Chapter 3

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CHAPTER 3: CELL STRUCTURE AND FUNCTION

BIG IDEA: Cells are the smallest unit of living matter that can carry out all processes required for life.

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Section 3.1: Cell Theory

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KEY CONCEPT: Cells are the basic unit of life
SECTION SUMMARY: Cells are the basic unit of life. The contributions of many scientists led to the discovery of cells and the development of the cell theory. The cell theory states that all organisms are made of cells, all cells are produced by other living cells, and the cell is the most basic unit of life.
MAIN IDEAS:

- Early studies led to the development of the cell theory.
- Prokaryotic cells lack a nucleus and most internal structures of eukaryotic cells.

VOCAB:

- Cell Theory: The theory that states that all living things are made up of cells, that cells are the basic units of organisms, that each cell in a multicellular organism has a specific job, and that cells come only from existing cells.
- Cytoplasm: The region of the cell within the membrane that includes the fluid, the cytoskeleton, and all of the organelles except the nucleus.
- Organelle: one of the small bodies that are found in the cytoplasm of a cell and that are specialized to perform a specific function.
- Prokaryotic Cell: Cell that does not have a nucleus or other membrane-bound organelles.
- Eukaryotic Cell: Cell that has a nucleus or other membrane-bound organelles.

TEKS:

- 3F: Research and describe the history of biology and contributions.
- 4A: Compare and contrast prokaryotic and eukaryotic cells.

CONNECT TO YOUR WORLD:
You and all other organisms are made of cells. As you saw on the previous page, a cell's structure is closely related to its function. Today, we know that cells are the smallest unit of living matter that can carry out all processes required for life. But before the 1600s, people had many other ideas about the basis of life. Like many breakthroughs, the discovery of cells was aided by the development of new technology—in this case, the microscope.
MAIN IDEA: Early studies led to the development of the cell theory
Almost all cells are too small to see without the aid of a microscope. Although glass lenses had been used to magnify images for hundreds of years, the early lenses were not powerful enough to reveal individual cells. The invention of the compound microscope in the late 1500s was an early step toward this discovery. The Dutch eyeglass maker Zacharias Janssen, who was probably assisted by his father, Hans, usually gets credit for this invention.
A compound microscope contains two or more lenses. Total magnification, the product of the magnifying power of each individual lens, is generally much more powerful with a compound microscope than with a single lens.
Discovery of Cells
In 1665, the English scientist Robert Hooke used the three-lens compound microscope shown in FIGURE 1.1 to examine thin slices of cork. Cork is the tough outer bark of a species of oak tree. He observed that cork is made of tiny, hollow compartments . The compartments reminded Hooke of small rooms found in a monastery, so he gave them the same name: cells. The plant cells he observed, shown in FIGURE 1.2(top), were dead. Hooke was looking only at cell walls and empty space.
Around the same time, Anton van Leeuwenhoek, a Dutch tradesman, was studying new methods for making lenses to examine cloth. As a result of his research, his single-lens microscopes were much more powerful than Hooke's crude compound microscope. In 1674, Leeuwenhoek became one of the first people to describe living cells when he observed numerous single-celled organisms swimming in a drop of pond water. Sketches of his "animalcules" are pictured in

FIGURE 1.2 (bottom).

As people continued to improve the microscope over the next century and a half, it became sturdier, easier to use, and capable of greater magnification. This combination of factors led people to examine even more organisms. They observed a wide variety of cell shapes, and they observed cells dividing. Scientists began to ask important questions: Is all living matter made of cells? Where do cells come from?

Cell Theory

The German scientist Matthias Schleiden also used compound microscopes to study plant tissue. In 1838, he proposed that plants are made of cells. Schleiden discussed the results of his work with another German scientist, Theodor Schwann, who was struck by the structural similarities between plant cells and the animal cells he had been studying. Schwann concluded that all animals are made of cells. Shortly thereafter, in 1839, he published the first statement of the cell theory, concluding that all living things are made of cells and cell products. This theory helped lay the groundwork for all biological research that followed. However, it had to be refined over the years as additional data led to new conclusions. For example, Schwann stated in his publication that cells form spontaneously by free-cell formation. As later scientists studied the process of cell division, they realized that this part of Schwann's idea was wrong. In 1855, Rudolf Virchow, another German scientist, reported that all cells come from preexisting cells. These early contributors are shown in FIGURE 1.3.

This accumulated research can be summarized in the cell theory, one of the first unifying concepts developed in biology. The major principles of the cell theory are the following:

- All organisms are made of cells.
- All existing cells are produced by other living cells.
- The cell is the most basic unit of li**fe**

MAIN IDEA: Prokaryotic cells lack a nucleus and most internal structures of eukaryotic cells.

The variety of cell types found in living things is staggering. Your body alone is made of trillions of cells of many different shapes, sizes, and functions. They include long, thin, nerve cells that transmit sensory information, as well as short, blocky, skin cells that cover and protect the body. Despite this variety, the cells in your body share many characteristics with one another and with the cells that make up every other organism. In general, cells tend to be microscopic in size and have similar building blocks. They are also enclosed by a membrane that controls the movement of materials into and out of the cell.

Within the membrane, a cell is filled with cytoplasm. Cytoplasm is a jellylike substance that contains dissolved molecular building blocks—such as proteins, nucleic acids, minerals, and ions. In some types of cells, the cytoplasm also contains organelles , which are structures specialized to per- form distinct processes within a cell. Most organelles are surrounded by a membrane. In many cells, the largest and most visible organelle is the nucleus, which stores genetic information.

As shown in FIGURE 1.4, cells can be separated into two broad categories based on their internal structures: prokaryotic cells and eukaryotic cells.

- Prokaryotic cells (pro-KAR-ee-AHT- VISUAL VOCAB ihk) do not have a nucleus or other membrane-bound organelles. Instead, the cell's DNA is suspended in the cytoplasm. Most prokaryotes are microscopic, single-celled organisms.
- Eukaryotic cells (yoo-KAR-ee-AHT-ihk) have a nucleus and other membrane- bound organelles. The nucleus, the largest organelle, encloses the genetic information. Eukaryotes may be multi-cellular or single-celled organisms.

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Section 3.2: Cell Organelles

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KEY CONCEPT: Eukaryotic cells share many similarities

SECTION SUMMARY: Eukaryotic cells share many similarities. They have a nucleus and other membrane-bound organelles that perform specialized tasks within the cell. Many of these organelles are involved in making proteins. Plant and animal cells share many of the same types of organelles, but both also have organelles that are specific to the cells' unique functions.

MAIN IDEAS:

- Cells have an internal structure.
- Several organelles are involved in making in processing proteins.
- Other organelles have various functions.
- Plant cells have cell walls and chloroplasts.

VOCAB:

- Cytoskeleton: The cytoplasmic network of protein filaments that plays an essential role in cell movement, shape, and division
- Nucleus: In a eukaryotic cell, a membrane-bound organelle that contains the cell's DNA and that has a role in processes such as growth, metabolism, and reproduction
- Endoplasmic reticulum: A system of membranes that is found in a cell's cytoplasm and that assists in the production, processing, and transport of proteins and in the production of lipids
- Ribosome: A cell organelle composed of RNA and protein; the site of protein synthesis
- Golgi apparatus: A cell organelle that helps make and package materials to be transported out of the cell.
- Vesicle: A small cavity or sac that contains materials in a eukaryotic cell; forms when part of the cell membrane surrounds the materials to be taken into the cell or transported within the cell.
- Mitochondrion: In eukaryotic cells, the cell organelle that is surrounded by two membranes and that is the site of cellular respiration, which produces ATP
- Vacuole: Organelle that is used to store materials, such as water, food, or enzymes, that are needed by the cell
- Lysosome: Organelle that contains enzymes
- Centriole: Small cylinder-shaped organelle made of protein tubes arranged in a circle; aids mitosis
- Cell Wall: Rigid structure that gives protection, support, and shape to cells in plants, algae, fungi, and bacteria.
- Chloroplast: An organelle found in plant and algae cells where photosynthesis occurs.

CONNECT TO YOUR WORLD:

Your body is highly organized. It contains organs that are specialized to perform particular tasks. For example, your skin receives sensory information and helps prevent infection. Your intestines digest food, your kidneys filter wastes, and your bones protect and support other organs. On a much smaller scale, your cells have a similar division of labor. They contain specialized structures that work together to respond to stimuli and efficiently carry out other necessary processes.

MAIN IDEA: Cells have an internal structure.

Like your body, eukaryotic cells are highly organized structures. They are surrounded by a protective membrane that receives messages from other cells. They contain membrane-bound organelles that perform specific cellular processes, divide certain molecules into compartments, and help regulate the timing of key events. But the cell is not a random jumble of suspended organelles and molecules. Rather, certain organelles and molecules are anchored to specific sites, which vary by cell type. If the membrane were removed from a cell, the contents wouldn't collapse and ooze out in a big puddle. How does a cell maintain this framework?

Each eukaryotic cell has a cytoskeleton, which is a flexible network of proteins that provide structural support for the cell. It is made of small protein subunits that form long threads, or fibers, that crisscross the entire cell, as shown in FIGURE 2.1. Three main types of fibers make up the cytoskeleton and allow it to serve a wide range of functions.

- Microtubules are long, hollow tubes. They give the cell its shape and act as “tracks” for the movement of organelles. When cells divide, microtubules form fibers that pull half of the DNA into each new cell.
- Intermediate filaments, which are somewhat smaller than microtubules, give a cell its strength.
- Microfilaments, the smallest of the three, are tiny threads that enable cells to move and divide. They play an important role in muscle cells, where they help the muscle contract and relax.

Cytoplasm, which you read about in Section 1, is itself an important contributor to cell structure. In eukaryotes, it fills the space between the nucleus and the cell membrane. The fluid portion, excluding the organelles, is called cytosol and consists mostly of water. The makeup of cytoplasm shows that water is necessary for maintaining cell structure. This is only one of many reasons that water is an essential component for life, however. Many chemical reactions occur in the cytoplasm, where water acts as an important solvent.

The remainder of this chapter highlights the structure and function of the organelles found in eukaryotic cells. As FIGURE 2.2 shows, plant and animal cells use many of the same types of organelles to carry out basic functions. Both cell types also have organelles that are unique to their needs.

MAIN IDEA: Several organelles are involved in making in processing proteins.

Much of the cell is devoted to making proteins. Proteins are made of 20 types of amino acids that have unique characteristics of size, polarity, and acidity. They can form very long or very short protein chains that fold into different shapes. And multiple protein chains can interact with each other. This almost limitless variety of shapes and interactions makes proteins very powerful. Proteins carry out many critical functions, so they need to be made correctly.

Nucleus

The nucleus (NOO-klee-uhs) is the storehouse for most of the genetic information, or DNA (deoxyribonucleic acid), in your cells. DNA contains genes that are instructions for making proteins. There are two major demands on the nucleus: (1) DNA must be carefully protected, and (2) DNA must be available for use at the proper times. Molecules that would damage DNA need to be kept out of the nucleus. But many proteins are involved in turning genes on and off, and they need to access the DNA at certain times. The special structure of the nucleus helps it meet both demands.

The nucleus also contains the nucleolus. The nucleolus is a dense region where tiny organelles essential for making proteins are assembled. These organelles, called ribosomes, are a combination of proteins and RNA molecules. They are discussed on the next page, and a more complete description of their structure and function is given in the chapter From DNA to Proteins.

Endoplasmic Reticulum and Ribosomes

A large part of the cytoplasm of most eukaryotic cells is filled by the endoplasmic reticulum, shown in FIGURE 2.4. The endoplasmic reticulum (EHN -duh-PLAZ-mihk rih-TIHK-yuh-luhm), or the ER, is an interconnected network of thin, folded membranes . The composition is very similar to that of the cell membrane and nuclear membranes. The ER membranes form a maze of enclosed spaces. The interior of this maze is called the lumen. Numerous processes, including the production of proteins and lipids, occur both on the surface of the ER and inside the lumen. The ER must be large enough to accommodate all these processes. how does it fit inside a cell?

The ER membrane has many creases and folds. if you have ever gone camping, you probably slept in a sleeping bag that covered you from head to foot. The next morning, you stuffed it back into a tiny little sack. how does the entire sleeping bag fit inside such a small sack? The surface area of the sleeping bag does not change, but the folds allow it to take up less space. likewise, the ER’s many folds enable it to fit within the cell.

In some regions, the ER is studded with ribosomes (RY-buh-SOHMZ), tiny organelles that link amino acids together to form proteins. Ribosomes are both the site of protein synthesis and active participants in the process. Ribosomes are themselves made of proteins and RNA. After assembly in the nucleolus, ribosomes pass through the nuclear pores into the cytoplasm, where most protein synthesis occurs.

Not all ribosomes are bound to the ER; some are suspended in the cytoplasm. in general, proteins made on the ER are either incorporated into the cell membrane or secreted. in contrast, proteins made on suspended ribosomes are typically used in chemical reactions occurring within the cytoplasm.

Surfaces of the ER that do not contain ribosomes are called smooth ER. Smooth ER makes lipids and performs a variety of other specialized functions, such as breaking down drugs and alcohol.

Golgi Apparatus

From the ER, proteins generally move to the Golgi apparatus, shown in FIGURE 2.5. The Golgi apparatus GOHL-jee) consists of closely layered stacks of membrane-enclosed spaces that process, sort, and deliver proteins. its membranes contain enzymes that make additional changes to proteins. The Golgi apparatus also packages proteins. Some of the packaged proteins are stored within the Golgi apparatus for later use. Some are transported to other organelles within the cell. Still others are carried to the membrane and secreted outside the cell.

Vesicles

Cells need to separate reactants for various chemical reactions until it is time for them to be used. Vesicles (VEHS-ih-kuhlz), shown in FIGURE 2.6, are a general name used to describe small, membrane-bound sacs that divide some materials from the rest of the cytoplasm and transport these materials from place to place within the cell. vesicles are generally short-lived and are formed and recycled as needed.

After a protein has been made, part of the ER pinches off to form a vesicle surrounding the protein. Protected by the vesicle, the protein can be safely transported to the Golgi apparatus. There, any necessary modifications are made, and the protein is packaged inside a new vesicle for storage, transport, or secretion.

MAIN IDEA: Other organelles have various functions.

Mitochondria

Mitochondria (MY -tuh-KAHN-dree-uh) supply energy to the cell. Mitochondria (singular, mitochondrion) are bean shaped and have two membranes, as shown in FIGURE 2.7. The inner membrane has many folds that greatly increase its surface area. Within these inner folds and compartments, a series of chemical reactions converts molecules from the food you eat into usable energy. You will learn more about this process in Cells and energy. Unlike most organelles, mitochondria have their own ribosomes and DNA. This fact suggests that mitochondria were originally free-living prokaryotes that were taken in by larger cells. The relationship must have helped both organisms to survive.

Vacuole

A vacuole (VAK-yoo-OHL) is a fluid-filled sac used for the storage of materials needed by a cell. These materials may include water, food molecules, inorganic ions, and enzymes. Most animal cells contain many small vacuoles. The central vacuole, shown in FIGURE 2.8, is a structure unique to plant cells. It is a single, large vacuole that usually takes up most of the space inside a plant cell. It is filled with a watery fluid that strengthens the cell and helps to support the entire plant. When a plant wilts, its leaves shrivel because there is not enough water in each cell’s central vacuole to support the leaf ’s normal structure. The central vacuole may also contain other substances, including toxins that would harm predators, waste products that would harm the cell itself, and pigments that give color to cells—such as those in the petals of a flower.

Lysosomes

Lysosomes (LY-suh- SOHMZ), shown in FIGURE 2.9, are membrane-bound organelles that contain enzymes. They defend a cell from invading bacteria and viruses. They also break down damaged or worn-out cell parts. lysosomes tend to be numerous in animal cells. Their presence in plant cells is still questioned by some scientists, but others assert that plant cells do have lysosomes, though fewer than are found in animal cells.

Recall that all enzymes are proteins. Initially, lysosomal enzymes are made in the rough ER in an inactive form. Vesicles pinch off from the ER mem- brane, carry the enzymes, and then fuse with the Golgi apparatus. There, the enzymes are activated and packaged as lysosomes that pinch off from the Golgi membrane. The lysosomes can then engulf and digest targeted molecules. When a molecule is broken down, the products pass through the lysosomal membrane and into the cytoplasm, where they are used again.

Lysosomes provide an example of the importance of membrane-bound structures in the eukaryotic cell. Because lysosomal enzymes can destroy cell components, they must be surrounded by a membrane that prevents them from destroying necessary structures. However, the cell also uses other methods to protect itself from these destructive enzymes. For example, the enzymes do not work as well in the cytoplasm as they do inside the lysosome.

Centrosome and Centrioles

The centrosome is a small region of cytoplasm that produces microtubules. In animal cells, it contains two small structures called centrioles. Centrioles OHLZ (SEHN-tree-OHIZ) are cylinder-shaped organelles made of short microtubules arranged in a circle. The two centrioles are perpendicular to each other, as shown in FIGURE 2.10. Before an animal cell divides, the centrosome, including the centrioles, doubles and the two new centrosomes move to opposite ends of the cell. Microtubules grow from each centrosome, forming spindle fibers. These fibers attach to the DNA and appear to help divide it between the two cells.

Centrioles were once thought to play a critical role in animal cell division. However, experiments have shown that animal cells can divide even if the centrioles are removed, making their role questionable. In addition, although centrioles are found in some algae, they are not found in plants.

Centrioles also organize microtubules to form cilia and flagella. Cilia look like little hairs; flagella look like a whip or a tail. Their motion forces liquids past a cell. For single cells, this movement results in swimming. For cells anchored in tissue, this motion sweeps liquid across the cell surface.

MAIN IDEA: Plant cells have cell walls and chloroplasts

Plant cells have two features not shared by animal cells: cell walls and chloro- plasts. Cell walls are structures that provide rigid support. Chloroplasts are organelles that help a plant convert solar energy to chemical energy.

Cell Walls:

In plants, algae, fungi, and most bacteria, the cell membrane is surrounded by a strong cell wall , which is a rigid layer that gives protection, support, and shape to the cell. The cell walls of multiple cells, as shown in FIGURE 2.11, can adhere to each other to help support an entire organism. For instance, much of the wood in a tree trunk consists of dead cells whose cell walls continue to support the entire tree.

Cell wall composition varies and is related to the different needs of each type of organism. In plants and algae, the cell wall is made of cellulose, a polysaccharide. Because molecules cannot easily diffuse across cellulose, the cell walls of plants and algae have openings, or channels. Water and other molecules small enough to fit through the channels can freely pass through the cell wall. In fungi, cell walls are made of chitin, and in bacteria, they are made of peptidoglycan.

Chloroplasts

Chloroplasts (KLAWR-uh-PLASTS) are organelles that carry out photosynthesis, a series of complex chemical reactions that convert solar energy into energy- rich molecules the cell can use. Photosynthesis will be discussed more fully in Cells and Energy. like mitochondria, chloroplasts are highly compartmentalized. They have both an outer membrane and an inner membrane. They also have stacks of disc-shaped sacs within the inner membrane, shown in FIGURE 2.12.

These sacs, called thylakoids, contain chlorophyll, a light-absorbing molecule that gives plants their green color and plays a key role in photosynthesis. like mitochondria, chloroplasts also have their own ribosomes and DNA. Scientists have hypothesized that they, too, were originally free-living prokaryotes that were taken in by larger cells.

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Section 3.3: Cell Membrane

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KEY CONCEPT: The cell membrane is a barrier that separates a cell from the external environment.

SECTION SUMMARY: The cell membrane is a barrier that separates a cell from the external environment. It is made of a double layer of phospholipids and a variety of embedded molecules. Some of these molecules act as signals; others act as receptors. The membrane is selectively permeable, allowing some but not all materials to cross.

MAIN IDEAS:

- Cell membranes are composed of two phospholipid layers.
- Chemical signals are transmitted across the cell membrane.

VOCAB:

- Cell Membrane: double-layer of phospholipids that forms a boundary between a cell and the surrounding environment and controls the passage of materials into and out of a cell
- Phospholipid: a lipid that contains phosphorus and that is a structural component in cell membranes
- Fluid Mosaic Model: a lipid that contains phosphorus and that is a structural component in cell membranes
- Selective Permeability: condition or quality of allowing some, but not all, materials to cross a barrier or membrane
- Receptor: protein that detects a signal molecule and performs an action in response

TEKS:

- 3E evaluate models according to their limitations in representing biological objects or events.
- 4B investigate and explain cellular processes, including homeostasis, energy conversions, transport of molecules, and synthesis of new molecules.
- 9A compare the structures and functions of different types of biomolecules, including carbohydrates, lipids, proteins, and nucleic acid.

CONNECT TO YOUR WORLD

Think about how the products you buy are packaged—a pint of berries, perhaps, or a tube of toothpaste. The berries are probably in a plastic container that has holes to allow air circulation. The toothpaste is in a tube strong enough to be squeezed without ripping. Both containers protect their contents but do so in different ways. Like these products, the cell needs protection, but it must also be able to respond to its surroundings. It is constantly taking in and getting rid of various molecules. The structure of the cell membrane allows it to perform all those functions.

MAIN IDEA: Cell membranes are composed of two phospholipid layers.

The cell membrane, or the plasma membrane, forms a boundary between a cell and the outside environment and controls the passage of materials into and out of a cell. The cell membrane consists of a double layer of phospho- lipids interspersed with a variety of other molecules. A phospholipid (FAHS -foh-LIHP-ihd) is a molecule composed of three basic parts:

- a charged phosphate group
- glycerol
- two fatty acid chains

Together, the glycerol and the phosphate group form the “head” of a phospholipid; the fatty acids form the “tail.” Because the head bears a charge, it is polar. Recall that water molecules are also polar. Therefore, the polar head of the phospholipid forms hydrogen bonds with water molecules. in contrast, the fatty acid tails are nonpolar and cannot form hydrogen bonds with water. As a result, the nonpolar tails are attracted to each other and repelled by water.

Because the membrane touches the cytoplasm inside the cell and the watery fluid outside the cell, the properties of polar heads and nonpolar tails cause the phospholipids to arrange themselves in layers, like a sandwich.

The polar heads are like the bread. They form the outer surfaces of the membrane, where they interact with the watery environment both outside and inside a cell. The nonpolar tails are like the filling. They are sandwiched between the layers of polar heads, where they are protected from the watery environment.

FIGURE 3.1 shows other molecules embedded within the phospholipid layers. They give the membrane properties and characteristics it would not otherwise have. These molecules serve diverse functions. Here are a few examples:

- Cholesterol molecules strengthen the cell membrane.
- Some proteins extend through one or both phospholipid layers and help materials cross the membrane. Other proteins are key components of the cytoskeleton. Different cell types have different membrane proteins.
- Carbohydrates attached to membrane proteins serve as identification tags, enabling cells to distinguish one type of cell from another.

Fluid Mosaic Model

Scientists have developed the fluid mosaic model, which describes the arrangement of the molecules that make up a cell membrane. This model of cell membrane structure takes its name from two characteristics. First, the cell membrane is flexible, not rigid. The phospholipids in each layer can move from side to side and slide past each other. As a result, the membrane behaves like a fluid, similar to a film of oil on the surface of water. However, proteins embedded in the membrane do not flip vertically. If one part of a protein is outside the membrane, it will stay outside the membrane. Second, the variety of molecules studding the membrane is similar to the arrangement of colorful tiles with different textures and patterns that make up a mosaic.

Selective Permeability

The cell membrane has the property of selective permeability, which means it allows some, but not all, materials to cross. Selective permeability is illustrated in FIGURE 3.2. The terms semipermeable and selectively permeable also refer to this property. As an example, outdoor clothing is often made of semipermeable fabric. The material is waterproof yet breathable. Molecules of water vapor from sweat are small enough to exit the fabric, but water droplets are too large to enter.

Selective permeability enables a cell to maintain homeostasis in spite of unpredictable, changing conditions outside the cell. Because a cell needs to maintain certain conditions to carry out its functions, it must control the import and export of certain molecules and ions. Thus, even if ion concentrations change drastically outside a cell, these ions won't necessarily interfere with vital chemical reactions inside a cell.

Molecules cross the membrane in several ways. Some of these methods require the cell to expend energy; others do not. How a particular molecule crosses the membrane depends on the molecule's size, polarity, and concentration inside versus outside the cell. In general, small nonpolar molecules easily pass through the cell membrane, small polar molecules are transported via proteins, and large molecules are moved in vesicles.

MAIN IDEA: Chemical signals are transmitted across the cell membrane

Recall that cell membranes may secrete molecules and may contain identifying molecules, such as carbohydrates. All these molecules can act as signals to communicate with other cells. How are these signals recognized?

A receptor is a protein that detects a signal molecule and performs an action in response. It recognizes and binds to only certain molecules, ensuring that the right cell gets the right signal at the right time. The molecule a receptor binds to is called a ligand. When a receptor and a ligand bind, they change shape. This change is critical because it affects how a receptor interacts with other molecules. Two major types of receptors are present in your cells.

Intracellular Receptor

A molecule may cross the cell membrane and bind to an intracellular receptor, as shown in FIGURE 3.3.The word intracellular means “within, or inside, a cell.” Molecules that cross the membrane are generally nonpolar and may be rela- tively small. Many hormones fit within this category. For example, aldosterone can cross most cell membranes. However, it produces an effect only in cells that have the right type of receptor, such as kidney cells. When aldosterone enters a kidney cell, it binds to an intracellular receptor. The receptor-ligand complex enters the nucleus, interacts with the DNA, and turns on certain genes. As a result, specific proteins are made that help the kidneys absorb sodium ions and retain water, both of which are important for maintaining normal blood pressure.

Membrane Receptor

A molecule that cannot cross the membrane may bind to a receptor in the cell membrane, as shown in FIGURE 3.4.The receptor then sends the message to the cell interior. Although the receptor binds to a signal molecule outside the cell, the entire receptor changes shape—even the part inside the cell. As a result, it causes molecules inside the cell to respond. These molecules, in turn, start a complicated chain of events inside the cell that tells the cell what to do. For instance, band 3 protein is a membrane receptor in red blood cells. When activated, it triggers processes that carry carbon dioxide from body tissues to the lungs.

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Section 3.4: Diffusion of Osmosis

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KEY CONCEPT: Materials move across membranes because of concentration differences.
SECTION SUMMARY: Materials move across membranes because of concentration differences. Diffusion is the movement of molecules in a fluid or gas from a region of higher concentration to a region of lower concentration. It does not require a cell to expend energy; it is a form of passive transport. Osmosis is the diffusion of water. Net water movement into or out of a cell depends on the concentration of the solution.

MAIN IDEAS:

- Diffusion and osmosis are types of passive transport.
- Some molecules diffuse through transport protein.

VOCAB:

- Passive Transport: the movement of substances across a cell membrane without the use of energy by the cell
- Diffusion: the movement of particles from regions of higher density to regions of lower density
- Concentration Gradient: a difference in the concentration of a substance across a distance
- Osmosis: the diffusion of water or another solvent from a more dilute solution (of a solute) to a more concentrated solution (of the solute) through a membrane that is permeable to the solvent
- Isotonic: solution that has an equal concentration of dissolved particles compared with another solution
- Hypertonic: describes a solution whose solute concentration is higher than the solute concentration inside a cell
- Hypotonic: describes a solution whose solute concentration is lower than the solute concentration inside a cell
- Facilitated Diffusion: the transport of substances through a cell membrane along a concentration gradient with the aid of carrier proteins

TEKS:

- 4B investigate and explain cellular processes, including homeostasis, energy conversions, transport of molecules, and synthesis of new molecules.
- 9A compare the structures and functions of different types of biomolecules, including carbohydrates, lipids, proteins, and nucleic acid.

CONNECT TO YOUR WORLD

If you have ever been stuck in traffic behind a truck full of pigs, you know that "unpleasant" fails to fully describe the situation. That is because molecules travel from the pigs to receptors in your nose, and your brain interprets those molecules to be a really bad odor. Or, perhaps you have tie-dyed a T-shirt and have seen dye molecules spread throughout the pot of water, turning it neon green or electric blue. Why does that happen? Why don't the molecules stay in one place?

Diffusion

Diffusion is the movement of molecules in a fluid or gas from a region of higher concentration to a region of lower concentration. It results from the natural motion of particles, which causes molecules to collide and scatter. Concentration is the number of molecules of a substance in a given volume, and it can vary from one region to another. A concentration gradient is the difference in the concentration of a substance from one location to another. Molecules diffuse down their concentration gradient—that is, from a region of higher concentration to a region of lower concentration.

In the tie-dye example, dye molecules are initially at a high concentration in the area where they are added to the water. Random movements of the dye and water molecules cause them to bump into each other and mix. Thus, the dye molecules move from an area of higher concentration to an area of lower concentration. Eventually, they are evenly spread throughout the solution. This means the molecules have reached a dynamic equilibrium. The concentration of dye molecules is the same throughout the solution (equilibrium), but the molecules continue to move (dynamic).

In cells, diffusion plays an important role in moving substances across the membrane. Small lipids and other nonpolar molecules, such as carbon dioxide and oxygen, easily diffuse across the membrane. For example, most of your cells continually consume oxygen, which means that the oxygen concentration is almost always higher outside a cell than it is inside a cell. As a result, oxygen generally diffuses into a cell without the cell expending any energy.

Osmosis

Water molecules, of course, also diffuse. They move across a semipermeable membrane from an area of higher water concentration to an area of lower water concentration. This process is called osmosis. It is important to recognize that the higher the concentration of dissolved particles in a solution, the lower the concentration of water molecules in the same solution. So, if you put 1 teaspoon of salt in a cup of water and 10 teaspoons of salt in a different cup of water, the first cup would have the higher water concentration.

A solution may be described as isotonic, hypertonic, or hypotonic relative to another solution. Note that these terms are comparisons; they require a point of reference, as shown in FIGURE 4.3. An isotonic solution has a solute concentration equal to the solute concentration inside a cell. A hypertonic solution has a solute concentration higher than the solute concentration inside a cell. A hypotonic solution has a solute concentration lower than the solute concentration inside a cell.

Some animals and single-celled organisms can survive in hypotonic environments. Their cells have adaptations for removing excess water. In plants, the rigid cell wall prevents the membrane from expanding too much.

MAIN IDEA: Some molecules diffuse through transport protein.

Some molecules cannot easily diffuse across a membrane. They may cross more easily through transport proteins—openings formed by proteins that pierce the cell membrane. Facilitated diffusion is the diffusion of molecules across a membrane through transport proteins. The word facilitate means “to make easier.” Transport proteins make it easier for molecules to enter or exit a cell. But the process is still a form of passive transport. The molecules move down a concentration gradient, requiring no energy expenditure by the cell.

There are many types of transport proteins. Most types allow only certain ions or molecules to pass. As FIGURE 4.4 shows, some transport proteins are simple channels, or tunnels, through which particles such as ions can pass. Others act more like enzymes. When bound, the protein changes shape, allowing the molecule to travel the rest of the way into the cell.

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Section 3.5: Active Transport, Endocytosis, and Exocytosis

Wednesday, April 17, 2019 7:46 PM

KEY CONCEPT: Cells use energy to transport materials that cannot diffuse across a membrane.
SECTION SUMMARY: Cells use energy to transport materials that cannot diffuse across a membrane. Active transport is the movement of molecules across a membrane from a region of lower concentration to a region of higher concentration—against a concentration gradient. The processes of endocytosis and exocytosis move substances in vesicles and also require energy

MAIN IDEAS:
- Proteins can transport materials against a concentration gradient.
- Endocytosis and exocytosis transport materials across the membrane in vesicles.

VOCAB:
- Active Transport: the movement of chemical substances, usually across the cell membrane, against a concentration gradient; requires cells to use energy
- Endocytosis: the process by which a cell membrane surrounds a particle and encloses the particle in a vesicle to bring the particle into the cell
- Phagocytosis: uptake of a solid particle into a cell by engulfing the particle
- Exocytosis: the process by which a substance is released from the cell through a vesicle that transports the substance to the cell surface and then fuses with the membrane to let the substance out

TEKS:
- 4B investigate and explain cellular processes, including homeostasis, energy conversions, transport of molecules, and synthesis of new molecules.
- 9A compare the structures and functions of different types of biomolecules, including carbohydrates, lipids, proteins, and nucleic acid.

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If you want to go up to the second floor of the mall, you're going to need help beating gravity. You could take an escalator, which uses energy to move you against gravity, much like transport proteins involved in active transport use energy to move molecules against a gradient. Alternatively, you might take the elevator, entering on the first floor and hopping out when the doors open on the second. In endocytosis and exocytosis, vesicles act like that elevator, surrounding molecules on one side of a membrane and releasing them into the other.

MAIN IDEA: Proteins can transport materials against a concentration gradient.

You just learned that some transport proteins let materials diffuse into and out of a cell down a concentration gradient. Many other transport proteins, often called pumps, move materials against a concentration gradient. Active transport drives molecules across a membrane from a region of lower concentration to a region of higher concentration. This process, shown in FIGURE 5.1,uses transport proteins powered by chemical energy. Cells use active transport to get needed molecules regardless of the concentration gradient and to maintain homeostasis.

Before we discuss active transport proteins, let's look at transport proteins in general. All transport proteins span the membrane, and most change shape when they bind to a target molecule or molecules. Some transport proteins bind to only one type of molecule. Others bind to two different types. Some proteins that bind to two types of molecules move both types in the same direction. Others move the molecules in opposite directions
Cells use energy to transport materials that cannot diffuse across a membrane. Active transport is the movement of molecules across a membrane from a region of lower

concentration to a region of higher concentration—against a concentration gradient. The processes of endocytosis and exocytosis move substances in vesicles and also require energy.

The key feature of active transport proteins is that they can use chemical energy to move a substance against its concentration gradient. Most use energy from a molecule called ATP, either directly or indirectly. For example, nerve cells, or neurons, need to have a higher concentration of potassium ions and a lower concentration of sodium ions than the fluid outside the cell. The sodium-potassium pump uses energy directly from the breakdown of ATP. It pumps three sodium ions out of the cell for every two potassium ions it pumps in. The proton pump, another transport protein, uses energy from the breakdown of ATP to move hydrogen ions (or protons) out of the cell. This action forms a concentration gradient of hydrogen ions (H^+), which makes the fluid outside the cell more positively charged than the fluid inside. In fact, this gradient is a form of stored energy that is used to power other active transport proteins. In plant cells, this gradient causes yet another protein to transport sucrose into the cell—an example of indirect active transport.

MAIN IDEA: Endocytosis and exocytosis transport materials 4B across the membrane in vesicles.

A cell may also use energy to move a large substance or a large amount of a substance in vesicles. Transport in vesicles lets substances enter or exit a cell without crossing through the membrane.

Endocytosis

Endocytosis (EN-doh-sy-TOH-sihs) is the process of taking liquids or fairly large molecules into a cell by engulfing them in a membrane. In this process, the cell membrane makes a pocket around a substance. The pocket breaks off inside the cell and forms a vesicle, which then fuses with a lysosome or a similar type of vesicle. Lysosomal enzymes break down the vesicle membrane and its contents (if necessary), which are then released into the cell.

Phagocytosis (FAG -uh-sy-TOH-sihs) is a type of endocytosis in which the cell membrane engulfs large particles. The word literally means “cell eating.” Phagocytosis plays a key role in your immune system. Some white blood cells called macrophages help your body fight infection. They find foreign materials, such as bacteria, and engulf and destroy them

Exocytosis

Exocytosis (EHK -soh-sy-TOH-sihs), the opposite of endocytosis, is the release of substances out of a cell by the fusion of a vesicle with the membrane. During this process, a vesicle forms around materials to be sent out of the cell. The vesicle then moves toward the cell’s surface, where it fuses with the membrane and releases its contents.

Exocytosis happens all the time in your body. In fact, you couldn’t think or move a muscle without it. When you want to move your big toe, for example, your brain sends a message that travels through a series of nerve cells to reach your toe. This message, or nerve impulse, travels along each nerve cell as an electrical signal, but it must be converted to a chemical signal to cross the tiny gap that separates one nerve cell from the next. These chemicals are stored in vesicles within the nerve cells. When a nerve impulse reaches the end of a cell, it causes the vesicles to fuse with the cell membrane and release the chemicals outside the cell. There they attach to the next nerve cell, which triggers a new electrical impulse in that cell.

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