OVERVIEW

Students play a board game that simulates the cell cycle, with each student in a group of four taking the role of a specific type of cell. As they progress through the cycle, students learn about the phases and events of the cycle.

KEY CONTENT

1. Cell functions are regulated to control and coordinate cell growth and division.
2. The cell cycle is the complete sequence of phases from the end of one cell division to the end of the next.
3. When normal cell regulation is disrupted, serious consequences, such as cancer, result.
4. Some types of cells, including blood and skin cells, divide more often than other types, such as liver and nerve cells.

KEY PROCESS SKILLS

1. Students record observations and identify trends.

MATERIALS AND ADVANCE PREPARATION

For the teacher

- Literary Transparency 2, “Read, Think, and Take Notes Guidelines” (optional)
- transparency of Scoring Guide: GROUP INTERACTION (GI)

For the class

- 6 Cell Cycle Game Key: Cancer Cell

For each group of four students

- Cell Cycle game board
- 4 9-ounce plastic cups, each containing a different color of modeling clay (red, green, yellow, and blue)
- 2 number cubes
- set of four Cell Cycle game keys (blood, liver, nerve, and skin)

For each student

- Student Sheet 13.1, “Cell Cycle Record Sheet”
- empty 9-ounce plastic cup
- Student Sheet 2.1, “Disease Information” from Activity 2
- sticky notes
- Scoring Guide: GROUP INTERACTION (GI) (optional)

Divide the four colors of clay into enough portions so that each group of four students receives one half-full cup of each color.

Masters for Scoring Guides are in Teacher Resources IV: Assessment.

TEACHING SUMMARY

Getting Started

- Introduce the importance of cell division and the cell cycle for normal growth and development of an organism.

Doing the Activity

- (GI ASSESSMENT) Students play the Cell Cycle simulation game.
- (GI ASSESSMENT)(LITERACY) Students discuss what happened to their cell types.
- (LITERACY) Students follow the Read, Think, and Take Note literacy strategy as they read a case study about cancer.

Follow-up

- (LITERACY) The class compares the five types of cells.
BACKGROUND INFORMATION

The cell cycle is the subject of intensive scientific and medical research because of its role in growth and cell differentiation, and because disruption of normal regulation of the cell cycle often leads to serious consequences, including cancer.

Cell Division

As an organism grows, its cells become more numerous, but not steadily larger. A cell cannot grow indefinitely because it cannot survive if its surface-area-to-volume ratio becomes too small. When this ratio is too small, there is not enough cell membrane surface to exchange nutrients and wastes and maintain cell homeostasis of the larger volume within. Growth of a multicellular organism, therefore, requires cells to divide. Cell division is the process by which a cell produces two genetically identical offspring, which scientists often refer to as daughter cells. Cell division includes mitosis, in which the replicated chromosomes divide and separate, and cytokinesis, in which the cytoplasm is divided. After division, each daughter cell has a complete set of chromosomes.

The Cell Cycle

Most cells in the human body have exited the cell cycle, and are in the G₀ phase. When protein growth factors or other molecular signals cause them to re-enter the cell cycle, they usually complete the cycle and divide. There are four main phases in the cell cycle. A newly formed cell progresses through these four phases in the following order: G₁, S, G₂, and M. G stands for growth or gap, and cell growth occurs during the two G phases. S is the synthesis phase in which DNA replication occurs. Both mitosis and cytokinesis take place during the M—mitosis—phase. Do not share this information with students until they have finished the game. One object of the game is for them to develop an understanding of these phases. The cell cycle is regulated by many factors, including a group of proteins called cyclins, which fluctuate in concentration and provide a sort of molecular clock for the cell cycle. Cancer results when cell division is no longer controlled. Some cells that have become cancerous do not respond to the protein regulators such as cyclin, and divide more frequently than needed. This kind of growth creates the masses of cells that become tumors, which damage, impinge on, or attach themselves to surrounding tissues. If these cells also lose the controls that determine where in the body they belong, they can migrate to other parts of the body (metastasize). Cancerous tumors, or malignant tumors, are those that grow without limitations, invade surrounding tissues, and metastasize. For example, lung cancer often metastasizes to the brain or bones. In contrast, benign tumors lack these characteristics and are not considered cancerous, although they can cause problems if they interfere with other tissues or organs. Some benign tumors can become cancerous.
**GETTING STARTED**

1. Begin by comparing a human zygote, embryo, and adult to each other. Explain that a zygote forms immediately upon fertilization. After four days, the human embryo has divided several times and is made of 64 cells. As these cells continue to divide, the embryo develops specialized cells, tissues, and organs. At about eight weeks the human embryo is called a fetus. The fetus develops until a baby is born at about 38 weeks after fertilization, and eventually an adult develops. Ask, *What happens during those days, months, and years to turn those early 64 cells of the embryo into a baby and then an adult?*

Students will likely say that the cells grow or divide and specialize. If not, bring out the idea that for a multicellular organism to grow its cells must divide, because cells cannot enlarge infinitely. Explain that the events that take place from the initial formation of one cell until it completes division to form two new daughter cells is called the cell cycle. Next ask, *Where in the body do you think cells must divide frequently in adults?*

Likely answers include the reproductive system, skin, and hair. Tell students that in adults, cells also divide frequently in other locations, for example to replace the linings of the digestive system and blood cells, which last only a few days or months, respectively. Ask, *What problems might result if certain cells in the body divide too slowly, or not at all?*

There will not be enough cells to replace those that die naturally or become damaged and die, and there will not be enough to perform those cells’ specialized functions. For example, if red blood cell forming cells, called blood stem cells, did not divide to produce blood cells fast enough or not at all, there would not be enough blood cells to deliver oxygen to the organs and tissues of the body. Explain also that some tissues and organs rarely need replacement, and so their cells stop dividing. If cells divide too frequently, there may be more than are needed, and they might run out of space or crowd other cells or organs. Then ask, *What preparations do you think are necessary so that a cell can divide to form two daughter cells?*

The cell must have sufficient numbers of organelles and enough cytoplasm to split between two cells. Also, since every cell has a complete copy of DNA, the DNA must be doubled before the cell divides.
DOING THE ACTIVITY

1. Demonstrate how to make a marble-sized piece of clay, and show how to enlarge it to 1.5 times its original size by adding a smaller piece of clay to simulate growth during G1. Show how to enlarge it to 2 times its original size by adding more clay, should the cell grow again during G2. When the cell is approximately twice its original size and its DNA has replicated, it is ready to divide. Demonstrate how students should pinch their cells into two approximately equal-sized daughter cells when the game key instructs them to do so.

2. [GI ASSESSMENT] Distribute the materials for the cell cycle simulation. Review the game board, which is an enlarged version of the cell cycle diagram in the Student Book. Be sure that each student in the group takes one of the four keys (blood, liver, nerve, or skin) and a cup of clay in the color that matches the key. Review the GROUP INTERACTION (GI) Scoring Guide. Tell students this activity is an opportunity for them to demonstrate their ability to work effectively in groups: groups will process and discuss information as they play the game and then meet to discuss their results as described below.

Monitor the groups or work with the whole class as they conduct Procedure Steps 1–5. Make sure each student is clear on the type of cell he or she has been assigned and has the appropriate color of clay according to the key in the Student Book. Allow them to continue working until they complete Procedure Step 9. Some students’ cells will become cancerous, and they will ask you for a Cell Cycle game key for cancer. If two or more students in the group have cells that become cancerous, they can share the cancer cell key.

Procedure

1. You will play the Cell Cycle game in your group of four. Each of you takes one of the four Cell Cycle game keys—blood, liver, nerve, or skin.

2. Based on your game key, you will play the game as a blood, liver, nerve, or skin cell. Record your cell type on Student Sheet 13.1, “Cell Cycle Record Sheet.”

3. Distribute the cups of clay according to the key below, with each person taking the color for his or her assigned cell type.

<table>
<thead>
<tr>
<th>CELL TYPE</th>
<th>CLAY COLOR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blood</td>
<td>red</td>
</tr>
<tr>
<td>Liver</td>
<td>blue</td>
</tr>
<tr>
<td>Nerve</td>
<td>green</td>
</tr>
<tr>
<td>Skin</td>
<td>yellow</td>
</tr>
</tbody>
</table>

4. Prepare a clay model of your cell. It should be about the size of a marble.

5. Place your model cell on the game board at the beginning of the game, near the start of the G1 phase. Each player’s cell has just completed the mitosis phase (M) of the cell cycle, and is ready to begin another cycle.

6. Begin round one of the game, with the blood cell person going first, and the rest of the group proceeding clockwise around your group. When it is your turn, roll both number cubes.

7. Look at your Cell Cycle game key to find out what the number you rolled means, and follow that instruction.

8. On Student Sheet 13.1, “Cell Cycle Record Sheet,” record what happened to your cell in this round of the game.

9. Tell your group members what happened to your cell.

10. Continue to play the game for at least 20 rounds of rolling the number cubes. Each round, roll the number cubes unless you were told by your Cell Cycle game key to skip the turn. Each time you roll, follow Steps 7, 8, and 9 to find out what happens to your cell, record the outcome, and share it with your group.
(LITERACY, GI ASSESSMENT) Set up five areas of the classroom, one for each type of cell: blood, liver, nerve, skin, and cancer. Direct students who represent these cell types to the appropriate area where they can discuss in an Informal Meeting of the Minds what happened to their cell type, as explained in Procedure Step 11. Circulate around the room, and, as needed, ask such questions as: Based on the simulation, does your cell type divide frequently or infrequently? What factors or events controlled whether the cell moved along in the cell cycle? What kinds of things might occasionally go wrong as the cell progresses through the cycle?

Have students return to their original groups, and instruct them to work together to prepare a chart (or other format you suggest) to summarize what kinds of things happened to each cell type. A sample is shown on the following page.

If necessary, project Literacy Transparency 2, “Read, Think, and Take Notes” guidelines to review with students. If you wish to assign the cancer case study for homework, make sure students take sticky notes with them so they can follow the Read, Think, and Take Note literacy strategy. Begin the next class by having students discuss with their partners or groups what they wrote on their sticky notes and the main points of the reading. A sample response for Student Sheet 2.1, “Disease Information” is shown at the end of Activity 13.

**FOLLOW-UP**

Discuss the similarities and differences in the cell cycles of the five types of cells. Similarities include the phases of the cell cycle, cyclin’s role as a regulatory factor, and coordination of cell cycle events and phases. For example, the chromosomes must be copied before a cell enters mitosis so that each daughter cell ends up with a complete copy of the chromosomes. Cells occasionally become cancerous because
normal control mechanisms failed. These cancer cells are often destroyed by the immune system. The main difference between the cell types was how long they remained in G₁ (or moved into a permanent G₀) before continuing through the cycle. This rate depends on the body’s need for and ability to replace this type of cell. A notable difference was the neuron’s inability to divide. Analysis Question 5 is a Quick Check assessment for students’ understanding that uncontrolled cell division often leads to formation of a tumor. Be sure to bring out that the cell cycle is regulated by proteins and other molecular factors, including the cyclin proteins. If the cell does not respond to these molecular signals or proceeds even when the cell is not fully prepared, the cell cycle becomes abnormal. This can damage the cell, leading to cell death or formation of cancer cells. Cancer cells lose the normal controls of cell division, which leads to the formation of tumors.
Woman 2 develops precancerous tissue at age 30 even though she was vaccinated for HPV at age 16. This is possible because the HPV vaccine does not protect against all types of HPV that can lead to cervical cancer.

7. Explain the main reasons why the outcomes at age 35 for the two women with cervical cancer vary in the following scenario:

<table>
<thead>
<tr>
<th>Outcomes for Two Cervical Cancer Patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>AGE</td>
</tr>
<tr>
<td>-----</td>
</tr>
<tr>
<td>16</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>30</td>
</tr>
<tr>
<td>35</td>
</tr>
<tr>
<td>36 and older</td>
</tr>
</tbody>
</table>

8. Based on the cancer case study, how is cancer related to the social, economic, and environmental aspects of sustainability?

**KEY VOCABULARY**

- cancer
- cytokinesis
- cell cycle
- daughter cell
- chromosome
- mitosis
- cyclin
- replication
SAMPLE RESPONSES

1. a. blood stem cell, skin stem cell
   b. liver
   c. nerve
   d. cancer

2. The factors that control a cell’s progress through the cell cycle include whether it has grown and replicated its DNA and the levels of a regulatory protein called cyclin.

3. Stage 1: G₁ (first gap or growth), the cell grows.
   Stage 2: S (synthesis), the cell’s DNA replicates.
   Stage 3: G₂ (second gap or growth), the cell grows more, until it is about twice its original size.
   Stage 4: M (mitosis) and cytokinesis, the cell divides. This begins with separation of the chromosomes, and then the two daughter cells separate.

4. a. Cells should only be signaled to enter the cell cycle when the body needs more of them. Otherwise, there is no reason for them to prepare for division.
   b. At each stage of the cell cycle, certain things must happen for a cell to go on to the next stage. For example, the cell’s DNA has to be copied so that when the cells divide, each cell has a complete copy of the DNA. Also, if cells don’t grow before they divide, they will be too small and may lack needed structures.

5. ✔ The cells will grow and divide so rapidly that there will be too many of them, and they will form a tumor. Often the tumor interferes with the function of the organ.

6. a. The drugs will kill a higher percentage of cancer cells because cancer cells divide more frequently. The drugs will kill them by interfering with the structures that are used for mitosis.
   b. Because white blood cells have to be replaced, the blood stem cells have to divide often, so the drugs will have more of an effect on white blood cells.
7. The two women in the case study had different outcomes because one had adequate health care and the other one did not. Specifically, the girl with access to health care was offered preventive measures: she was screened and vaccinated early to reduce the risk of developing cervical cancer. When she developed precancerous cervical tissue, it was removed and prevented from developing into cancer.

8. Cancer causes anxiety, pain, suffering, and sometimes death, and takes a heavy toll on patients and their families. This is one social impact of the disease. Social factors, such as lifestyle choices and behaviors, can also increase the risk for some cancers, such as smoking, drinking alcohol, dietary selections, being obese, lack of exercise, and engaging in unprotected sex. Cancer has an economic impact on families and society due to the high cost of care, and the lack of productivity if people with cancer cannot work. Environmental factors, such as exposure to tobacco smoke or air and water pollution, increase cancer risk. People may be exposed to these environmental factors based on where they live or work.

**REVISIT THE CHALLENGE**

Review the phases of the cell cycle with the class. Make sure they understand key events of each phase and their importance in producing normal daughter cells. Emphasize the importance of the role of proteins in coordinating all steps of the cell cycle.
depending on the cancer. Radiation therapy directs X-rays or other high-energy particles to the area of the tumor to damage the genetic material inside the cancer cells and kill them. Normal cells in the radiated area are sometimes damaged but are usually replaced by division of the normal cells that remain.

CHALLENGES TO PREVENTION AND TREATMENT
Challenges vary depending on the type of cancer. It is often difficult for people to avoid or control environmental risk factors for cancer simply because some of these factors are found in the environment. For example, several industrial chemicals have been associated with increased lung cancer risk, including asbestos, arsenic, nickel, chromium, zinc, and radon. People might be exposed to these chemicals in their work environment or home. Research suggests that up to 13% of lung cancer cases in men and 5% in women are due to occupational hazards. Also, many people cannot avoid exposure to air pollution if they live in urban areas where pollution levels are high. And for many people, making a behavioral change, such as quitting smoking, is very hard to do.

While screening may detect cancer early, it can only be effective if there is a treatment strategy for that cancer. Also, for many cancers, cost-effective early diagnostic tests have not yet been developed. The drawbacks of chemotherapy and radiation therapy are that they kill many normal cells, not just cancer cells. Fatigue, nausea, diarrhea, loss of appetite, and hair loss are just some of the side effects that might be mild or severe, depending on the drugs and course of radiation. Although cancer might strike anyone, poor people in low-income developing countries have a lower chance of surviving the disease than those in higher-income countries. The preventive and treatments available for cancer are often too expensive in the lower-income countries, and there may be few, if any, accessible hospitals or health care professionals capable of providing the care needed.
**Disease Information**

<table>
<thead>
<tr>
<th>Disease</th>
<th>Cancer</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Description of disease and symptoms</strong></td>
<td>People all over the world, at all income levels get cancer. Cancer refers to any of more than 100 diseases that occur when cells lose the normal controls that regulate growth and division in the cell cycle.</td>
</tr>
<tr>
<td><strong>Cellular mechanism of disease</strong></td>
<td>Most cancers grow through a number of cell cycles that results in a mass of cells called a tumor. Mutations in genes that stimulate or stop cell division can cause cancer through unregulated cell growth and division that lead to tumors.</td>
</tr>
<tr>
<td><strong>Social factors</strong></td>
<td>Some risk factors for cancer are: tobacco use, being obese, lack of physical activity, diet, alcohol use, infection with a certain virus, urban air pollution, and indoor smoke from burning fuels. Some of these can be difficult to avoid depending on where people live. Behavior can be difficult to change. Screening, education, tobacco/alcohol programs, and vaccination can prevent some cancers.</td>
</tr>
<tr>
<td><strong>Economic factors</strong></td>
<td>Preventions and treatments can be expensive for people in developing countries. Some countries may not have hospitals or health care professionals to provide proper treatment or screening.</td>
</tr>
<tr>
<td><strong>Environmental factors</strong></td>
<td>Toxicants, tobacco smoke, pollution, asbestos, and viruses in the environment can cause mutations</td>
</tr>
</tbody>
</table>