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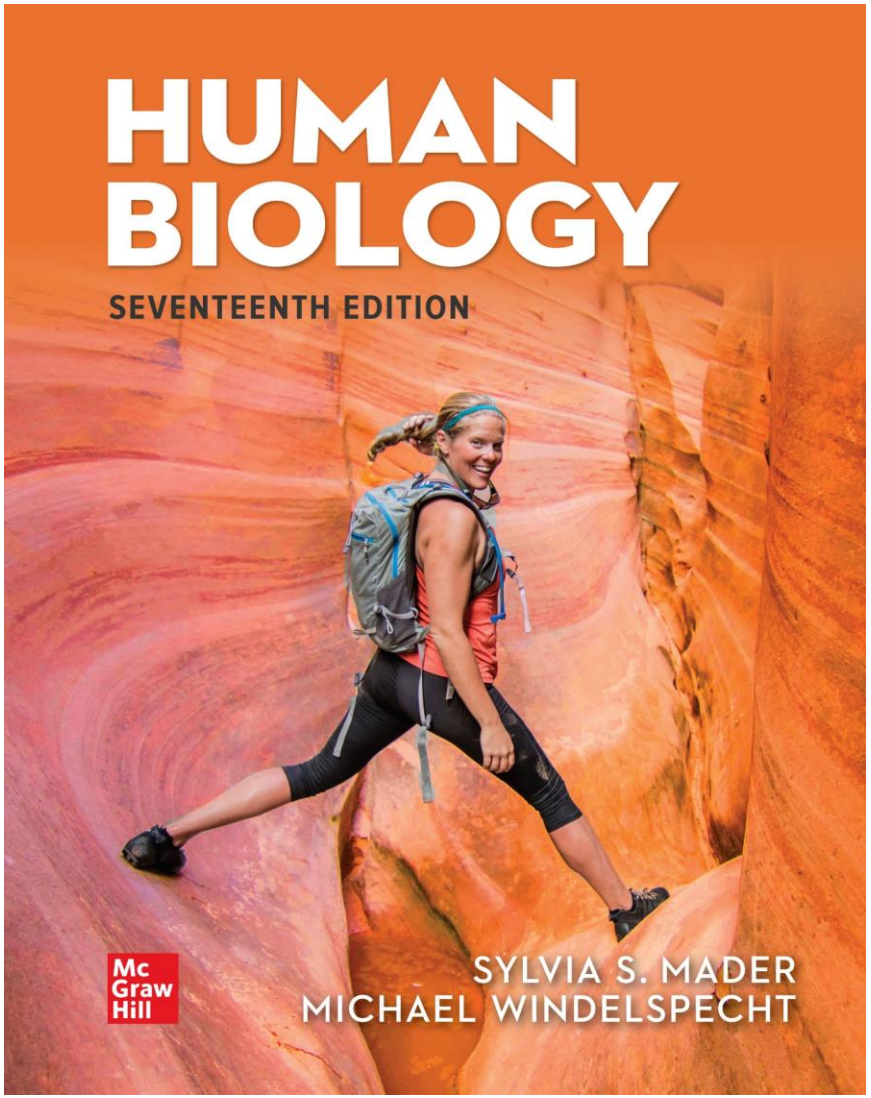

HUMAN BIOLOGY

Seventeenth Edition

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Chapter 19
Cell Division

19.1 Chromosomes 1

Learning Outcomes:

- Distinguish between a chromosome and chromatin.
- Explain the purpose of a karyotype.
- Describe the purpose of the centromere in relation to the sister chromatids.

19.1 Chromosomes 2

The nucleus holds all the genetic material to direct all the functions in the body.

Chromosomes—made of DNA.

- The instructions in each chromosome are contained within genes, which in turn are composed of DNA.

19.1 Chromosomes 3

Chromosomes, continued.

Contain proteins that assist in the organizational structure.

- Collectively, the DNA and proteins are called **chromatin.**

Humans have 46 chromosomes, in 23 pairs.

- 22 of these pairs are called **autosomes**—found in both males and females.
- One pair is called the **sex chromosomes**, because they contain genes that control gender.

19.1 Chromosomes 4

Chromosomes, concluded.

Males have the sex chromosomes X and Y, and females have two X chromosomes.

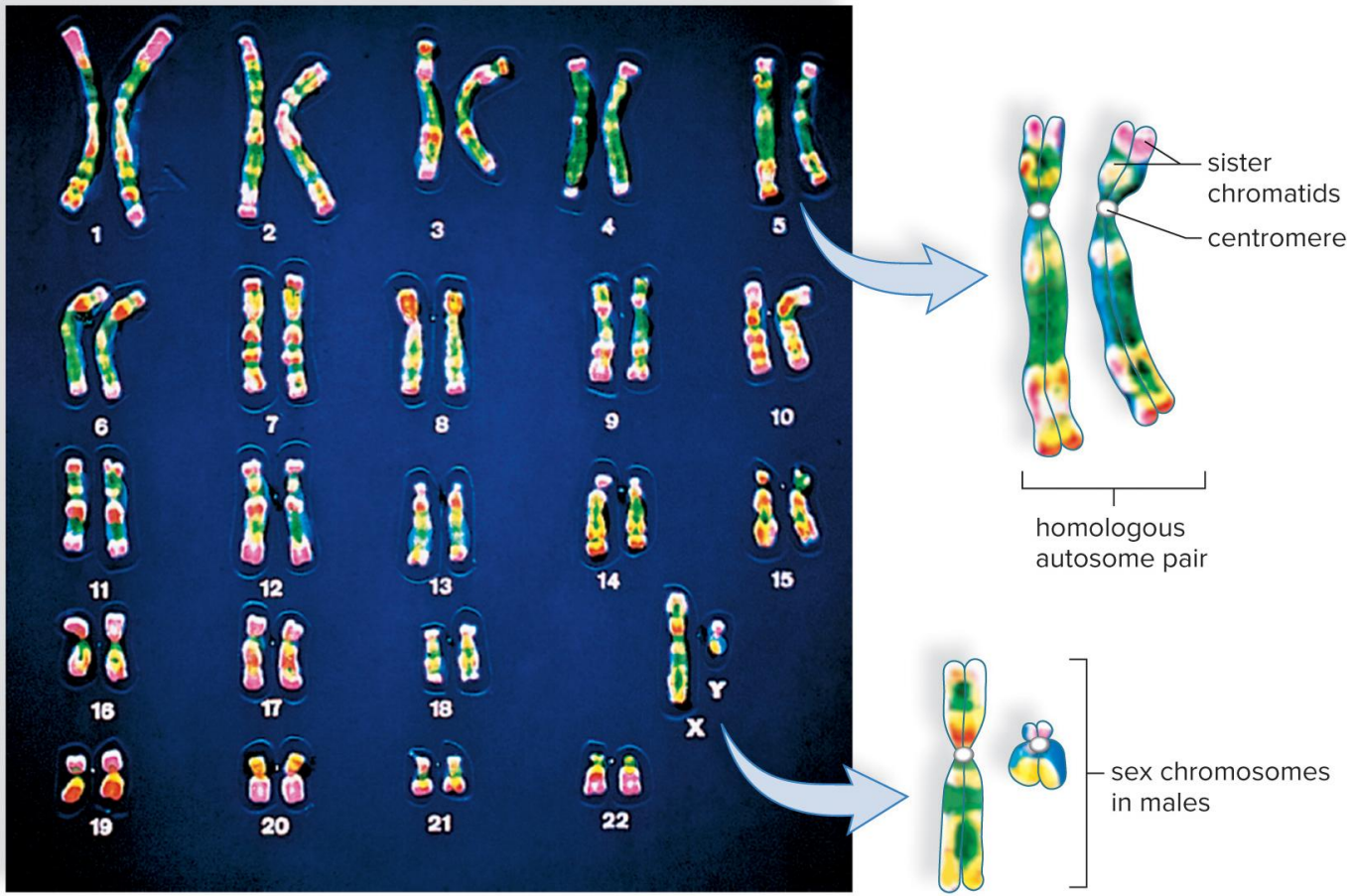
- The Y chromosome contains the *SRY* gene that causes testes to develop.

Karyotypes 1

Karyotypes.

- A display of the chromosomes present in a cell.
- When a cell divides, chromatin condenses to form chromosomes.
- Staining causes the chromosomes to have dark and light cross-bands of varying widths, and a computer uses these, in addition to size and shape, to pair up the chromosomes.

A Karyotype of Human Chromosomes (Figure 19.1)



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(photo): CNRI/Science Source

Karyotypes 2

Karyotypes, continued.

Mitosis—cell division that begins when the fertilized egg starts dividing.

- Ensures that every cell is **diploid** (has 46 chromosomes).

In dividing cells, each chromosome is composed of two identical parts called **sister chromatids.**

- Sister chromatids contain the same genes.

Karyotypes 3

Karyotypes, continued.

Sister chromatids, continued.

- **Genes** are the units of heredity that control traits.
  - For example, eye color and metabolism.
- Collectively, genes contain the instructions for how our bodies conduct the characteristics of life.

Karyotypes 4

Karyotypes, concluded.

Centromere—holds the chromatids together until cell division occurs.

- Cell division separates the sister chromatids, forming new independent chromosomes (or daughter chromosomes) that are then allocated to new cells.
- Once in the new cell, these chromosomes are replicated, forming new sister chromatids.

Check Your Progress 19.1

- Explain the purpose of chromosomes in a cell.
- Describe how a karyotype can be used to determine the number of chromosomes in a cell.
- Explain why sister chromatids are genetically the same.

19.2 The Cell Cycle 1

Learning Outcomes:

- List the stages of the cell cycle and state the purpose of each.
- Describe the purpose of the checkpoints in the cell cycle.
- Distinguish between mitosis and cytokinesis.

19.2 The Cell Cycle 2

Cell cycle—has two parts: **interphase** and **cell division.**

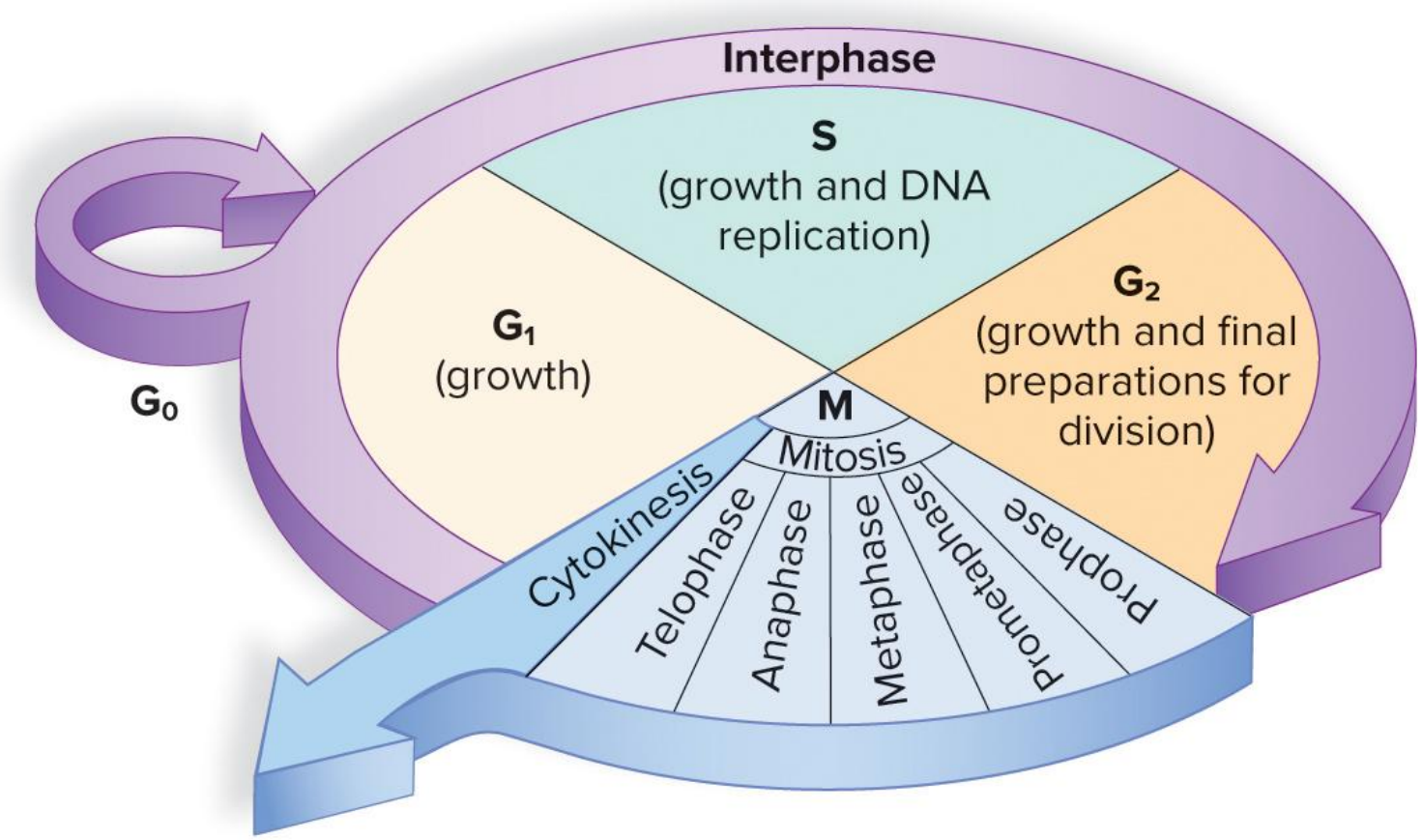
- Prior to cell division, the chromatin is typically spread throughout the nucleus as a tangled mass of threads.

Interphase 1

Most of the cell cycle is spent in **interphase.**

- Organelles carry on their usual functions.
- The cell gets ready to divide: it grows larger, the number of organelles doubles, and the amount of chromatin doubles (DNA replication).
- Divided into three main stages: **G_1, S, G_2.**

Stages of the Cell Cycle (Figure 19.2)



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Interphase 2

Phases of interphase:

G_1 stage—the cell performs its normal function.

- Also doubles its organelles and accumulates the materials needed for DNA synthesis.

S stage—DNA replication.

- After the S stage, each chromosome consists of two identical **sister chromatids.**

G_2 stage—synthesizes the proteins needed for cell division.

Interphase 3

The amount of time the cell spends in interphase varies widely.

Some cells, such as nerve and muscle cells, typically do not complete the cell cycle and are permanently arrested in G_1.

- Because they won't ever continue to the S and G_2 phases, they are instead said to be in a **G_0 stage.**

Embryonic cells spend very little time in G_1 and complete the cell cycle in a few hours.

Mitosis and Cytokinesis 1

Following interphase is cell division.

Cell division has two stages: **M** (for “mitosis”) **stage** and **cytokinesis.**

- **Mitosis** is a type of nuclear division.
  - Also referred to as **duplication division** since each new nucleus contains the same number and type of chromosomes as the former cell.
- **Cytokinesis**—division of the cytoplasm.

Mitosis and Cytokinesis 2

The cell cycle occurs continuously in certain tissues.

Mitosis is balanced by the process of **apoptosis,** or programmed cell death.

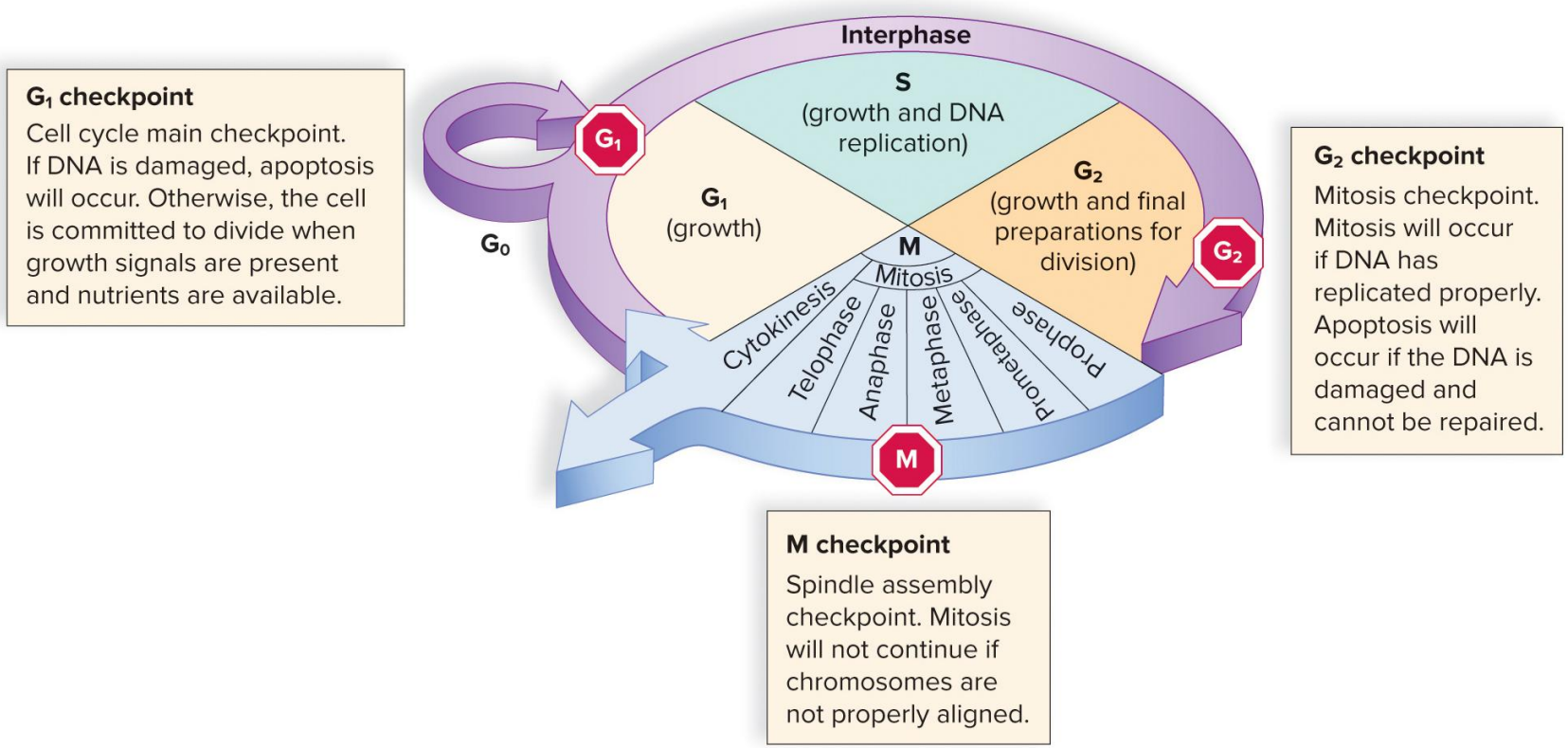
- Apoptosis occurs when cells are no longer needed or have become excessively damaged.

Cell Cycle Control

The cell cycle is controlled by **checkpoints**, which delay it until certain conditions are met.

- That is, **G_1 checkpoint, G_2 checkpoint,** and the **mitotic checkpoint.**
- The cell cycle may also be controlled by external factors, such as hormones and growth factors.
- Failure of the cell cycle control mechanisms may result in unrestricted cell growth, or cancer.

Control of the Cell Cycle (Figure 19.3)



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Checkpoints 1

G_1 checkpoint.

- If the cell cycle passes this checkpoint, the cell is committed to divide.
- If the cell does not pass this checkpoint, it can enter G_0, where it performs normal functions but does not divide.
- Proper growth signals, such as growth factors, must be present for a cell to pass the G_1 checkpoint.

Checkpoints 2

G_1 checkpoint, continued.

The integrity of the DNA is also checked.

- If DNA is damaged, proteins such as **p53** can stop the cycle at this checkpoint and place the cell in G_0.
- If the DNA can be repaired, it may reenter the cell cycle; if not, it may undergo apoptosis.

Checkpoints 3

G_2 checkpoint.

The cell cycle halts here until the cell verifies that DNA has replicated.

- Prevents the initiation of the M stage unless the chromosomes are duplicated.

If DNA is damaged, arresting the cell cycle allows time for the damage to be repaired so that it is not passed on to daughter cells.

Checkpoints 4

Mitotic checkpoint.

- Occurs between metaphase and anaphase to make sure the chromosomes are properly attached to the spindle so can be distributed accurately to the daughter cells.

External Control 1

External control.

An external signal, such as a hormone or growth factor, can stimulate a cell to divide.

- It binds to a receptor in the plasma membrane of a target cell.
- The signal is then relayed from the receptor to proteins inside the cell.
- The proteins form a pathway called the **signal transduction pathway**; they pass the signal from one to the next.

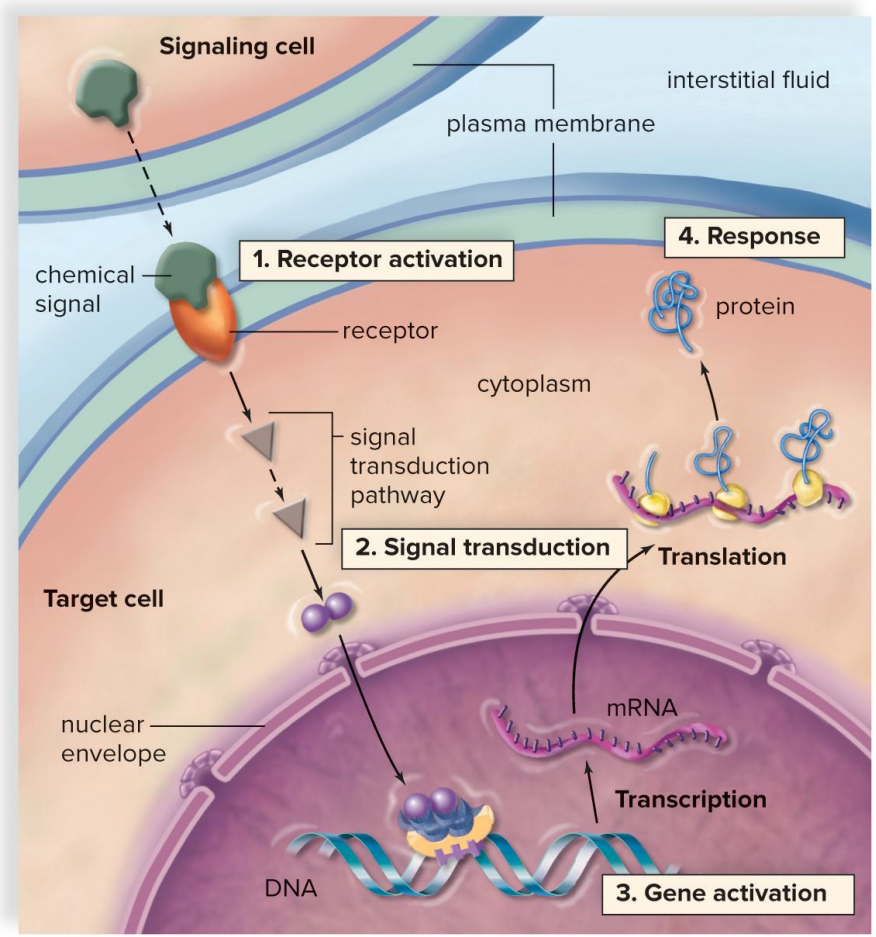
External Control 2

External control, continued.

The last signal of the signal transduction pathway activates genes in the nucleus.

- The expression of these genes may stimulate or inhibit the cell cycle.
  - Genes called **proto-oncogenes** stimulate the cell cycle, and genes called **tumor suppressor genes** inhibit the cell cycle.

External Controls of the Cell Cycle (Figure 19.4)



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Check Your Progress 19.2

- Describe the cell cycle, and list the locations of each phase and checkpoint.
- Explain the purpose of the S phase in the cell cycle.
- Explain how checkpoints help protect the cell against unregulated cell growth.
- Summarize why external controls may be necessary to regulate the cell cycle.

19.3 Mitosis 1

Learning Outcomes:

- Explain the purpose of mitosis.
- Explain the events that occur in each stage of mitosis.
- State the purpose of cytokinesis.

19.3 Mitosis 2

Mitosis.

- Creates new cells in the developing embryo, fetus, and child.
- Responsible for replacement of cells in adults.
- During mitosis, the cell that divides is called the **parent cell,** and the new cells are called **daughter cells.**
- Referred to as **duplication division** since the two daughter cells are genetically identical to the parent cell.

The Importance of Mitosis (Figure 19.5)

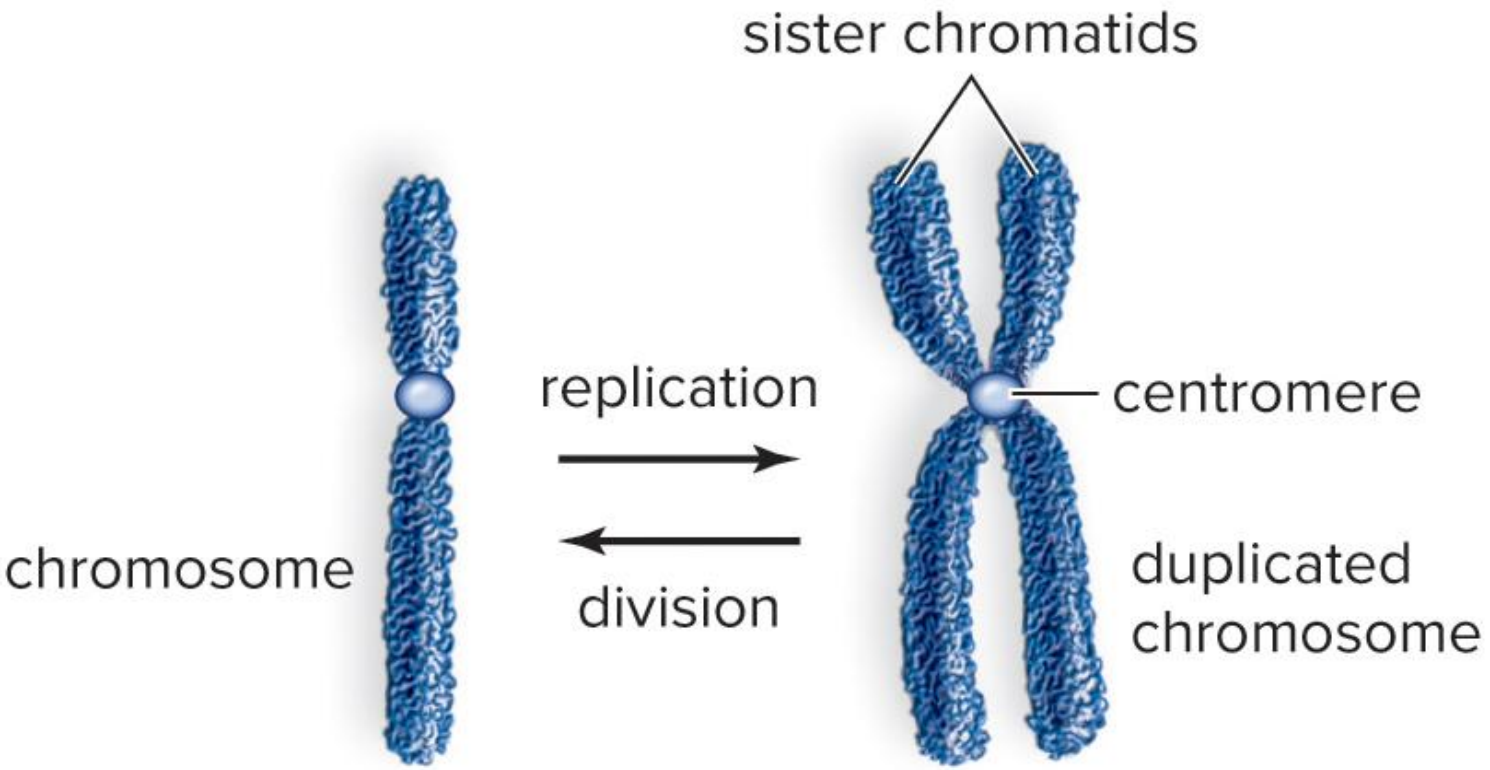
(fresh wound): Scott Camazine/Science Source; (healing wound): Ted Kinsman/ Science Source

Overview of Mitosis 1

DNA is replicated during the S phase of interphase.

- At the end of the S phase, each chromosome contains two identical parts, called sister chromatids, held together at a centromere.

Relationship Between DNA Replication and DNA Division (Figure 19.6)



Overview of Mitosis 2

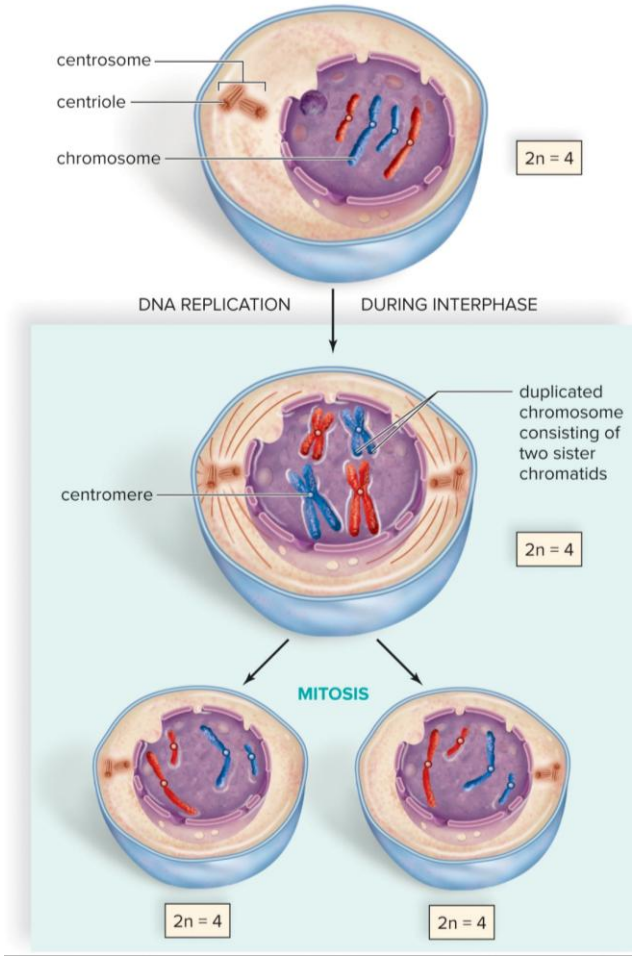
As mitosis begins, the chromosomes condense.

Following separation during mitosis, each chromatid is called a **chromosome.**

Each daughter cell gets a complete set of chromosomes and is **diploid (2n)**.

- The daughter cells are genetically identical to each other and to the parent cell.

An Overview of Mitosis (Figure 19.7)



The Mitotic Spindle 1

Centrosome—the microtubule organizing center of the cell.

After they duplicate, they separate and form the poles of the **mitotic spindle,** where they assemble the microtubules that make up the spindle fibers.

- The chromosomes are attached to the spindle fibers at their centromeres.

Aster—an array of microtubules at the poles.

Each centrosome contains a pair of **centrioles,** which consist of short cylinders of microtubules.

Phases of Mitosis

Mitosis is divided into phases: **prophase, prometaphase, metaphase, anaphase,** and **telophase.**

- The stages are continuous; one stage flows from the other with no noticeable interruption.

Prophase

Prophase.

The centrosomes have duplicated, and move toward opposite ends of the nucleus.

Spindle fibers appear.

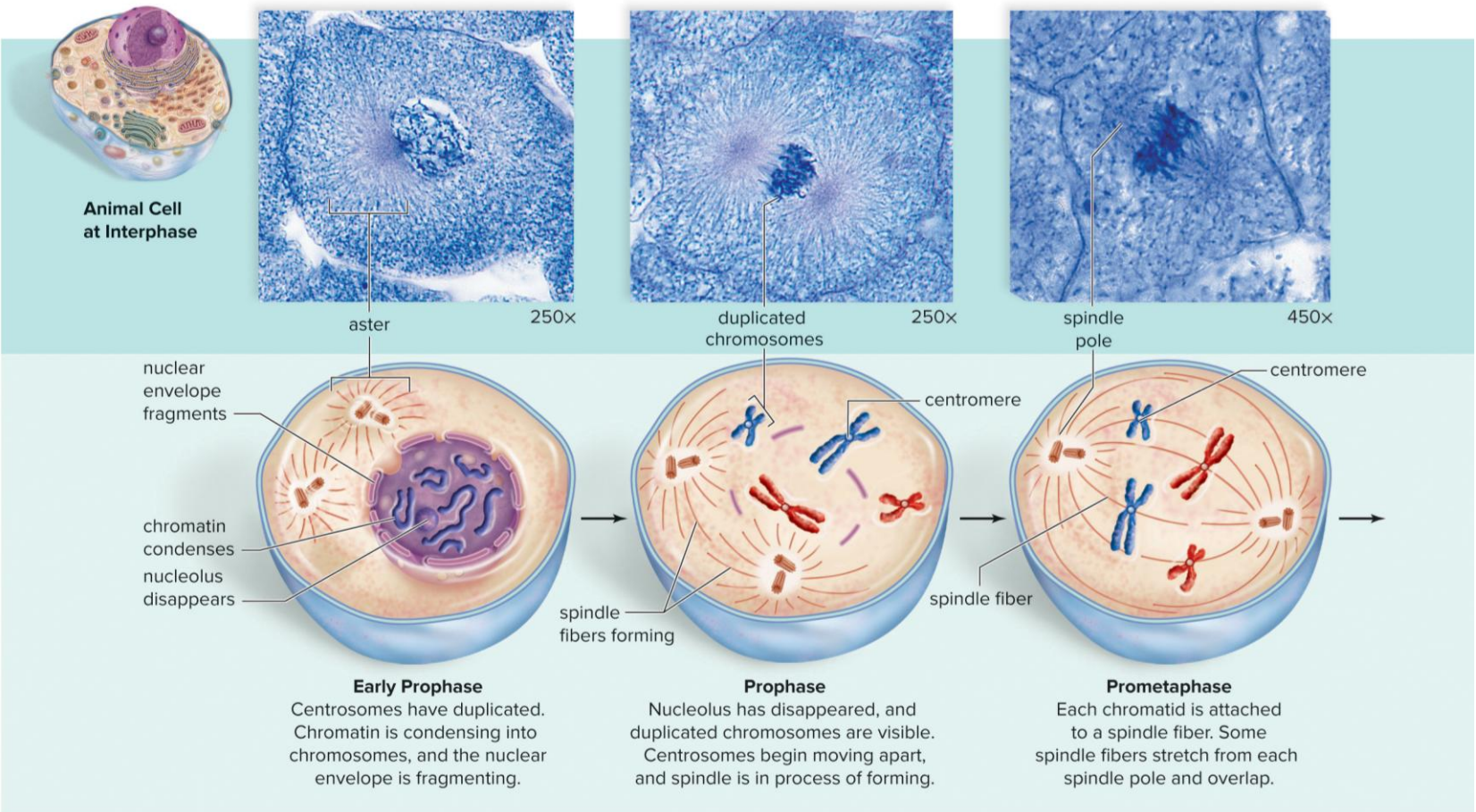
The nuclear envelope begins to fragment.

The nucleolus disappears.

The chromosomes condense (are now visible).

- Each is composed of two sister chromatids held together at a centromere.

Stages of Mitosis (Figure 19.8, Left) [1]



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(photos) (early prophase, prophase): Ed Reschke; (prometaphase): Michael Abbey/Science Source

Prometaphase

Prometaphase.

- The spindle fibers attach to the centromeres as the chromosomes continue to shorten and thicken.
- Chromosomes are randomly placed in the nucleus.

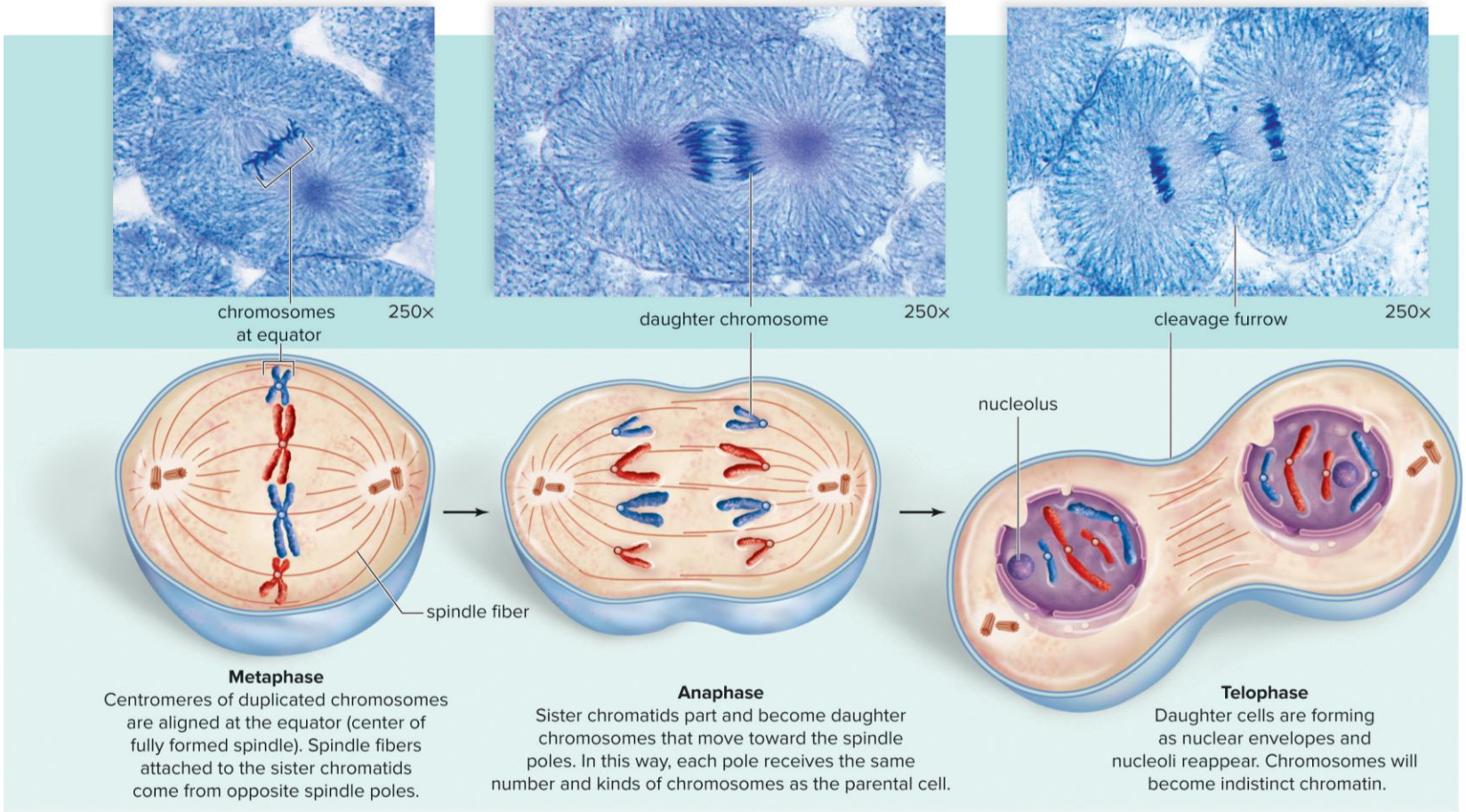
Metaphase

Metaphase.

The **metaphase plate** is a plane perpendicular to the axis of the spindle and equidistant from the poles.

- The chromosomes, attached to spindle fibers, line up at the metaphase plate.

Stages of Mitosis (Figure 19.8, Right) 2



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(photos) (metaphase, anaphase, telophase): Ed Reschke

Anaphase

Anaphase—centromeres divide.

The sister chromatids separate and move toward opposite poles of the spindle.

- Sister chromatids are now called chromosomes.

Telophase

Telophase.

- Begins when chromosomes arrive at the poles.
- Chromosomes become indistinct chromatin again.
- The spindle disappears.
- The nuclear envelope reappears.
- The nucleolus reappears.
- Characterized by the presence of two daughter nuclei.

Cytokinesis

Cytokinesis—division of the cytoplasm and organelles.

An indentation called a **cleavage furrow** passes around the circumference of the cell.

- Actin filaments form a contractile ring; as the ring becomes smaller, the cleavage furrow pinches the cell in half.

Think, Pair, Share

13. What is the role of centrosomes in mitosis?

14. What are the 5 phases of mitosis and what happens in each?