Key Terms

interphase
cell cycle
cell cycle checkpoint
tumour
cancer

1.4 The Cell Cycle

As shown in **Table 1.3**, the life span of different types of cells varies widely. Some cells live a rough life, exposed to constant abrasion (rubbing) and chemicals that are sometimes toxic. This describes the experience of the cells that line your stomach, and those that make up your skin. They have short lifetimes compared with muscle cells, which last an average of 15 years. Nerve cells may last even longer. This means that cell division happens frequently in some parts of your body, but is a rare event in other parts.

Table 1.3 Average Life Span of Various Human Body Cells

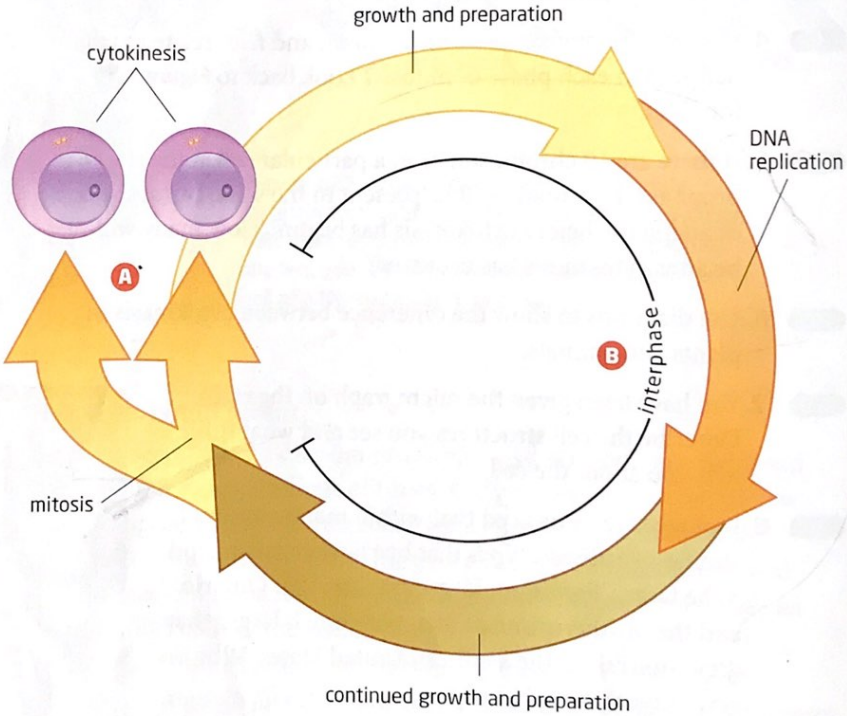
Type of Body Cell	Average Life Span
Brain	30–50 years
Red blood	120 days
Stomach lining	2 days
Liver	200 days
Intestine lining	3 days
Skin	20 days

Stages of the Cell Cycle

For your body to function properly, the cell division process must be carefully controlled. Some types of cells must be "encouraged" to divide, and others must be "encouraged" to remain as they are. This is the job of molecules, mostly proteins, that carry signals among cells, sharing information about various cells' abundance and health. These molecules control the cell cycle. As you can see in **Figure 1.28**, the **cell cycle**—the life cycle of a cell— consists of two main phases: cell division and **interphase**.

interphase periods of growth in the life of a cell; consists of two growth stages and a stage of DNA replication

cell cycle a continuous sequence of cell growth and division, including the stages of interphase, mitosis, and cytokinesis



A Cell division First, the cell's nucleus divides into two parts during mitosis. Then, the two nuclei and cell contents divide into two daughter cells during cytokinesis.

B Interphase Cells do whatever activities they are designed to do, such as producing specific proteins. For example, a muscle cell might produce the proteins that allow muscles to contract. It also does the things that *all* cells do, such as taking in oxygen and glucose, releasing energy from glucose (cellular respiration), and removing wastes. In addition, DNA replicates in preparation for cell division. Before and after the DNA replicates are two periods during which the cell produces more organelles and grows larger.

Figure 1.28 The cell cycle for all cells consists of two main stages, but different types of cells spend different amounts of time in each stage.

Checkpoints: Can This Cell Pass?

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Controlling the timing and rate of cell division in different parts of a plant or animal is vital to normal growth and development. Too few or too many cells in any one body part can lead to serious problems. Although many details are not understood, scientists have a general picture of how the cell cycle is controlled in many cells.

Researchers have discovered that there are three main points at which the cell "checks" its growth. **Figure 1.29** shows how these **cell cycle checkpoints** work. At each checkpoint, specialized proteins act like stop signs. Unless they receive specific go-ahead signals, they will not let the cell cycle proceed. In general, cell division will not occur if

- there are not enough nutrients to support cell growth
- the DNA has not replicated
- the DNA is damaged

cell cycle checkpoints a point in the life of a cell when proteins determine whether cell division should or should not occur

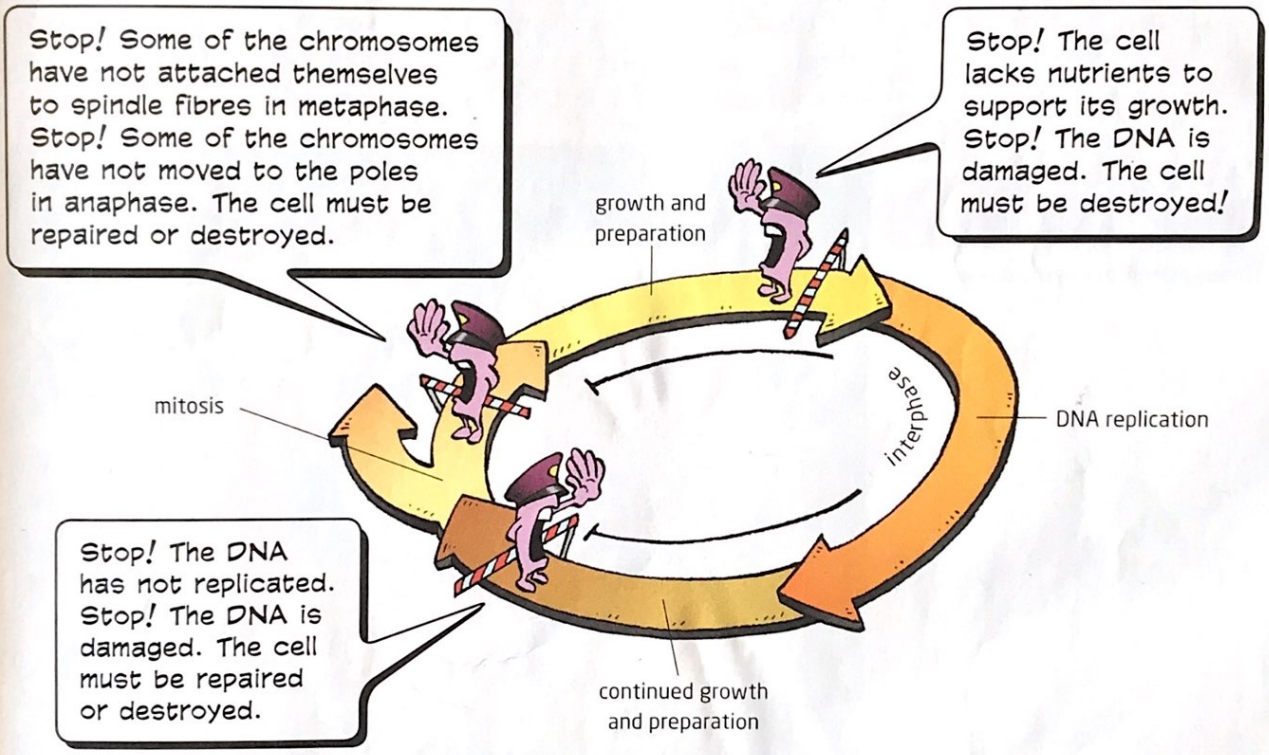

Figure 1.29 Checkpoints in the cell cycle ensure that cell division occurs only when required.

For many cells, the first checkpoint after mitosis seems to be the most important. Many cells leave the cycle at this point, often just because more cells of that type are not required. The body does not need that cell to divide, so it does not receive a go-ahead signal. Cells that leave the cycle enter a non-dividing stage. Most cells in the human body—all muscle and nerve cells, for example—are in this stage.

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Cell Death

Some cells do not leave the cell cycle to become specialized—they leave the cell cycle because it is time for them to die. In some cases, this is because they have been damaged beyond repair, perhaps by physical forces or by exposure to toxic chemicals. The contents of the cells leak out, often irritating surrounding cells, causing swelling and redness in that body part.

Cell Suicide

Other cells carry out a kind of suicide. In this case, a cell breaks down in an organized way. Its contents are packaged and distributed so that other cells can use them. Scientists have learned that this type of death is pre-programmed into cells, determined by what are often called "suicide genes." These genes code for proteins whose job is to kill cells in specific situations. For example, as you can see in **Figure 1.30**, suicide genes are responsible for normal finger and toe development in human embryos.

Cells may also ensure their own death when their survival would be a threat to the organism. This would happen if a cell were infected with a virus, for example, or if its DNA had been damaged.

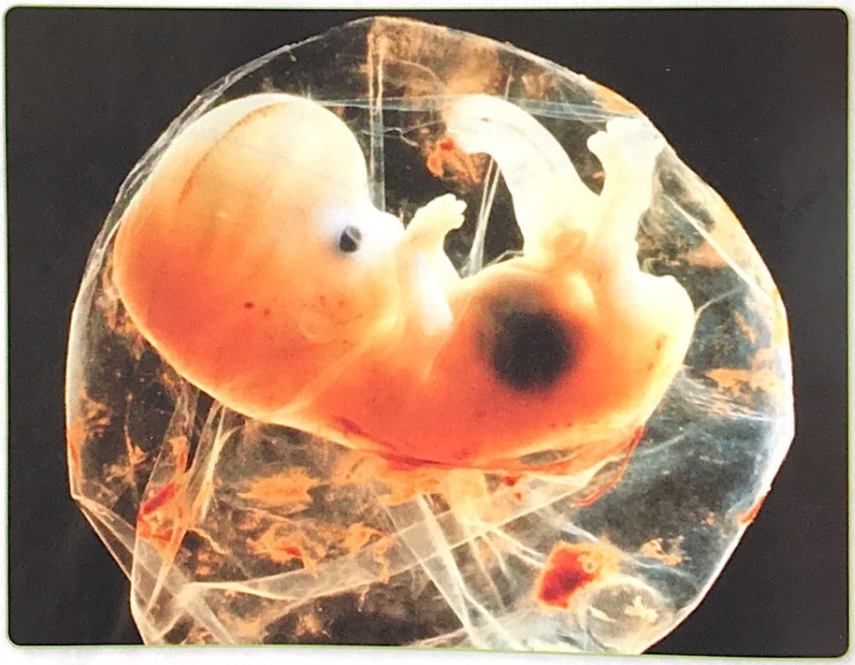


Figure 1.30 In various birds and mammals, the parts of the embryo that develop into hands and feet are solid at first. Separated fingers or toes are produced through the programmed death of the cells between the digits.

Cancer and the Cell Cycle

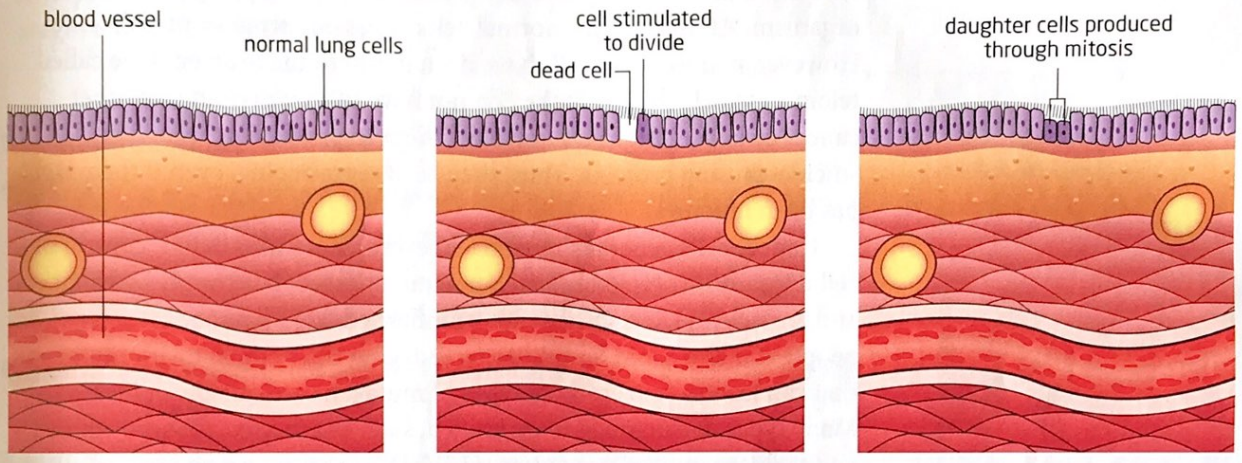
Some cells start out normally, but are then transformed so that they ignore the stop signs in the cell cycle. Instead of leaving the cell cycle to die, they divide repeatedly and excessively, forming a clump of cells called a **tumour**, which you can see in **Figure 1.31**.

tumour an abnormal clump or group of cells

Effects of Cancer on Other Tissues

These abnormal cells, with further mutations, can become **cancer**. Some cancers can spread to other body parts and continue dividing uncontrollably there. Tumours reduce the effectiveness of other body tissues. For example, the abnormal cancerous cells that are part of a lung tumour take up space in the lung that should be filled with normal cells performing normal lung functions. In addition, the abnormal cells use up nutrients that are needed by the normal cells.

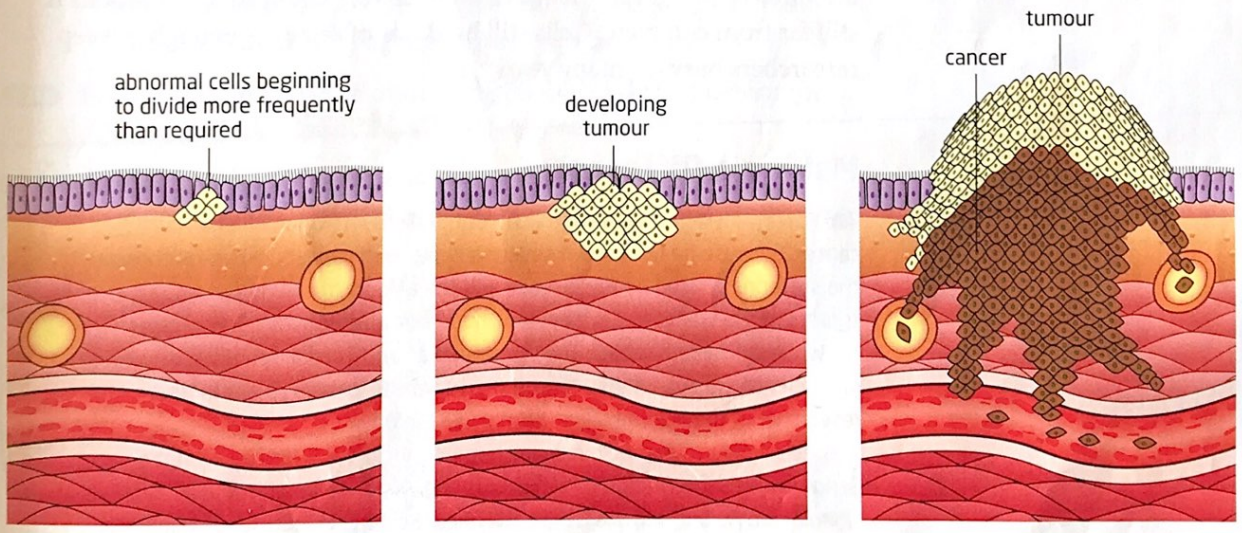
cancer cells with abnormal genetic material that are dividing uncontrollably and can spread to other body parts



In healthy tissue, cell division is carefully controlled by chemical messages that pass from cell to cell.

As cells mature and die, a normal part of the cell cycle, other cells are stimulated to divide and replace them.

The rate of cell division is normally equal to the rate of cell death.



Sometimes cells lose the normal constraints on their rate of division. They begin to divide much more often and no longer function normally. All the cells that result from their division also divide uncontrollably, so the abnormal cells multiply rapidly.

The mass of rapidly dividing cells grows to form a tumour. Further changes to the cells can produce cancer. The cancer cells invade and destroy neighbouring cells.

Eventually, some cancer cells may break away, move into the circulatory system, and spread to a new location in the body, where they again begin to divide uncontrollably.

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Figure 1.31 Abnormal cell division is responsible for the development of tumours and cancer.

Suggested Investigation

Data Analysis Investigation 1-C, Does the Patient Have Cancer? on page 50

Losing Control

Most normal cells are attached to a surface while they divide. If a normal cell senses that it is not attached, it stops dividing. Many cancer cells, however, have a mutation that allows them to keep dividing even when they are not attached to a surface. This mutation encourages the abnormal cells in a tumour to spread. Still other cancer cells have mutations affecting the proteins that check and repair any errors made during DNA replication. These mutations, in turn, lead to more mutations.

Most normal cells can undergo 20 to 30 rounds of cell division. Any more divisions might result in mutated cells that might harm the organism. At this point, a normal cell carries out programmed suicide. However, many cancer cells have been found to make an enzyme called telomerase, which signals they do not have to stop dividing. In other cancer cells, mutations do not allow them to produce or recognize suicide-causing proteins. Thus, they keep reproducing, even if their DNA has been mutated.

Cancer cells generally must have several mutations before control of cell division is completely lost. Some mutations occur simply by chance and are unavoidable. Others can be inherited from parents. However, people can also avoid mutations by reducing their contact with mutagens that can lead to cancer; these types of mutagens are called *carcinogens*. Many types of carcinogens are known, such as asbestos, tobacco smoke, and the human papilloma virus (HPV). More are being discovered all the time. Cancer prevention—reducing gene mutations—is perhaps the best way to avoid cancer. However, cancer is a complex disease. Its causes are varied and our knowledge of how cells are changed by mutations is still far from complete. Cells still hold lots of secrets—enough to keep researchers busy for many years.

Making a Difference

Ted Paranjothy's goal is to contribute to the discovery of a universal cure for cancer. Because he has known several people with cancer, Ted has witnessed the suffering caused by the disease and the effects of chemotherapy, a cancer treatment. He wants to develop new, non-toxic alternatives to chemotherapy.

While still in high school, Ted discovered an anti-cancer agent while working on a science project. He also co-authored scientific papers as a volunteer researcher at the Manitoba Institute of Cell Biology.

Ted's work has earned him many honours, including a first place in the Sanofi-aventis International BioGENEius Challenge, a Manning Young Canadian Innovation Award, and the Canadian Cancer Society Researcher of Tomorrow Award. Ted has also volunteered with patients at a hospital and won an award for his community service. In 2007, Ted was named one of Canada's Top 20 Under 20. He attends the University of Manitoba and plans to become a physician-scientist, involved in both patient care and cancer research.

What could you do to help people with cancer in your community?