Chapter 5

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BIG IDEA: Cells have their own life cycle that includes reproduction, growth, and regulation, which allows organisms to carry out life functions and grow.

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Section 5.1: The Cell Cycle

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KEY CONCEPT: Cells have distinct phases of growth, reproduction, and normal functions.
SECTION SUMMARY: Cells have distinct phases of growth, reproduction, and normal functions. The cycle has four main stages: G_1, S, G_2, and M. The length of the cycle can vary, resulting in different rates of cell division. This variability is based on the body's need for different cell types. Cells also divide because they need a sufficient surface area-to-volume ratio to move materials into and out of the cell.

MAIN IDEAS:

- The cell cycle has four main stages.
- Cells divide at different rates.
- Cell size is limited.

VOCAB:

- Cell Cycle: Pattern of Growth, DNA Replication, and Cell Division that occurs in a eukaryotic cell.
- Mitosis: In eukaryotic cells, a process of cell division that forms two new nuclei each of which have the same number of chromosomes.
- Cytokinesis: The division of the cytoplasm of a cell; Cytokinesis follows the division of the cell's nucleus by mitosis or meiosis,

TEKS:

- 5A describe the stages of the cell cycle, including deoxyribonucleic acid (DNA) replication and mitosis, and the importance of the cell cycle to the growth of organism

CONNECT TO YOUR WORLD

> Many of life's little chores can be quietly satisfying and rather fun. Washing dishes by hand, however, is not so fun, which is why some clever person made the dishwasher. This handy invention soaks, washes, and rinses your dishes to a spot-free, sanitary sparkle. You unload the dishes, and the machine is ready to start the cycle all over again. A cell goes through a cycle, too. This cycle of growth, DNA synthesis, and division is essential for an organism to grow and heal. If it goes out of control, abnormal cell growth may occur, resulting in cancer cells like those shown on the previous page.

MAIN IDEA: The cell cycle has four main stages.

Just as all species have life cycles, from tiny Chihuahuas to massive beluga whales, cells also have a life cycle. The cell cycle is the regular pattern of growth, DNA duplication, and cell division that occurs in eukaryotic cells. FIGURE 1.1 shows its four main stages: gap 1, synthesis, gap 2, and mitosis. Gap 1, synthesis, and gap 2 together make up what is called interphase. The stages of the cell cycle get their names from early studies of cell division. Scientists' observations were limited by the microscopes of the time. When a cell was not actively dividing, they could not see activity in it. Thus, they originally divided the cell cycle into two parts: interphase, when the cell appeared to be at rest, and mitosis, when the cell was dividing. Improved techniques and tools later allowed scientists to detect the copying of DNA (DNA synthesis), and they changed their description of the cell cycle to include the synthesis stage. Since they still could not see anything happening during the other parts of interphase, scientists named the periods between mitosis and synthesis "gap 1" and "gap 2." Eventually scientists learned that, during interphase, cells carry out their normal functions and undergo critical growth and preparation for cell division.

Gap 1 (G_1)

> The first stage of the cell cycle is gap 1 (G1). During G1, a cell carries out its normal functions. If it is a skeletal muscle cell, it contracts to move joints. If it is an adrenal cell, it secretes hormones such as adrenaline. If it is an intestinal cell, it absorbs nutrients. During G1, cells also increase in size, and organelles increase in number. A cell spends most of its time in the G1 stage, although the length of this stage varies by cell type. During G1, the cell must pass a critical checkpoint before it can proceed to the synthesis stage. Just as it

would be dangerous for you to run, a marathon if you had not slept or eaten for several days, it would also be dangerous for your cells to continue dividing if certain, conditions were not met. For instance, most animal cells need enough nutrition, adequate size, and relatively un-damaged DNA to divide successfully. They also need specific signals from other cells, telling them whether more cell division is needed.

Synthesis (S)

The second stage of the cell cycle is the synthesis (S) stage. Synthesis means "the combining of parts to make a whole." During the S stage, the cell makes a copy of its nuclear DNA. In eukaryotes, DNA is located in the nucleus. During interphase, it is loosely organized and appears grainy in photographs. By the end of the S stage, the cell nucleus contains two complete sets of DNA.

Gap 2 (G2)

Gap two (G2) is the third stage of the cell cycle. During G2, cells continue to carry out their normal functions, and additional growth occurs. Like G1, this stage includes a critical checkpoint. Everything must be in order—adequate cell size, undamaged DNA—before the cell goes through mitosis and division.

Mitosis (M)

Mitosis (M), the fourth stage of the cell cycle, includes two processes: mitosis and cytokinesis. Mitosis (my-TOH-sihs) is the division of the cell nucleus and its contents. During mitosis, the nuclear membrane dissolves, the duplicated DNA condenses around proteins and separates, and two new nuclei form. Lastly, cytokinesis (SY-toh-kuh-NEE-sihs) is the process that divides the cell cytoplasm. The result is two daughter cells that are genetically identical to the original cell.

The stages of the cell cycle and the proteins that control it are similar in all eukaryotes. For example, scientists have demonstrated that some of the molecules that regulate checkpoints in the yeast cell cycle can work in human cells, too. Such similarities suggest that eukaryotes share a common ancestry.

MAIN IDEA: Cells divide at different rates.

Rates of cell division vary widely, as shown in FIGURE 1.2.The prokaryotic cell cycle is similar but not identical to that of eukaryotic cells. Recall that prokaryotes do not have the membrane-bound organelles and cytoskeleton found in eukaryotes. Thus, prokaryotic cells typically divide much faster than do eukaryotic cells.

The rate at which your cells divide is linked to your body's need for those cells. In human cells, the S, G2, and M stages together usually take about 12 hours. The length of the G1 stage differs most from cell type to cell type. The rate of cell division is greater in embryos and children than it is in adults. Children have a shorter cell cycle, and many of their organs are still developing. However, the rate of cell division also varies within different tissues of the adult body. The internal lining of your digestive tract receives a lot of wear and tear. As a result, cells that line your stomach and intestine are replaced every few days. In contrast, cells that make up the rest of your intestine (mainly smooth muscle) and many of your internal organs, such as lungs, kidneys, and liver, divide only occasionally, in response to injury or cell death. Cells that divide only rarely are thought to enter a stage that some scientists call G0. In G0, cells are unlikely to divide, although they continue to carry out their normal functions. Some cells, such as neurons, appear to stay permanently in the G0 stage. However, some data suggest that neurons actually can divide, and this question continues to be actively researched. Other cells, such as lymphocytes, a type of white blood cell, may remain in G0 for years until they recognize an invader. Once the invader binds to a lymphocyte receptor, the lymphocyte goes through rapid cell divisions to help fight infection.

MAIN IDEA: Cell size is limited.

Cells have upper and lower size limits. If cells were too small, they could not contain all of the necessary organelles and molecules. For instance, a cell with too few mitochondria would not have enough energy to live. However, cells cannot grow beyond a certain size, even if surrounded by plenty of nutrients. The upper limit on cell size is due to the ratio of

cell surface area to volume. Recall that oxygen, nutrients, and wastes move across the cell membrane, or the surface of the cell. These materials must be transported in adequate amounts and with adequate speed to keep the inside of the cell functioning. However, as a cell increases in size, its volume increases faster than its surface area, as shown in Figure 1.3. Therefore, a further increase in size could result in a surface area too small for the adequate exchange of materials.

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Section 5.2 Mitosis and Cytokinesis

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KEY CONCEPT: Cells divide during Mitosis and Cytokinesis
SECTION SUMMARY: Cells divide during mitosis and cytokinesis. Mitosis divides the nucleus into two genetically identical nuclei in a four-phase process: prophase, metaphase, anaphase, and telophase. In prophase, the duplicated chromosomes condense tightly. Cytokinesis actually divides the cell cytoplasm.

MAIN IDEAS:

- Chromosomes condense at the start of mitosis.
- Mitosis and Cytokinesis produce two genetically identical daughter cells.

VOCAB:

- Chromosome: In a eukaryotic cell, one of the structures in the nucleus that are made up of DNA and protein; in a prokaryotic cell, the main ring of DNA.
- Histone: A type of protein molecule found in the chromosomes of eukaryotic cells but not prokaryotic cells.
- Chromatin: The substance that composes eukaryotic chromosomes; it consists of specific proteins DNA and small amounts of RNA.
- Chromatid: One of the two strands of a chromosome that become visible during meiosis or mitosis.
- Centromere: The region of the chromosome that holds the two sister chromatids together during mitosis.
- Telomere: The region at the tip of a chromosome; a region of repeating DNA sequences that form one of the end points of the DNA segment that makes up a chromosome.
- Prophase: First phase of mitosis when chromatin condenses, the nuclear envelope breaks down, the nucleolus disappears, and the centrosomes and centrioles migrate to opposite sides of the cell.
- Metaphase: Second phase of mitosis when spindle fibers align the chromosomes along the cell equator.
- Anaphase: third phase of mitosis during which chromatids separate and are pulled to opposite sides of the cell.
- Telophase: last phase of mitosis when a complete set of identical chromosomes is positioned at each pole of the cell, the nuclear membranes start to form, the chromosomes begin to uncoil, and the spindle fibers disassemble.

TEKS:

- 2G: analyze, evaluate, make inferences, and predict trends from data
- 5A describe the stages of the cell cycle, including deoxyribonucleic acid (DNA) replication and mitosis, and the importance of the cell cycle to the growth of organism

CONNECT TO YOUR WORLD

When you were a child, perhaps you attended a birthday party where goody bags were handed out. Whoever stuffed the bags had to make sure that each bag had exactly the same number of erasers, candies, and stickers. Otherwise, some ill-mannered child (not you, of course) might have raised a fuss if an item was missing. In a similar way, your cells must receive a full set of DNA—no more, no less—to work properly. Dividing DNA is a complicated task because the DNA is so long and stringy. Mitosis is an amazing process that efficiently sorts two sets of DNA and divides them between two nuclei.

MAIN IDEA: Chromosomes condense at the start of mitosis.

DNA is a double-stranded molecule made of four different subunits called nucleotides. A chromosome is one long continuous thread of DNA that consists of numerous genes along with regulatory information. Your body cells have 46 chromosomes each. If stretched out straight and laid end to end, the DNA in just one of your cells would be about 3 meters (10 feet) long. How does it fit inside the nucleus of a microscopic cell?

DNA wraps around proteins that help organize and condense it. During interphase, or when a cell is not dividing, DNA is loosely organized—it looks a bit like spaghetti. During mitosis, however, your chromosomes are tightly condensed, as shown in FIGURE 2.1. These changes in DNA's organization allow a cell to carry out its necessary functions. During all of interphase, proteins must access specific genes for a cell to make specific proteins or to copy the entire DNA sequence. During mitosis, the duplicated chromosomes must condense to be divided between two nuclei.

If chromosomes remained stringy during mitosis, they could become entangled. Perhaps a cell would get two copies of one chromosome and no copies of a different one. FIGURE 2.2 shows the process that converts a chromosome from a linear strand of DNA to its highly condensed form. The key to this process is the association between DNA and proteins.

At almost all times during the cell cycle, each of your chromosomes is associated with a group of proteins called histones. DNA wraps around histones at regular intervals, similar to beads on a string. The complex of protein and DNA that makes up the chromosome is called chromatin. Parts of the histones interact with each other, further compacting the DNA. At the "spaghetti" stage, the combination of DNA and proteins is loose. The word "loose" describes how much the DNA strand folds back on itself; it does not mean the DNA is loosely wrapped around the histones.

As a cell progresses into mitosis, chromatin further condenses. It continues to coil more and more tightly around organizing proteins, finally forming small, thick rods. Recall that each chromosome has already been copied during the previous S stage. Thus, the chromosome looks similar to an "X" in which the left and right halves are two identical DNA double helixes. One half of a duplicated chromosome is called a chromatid (KROH-muh-tihd). Together, the two identical chromatids are called sister chromatids. Sister chromatids are held together at the centromere (SEHN-truh-MEER), a region of the condensed chromosome that looks pinched.

In addition, the ends of DNA molecules form structures called telomeres (TEHL-uh-meers), which are made of repeating nucleotides that do not form genes. They prevent the ends of chromosomes from accidentally attaching to each other, and they help prevent the loss of genes. A short section of nucleotides is lost from a new DNA molecule each time it is copied. It is important that these nucleotides are lost from telomeres, not from the genes themselves.

MAIN IDEA: Mitosis and Cytokinesis produce two genetically identical daughter cells.

The combined processes of mitosis and cytokinesis produce two genetically identical daughter cells. Following along in **figure 2.4** as you read about the process in more detail below.

Interphase

Interphase plays an important role in preparing the cell to divide. It provides critical time for the duplication of organelles and for DNA replication. By the end of interphase, an individual cell has two sets of DNA, or chromosomes, and is large enough to divide.

Mitosis

Mitosis divides a cell's nucleus into two genetically identical nuclei, each with its own single, full set of DNA. This process occurs in all of your body cells-except those that form eggs or sperm-and prepares them for cytokinesis. Although mitosis and cytokinesis are continuous processes, scientists have divided them into phases to make them easier to understand and discuss. The four main phases of mitosis are prophase, metaphase, anaphase, and telophase. Cytokinesis begins during late anaphase or telophase.

- During prophase, chromatin condenses into tightly coiled chromosomes. Each consists of two identical sister chromatids. The nuclear envelope breaks down, the nucleolus disappears, and the centrosomes and centrioles begin to migrate to opposite sides of the cell. Organized microtubules called spindle fibers grow from the centrioles and radiate toward the center of the cell.
- In metaphase, the spindle fibers attach to a protein structure on the centromere of each chromosome and align the chromosomes alone the cell equator, around the middle of the cell.

- During anaphase, sister chromatids separate from each other. The spindle fibers begin to shorten, pulling the sister chromatids away from each other and toward opposite sides of the cell.
- In telophase, a complete set of identical chromosomes is positioned at each pole of the cell. The nuclear membranes start to form, the chromosomes begin to uncoil, and the spindle fibers fall apart.

Cytokinesis

Cytokinesis divides the cytoplasm into two cells and completes a full stage of the cell cycle. Cytokinesis differs in animal and plant cells. In animal cells, the membrane firms a furrow, or trench, that is pulled inward by tiny filaments, like a drawstring. Gradually the membrane pinches closed, forming a separate cell around each nucleus

During cytokinesis in plant cells, the membrane cannot pinch inward because of the cell wall. Instead, a cell plate forums between the two nuclei. It is made by the Golgi apparatus, which supplies the new plasma membrane. A new wall then grows as cellulose and other materials are laid down. Typically, the cytoplasm is divided evenly between daughter cells in both plant and animal cells.

The formation of new cells is critical in both multicellular and single-celled organisms. Single-celled organisms use cell division to reproduce, whereas multicellular organisms use it for growth, development, and repair.

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Section 5.3: Regulation of the Cell Cycle

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KEY CONCEPT: Cell cycle regulation is necessary for healthy growth
SECTION SUMMARY: Cell cycle regulation is necessary for health growth. Cell growth and division are regulated by both external factors, such as hormones and growth factors, and internal factors, such as cycling and kinases. When proper regulation of cell growth is disrupted, a cell may become cancerous. Cancer cells grow more rapidly the do normal cells and form clumps called tumors that may metastasize to other regions of the body.
MAIN IDEAS:

- Internal and external factors regulate cell division.
- Cell division is uncontrolled in cancer.

VOCAB:

- Growth factor: Broad group of proteins the simulate cell division.
- Apoptosis: Programed cell death.
- Cancer: A type of disorder of cell growth that results in invasion and destruction of surrounding heathy tissue by abnormal cells.
- Benign: Having no dangerous effect on health, especial referring to an abnormal growth of cells that are not cancerous.
- Malignant: Cancerous tumor in which cells break away and spread to other parts of the body, causing harm to the organism's health.
- Metastasize: To spread by transferring a disease-causing agent from the site of the disease to other parts of the body.
- Carcinogen: Carcinogen substance that produces or promotes the development of cancer.

TEKS:

- 5A: describe the stages of the cell cycle, including deoxyribonucleic acid (DNA) replication and mitosis, and the importance of the cell cycle to the growth of organism.
- 5B: Examine specialized cells, including roots, stems, and leaves of plants; and animal cells such as blood, muscle, and epithelium.
- 5C: Describe the roles of DNA, ribonucleic acid (RNA) and environmental factors in cell differentiation.
- 5D: Recognize that disruptions of the cell cycle lead to diseases such as cancer.
- 9C: Identify and investigate the role of enzymes

CONNECT TO YOUR WORLD

Have you ever watched a movie in which people play with the elements of nature? They might bring back dinosaurs or make a new flanged robot. And have you noticed that these movies are always scrap? That's because things go out of control. The robots take over, or the dinosaurs star eating humans. If cell growth goes out of control in your body, the result can be even scarier. Cancer is uncontrolled cell growth and results from many factors that affect the cell cycle. So how does your body regulate all the millions of cell divisions happening in your body?

MAIN IDEA: Internal and external factors regulate cell division.

Both external and internal factors regulate the cell cycle in eukaryotic cells. External factors come from outside the cell. They include messages from nearby cells and from distant parts of the organism's body.
Internal factors come from inside the cell and include several types of molecules found in the cytoplasm. Both types of factors work together to help your body control the process of cell division.

External Factors

External factors that help regulate the cell cycle include physical and chemical signals. One example of a physical signal is cell-to-cell contact. Most mammal cells grown in the

laboratory form a single layer on the bottom of a culture dish, as shown in FIGURE 3.1. Once a cell touches other cells, it stops dividing. The exact reason for this phenomenon is unknown. One hypothesis is that receptors on neighboring cells bind to each other and cause the cells' cytoskeletons to form structures that may block the signals that trigger growth.

Many cells also release chemical signals that tell other cells to grow. For example, growth factors are a broad group of proteins that stimulate cell division. Growth factors bind to receptors that activate specific genes to trigger cell growth. In general, cells grow and divide in response to a combination of different growth factors, not just one.

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Some growth factors affect many types of cells. For example, platelets are sticky fragments of bone marrow cells. They form clots that help stop bleeding. Platelets store a type of growth factor that helps your body repair wounds by triggering the growth of many cell types. Other growth factors have more specific targets. For instance, erythropoietin (ih-RIHTH-roh-poy-EE-tihn) stimulates the production only of cells that will become red blood cells. Red blood cells carry oxygen. If you moved from the coast to the mountains, your blood oxygen levels would be lower because the air pressure is lower at higher altitudes. The decrease in blood oxygen levels would cause your body to produce more erythropoietin. That factor would increase the number of red blood cells and raise your blood oxygen levels.

Various hormones may also stimulate the growth of certain cell types. In growth hormone results in bone growth and also affects your protein and fat metabolism.

Internal Factors

When external factors bind to their receptors, they can trigger internal factors that affect the cell cycle. Two of the most important and well-studied internal factors involved in the eukaryotic cell cycle are kinases and cyclins. A kinase is an enzyme that, when activated, transfers a phosphate group from one molecule to a specific target molecule. This action typically increases the energy of the target molecule or changes its shape. Your cells have many types of kinases, and they are almost always present in the cell. Those kinases that help control the cell cycle are activated by cyclins. Cyclins are a group of proteins that are rapidly made and destroyed at certain points in the cell cycle. These two factors help a cell advance to different stages of the cell cycle when cells bind to each other.

Apoptosis

Just as some cells need to grow and divide, other cells need to die. Apoptosis (AP-uhp-TOH-sihs) is programmed cell death. It occurs when internal or external signals activate genes that help produce self-destructive enzymes. Many questions remain about this process. What is known is that the nucleus of an apoptotic cell tends to shrink and break apart, and the cell is recognized by specialized cells in the immune system. These cells very tidily gobble up the apoptotic cell and recycle its chemical parts for use in building other molecules. FIGURE 3.2 shows a classic example of apoptosis. In the early stages of development, human embryos have webbing between their fingers and toes, or digits. Before a baby is born, those cells typically go through apoptosis. Most babies are born with little unwebbed fingers and toes they love to put in their mouths.

MAIN IDEA: Cell division is uncontrolled in cancer.

Cancer is the common name for a class of diseases characterized by uncontrolled cell division. It arises when regulation of the cell cycle is disrupted. Unlike healthy cells, cancer cells grown in a culture dish continue to divide, even when surrounded by neighboring cells. Cancer cells can also continue to divide in the absence of many of the growth factors required for division in healthy cells. As a result, they divide much more often than do healthy cells.

Cancer cells form disorganized clumps called tumors. In a benign tumor, the cancer cells

typically remain clustered together. This means the tumor may be relatively harmless and can probably be cured by removing it. However, if a tumor is malignant, some of the cancer cells can break away, or metastasize (mih-TAS-tuh-syz), from the tumor. These breakaway cells can be carried in the bloodstream or lymphatic system to other parts of the body, as shown in FIGURE 3.3, where they can form more tumors, called metastases. Once a tumor metastasizes, it is much more difficult to entirely rid the body of tumors.

But why are tumors harmful? Cancer cells do not perform the specialized functions needed by the body. In the lung, for example, cancer cells do not exchange oxygen and carbon dioxide. In the brain, they do not transmit the carefully ordered electrical messages needed to interpret information. Therefore, the body has large clumps of rapidly dividing cells that require lots of food and a hearty blood supply but that contribute nothing to the body's function. In addition, a growing tumor can exert great pressure on surrounding organs. For instance, a tumor growing inside the skull will cramp the brain for space, and some regions will be unable to function properly. If cancer cells continue to grow unchecked, they will eventually kill the organism.

Cancer cells come from normal cells that have suffered damage to the genes that help make proteins involved in cell-cycle regulation. Most cancer cells carry mutations, or errors, in two types of genes. One type, called oncogenes, accelerate the cell cycle. The second type act as cell-cycle brakes. Mutations in these genes can be inherited. For instance, some breast cancers appear to be caused by inherited errors in specific genes. Other mutations can be caused by exposure to radiation or chemicals. For example, some skin cancers are due to DNA damage caused by ultraviolet radiation from sunlight. Sub- stances known to produce or promote the development of cancer are called carcinogens (kahr-SIHN-uh-juhnz). These include tobacco smoke and certain air pollutants, which are both associated with lung cancer. Some mutated forms of oncogenes are even carried by viruses; one such virus can cause cervical cancer.

Standard cancer treatment often involves both radiation and chemotherapy. Radiation therapy is the use of radiation to kill cancer cells and shrink tumors. It works by damaging a cell's DNA so much that the cell cannot divide. Radiation is usually localized—that is, its use is targeted to a specific region—because it can also hurt healthy cells. Chemotherapy uses certain drugs, often in combination, to kill actively dividing cells. Like radiation, it kills both cancerous and healthy cells. However, chemotherapy is systemic— drugs travel throughout the entire body.

Medical researchers use laboratory-grown cancer cells in their search for cancer treatments. Much of what is known about the cell cycle has come from studies that use cancer cells. The most famous cancer cells used for research are called HeLa cells. HeLa cells were originally obtained in 1951 from a cervical tumor removed from a woman named Henrietta Lacks. This cell line continues to be grown and studied in laboratories all over the world.

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Section 5.4: Asexual Reproduction

Wednesday, April 17, 2019 8:14 PM

KEY CONCEPT: Many organisms reproduce by cell division.
SECTION SUMMARY: Many organisms reproduce by cell division. Most prokaryotes reproduce through a binary fission, in which a cell divides into two approximately equal parts. Some eukaryotes reproduce through mitosis. The offspring that result from asexual reproduction are genetically identical to the parent organism, except when mutations occur. Whether being identical is and advantage or disadvantage depends on the environment.
MAIN IDEAS:

- Binary fission is similar in function to mitosis.
- Some eukaryotes reproduce through mitosis.

VOCAB:

- Asexual Reproduction: Reproduction that does not involve the Union of gametes and in which a single parent produces offspring that are genetically identical to the parent
- Binary Fission: A form of asexual reproduction in single-celled organisms by which one cell divides into two cells of the same size.

CONNECT TO YOUR WORLD:

In this flashy world of ours, you may think that the bacterium would have little chance of finding a mate. No dazzling smile, no fancy hair products, no shiny car, and-if we are brutally honest-not even a brain. With all of these limitations, it may seem that our bacteria friends would be destined to die out. And yet, bacteria are found in abundance and live just about everywhere on Earth. How can there be so much bacteria?

MAIN IDEA: Binary fission is similar in function to mitosis.

Reproduction is a process that makes new organisms from one or more parent organisms. It happens in two ways—sexually and asexually. Sexual reproduction involves the joining of two specialized cells called gametes (eggs and sperm cells), one from each of two parents. The offspring that result are genetically unique; they have a mixture of genes from both parents. In contrast, asexual reproduction is the production of offspring from a single parent and does not involve the joining of gametes. The offspring that result are, for the most part, genetically identical to each other and to the single parent.

Binary Fission and Mitosis

Most prokaryotes reproduce through Binary fission (BY-nuh-ree FIHSH-uhn), the asexual reproduction of a single-celled organism by which the cell divides into two cells of the same size. Binary fission and mitosis have similar results. That is, both processes form two daughter cells that are genetically identical to the parent cell. However, the actual processes are different in several important ways.

As you already learned, prokaryotes such as bacteria do not have nuclei. They also do not have spindle fibers. And although they have DNA, prokaryotes have much less DNA than do most eukaryotes. The DNA of most bacteria is in the form of a single circular chromosome.

Binary fission, shown in FIGURE 4.1, starts when the bacterial chromosome is copied. Both chromosomes are attached to the cell membrane. As the cell grows and gets longer, the chromosomes move away from each other. When the cell is about twice its original size, it undergoes cytokinesis. The membrane pinches inward, and a new cell wall forms between the two chromosomes, which completes the separation into two daughter cells.

Advantages and Disadvantages of Asexual Reproduction

Very often, whether something is helpful or harmful depends on the situation. In favorable environments that do not change much, asexual reproduction can be more efficient than sexual reproduction. Recall that asexual reproduction results in genetically identical offspring. If they are well suited to the environment, genetic variation could be more

harmful than helpful. In other words, if it isn't broke, don’t fix it.

However, asexual reproduction may be a disadvantage in changing conditions. Genetically identical offspring will respond to the environment in the same way. If population members lack traits that enable them to reproduce in a changed environment, the entire population could die off. In contrast, sexual reproduction increases genetic diversity, which raises the chance that some individuals will survive in changing conditions.

Keep in mind, however, that the act of asexual reproduction itself is not more efficient; rather, the associated costs of sexual reproduction are greater. For example, all asexually reproducing organisms can potentially reproduce. Suppose two organisms each have ten offspring. If one organism reproduces asexually, all ten offspring can have offspring of their own. If the other organism reproduces sexually, having five females and five males, only the five females can bear offspring. In addition, sexually reproducing organisms must attract a mate. This effort involves not only the time and energy needed to find a mate but also many structures, signals, and behaviors that have evolved to attract mates. Organisms that reproduce asexually do not have these costs.

MAIN IDEA: Some eukaryotes reproduce through mitosis.

Some eukaryotes also reproduce asexually, through mitosis. Have you ever grown a new plant from a stem cutting? Or seen a new sea star growing from the arm of another one? These new organisms are the result of mitotic reproduction and are therefore genetically the same as the parent organism. Mitotic reproduction is especially common in simpler plants and animals. It occurs in both multicellular and unicellular eukaryotes. It can take several forms, including budding, fragmentation, and vegetative reproduction.

In budding, a small projection grows on the surface of the parent organism, forming a separate new individual. The new organism may live independently or attached as part of a colony. For instance, hydras and some types of yeast reproduce by budding. Examples are shown in FIGURE 4.3.

In fragmentation, a parent organism splits into pieces, each of which can grow into a new organism. Flatworms and sea stars both reproduce by fragmentation. Many plants, including strawberries and potatoes, reproduce via vegetative reproduction. In general, vegetative reproduction involves the modification of a stem or underground structures of the parent organism. The offspring often stay connected to the original organism, through structures called runners, for example.

Many organisms can reproduce both asexually and sexually. The form of reproduction may depend on the current conditions. The sea anemone can reproduce in many ways. It can reproduce asexually by dividing in half, by breaking off small pieces from its base, or by budding. It can also reproduce sexually by making eggs and sperm. Some species of anemone have separate males and females. In other anemone species, the same organism can produce both eggs and sperm cells.

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Section 5.5: Multicellular Life

Wednesday, April 17, 2019 8:15 PM

KEY CONCEPT: Cells work together to carry out complex functions
SECTION SUMMARY: Cells work together to carry out complex functions. Within multicellular organisms, cells form tissues, tissues form organs, and organs form organ systems. The cells differentiate to perform specific functions. Much of this specialization is determined by a cell's location within the developing embryo. Stem cells are a special type of cell that continue to divide and renew themselves for long periods of time.

MAIN IDEAS:

- Multicellular organisms depend on interactions among different cell types
- Specialized cells preform specific functions
- Stem cells can develop into different cell types

VOCAB:

- Tissue: A group of similar cells that preform a common function.
- Organ: A collection of tissues that carry out a specialized function of the body.
- Organ System: Two or more organs that work in coordinated way to carry out similar functions.
- Cell Differentiation: The process by which a cell becomes specialized for a specific structure or function during multicellular development.
- Stem Cell: Cell that can divide for long periods of time while remaining undifferentiated.

TEKS:

- 5B: Examine specialized cells, including roots, stems, and leaves of plants; and animal cells such as blood, muscle, and epithelium.
- 5C: Describe the roles of DNA, ribonucleic acid (RNA) and environmental factors in cell differentiation.
- 10C: Analyze the levels of organization in biological systems and relate the levels to each other and to the whole system

CONNECT TO YOUR WORLD

Each of us enters this world as a helpless infant. At first, your ability to eat solid foods or take your first steps elicits a great deal of praise. Over time, however, your development of normal skills gets far less attention. By the time you reach the age of 18, people want to know what you plan to do with your life. Will you build houses or design clothing or treat patients? What will your specialty be? Cells, too, undergo specialization to carry out the complex functions required by the body.

MAIN IDEA: Multicellular organisms depend on interactions among different cell types

Within multicellular organisms, cells communicate and work together in groups that form increasingly larger, more complex structures. This arrangement progresses from cells to tissues to organs to organ systems, as shown in FIGURE 5.1. Tissues are groups of cells that work together to perform a similar function. Groups of tissues that work together to perform a specific function or related functions are called organs. For instance, plants have photosynthetic tissues made of chlorophyll-containing cells. Conductive tissues transport sugars, water, and minerals to and from other parts of the plant. Protective tissues help prevent water loss. Together, these and other tissues form a leaf, the plant's food-producing organ.

Organs that carry out similar functions are further grouped into organ systems. In plants, the shoot system is above the ground. It includes stems that support the plant, leaves that capture radiant energy, and flowers that aid reproduction. Beneath the ground, the root system has different types of roots and root hairs that anchor the plant and absorb water and minerals.

As organ systems work together, they help an organism maintain homeostasis. For example, plants need to maintain a certain level of water within their cells, otherwise they will wilt and die. They absorb water through their roots and expel it as water vapor through

openings in their leaves called stomata. Stomata are controlled by special cells called guard cells, which close the stomata when a plant's water intake cannot keep up with its water loss.

MAIN IDEA: Specialized cells preform specific functions

It is easy to see that a skin cell can divide to make a new skin cell, or that a single bacterium can generate another bacterium. But how does a complex organism like you develop? Your body began as a single fertilized egg. If the egg simply divided to make lots of identical cells, it would not form a baby. To form the intricate structures that make up your body and the bodies of countless organisms around you, cells must specialize.

Cell differentiation is the process by which a cell becomes specialized for a specific structure or function during multicellular development. While almost every cell in your body has a full set of DNA, each type of cell expresses only the specific genes it needs to carry out its function. That is, a cell differentiates among the genes and uses only certain ones. You can think of your DNA as a cookbook. When you want to make a specific dish, you select that recipe and carry out its instructions. If you need to make a dessert, you might choose brownies. If you need to make a main course, you might fix lentil stew. The dishes are very different, but they all come from the same cookbook.

A cell's location within the embryo helps determine how it will differentiate. In plant cells, the first division of a fertilized egg is unequal, or asymmetric, as shown in FIGURE 5.2. The apical cell forms most of the embryo, including the growth point for stems and leaves. The major role of the basal cell is to provide nutrients to the embryo; it also creates the growth point for the roots. Plant cells cannot easily migrate because of the cell wall, but they adapt to changing conditions and continue to develop throughout their lifetime.

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As the plant grows, new cells continue to differentiate based on their location. For example, cells on the outer layer of a leaf may become epidermal cells that secrete a waxy substance that helps prevent water loss. Cells on the lower leaf surface may become guard cells that control the exchange of water, air, and carbon dioxide.

In animals, an egg undergoes many rapid divisions after it is fertilized. The resulting cells can migrate to a specific area, and the cells quickly begin to differentiate. The early animal embryo generally takes the shape of a hollow ball. As the embryo develops, part of the ball folds inward, forming an inner layer and creating an opening in the outer cell layer. A middle layer of cells then forms. As shown in FIGURE 5.3, in vertebrates, the outer cell layer differentiates to form the outer layer of skin and elements of the nervous system, such

as the brain and spinal cord. The middle cell layer forms bones, muscles, kidneys, and the inner layer of skin. The inner cell layer forms internal organs, such as the pancreas, lungs, and digestive system lining.

MAIN IDEA: Stem cells can develop into different cell types

Stem cells are a unique type of body cell that can (1) divide and renew themselves for long periods of time, (2) remain undifferentiated in form, and (3) differentiate into a variety of specialized cell types. When a stem cell divides, it forms either two stem cells or one stem cell and one specialized cell.

Stem Cell Classification

Stem cells can be classified by their ability, or potential, to develop into the differentiated cell types of different tissues. In general, the more differentiated a stem cell already is, the fewer the types of cells it can form.

- Totipotent stem cells can grow into any other cell type. Only a fertilized egg and the cells produced by the first few divisions of an embryo are totipotent.
- Pluripotent stem cells can grow into any cell type except for totipotent stem cells.
- Multipotent stem cells can grow only into cells of a closely related cell family.

Stem cells are also classified by their origin, as either adult or embryonic. Adult stem cells have been studied for decades, but the ability to grow human embryonic stem cells was not developed until 1998. Since that time, embryonic stem cells have attracted great attention because of their potential to form almost any cell type.

Adult Stem Cells

Adult stem cells are partially undifferentiated cells located among the specialized cells of many organs and tissues. They are found all over the body, in the brain, liver, bone marrow, skeletal muscle, dental pulp, and even fat. These stem cells are also found in children and in umbilical cord blood, so the term somatic stem cell is more accurate although less frequently used.

A major advantage of adult stem cells is that they can be taken from a patient, grown in culture, and put back into the patient. Thus, the risk of transplant rejection by a patient's immune system is very low. This method also avoids many ethical issues associated with using embryonic stem cells.

Adult stem cells currently pose many disadvantages as well. They are few in number, difficult to isolate, and sometimes tricky to grow. They may also contain more DNA abnormalities than do embryonic stem cells. For years, much evidence suggested that adult stem cells were multipotent. This would mean that a stem cell from fat would produce only fat cells, never muscle cells.

Newer data suggest otherwise. Adult stem cells treated with the right combination of molecules may give rise to a completely different type of tissue. This process, called trans differentiation, remains an active area of research.

Embryonic Stem Cells

Most embryonic stem cells come from donated embryos grown in a clinic. These embryos are the result of in vitro fertilization, a process by which eggs are fertilized outside a woman's body. The stem cells are taken from a cluster of undifferentiated cells in the three-to-five-day-old embryo. These cells, called the inner cell mass, do not have the characteristics of any specific cell type. Because they are pluripotent, they can form any of the 200 cell types of the body. They can also be grown indefinitely in culture. These qualities offer hope that many diseases will be treatable or even curable. Stem cells have long been used to treat patients with leukemia and lymphoma, and people with diabetes might someday be cured if nonworking cells in the pancreas are replaced with healthy, growing cells. Even damaged organs might be strengthened by an injection of healthy cells. Embryonic stem cells also have a downside. If these cells are used in treatment, a patient's body might reject them as foreign material. A different possibility is that the stem cells could grow unchecked in a patient's body and form a tumor. The use of embryonic stem cells also raises many ethical questions. FIGURE 5.4 shows the most common method of obtaining embryonic stem cells. This method currently involves destruction of the embryo,

which some people consider ethically unacceptable.

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