Cell division is the basis of reproduction for all organisms, and also for the development and growth of multicellular organisms. The complete sequence of phases from the end of one cell division to the end of the next is called the cell cycle. The cell cycle is divided into a sequence of four phases, shown in the diagram below. One of these four phases, called mitosis, is the stage at which the cell divides to produce two new—or offspring—cells.

A group of cell-cycle control proteins regulates the phases of the cell cycle to ensure that all events needed for normal cell division take place before division begins. Cell-cycle regulation also ensures that specific cell types divide at the right time and place. For example, in the human body red blood cells must be replaced about every 120 days. If the stem cells that differentiate into red blood cells become under- or over-active, either too few or too many red blood cells are produced. Regulation of the cell cycle also ensures that a cell completes the growth and synthesis phases so that it will divide properly. When cell growth and division proceed abnormally, cancer might result.

**Challenge**

What happens during each phase of the cell cycle, and how are the phases regulated?

**MATERIALS**

**FOR EACH GROUP OF FOUR STUDENTS**
- Cell Cycle game board
- 4 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”
- Student Sheet 2.1, “Disease Information” from Activity 2
- empty plastic cup
- sticky notes
**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.

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.

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**Cell Cycle Game Key**

<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>
11. Following your teacher’s instructions, join a group of other students who had
the same type of cell as yours. Discuss with these students, and record in your
science notebook, what kinds of things happened to this cell type.

12. Rejoin your original group.

13. Work with your group to prepare a chart that summarizes what you learned
about each of the four types of cells.

14. Follow your teacher’s directions for reading the case study about cancer. As
you read, use the Read, Think, and Take Note strategy.

15. Fill in the information for cancer on Student Sheet 2.1, “Disease Informa-
tion,” after you read the case study.

**Analysis**

1. Of the cell types you investigated, which divide:
   a. frequently?
   b. occasionally, as needed?
   c. never, or almost never?
   d. more frequently than normal and without control?

2. What kinds of factors regulate a cell’s progress through the cell cycle?

3. Beginning with *G₁*, list the four phases of the cell cycle in order, and describe
what happens in each phase.

4. Why is it important for each of the following to be regulated?
   a. Entry into the cell cycle
   b. Progress from one phase of the cell cycle to the next

5. A cell in the liver divides. Its offspring and all of their offspring continue to
divide as fast as they grow and synthesize DNA. Is this likely to be a problem?
Why or why not?

6. Many of the drugs given to people to fight their cancers damage the cellular
structures involved in mitosis. Explain:
   a. why these drugs kill a higher percentage of cancer cells than normal cells.
   b. whether you would expect the drugs to have more of an effect on normal
white blood cells or on normal neurons.
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>AGE</th>
<th>WOMAN 1</th>
<th>WOMAN 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>16</td>
<td>No access to screening for abnormal cervical tissues with a Pap smear test or HPV test</td>
<td>Begins regular screening for abnormal cervical tissues with a Pap smear test, and education from the doctor about the risks of cervical cancer</td>
</tr>
<tr>
<td></td>
<td>No access to vaccine for HPV</td>
<td>Receives HPV vaccine that prevents infection by some types of HPV</td>
</tr>
<tr>
<td>30</td>
<td>Abnormal vaginal bleeding begins, indicating the likelihood of early stage cervical cancer.</td>
<td>Pap smear reveals some precancerous cervical tissue from a type of HPV for which there is no vaccine.</td>
</tr>
<tr>
<td></td>
<td>No access to adequate health care to detect and remove any abnormal cervical tissue</td>
<td>Precancerous tissue is removed with a simple surgical procedure to prevent progression to cancer.</td>
</tr>
<tr>
<td>35</td>
<td>A progression to advanced cervical cancer begins.</td>
<td>Leading a healthy life</td>
</tr>
<tr>
<td>36 and older</td>
<td>Advanced stages of cervical cancer</td>
<td>Continues to get regular screening</td>
</tr>
<tr>
<td></td>
<td>No access to adequate health care, even to ease the pain associated with advanced stages of the cancer</td>
<td></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
- **cell cycle**
- chromosome
- cyclin
- cytokinesis
- daughter cell
- **mitosis**
- replication
The term cancer refers to more than 100 diseases that result when cells lose the normal controls that regulate their growth and division in the cell cycle. These cells continuously divide even when no new cells are needed. In most types of cancer, as an original cancer cell divides through multiple cell cycles, a mass of cells develops to form a tumor. However, some types of cancer, such as leukemia, rarely produce tumors. Leukemia results when abnormal white blood cells are produced too rapidly or do not die within the normal lifetime of white blood cells. These cells crowd the blood and prevent normal blood cells from performing their functions. Mutations, or errors, in some genes can cause cancer. Some of these genes normally stimulate cell division, while others normally stop cell division. Mutations in these genes can lead to unregulated cell growth and division that result in tumors.

Cervical cancer is an example of a cancer that is linked to an infection from a virus, in this case human papillomavirus (HPV). Women worldwide are at risk of being infected by this sexually transmitted virus. There are more than 100 types of HPV, about 30 types infect the genital regions of men and women, and a few have been shown to cause cervical cancer in women.

(Continued on next page)
Cancer sometimes develops when environmental factors or viruses interact with certain genes to cause mutations. Environmental factors that lead to cancer include exposure to such chemicals as tobacco smoke, air pollutants, and asbestos. The chemicals produced when tobacco burns put people who smoke, and who are regularly exposed to tobacco smoke, at a higher risk of developing lung cancer than non-smokers. In fact, approximately 10%–15% of smokers develop lung cancer, and smokers are 10–20 times more likely to get lung cancer than nonsmokers. Other environmental factors, including various kinds of radiation, also cause cancer.

**Cancer Preventions and Treatment**

The World Health Organization reports that approximately 30% of cancer cases could be prevented by addressing such risk factors as:

- tobacco use
- being overweight or obese
- lack of physical activity
- lack of fruits and vegetables in the diet
- alcohol abuse
- sexually transmitted HPV infection
- urban air pollution
- indoor smoke from household use of solid fuels, such as wood

There are a number of programs and a few vaccines that help people reduce or eliminate their risk factors for cancer. The table below shows examples.

The main ways that cancers are treated are surgery, chemotherapy, radiation therapy, or a combination of those. Surgeries to treat cancer include removing the tumor and surrounding tissues, removing the tumor and the organ it is in, and sometimes removing lymph nodes where the cancer may have spread. Surgeons also might remove just part of a tumor to relieve pain or open any blockages the tumor is causing. Chemotherapy involves taking certain drugs that kill cells, including cancer cells. Chemotherapy might follow surgery or be used alone or in combination with radiation therapy.

<table>
<thead>
<tr>
<th>Preventive Measure</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vaccines</td>
<td>Vaccination for the hepatitis B virus that can cause liver cancer</td>
</tr>
<tr>
<td>Vaccination for HPV, which causes cervical cancer</td>
<td></td>
</tr>
<tr>
<td>Tobacco and alcohol-abuse programs</td>
<td>Increase taxes on tobacco and alcohol</td>
</tr>
<tr>
<td></td>
<td>Educate the public about health risks</td>
</tr>
<tr>
<td></td>
<td>Ban smoking in public and commercial areas</td>
</tr>
<tr>
<td>Health education in schools and the workplace</td>
<td>Promotion of healthy diet and exercise</td>
</tr>
<tr>
<td>Screening</td>
<td>HPV test and pap smear for cervical cancer</td>
</tr>
<tr>
<td></td>
<td>Colonoscopy or other screening for colon and rectal cancer</td>
</tr>
</tbody>
</table>

A diet high in fat and calories and low in fruits and vegetables, as shown at far left, increases a person’s risk of developing some cancers, as compared to the diet shown at near left.
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 15% 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 preventions 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.