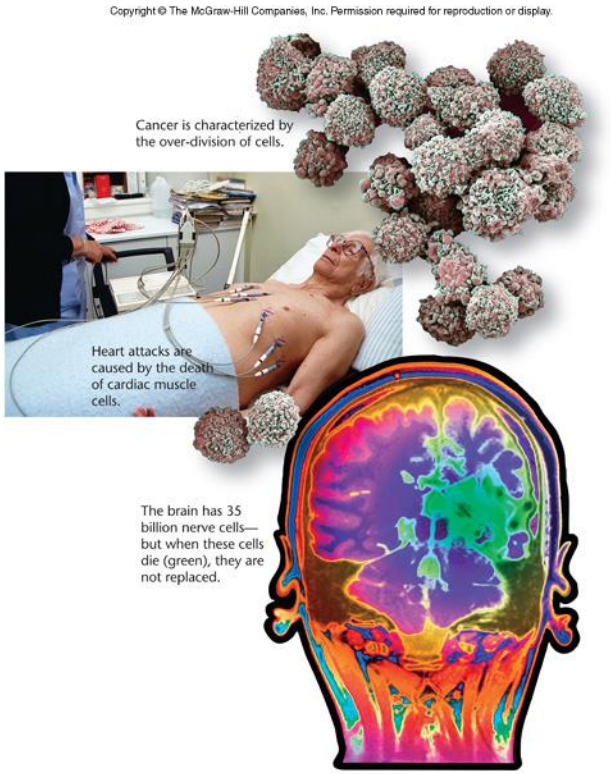
Essentials of Biology

Sylvia S. Mader

Chapter 8
Lecture Outline

Prepared by: Dr. Stephen Ebbs
Southern Illinois University Carbondale



The Basics of Cellular Reproduction

- One element of the cell theory is that all cells arise from pre-existing cells.
- The cells of multicellular organisms are produced by trillions of episodes of cellular reproduction, originating from a single cell.
- Cellular division also replaces worn-out or damaged cells in the body.

- In unicellular organisms, division of one cell reproduces the entire organism (asexual reproduction)
- Multicellular eukaryotes depend on cell division for
  - Development from a fertilized cell
  - Growth
  - Repair
- Cell division is an integral part of the **cell cycle**, the life of a cell from formation to its own division

The Basics of Cellular Reproduction

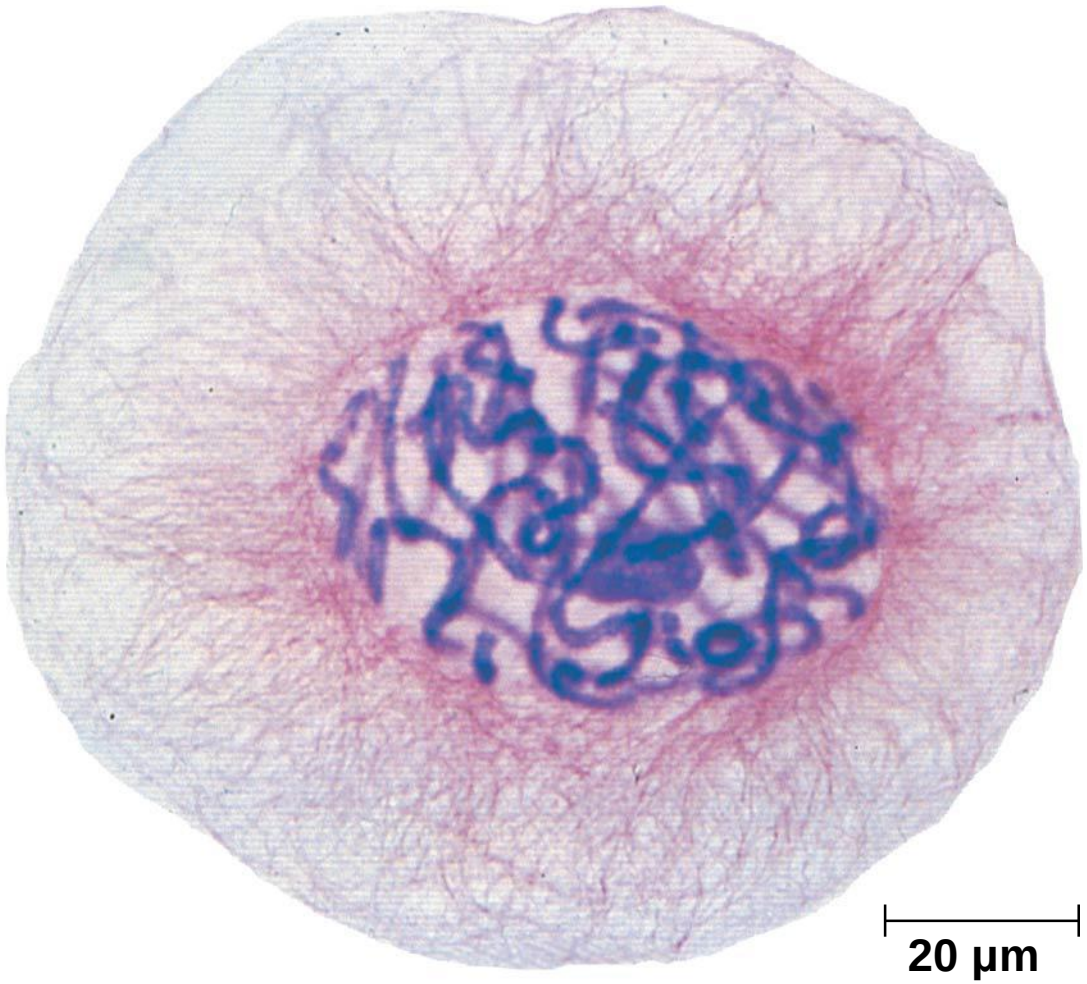
- Most cell division results in daughter cells with identical genetic information, DNA
- The exception is meiosis, a special type of division that can produce sperm and egg cells

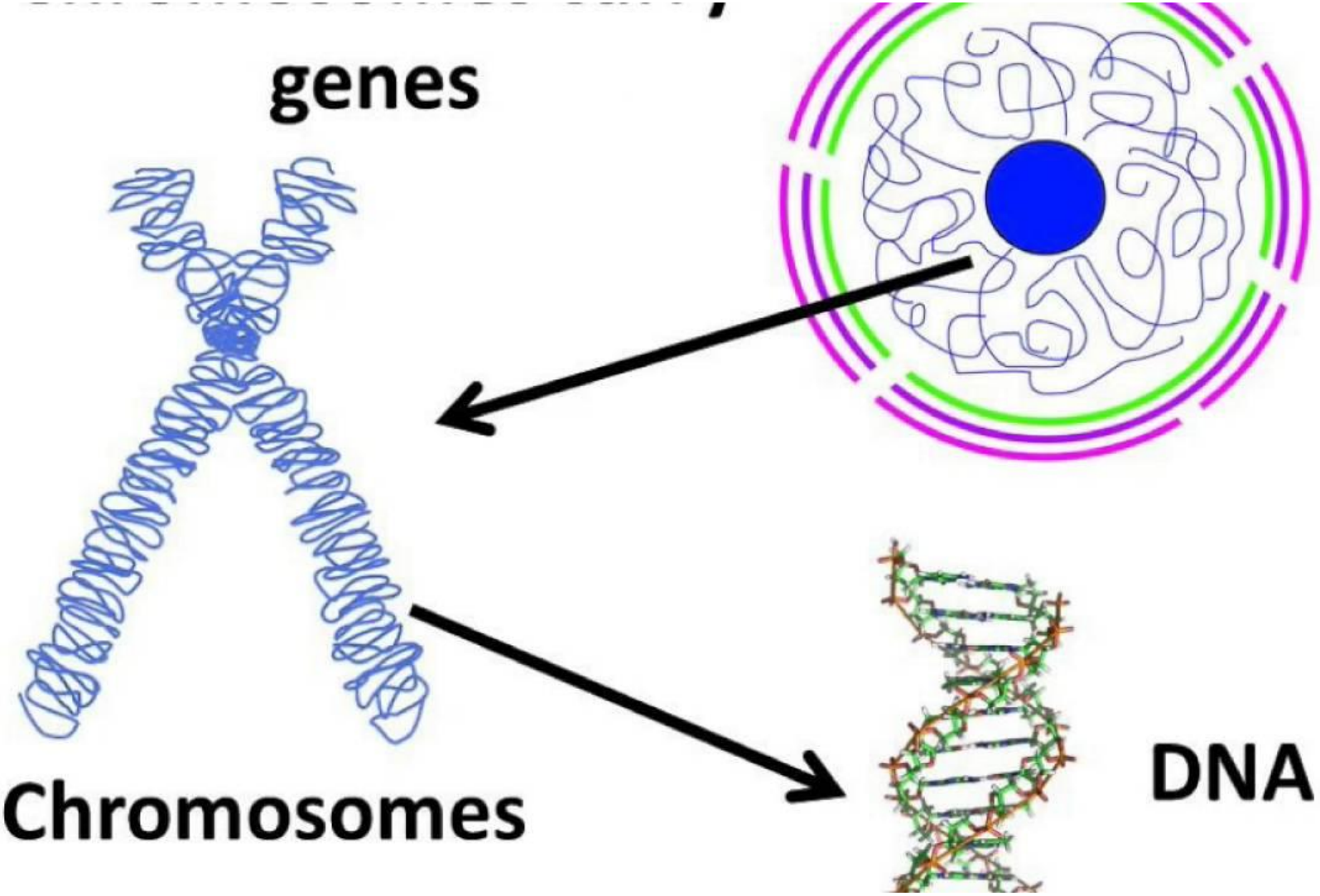
Cellular Organization of the Genetic Material

- All the DNA in a cell constitutes the cell's **genome**
- A genome can consist of a single DNA molecule (common in prokaryotic cells) or a number of DNA molecules (common in eukaryotic cells)
- DNA molecules in a cell are packaged into **chromosomes**

- Eukaryotic chromosomes consist of **chromatin**, a complex of DNA and protein that condenses during cell division
- Every eukaryotic species has a characteristic number of chromosomes in each cell nucleus
- **Somatic cells** (nonreproductive cells) have two sets of chromosomes
- **Gametes** (reproductive cells: sperm and eggs) have half as many chromosomes as somatic cells

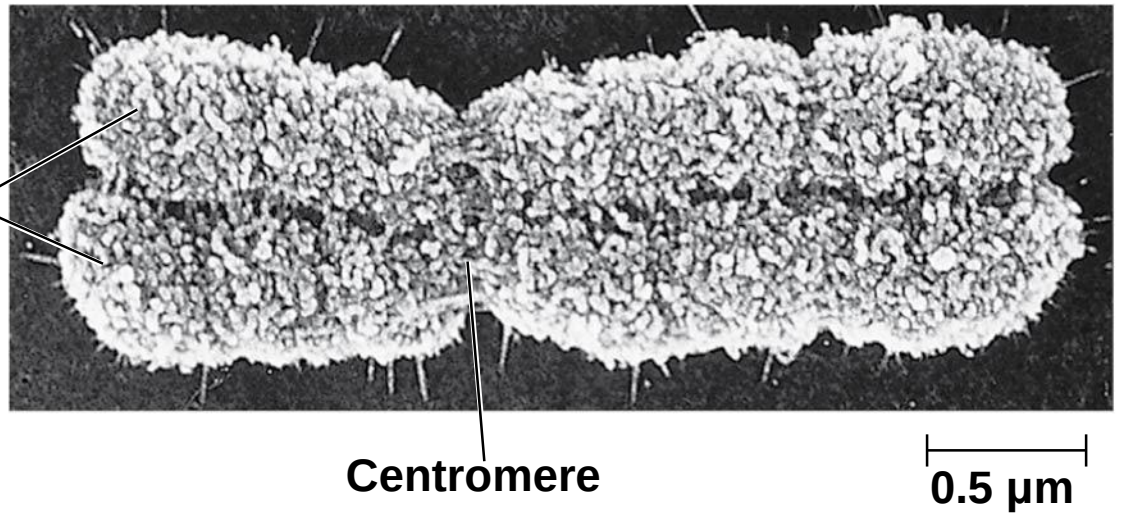
Figure 12.3



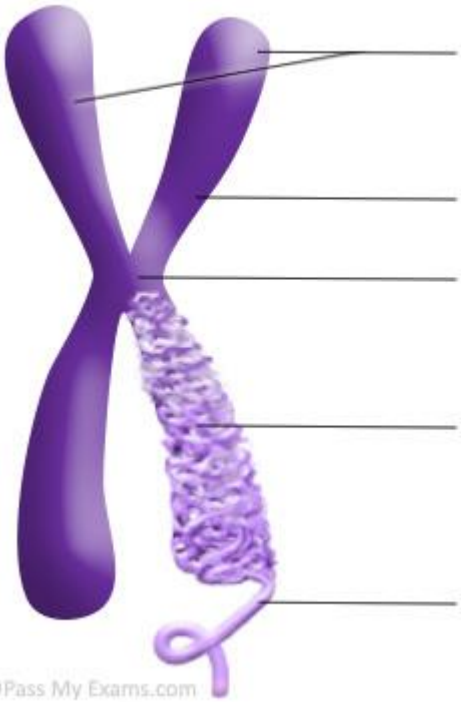

genes
Chromosomes
DNA

Distribution of Chromosomes During Eukaryotic Cell Division

- In preparation for cell division, DNA is replicated and the chromosomes condense
- Each duplicated chromosome has two **sister chromatids** (joined copies of the original chromosome), attached along their lengths by cohesins
- The **centromere** is the narrow “waist” of the duplicated chromosome, where the two chromatids are most closely attached



One Chromosome



Two Identical Chromatids
One is an exact copy of the other and each contains one DNA molecule.

p arm – short arm structure

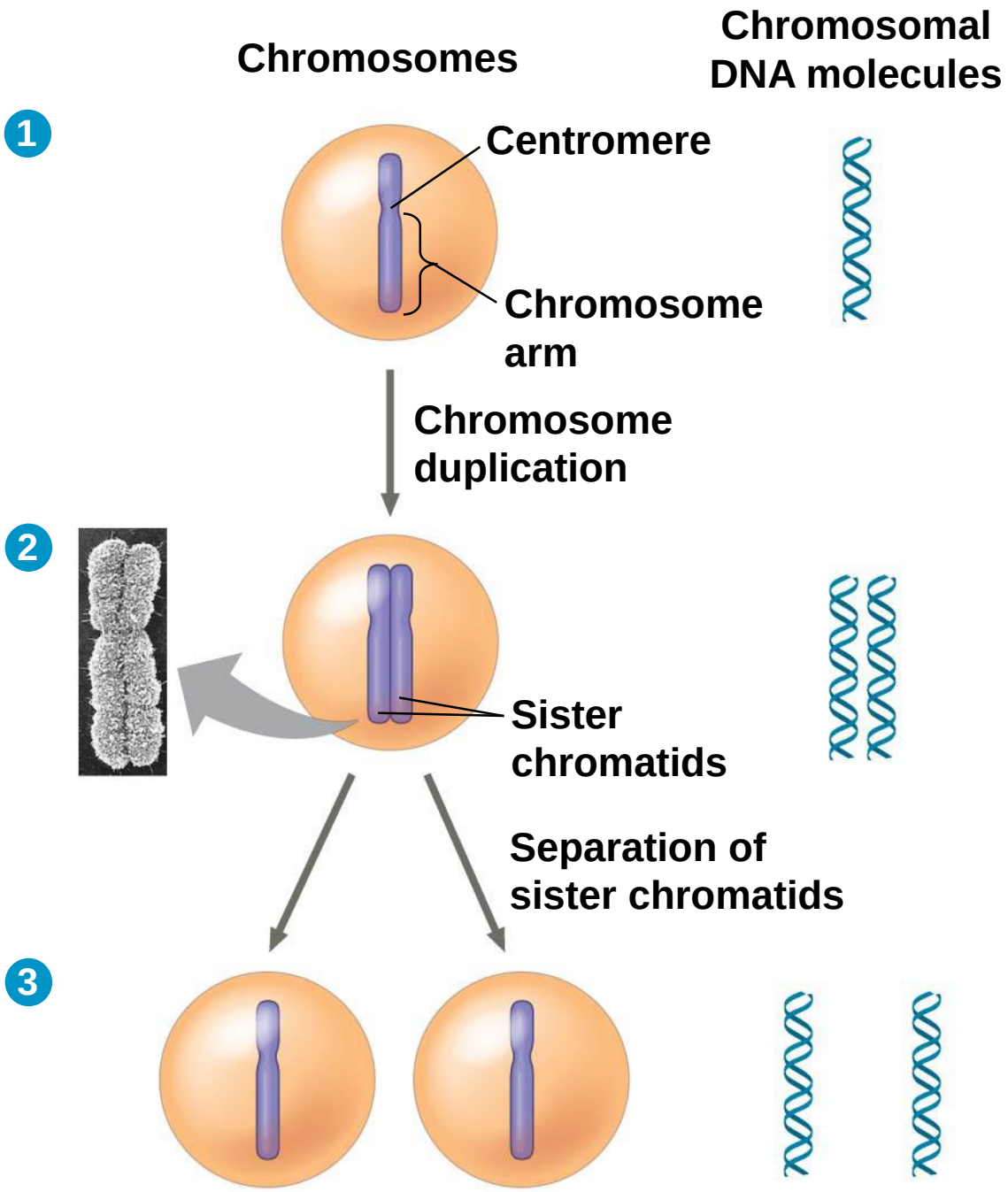
Centromere – constricted point of the chromosome

q arm – long arm structure

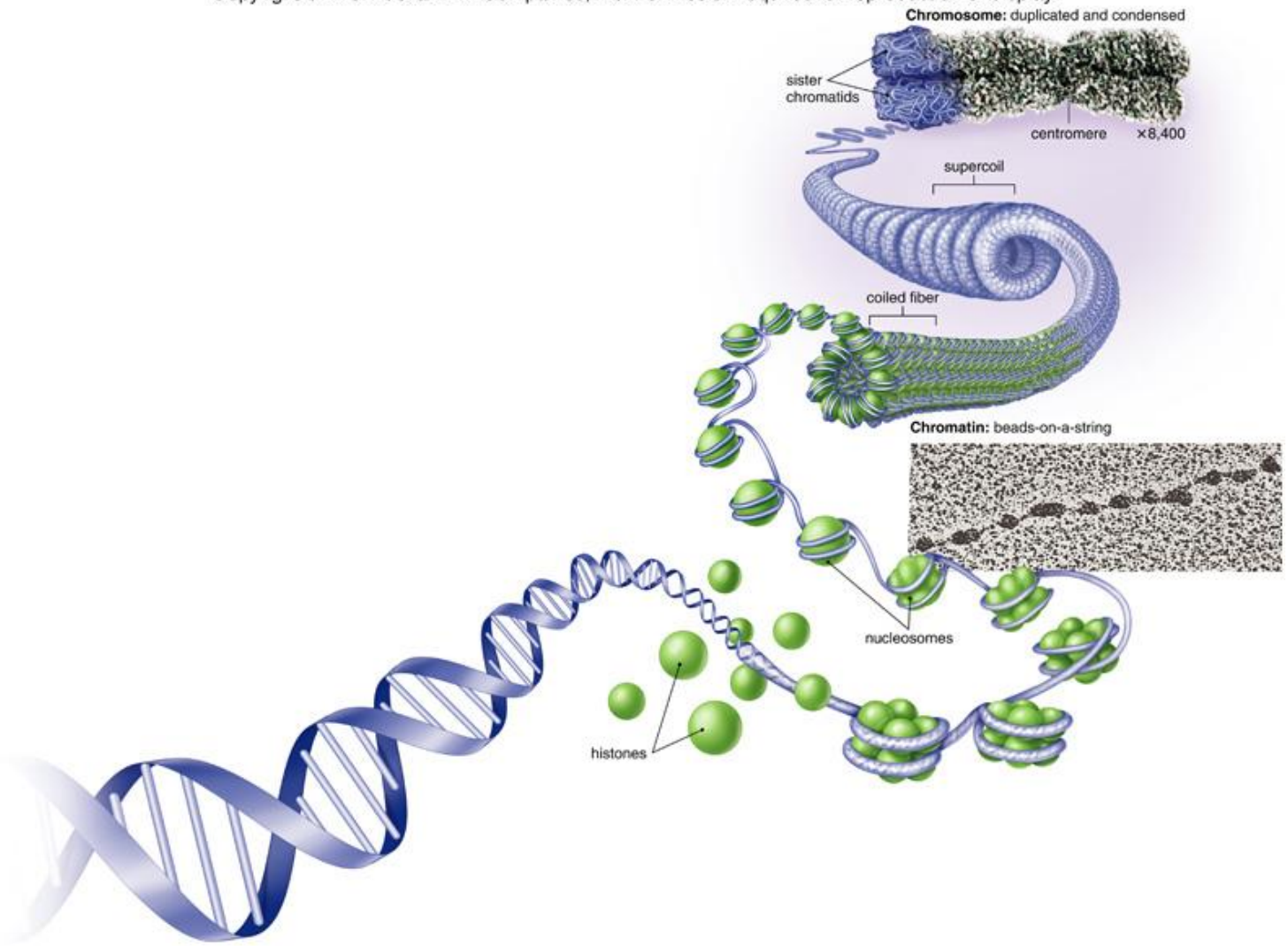
DNA molecule – long string like DNA molecule formed into a compact structure by proteins called histones.

- During cell division, the two sister chromatids of each duplicated chromosome separate and move into two nuclei
- Once separate, the chromatids are called chromosomes
- Eukaryotic cell division consists of
  - **Mitosis**, the division of the genetic material in the nucleus
  - **Cytokinesis**, the division of the cytoplasm

Figure 12.5-3


Chromosomes
Chromosomal DNA molecules
1
Centromere
Chromosome arm
Chromosome duplication
2
Sister chromatids
Separation of sister chromatids
3

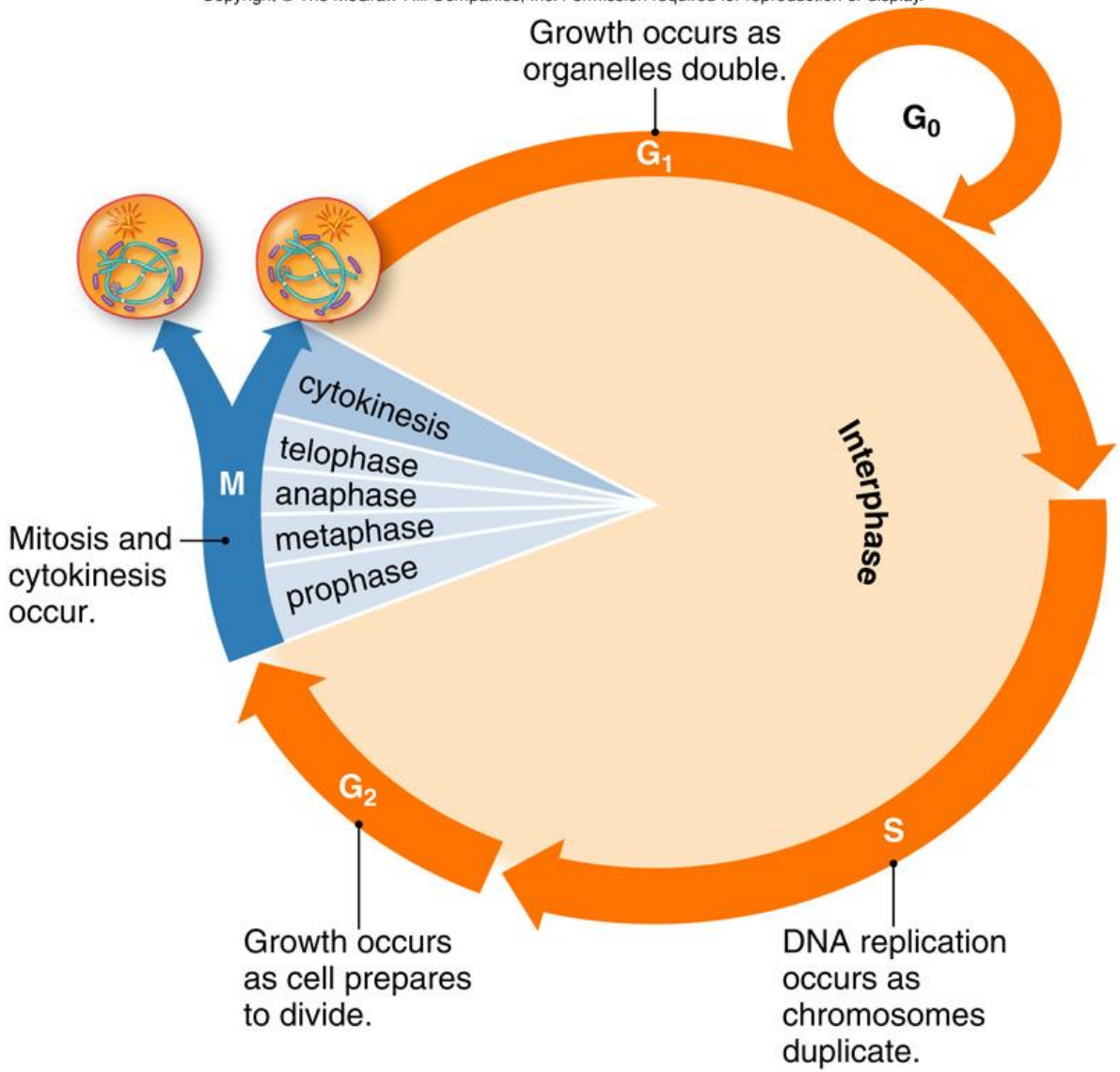
Chromatin to Chromosomes (cont.)



The Cell Cycle

- The process of cellular reproduction involves an ordered series of steps called the cell cycle.
- The cell cycle spans the period of time from the production of a daughter cell to the cellular reproduction of that cell to produce two new daughter cells.
- The cell cycle consists of
  - **Mitotic (M) phase** (mitosis and cytokinesis)
  - **Interphase** (cell growth and copying of chromosomes in preparation for cell division)

Interphase (cont.)



Interphase

- A cell spends most of its existence in a phase of the cell cycle called interphase.
- Most of interphase involves the normal activities and functions of that cell.
- Part of interphase is spent preparing the cell for cell division.

Interphase

- Interphase has three stages.
  - During the G_1 phase the cell grows (increases in size) and doubles the number of organelles and accumulates resources for DNA replication.
  - DNA replication begins during the S phase of interphase to create the duplicate DNA strand. The original and duplicate DNA strand are called sister chromatids.
  - During the G_2 phase the cell synthesizes the proteins needed for cell division.

M (Mitotic) Stage

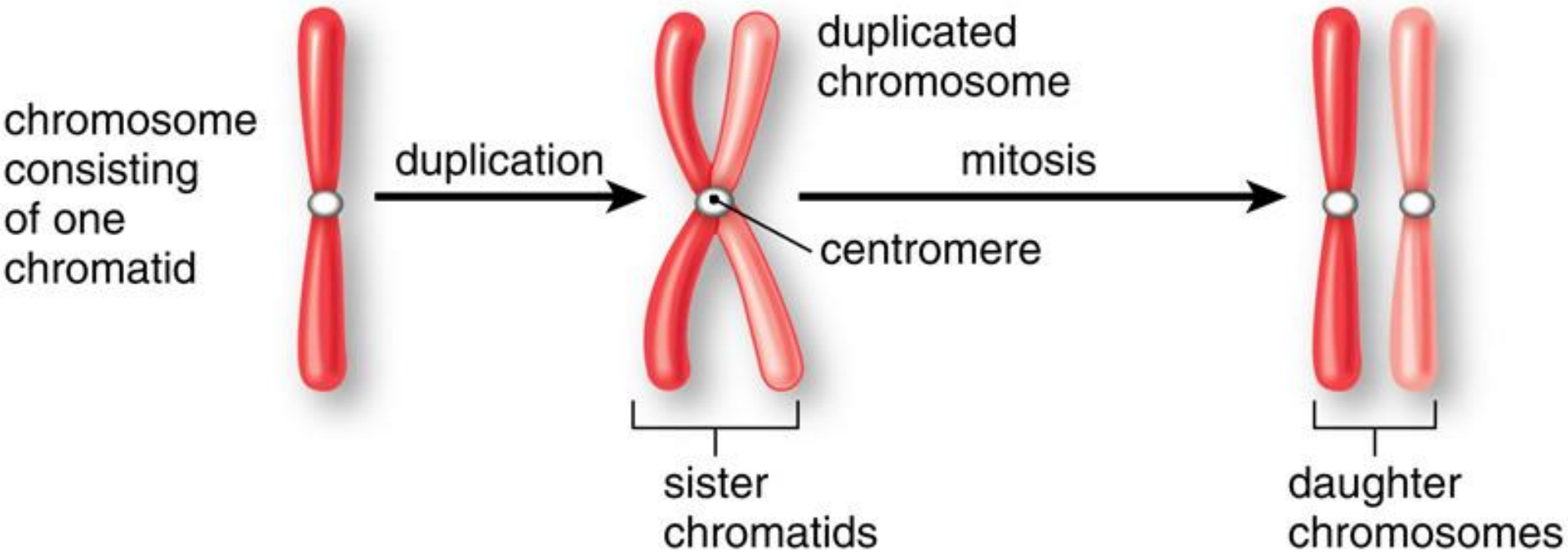
- The division of the cell occurs during the M (mitotic) stage of the cell cycle.
  - The division of the nuclear material (DNA) is called mitosis.
  - The division of the cytoplasm and its contents is called cytokinesis.

Mitosis and Cytokinesis

- The separation of the sister chromatids during mitosis produces two genetically identical daughter chromosomes.

- The daughter cells produced by mitosis have the same number of chromosomes as the original cell, each of which has the identical content.

8.3 Mitosis and Cytokinesis (cont.)



The Spindle

- In most eukaryotic cells, the separation of identical chromatids during mitosis utilizes spindle fibers.

- Spindle fibers are assembled from the microtubule proteins of the cytoskeleton.

- The spindle fibers are organized by the centrosome.

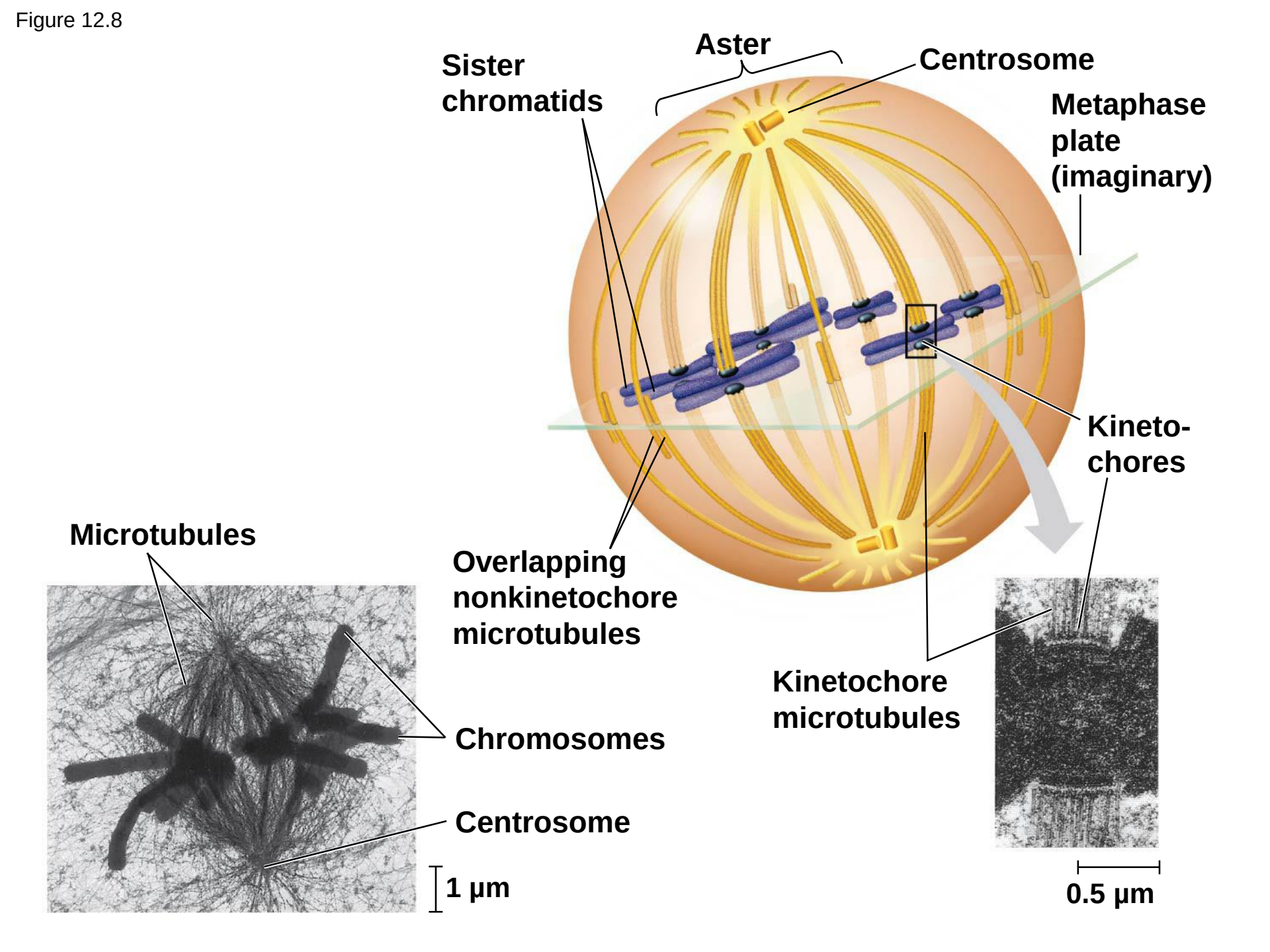
The Spindle (cont.)

- In animal cells, centrosomes consists of two parts.
  - Two centrioles
  - An array of microtubules called an aster
- The centromeres migrate prior to mitosis to opposite poles of the nucleus.
- A spindle attaches to each centrosome and stretches across the nucleus, overlapping at the spindle equator.

The Spindle (cont.)

- The spindles attach to each duplicated chromosome at the kinetocore to facilitate the separation of the sister chromatids.
- **Kinetochores** are protein complexes associated with centromeres

Figure 12.8


Aster
Sister chromatids
Centrosome
Metaphase plate (imaginary)
Kineto-chores
Microtubules
Overlapping nonkinetochore microtubules
Kinetochore microtubules
Chromosomes
Centrosome
1 µm
0.5 µm

Phases of Mitosis in Animal Cells

- The separation of the sister chromatids during mitosis occurs in four phases.
  - Prophase - prometaphase
  - Metaphase
  - Anaphase
  - Telophase
- Although divided into four phases, the separation of sister chromatids during mitosis is a continuous process.
- Cytokinesis, the separation of the cytoplasm and its contents, occurs after mitosis.

Phases of Mitosis in Animal Cells

- Prophase:

- Chromatin condenses and chromosomes become visible.
- The chromosomes are already duplicated (from S phase of the interphase).
- The nucleolus disappears and the nuclear envelope starts to fragment.
- The spindle begins to assemble and the centrosomes migrate away from each others.

- Prometaphase:

- Kinetochores appear at each side of the duplicated chromosomes and attach to the spindle fibers, but the chromosomes are still not aligned.

- Metaphase:

- The chromosomes are aligned in the middle of the cell at the metaphase plate.

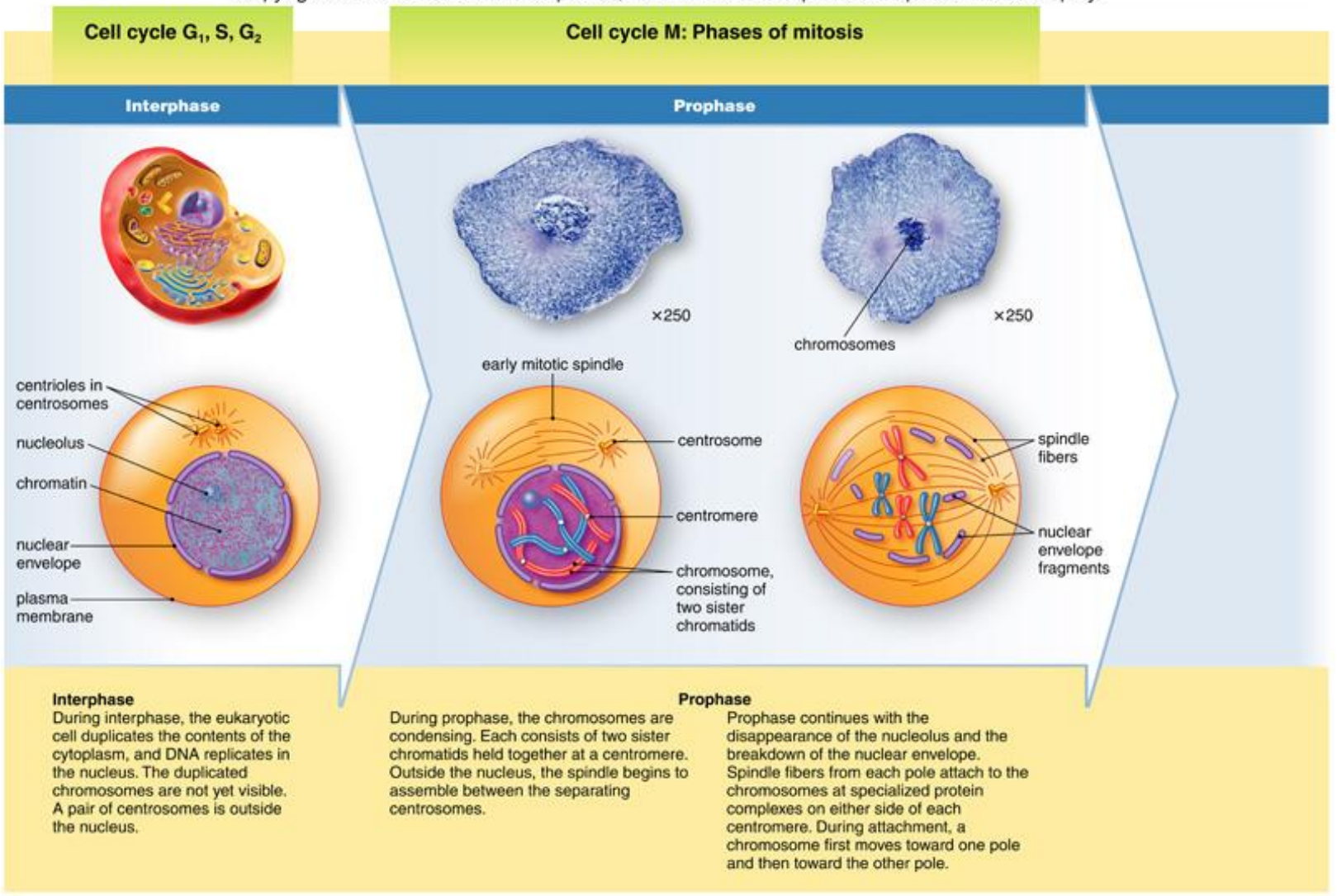
- Anaphase:

- The two sister chromatids of each duplicated chromosome separate at the centromere.
- The separated daughter chromosomes move toward the poles of the cell pulled by the mitotic spindle fibers.
- Anaphase is the shortest phase of mitosis.

- Telophase:

- The spindle disappears and new nuclear envelopes form around the chromosomes.
- The chromosomes become more diffuse chromatin again and the nucleolus reappears in each daughter cell side.

Phases of Mitosis in Animal Cells (cont.)



Phases of Mitosis in Animal Cells (cont.)

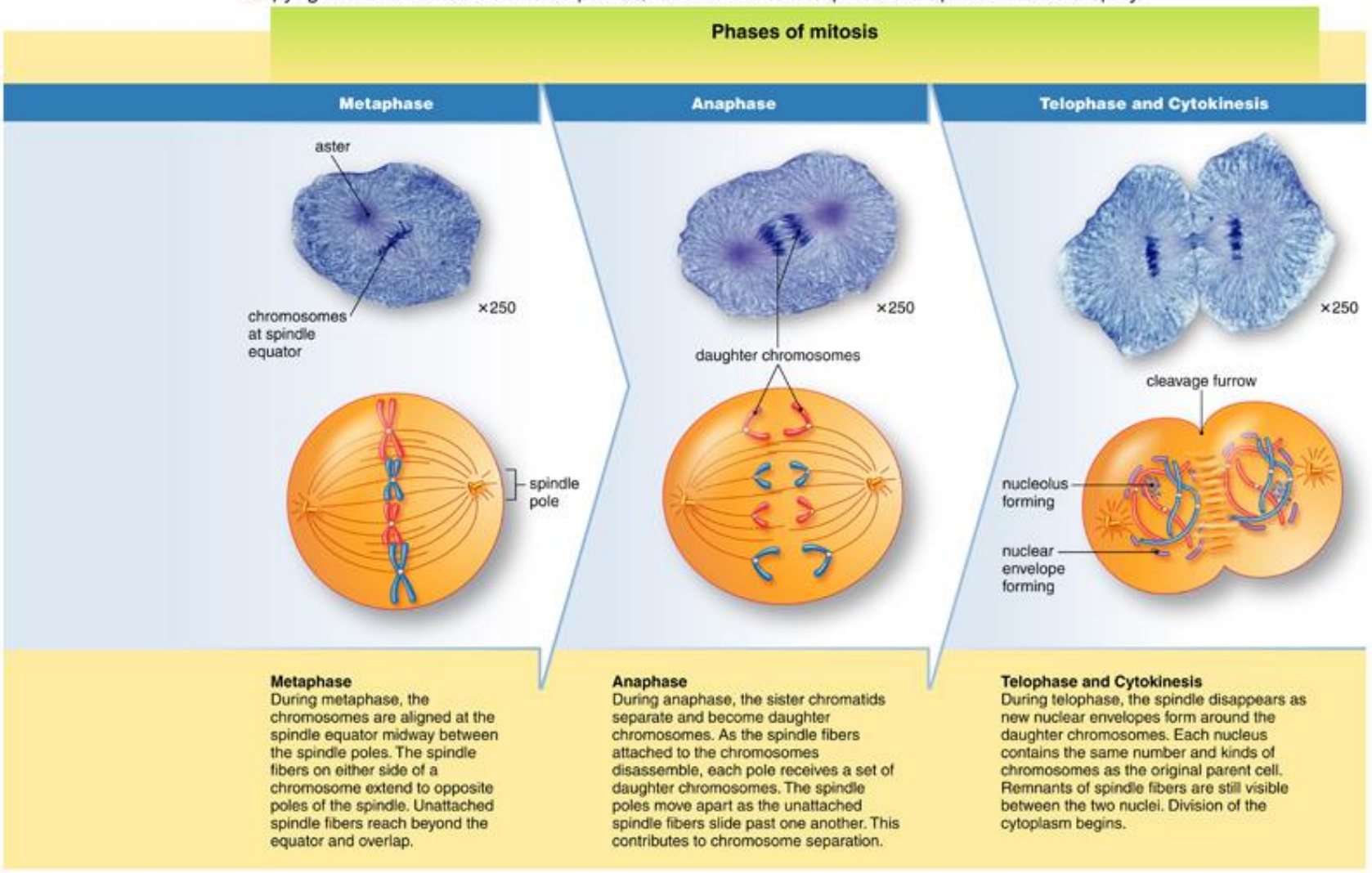


Figure 12.7d

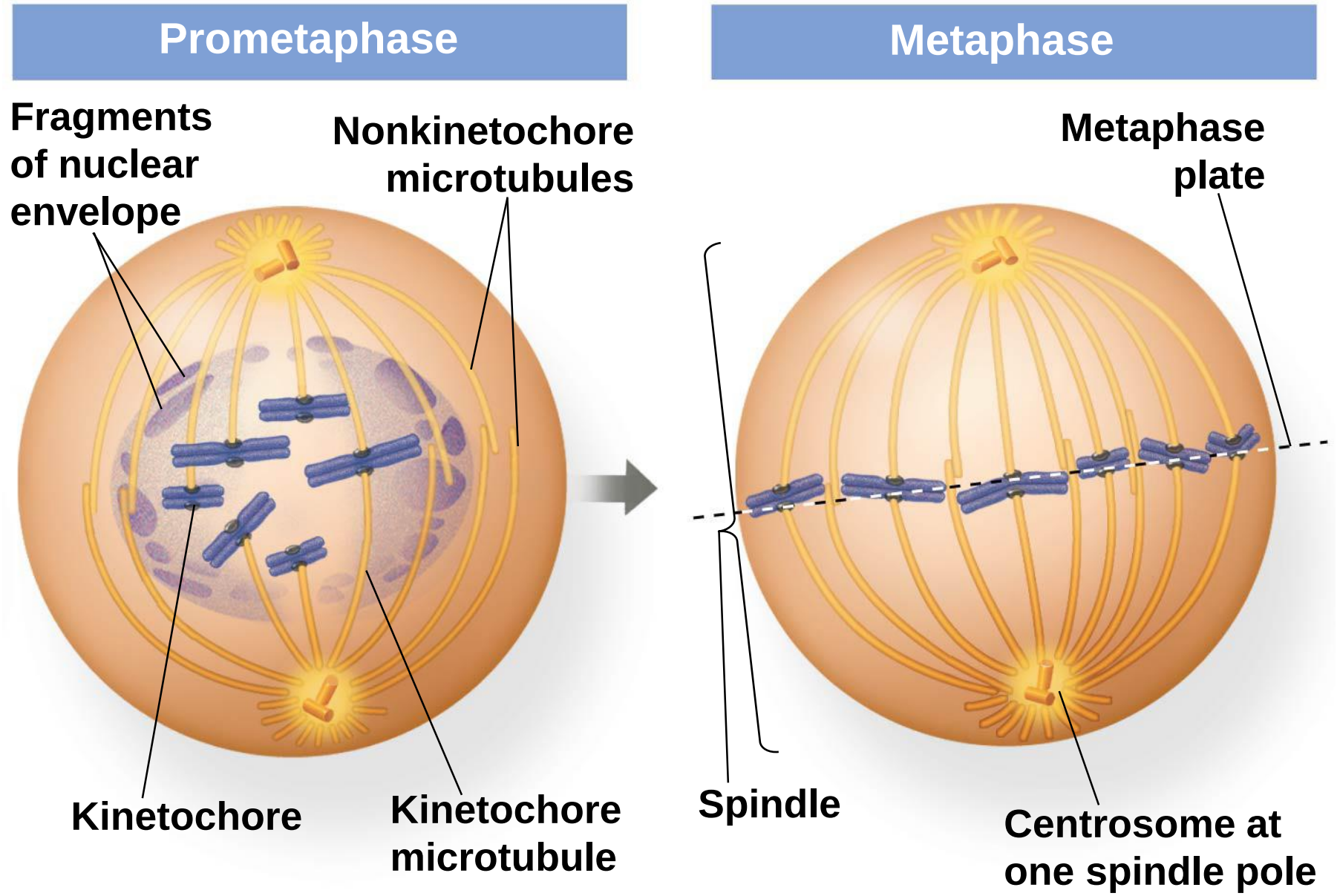
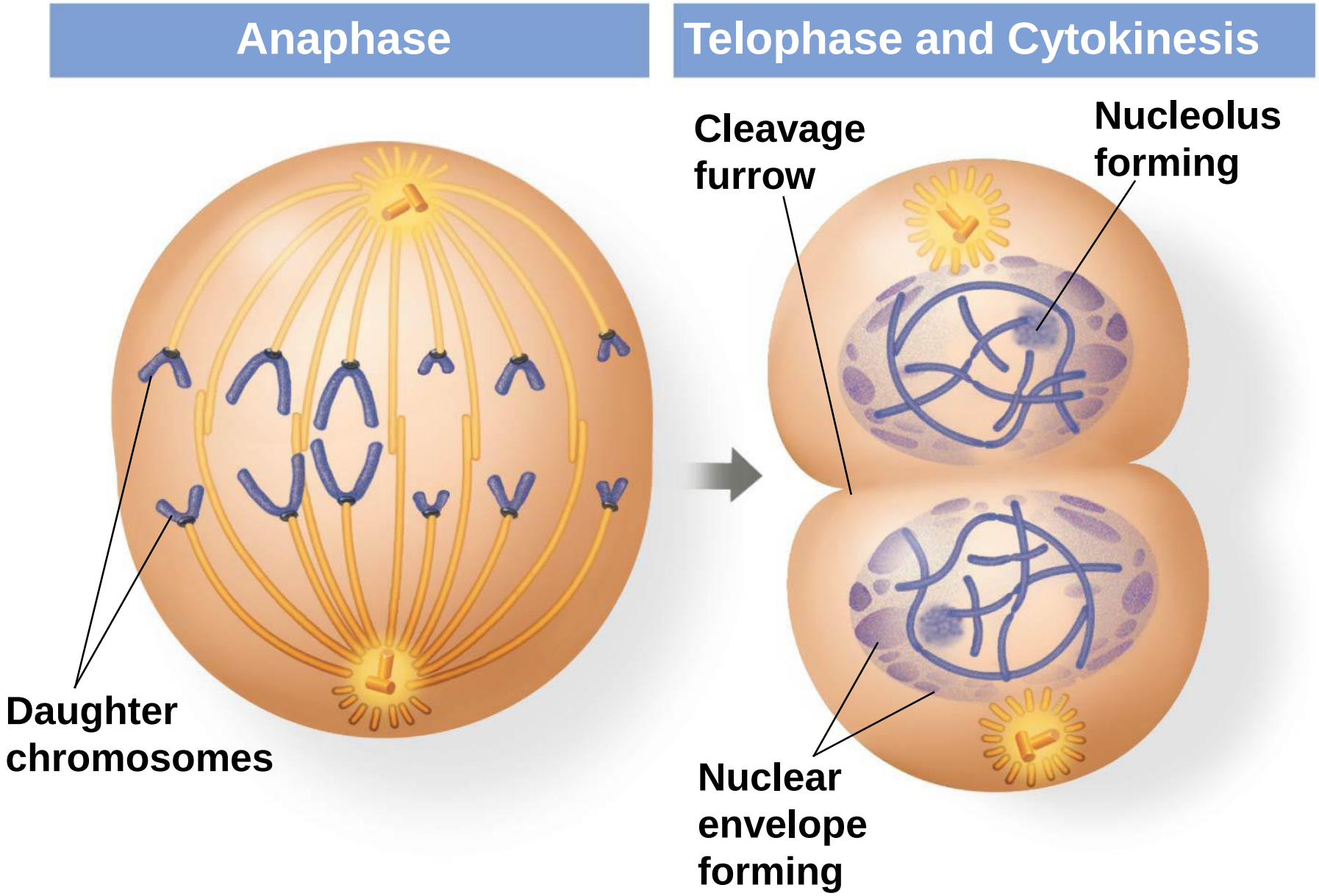
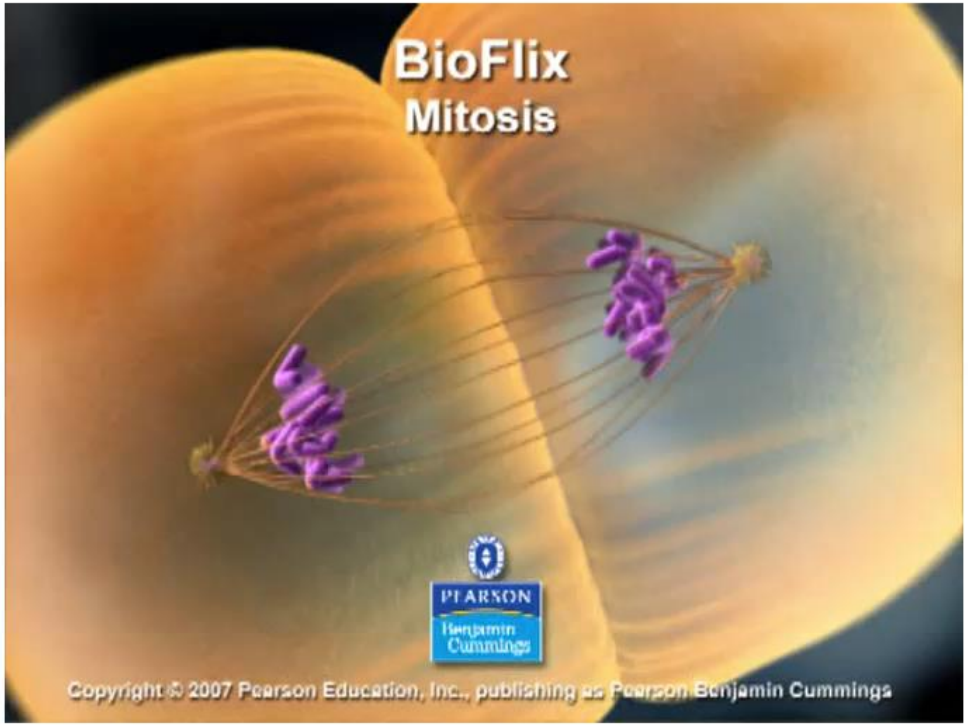

Prometaphase
Metaphase
Fragments of nuclear envelope
Nonkinetochore microtubules
Metaphase plate
Kinetochore
Kinetochore microtubule
Spindle
Centrosome at one spindle pole

Figure 12.7e


Anaphase
Telophase and Cytokinesis
Cleavage furrow
Nucleolus forming
Daughter chromosomes
Nuclear envelope forming

BioFlix: Mitosis

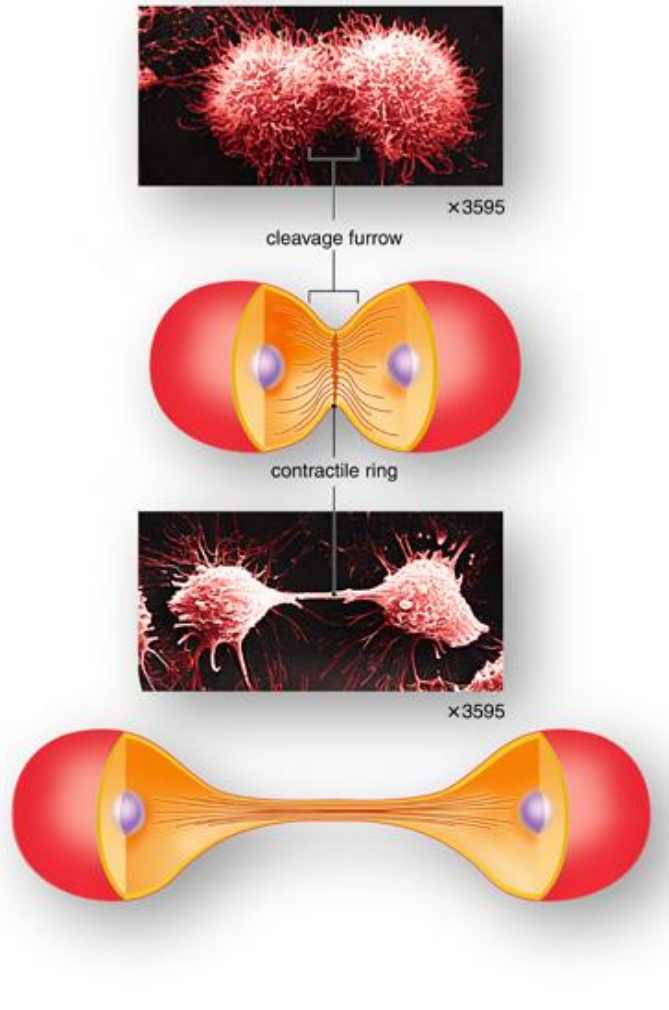


Cytokinesis in Animal and Plant Cells

- Cytokinesis does not always occur after mitosis.
- If cytokinesis does not occur, the cell will be multinucleated (have multiple nuclei).
- When cytokinesis does occur, it occurs differently in animal and plant cells.

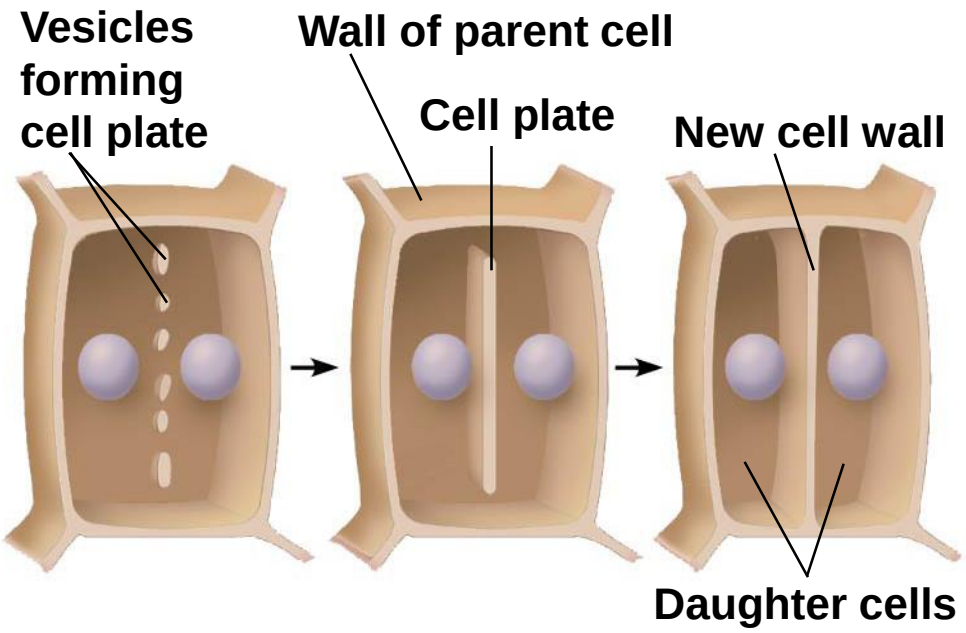
Cytokinesis in Animal Cells

- Cytokinesis in animal cells begins during anaphase as a cleavage furrow, an indentation of the membrane.
- Actin filaments form a band called contractile ring, which constricts to deepen the furrow until the cytoplasm is separated between the two daughter cells.

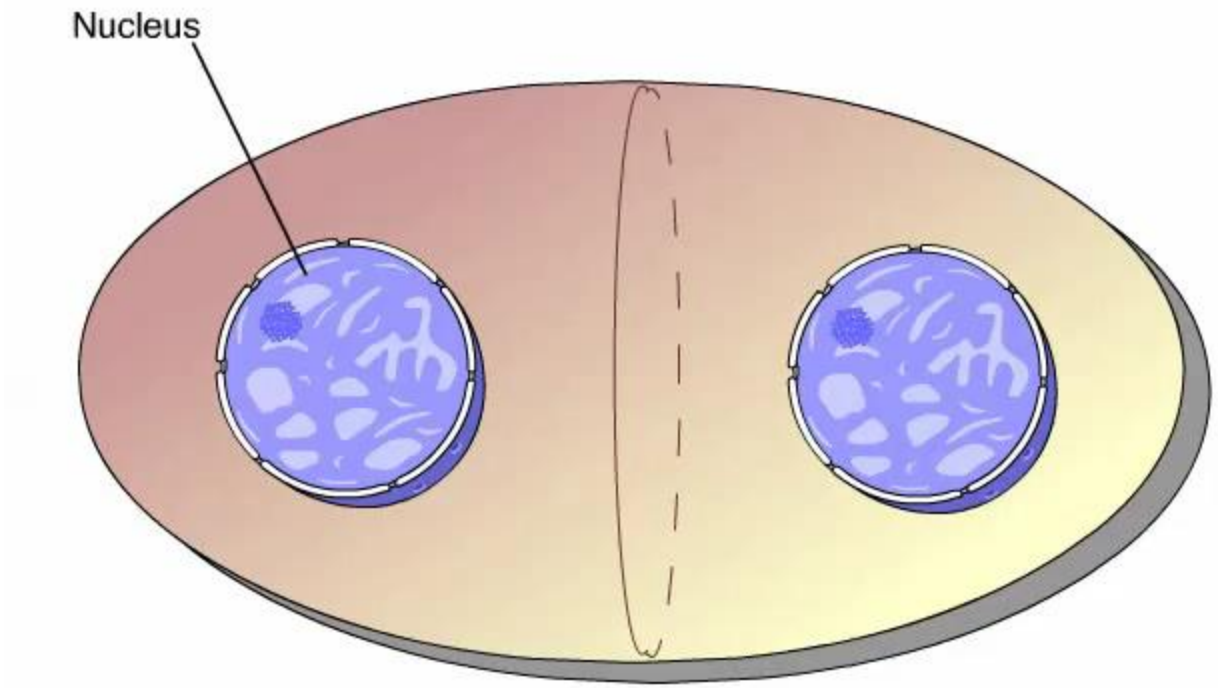


Cytokinesis in Plant Cells

- Plant cells undergo cytokinesis by forming a new cell wall between the daughter cells.
- The Golgi apparatus produces vesicles that fuse to form the cell plate.
- The cell plate expands until the cytoplasm is divided.



Animation: Cytokinesis



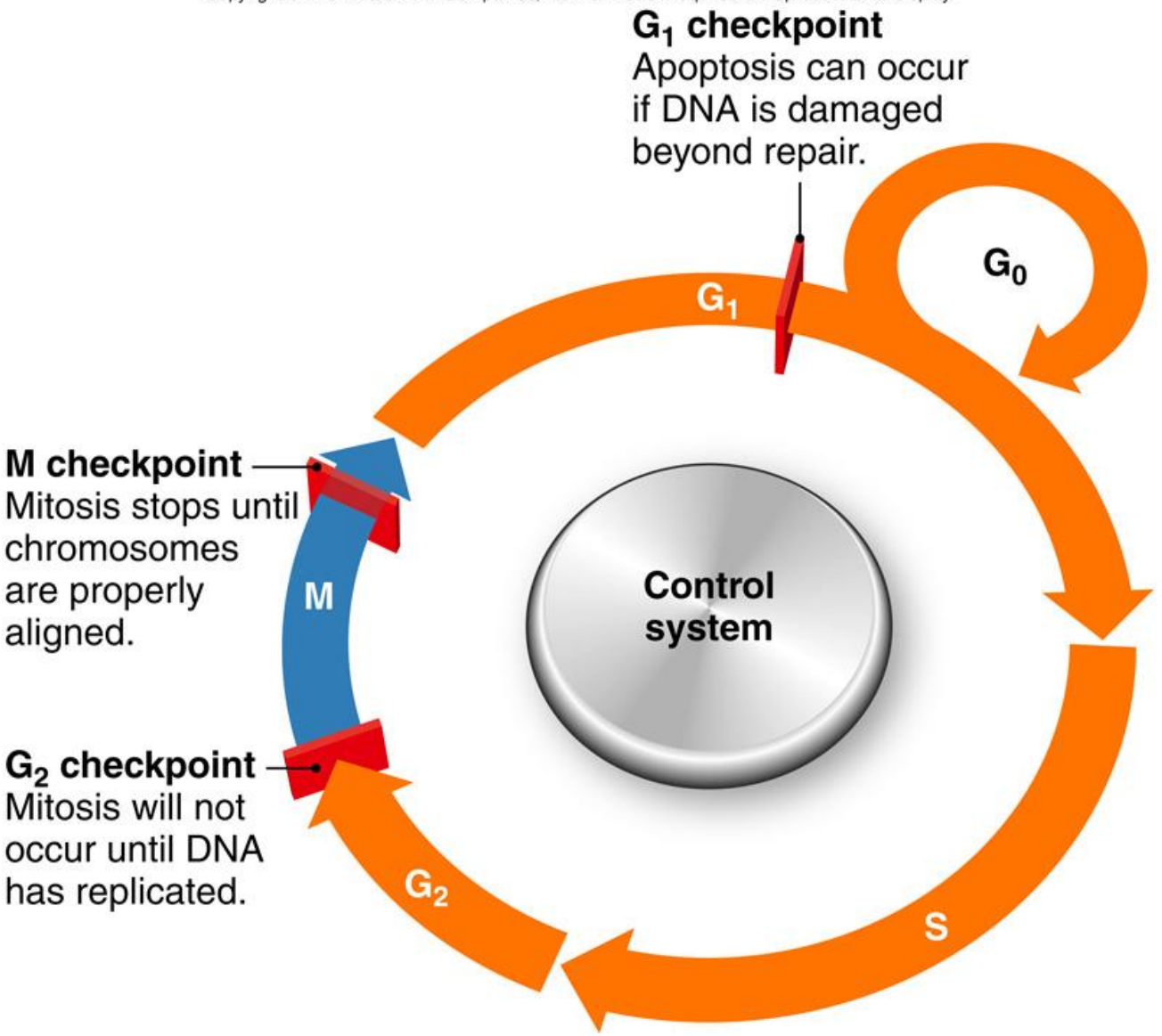
The Cell Cycle Control System

- The cell cycle is tightly regulated to insure that it is completed correctly.
- The control system of the cell cycle insures that the stages of interphase occur sequentially in the correct order.
- The cell cycle has checkpoints that control the progression of the cell cycle.
- Groups of proteins increase and decrease during the cell cycle.

- The G_1 checkpoint is important because passing this point commits the cell to division.
- If a cell does not pass the G_1 checkpoint, it may be held in G_0.
- A protein called p53 stops the cycle at the G_1 checkpoint if DNA is damaged, and initiates DNA repair process. If DNA damage is not corrected, p53 levels rise and bring about apoptosis.
- Another protein, called RB protein, it interprets the growth signals and availability of nutrients, it prevents excessive cell growth by inhibiting cell cycle progression until a cell is ready to divide.

- The G_2 checkpoint is the point at which the cell cycle pauses until DNA replication has been completed. If DNA is damaged, G_2 checkpoint offers the opportunity for DNA damage.
- M checkpoint also occurs during mitosis at which division pauses until the chromosomes are distributed accurately to the daughter cells.

Cell Cycle Checkpoints (cont.)



Internal and External Signals

- The cell cycle checkpoints are controlled by internal signals and external signals.

- Internal signals trigger the activity of proteins associated with cell division.
  - Kinases help regulate DNA synthesis during the S stage of interphase.
  - Cyclins and kinases control the transition of the cell cycle from G_2 to mitosis.

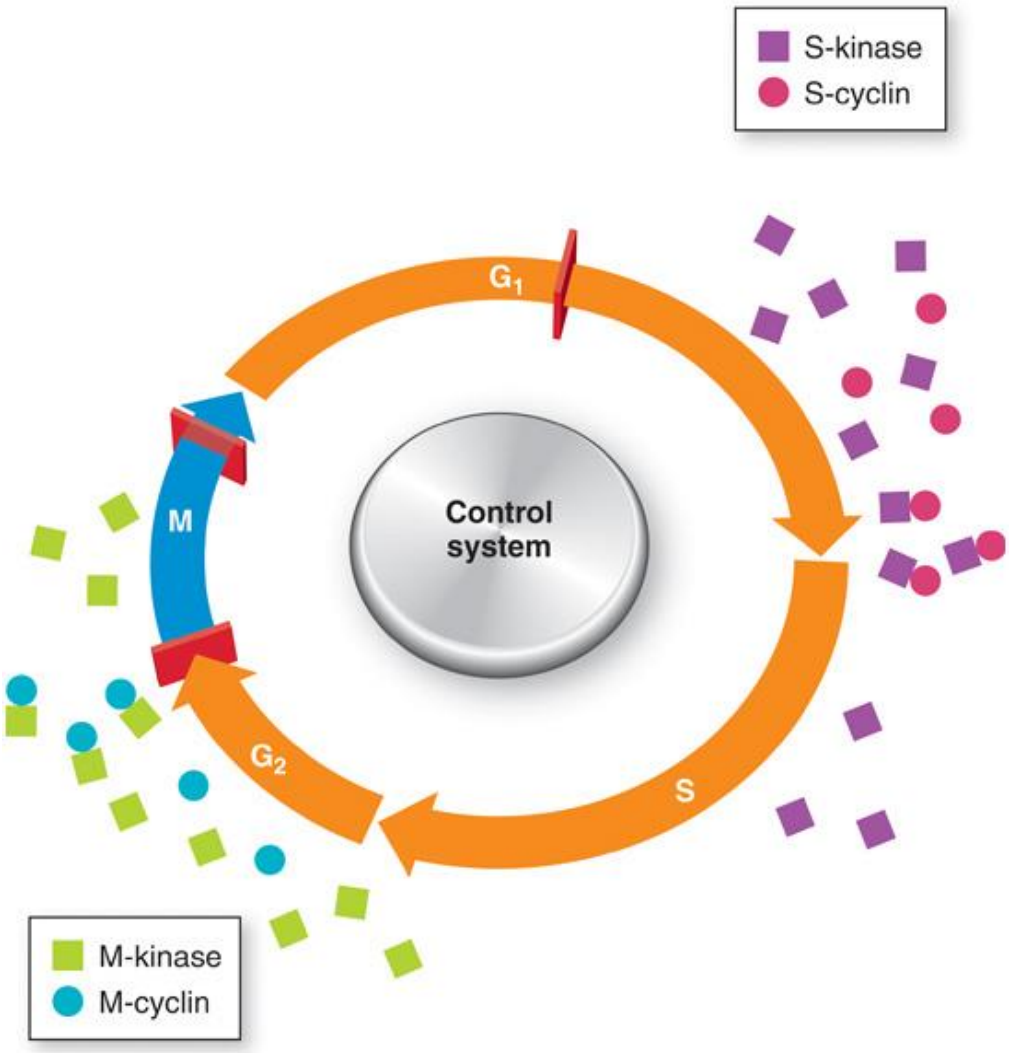
Internal and External Signals (cont.)

- Growth factors and hormones are external signals that stimulate cells to move through the cell cycle.

- Cell division can be inhibited by the proximity of other cells of the same type, a process called contact inhibition.

- DNA sequences called telomeres regulate the number of divisions that a cell undergoes.

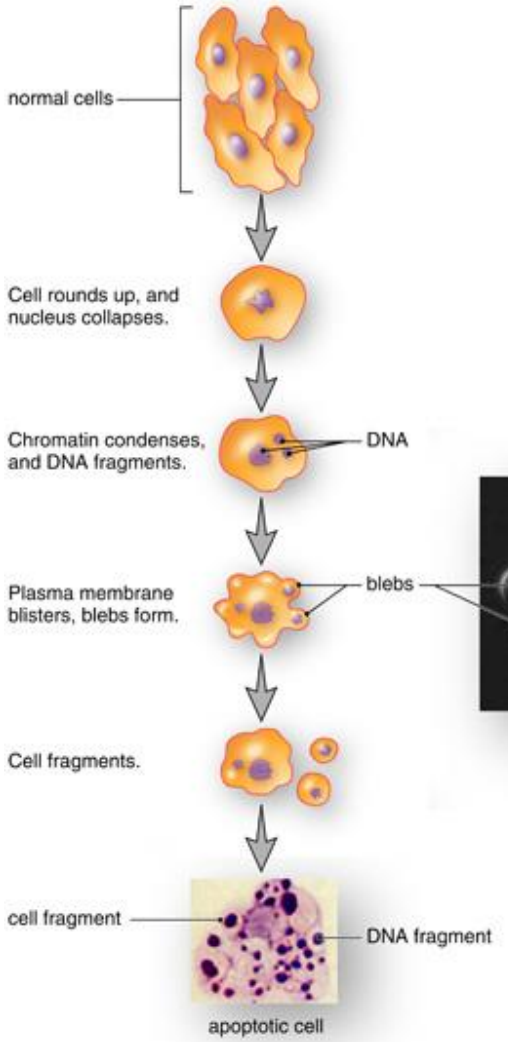
Internal and External Signals (cont.)

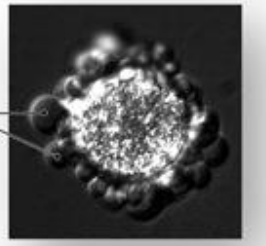


Apoptosis

- Apoptosis is the intentional, programmed death of a cell.
- The control of cell division and apoptosis keeps the number of somatic cells in multicellular organisms in check.
- Apoptosis can also be used to remove damaged or malfunctioning cells.

Apoptosis (cont.)

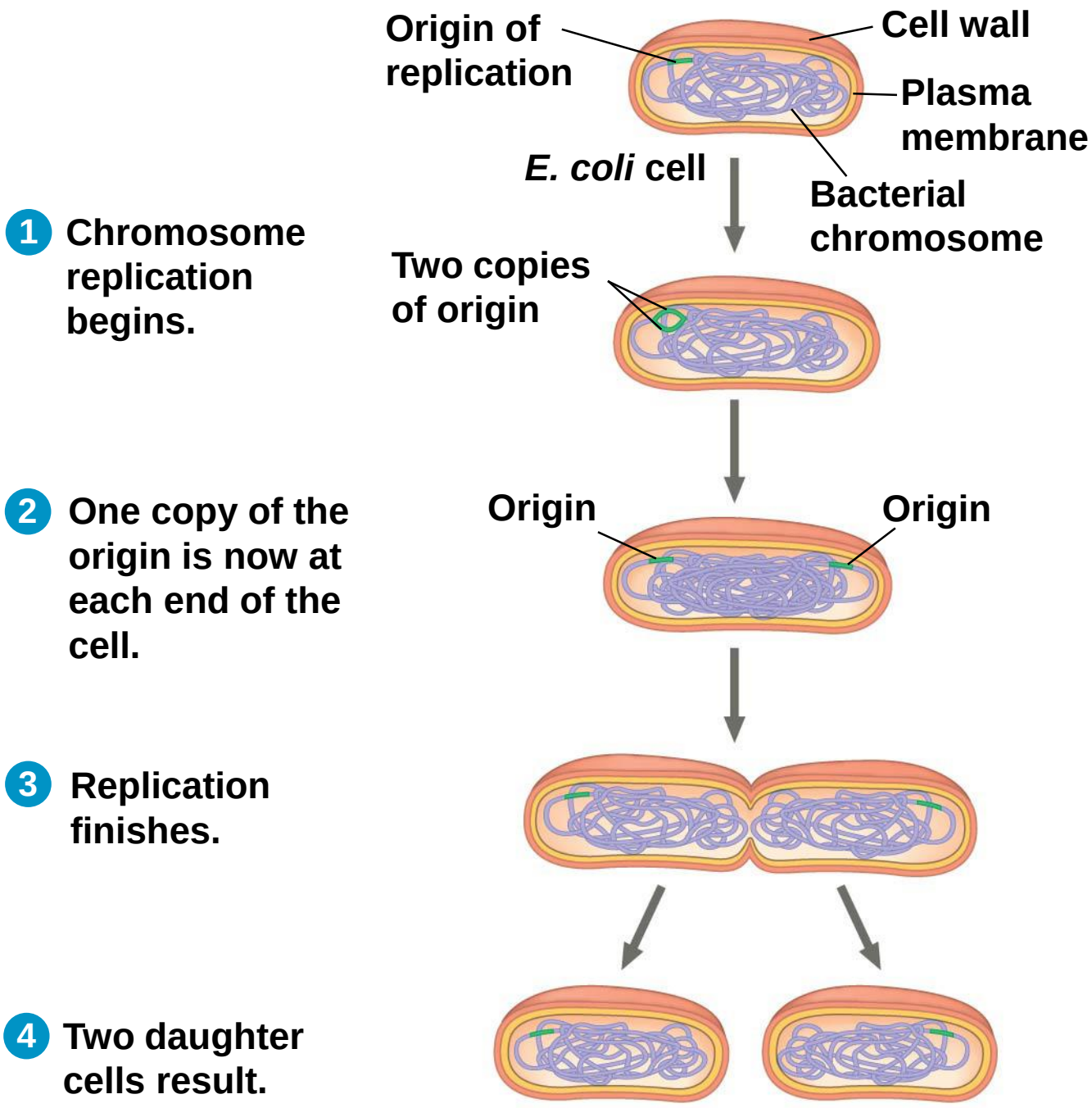




Binary Fission in Bacteria

- Prokaryotes (bacteria and archaea) reproduce by a type of cell division called **binary fission**
- In binary fission, the chromosome replicates (beginning at the **origin of replication**), and the two daughter chromosomes actively move apart
- The plasma membrane pinches inward, dividing the cell into two

Figure 12.12-4



8.5 The Cell Cycle and Cancer

- Cancer is a disease of the cell cycle.
- The regulation of the cell cycle is lost and uncontrolled cell division occurs.
- Cancers are classified by their location.
  - Carcinomas are cancers of the organs.
  - Sarcomas are cancers of the muscles.
  - Leukemias are cancers of the blood.

Characteristics of Cancer Cells

- Carcinogenesis is the development of cancerous cells with specific characteristics.
- Cancer cells lack differentiation, meaning that they have failed to acquire the specialized structure or function that the cell should have.
- Cancer cells have abnormally large nuclei and/or nuclei with an abnormal number of chromosomes.

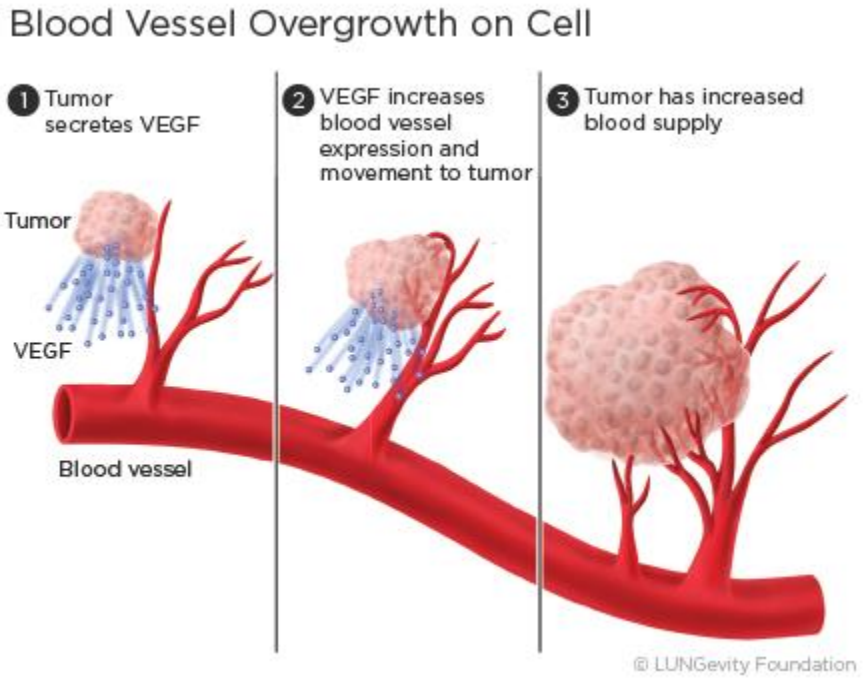
Characteristics of Cancer Cells (cont.)

- Cancer cells form a mass of dividing cells called a tumor.

- Tumors can undergo metastasis.
  - A benign tumor is encapsulated and does not invade neighboring tissue.
  - Cancer in situ remains in its place of origin.
  - During metastasis, a malignant tumor invades neighboring tissues and spreads through the body.

Characteristics of Cancer Cells

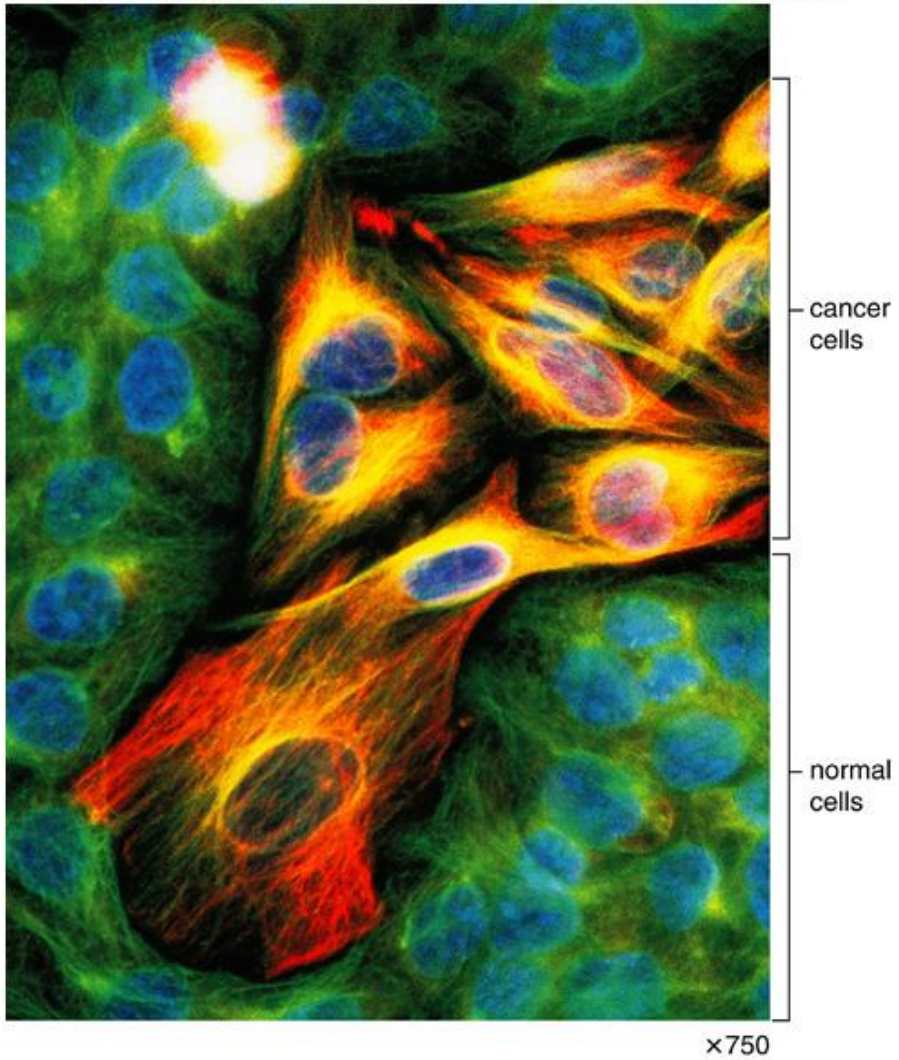
- Angiogenesis can occur, in which new blood vessels form to feed nutrients and oxygen to a cancerous tumor.
- Prevention of angiogenesis can be used to treat some cancers.



Cancer Treatment

- Cancer treatments are designed to remove cancer cells or interfere with their ability to divide.
  - Surgery can be used to remove the cancer.
  - Radiation therapy is used to kill cancerous cells by damaging their DNA.
  - Chemotherapy drugs are used to kill cancer cells that have metastasized.
  - Hormonal therapy is used to interrupt the signals that contribute cancer cell division.

Cancer Treatment (cont.)



Prevention of Cancer

- Evidence suggests that the risk of certain types of cancer can be reduced with changes in lifestyle.
  - Adoption of protective behaviors
  - Consumption of a protective diet

Protective Behaviors

- The risk of cancer can be reduced by avoiding potentially harmful activities.
  - Cigarette smoking and smokeless tobacco
  - Sunbathing
  - Excessive alcohol consumption

Protective Diet

- Evidence suggests that the risk of certain types of cancer can be reduced by following specific dietary guidelines.
  - Increased consumption of foods rich in vitamin A and C
  - Avoidance of salt-cured, pickled, or smoked foods
  - Increased consumption of vegetables from the cabbage family.

Protective Diet (cont.)