5.3 Regulation of the Cell Cycle

KEY CONCEPT Cell cycle regulation is necessary for healthy growth.

MAIN IDEAS

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

VOCABULARY

growth factor, p. 144
apoptosis, p. 145
cancer, p. 146
benign, p. 146
malignant, p. 146
metastasize, p. 146
carcinogen, p. 146

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Connect Have you ever watched a movie in which people play with the elements of nature? They might bring back dinosaurs or make a newfangled robot. And have you noticed that these movies are always scary? That's because things go out of control. The robots take over, or the dinosaurs start 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.

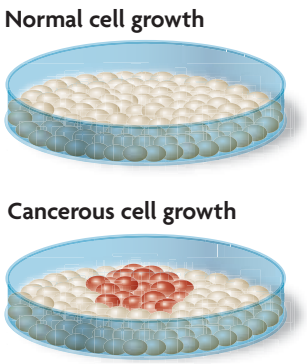
Internal factors come from inside the cell and include several types of molecules found in the cytoplasm. Both types of factors work together to help your body control the process of cell division.

External Factors

External factors that help regulate the cell cycle include physical and chemical signals. One example of a physical signal is cell–cell contact. Most mammal cells grown in the laboratory form a single layer on the bottom of a culture dish, as shown in **FIGURE 5.8.** 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.

FIGURE 5.8 Normal animal cells (top) respond to external factors and stop dividing when they touch each other. Cancer cells (bottom) fail to respond and form clumps.



Some growth factors affect many different 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 different 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 particular, 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 5.9** 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.

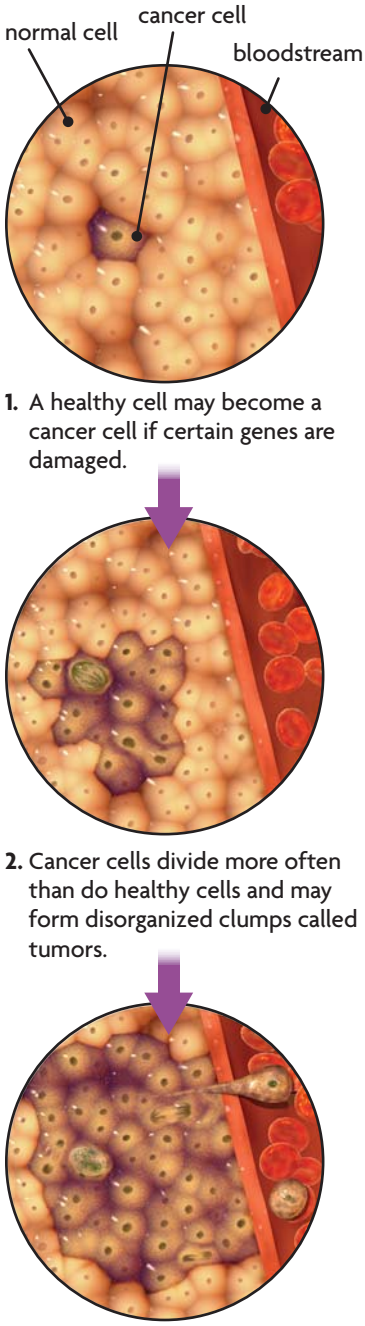
Predict **Suppose a child was born whose receptors for growth hormone did not work properly. How do you think this would affect the child's development?**

FIGURE 5.9 Human embryos have webbed digits early in their development. The cells between the digits undergo apoptosis during later stages of development. As a result, the baby is born with unwebbed fingers and toes.

MAIN IDEA

Cell division is uncontrolled in cancer.

FIGURE 5.10 Cancer cells form tumors that may metastasize to other parts of the body.



Cancer is the common name for a class of diseases characterized by uncontrolled cell division. It arises when regulation of the cell cycle breaks down. 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 lymph system to other parts of the body, as shown in **FIGURE 5.10,** 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. Substances 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.

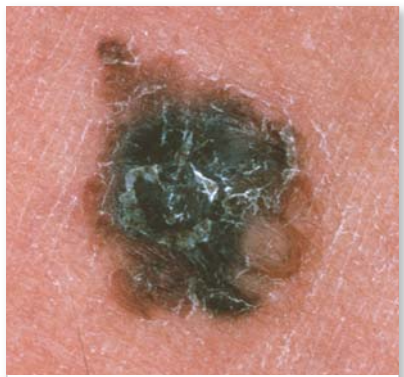


FIGURE 5.11 This cancerous mole is an example of a skin cancer, which may metastasize quickly.

QUICK LAB OBSERVING

Cancer

In this lab, you will compare normal cells with cancerous cells and observe the differences between them.

MATERIALS
- microscope
- slides of normal cells
- slides of cancerous cells

PROBLEM How do normal and cancerous cells compare?

PROCEDURE

1. Examine the slides of normal cells under the microscope. Draw and describe your observations.
2. Repeat step 1 with slides of cancer cells.

ANALYZE AND CONCLUDE

1. **Compare** How does the structure of the normal cells compare with the structure of the cancerous cells for each of the slides you viewed?
2. **Infer** Cancer cells not only appear different from normal cells but they also divide more rapidly. Why do you think chemotherapy, a common treatment for cancer, results in the loss of hair?

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.

Analyze HeLa cells are also used to study cell signaling processes. What might be a disadvantage of using cancer cells to study processes occurring in healthy cells?

5.3 ASSESSMENT

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REVIEWING MAIN IDEAS

1. Describe what a **growth factor** is and how it influences the cell cycle.
2. Explain how **cancer** cells differ from healthy cells.

CRITICAL THINKING

3. **Contrast** How do **benign** and **malignant** tumors differ?
4. **Hypothesize** Suppose chromosomes in a skin cell are damaged by ultraviolet radiation. If the damaged genes do not affect cell cycle regulation, do you think the cell will become cancerous? Explain.

Connecting CONCEPTS

5. **Cell Organelles** Some anticancer drugs prevent microtubules from forming spindle fibers. Why do you think these drugs might be effective treatments for cancer?