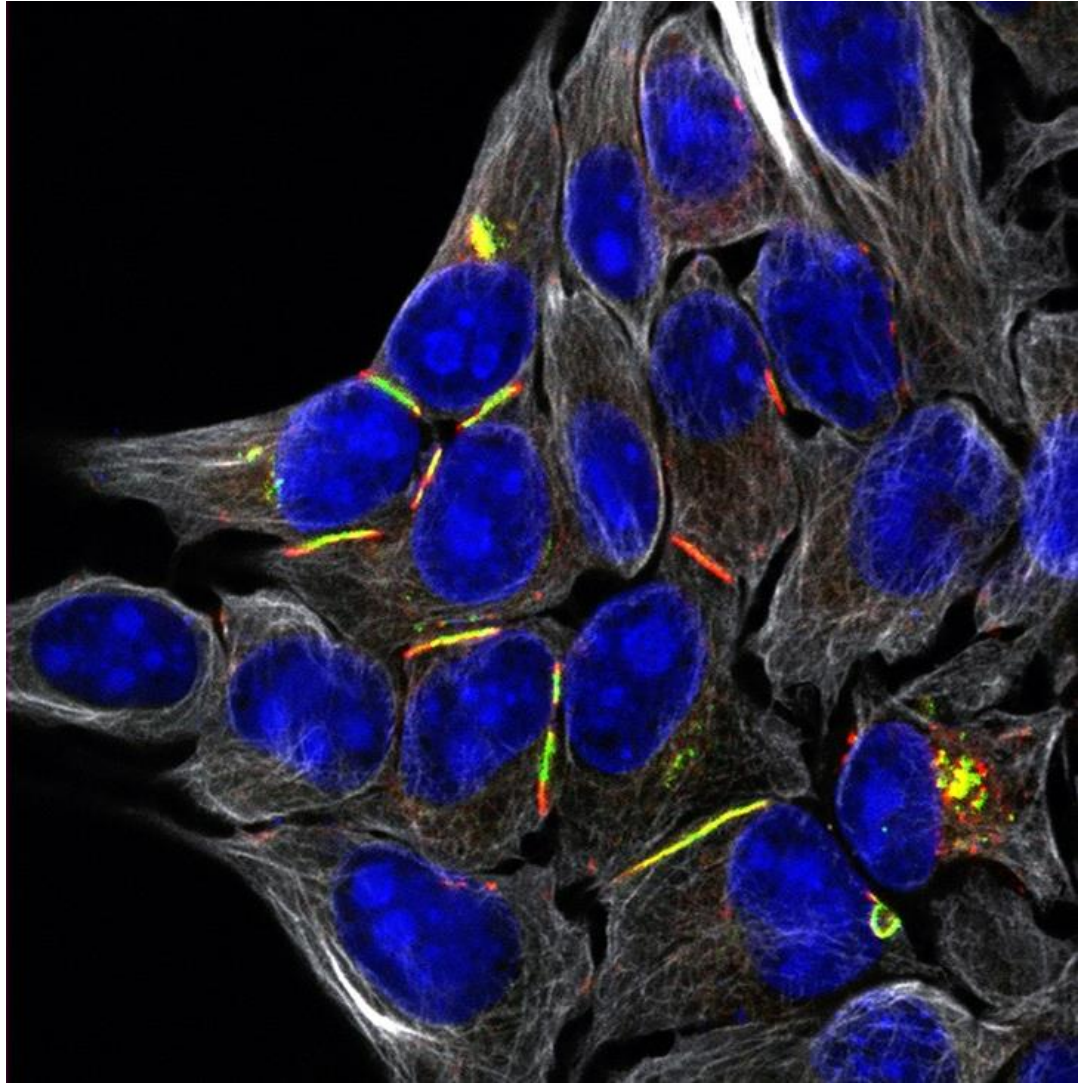
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Almost all eukaryotic organisms derive energy directly or indirectly from the sun. Therefore, which organelle is the most important for life as we know it?

1. Nucleus
2. Endoplasmic reticulum
3. Golgi
4. Chloroplast
5. Mitochondria

3.8–3.11
Molecules move
across membranes
in several ways.



3.8 Passive transport is the spontaneous diffusion of molecules across a membrane.

There are two types of passive transport:

1. Diffusion
2. Osmosis

Diffusion and Concentration Gradients

- Solutes
- Solvents

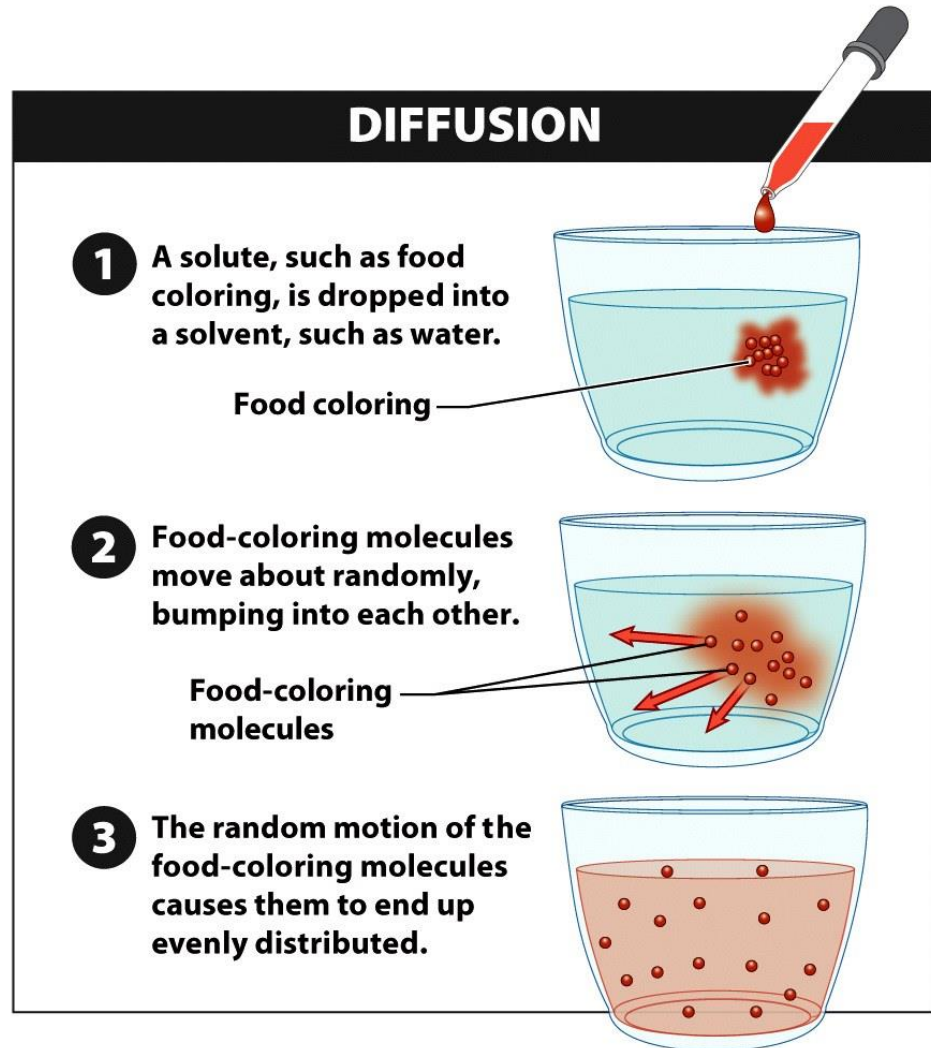


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Simple Diffusion

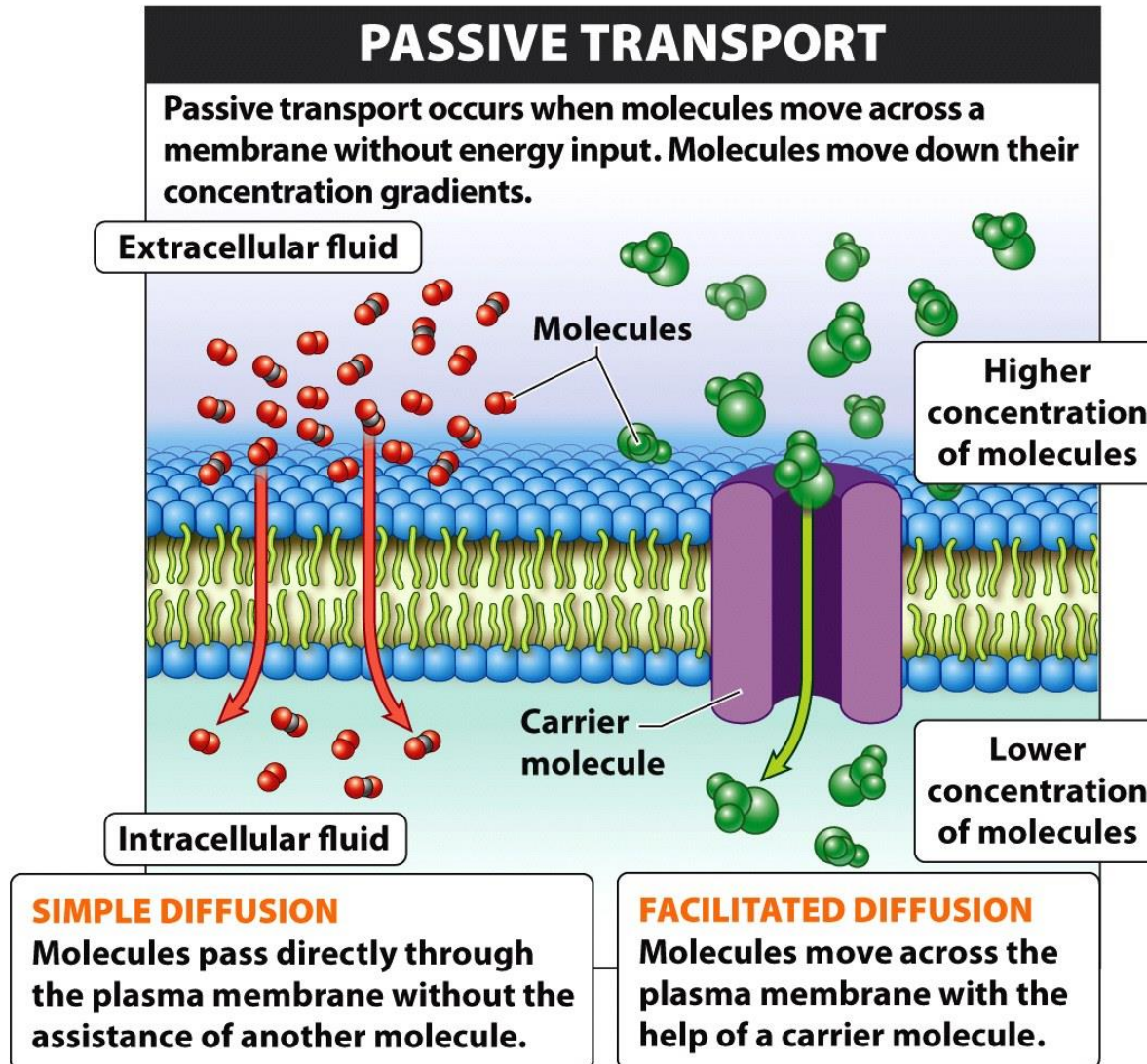


Figure 3-17

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Facilitated Diffusion

- Most molecules can't get through plasma membranes on their own.

- Carrier molecules
 - Transport proteins

Take-home message 3.8

- ❑ Cells must acquire necessary materials, such as food molecules, from outside the cell.
- ❑ Cells must remove metabolic waste molecules and molecules for use elsewhere in the body.

Take-home message 3.8

- ❑ In passive transport—which includes simple and facilitated diffusion and osmosis—the molecular movement occurs spontaneously, without the input of energy.
- ❑ This generally occurs as molecules move down their concentration gradient.

3.9 Osmosis is the passive diffusion of water across a membrane.

OSMOSIS

Osmosis is a type of passive transport by which water diffuses across a membrane, in order to equalize the concentration of water inside and outside the cell. The direction of osmosis is determined by the total amount of solutes on either side of the membrane.

	PLANT CELL	ANIMAL CELL (RED BLOOD-CELL)
ISOTONIC SOLUTION <ul style="list-style-type: none">• Solute concentrations are balanced.• Water movement is balanced.		
HYPOTONIC SOLUTION <ul style="list-style-type: none">• Solute concentrations are lower in the extracellular fluid.• Water diffuses into cells.		
HYPERTONIC SOLUTION <ul style="list-style-type: none">• Solute concentrations are higher in the extracellular fluid.• Water diffuses out of cells.		

Extracellular fluid

Unlike plant cells, animal cells may explode in hypotonic solutions because they don't have a cell wall to limit cellular expansion.

Water will always move toward a region having a greater concentration of solutes.

Figure 3-18

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Cells in Solution

□ **Tonicity**

- The relative concentration of solutes outside of the cell relative to inside the cell

Hypertonic

Hypotonic

Isotonic

OSMOSIS IN ACTION

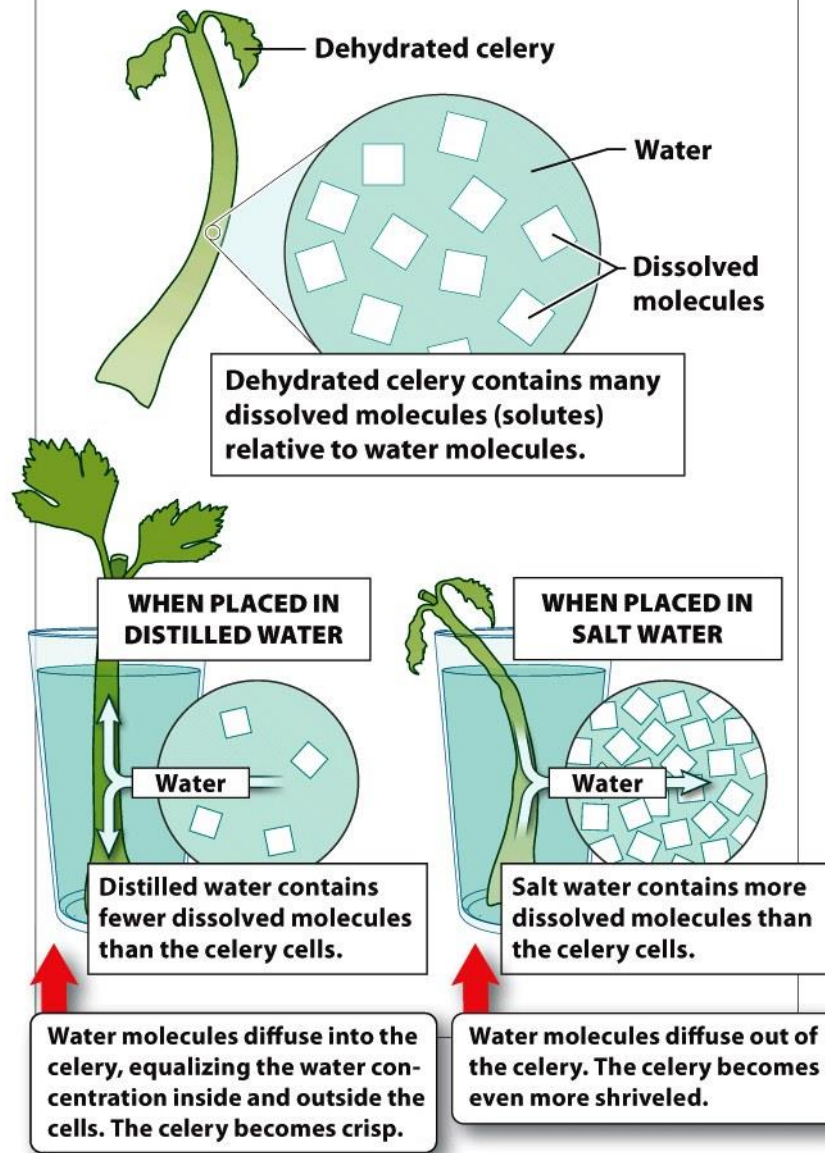


Figure 3-19

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How do laxatives relieve constipation?

- ❑ Milk of magnesia and magnesium salts
- ❑ Water moves via osmosis from the cells into the intestines.

The Direction of Osmosis

- Determined only by a difference in ***total concentration*** of all the molecules dissolved in the water
- It does not matter what solutes they are.

Take-home message 3.9

- ❑ The diffusion of water across a membrane is a special type of passive transport called osmosis.
- ❑ Water molecules move across the membrane until the concentration of water inside and outside of the cell is equalized.

3.10 In active transport, cells use energy to move small molecules.

Molecules can't always move spontaneously and effortlessly in and out of cells.

Primary Active Transport: *Uses Energy Directly from ATP*

ACTIVE TRANSPORT

Active transport occurs when the movement of molecules into and out of a cell requires the input of energy. For example, in response to eating, the cells lining your stomach use ATP to pump large numbers of H^+ ions into the stomach.

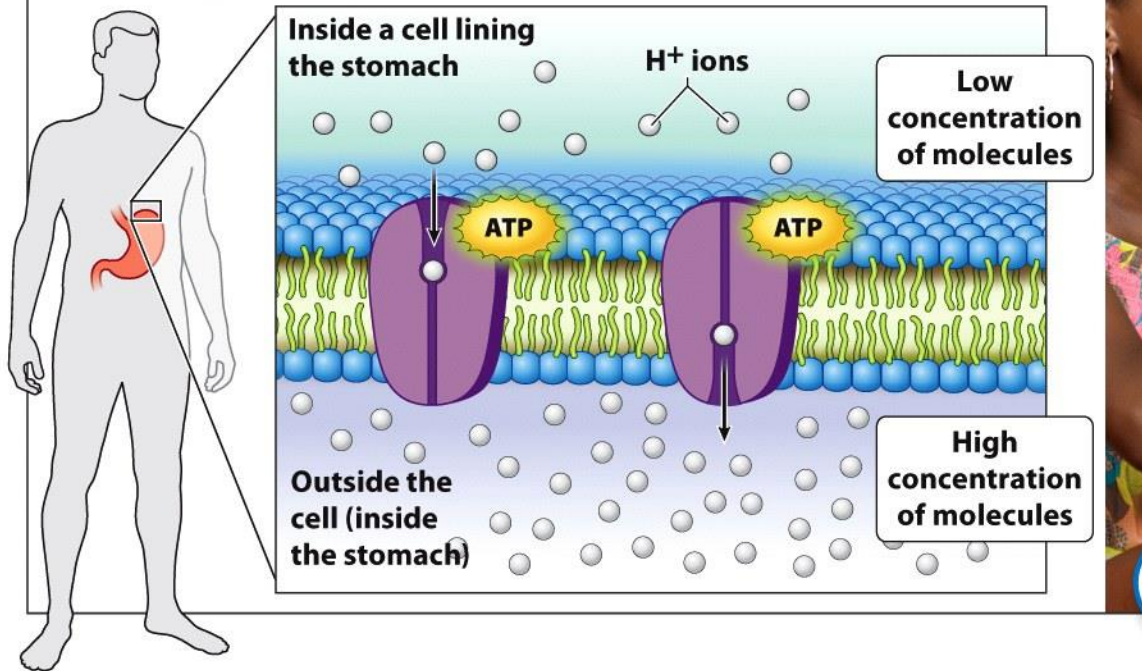


Figure 3-20

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Active Transport

- An indirect method many transporter proteins use for fueling their activities
- The transport protein moves one molecule against its concentration gradient

Secondary Active Transport

- No ATP is used *directly*.
- At some other point and in some other location, energy from ATP was used to pump one of the types of molecules involved against their concentration gradient.

Take-home message 3.10

- In active transport, moving molecules across a membrane requires energy.
- Active transport is necessary if the molecules to be moved are very large or if they are being moved against their concentration gradient.

Take-home message 3.10

- Proteins embedded within the plasma membrane act like motorized revolving doors to actively transport the molecules.

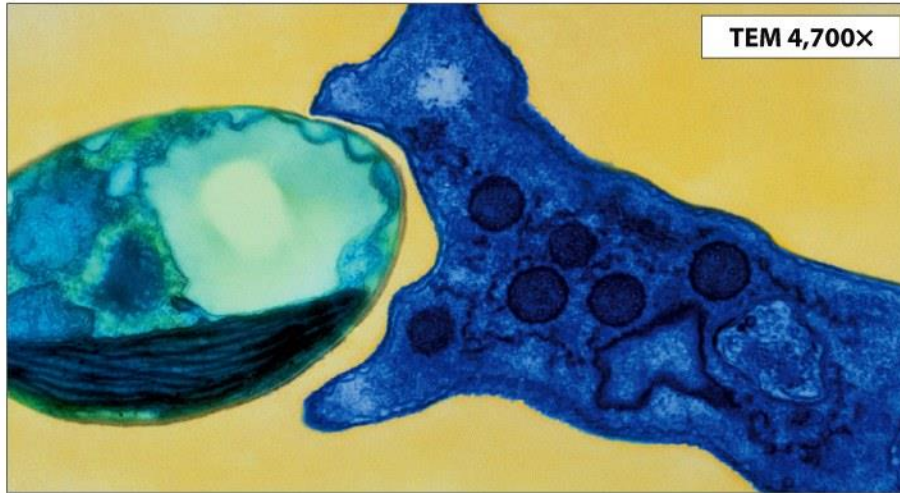
3.11 Endocytosis and exocytosis are used for bulk transport of particles.

Many molecules are just too big to get into a cell by passive or active transport.

Two types of endocytosis:

1. Phagocytosis
2. Pinocytosis

PHAGOCYTOSIS



Phagocytosis is a type of endocytosis by which cells engulf large particles.

Plasma membrane

Large particle

Extracellular fluid

Intracellular fluid

1 The plasma membrane forms a pocket-like vesicle around a large particle.

2 The particle is transported into the cell in a vesicle.

Vesicle

Figure 3-21

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Pinocytosis: the process of cells taking in dissolved particles and liquid

EXOCYTOSIS

Exocytosis is the method by which cells export products for use in another location.

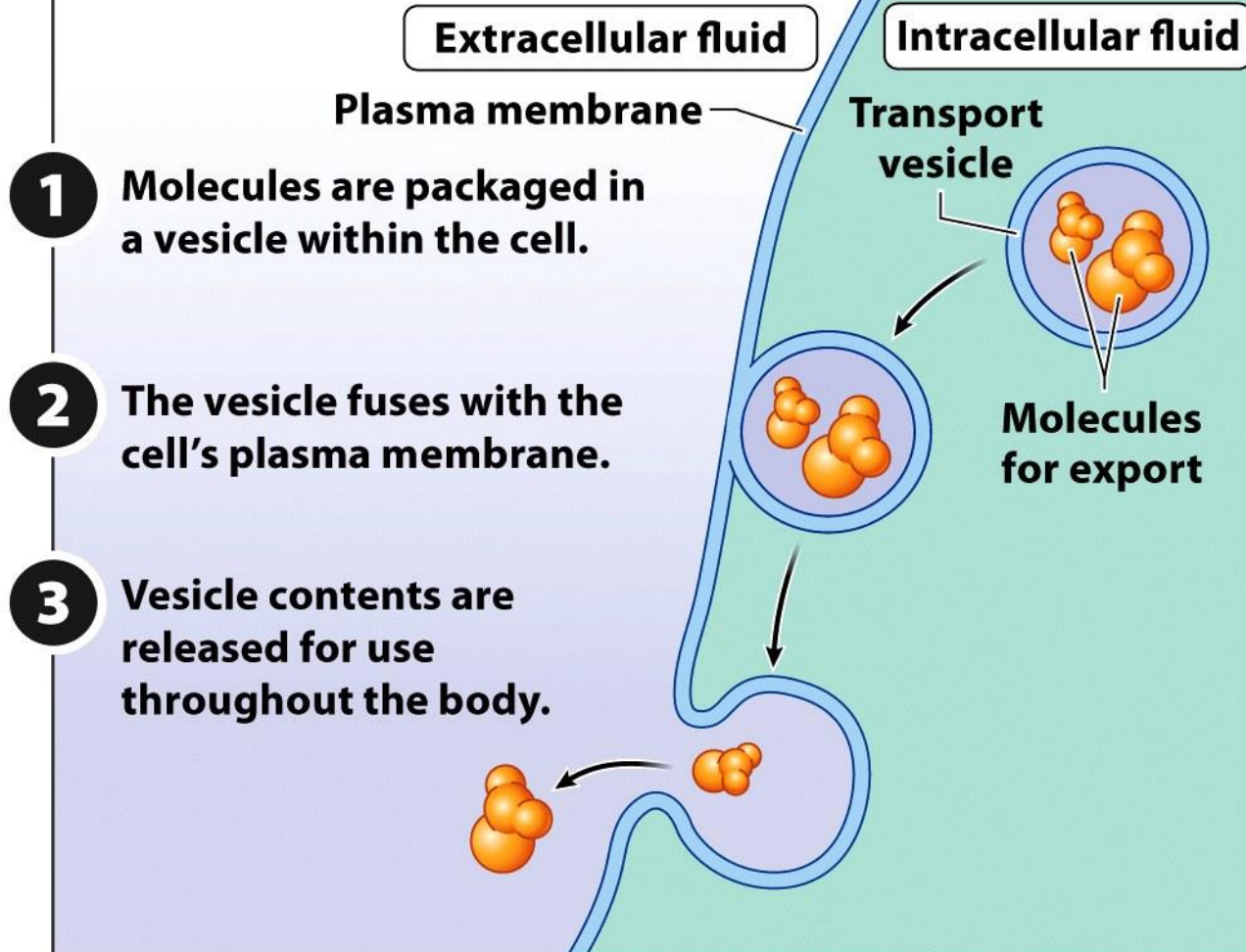


Figure 3-24

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When a woman nurses her baby, proteins are released from the mammary cells, accumulate in the ducts of the breast, and flow out of the nipple. Which process listed below is involved?

1. Phagocytosis
2. Pinocytosis
3. Receptor-mediated endocytosis
4. Exocytosis

Take-home message 3.11

- When molecules cannot get into a cell via diffusion or a pump (e.g., when the molecules are too big), cells can engulf the materials with their plasma membrane in a process called **endocytosis**.
- Similarly, molecules can be moved out of a cell via **exocytosis**.

Take-home message 3.11

- In both processes the plasma membrane moves to surround the molecule and forms a little vesicle that can be pinched off inside the cell or fuse with the plasma membrane and dump its contents outside of the cell.

Take-home message 3.21

- The chloroplast is an organelle in plants and algae in which photosynthesis occurs.
- Chloroplasts may have originally been bacteria that were engulfed by a predatory cell by endosymbiosis.