Cell Division

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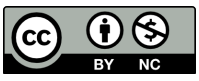


CHAPTER 1

Cell Division

Lesson Objectives

- Explain why cells need to divide.
- List the stages of the cell cycle and explain what happens at each stage.
- List the stages of mitosis and explain what happens at each stage.

Check Your Understanding

- What is the cell theory?
- In what part of your cells is the genetic information located?

Vocabulary

- anaphase
- cancer
- cell cycle
- chromosome
- cytokinesis
- daughter cell
- interphase
- metaphase
- mitosis
- parent cell
- prophase
- sister chromatids
- spindle
- telophase

Why Cells Divide

Imagine the first stages of life. In humans, a sperm fertilizes an egg, forming the first cell. But humans are made up of trillions of cells, so where do the new cells come from? Remember that according to cell theory, all cells must come from existing cells. From that one cell, an entire baby will develop.

How does a new life go from one cell to so many? The cell divides in half, creating two cells. Then those two cells divide, for a total of four cells. The new cells continue to divide and divide. One cell becomes two, then four, then eight, and so on (**Figure** 1.1).

Besides the development of a baby, there are many other reasons that cell division is necessary for life:

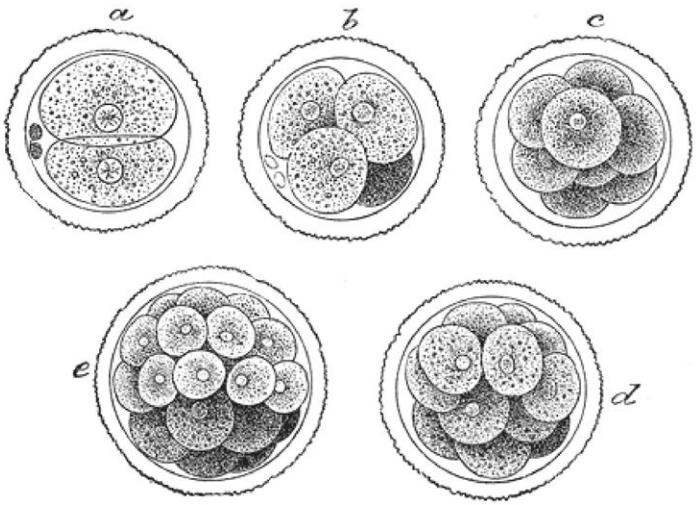


FIGURE 1.1

Cells divide repeatedly to produce an embryo. Previously the one-celled zygote (the first cell of a new organism) divided to make two cells (a). Each of the two cells divides to yield four cells (b), then the four cells divide to make eight cells (c), and so on. Through cell division, an entire embryo forms from one initial cell.

1. To grow and develop, you must form new cells. Imagine how often your cells must divide during a growth spurt. Growing just an inch requires countless cell divisions.
2. Cell division is also necessary to repair damaged cells. Imagine you cut your finger. After the scab forms, it will eventually disappear and new skin cells will grow to repair the wound. Where do these cells come from? Some of your existing skin cells divide and produce new cells.
3. Your cells can also simply wear out. Over time you must replace old and worn-out cells. Cell division is essential to this process.

The Cell Cycle

The process of cell division in eukaryotic cells is carefully controlled. The **cell cycle** is the lifecycle of a cell, with cell division at the end of the cycle. Like a human lifecycle that is made up of different phases, like childhood, adolescence, and adulthood, there are a series of steps that lead to cell division (**Figure** 1.2).

These steps can be divided into two main components, interphase and mitosis.

1. Interphase: The stage when the cell mostly performs its "everyday" functions. For example, it is when a kidney cell does what a kidney cell is supposed to do.
2. Mitosis: The stage when the cell prepares to become two cells.

Most of the cell cycle consists of **interphase,** the time between cell divisions. Interphase can be divided into three stages:

1. The first growth phase (G1): During the G1 stage, the cell doubles in size and doubles the number of organelles.
2. The synthesis phase (S): The DNA is replicated during this phase. In other words, an identical copy of all the cell's DNA is made. This ensures that each new cell has a set of genetic material identical to that of the parental cell. DNA replication will be further discussed in lesson 5.3.
3. The second growth phase (G2): Proteins are synthesized that will help the cell divide. At the end of interphase, the cell is ready to enter mitosis.

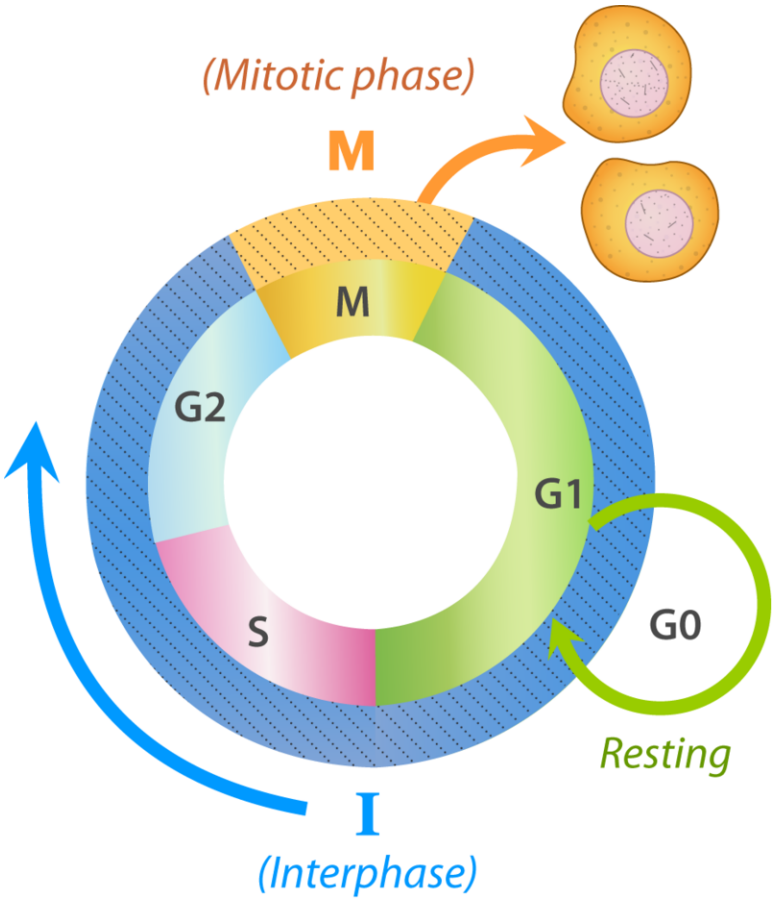
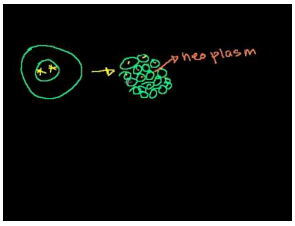


FIGURE 1.2

The cell cycle is the repeated process of growth and division. Notice that most of the cell cycle is spent in interphase (G1, S, and G2) (I). G0 is a resting state of the cell cycle.

During **mitosis**, the nucleus divides. Mitosis is followed by **cytokinesis**, when the cytoplasm divides, resulting in two cells. After cytokinesis, cell division is complete. Scientists say that one **parent cell**, or the dividing cell, forms two genetically identical **daughter cells,** or the cells that divide from the parent cell. The term "genetically identical" means that each cell has an identical set of DNA, and this DNA is also identical to that of the parent cell. If the cell cycle is not carefully controlled, it can cause a disease called **cancer**, which causes cell division to happen too fast. A tumor can result from this kind of growth.

Cancer is discussed in the video at http://www.youtube.com/watch?v=RZhL7LDPk8w . (12:36).



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Two animations of the cell cycle are available at the following links. See if you can explain what is happening in these animations.

- http://www.wisc-online.com/objects/index_tj.asp?objID=AP13604
- http://www.cellsalive.com/cell_cycle.htm

Mitosis and Chromosomes

The genetic information of the cell, or DNA, is stored in the nucleus. During mitosis, two nuclei (plural for nucleus) must form, so that one nucleus can be in each of the new cells. The DNA inside of the nucleus is also copied. The copied DNA needs to be moved into the nucleus, so each cell can have a correct set of genetic instructions.

To begin mitosis, the DNA in the nucleus wraps around proteins to form **chromosomes**. Each organism has a unique number of chromosomes. In human cells, our DNA is divided up into 23 pairs of chromosomes. After the DNA is replicated during the S stage of interphase, each chromosome has two identical molecules of DNA, called **sister chromatids**, forming the "X" shaped molecule depicted in **Figure** 1.3.

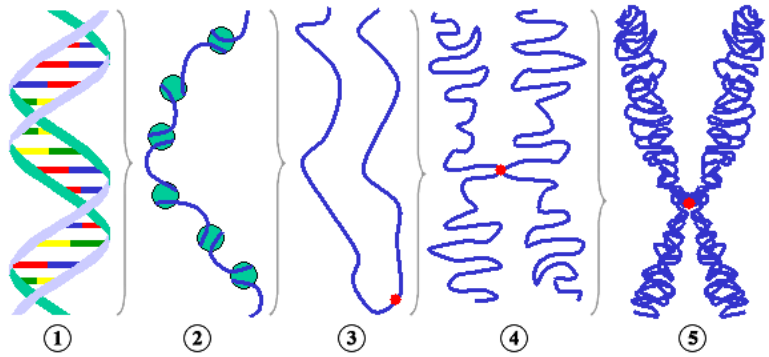


FIGURE 1.3

The DNA double helix wraps around proteins (2) and tightly coils a number of times to form a chromosome (5). This figure shows the complexity of the coiling process. The red dot shows the location of the centromere, where the microtubules attach during mitosis and meiosis.

The Four Phases of Mitosis

During mitosis, the two sister chromatids must be split apart. Each resulting chromosome is made of *1/2* of the "X". Through this process, each daughter cell receives one copy of each chromosome. Mitosis is divided into four phases (**Figure** 1.4):

1. **Prophase**: The chromosomes "condense," or become so tightly wound that you can see them under a microscope. The wall around the nucleus, called the nuclear envelope, disappears. **Spindles** also form and attach to chromosomes to help them move.
2. **Metaphase**: The chromosomes line up in the center of the cell. The chromosomes line up in a row, one on top of the next.
3. **Anaphase**: The two sister chromatids of each chromosome separate, resulting in two sets of identical chromosomes.
4. **Telophase**: The spindle dissolves and nuclear envelopes form around the chromosomes in both cells.

Each new nucleus contains the exact same number and type of chromosomes as the original cell. The cell is now ready for cytokinesis, which literally means "cell movement." The cells separate, producing two genetically identical cells, each with its own nucleus. **Figure** 1.5 is a representation of dividing plant cells.

The phases of mitosis are discussed in the video: http://www.youtube.com/watch?v=LLKX_4DHE3I (20:42).

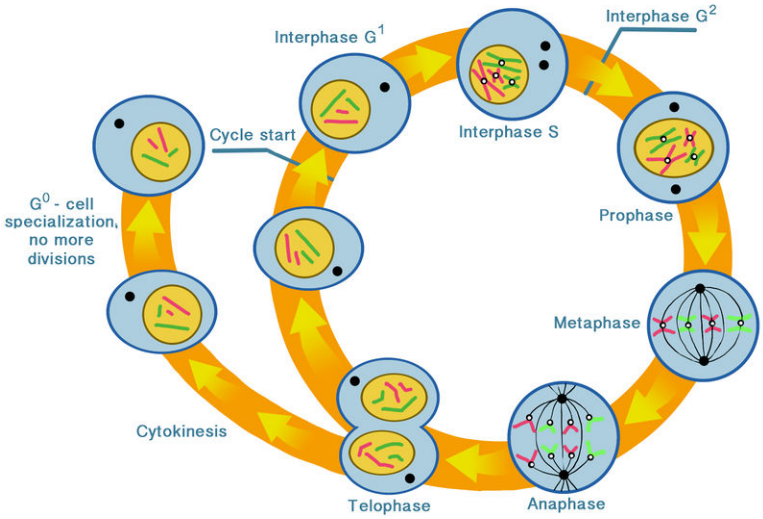
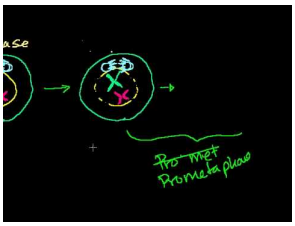


FIGURE 1.4

An overview of the cell cycle and mitosis: during prophase the chromosomes condense, during metaphase the chromosomes line up, during anaphase the sister chromatids are pulled to opposite sides of the cell, and during telophase the nuclear envelope forms.



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Additional animations of mitosis can be viewed at the following links:

- http://www.cellsalive.com/mitosis.htm
- http://www.youtube.com/watch?v=7hQ5xXJSmK4

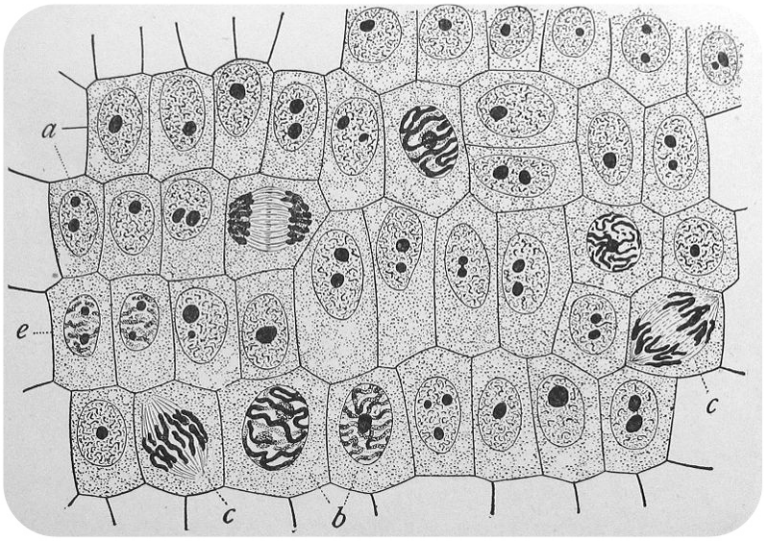
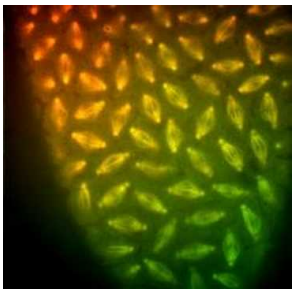


FIGURE 1.5

This is a representation of dividing plant cells. Cell division in plant cells differs slightly from animal cells as a cell wall must form. Note that most of the cells are in interphase. Can you find examples of the different stages of mitosis?

Mitosis in Real Time can be viewed at http://www.youtube.com/watch?v=m73i1Zk8EA0 (0:19).



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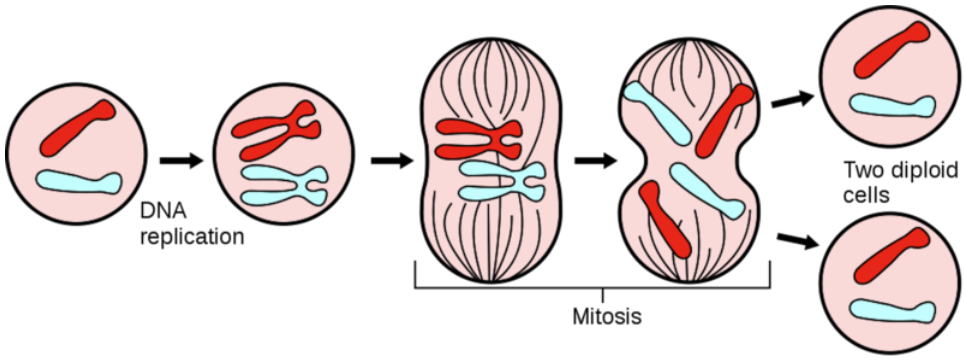
Lesson Summary

- Cells divide for growth, development, reproduction and replacement of injured or worn-out cells.
- The cell cycle is a series of controlled steps by which a cell divides.
- During mitosis, the newly duplicated chromosomes are divided into two daughter nuclei.
- This summary diagram depicts one cell dividing into two genetically identical cells. Mitosis occurs after DNA replication. A diploid cell has two sets of chromosomes, as is shown here.



Review Questions

Recall

1. In what phase of mitosis are chromosomes moving toward opposite sides of the cell?
2. In what phase of mitosis do the duplicated chromosomes condense?
3. What step of the cell cycle is the longest?
4. What is the term for the division of the cytoplasm?
5. What happens during the S stage of interphase?

Apply Concepts

6. Interphase used to be considered the “resting” stage of the cell cycle. Why is this not correct?
7. What are some reasons that cells divide?

8. During what stage of the cell cycle does the cell double in size?
9. Why must cell division be tightly regulated?

Critical Thinking

10. What would happen if the cells in your liver stopped going through the process of mitosis?
11. What do you think might happen if mitosis could NOT stop happening to the cells in your brain?

Further Reading / Supplemental Links

- http://www.biology.arizona.edu/Cell_bio/tutorials/cell_cycle/cells3.html
- http://biology.clc.uc.edu/courses/bio104/mitosis.htm

Points to Consider

- How might a cell without a nucleus divide?
- How are new cells made that include the DNA of two parents?

References

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