Chapter 12

The Cell Cycle

PowerPoint® Lecture Presentations for

Biology

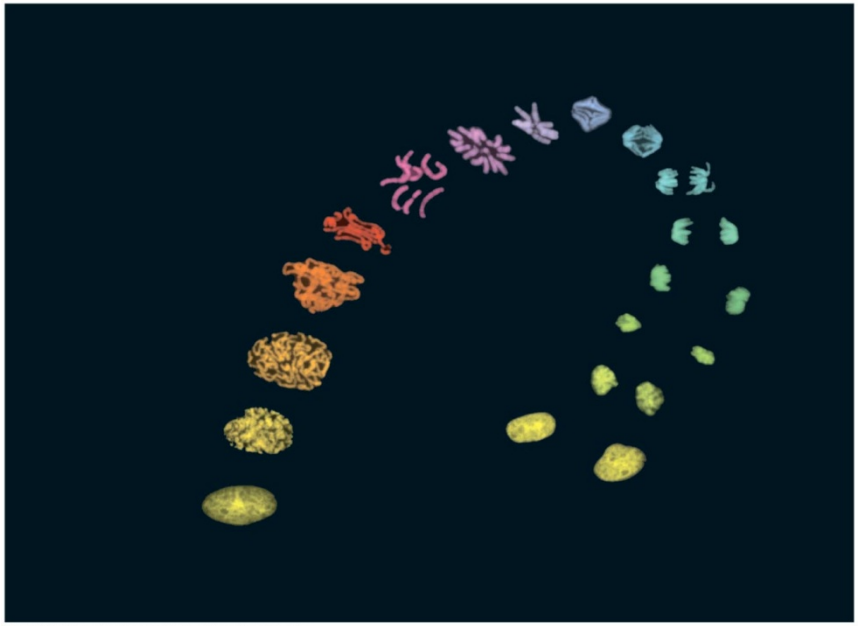
Eighth Edition

Neil Campbell and Jane Reece

Lectures by Chris Romero, updated by Erin Barley with contributions from Joan Sharp

Overview: The Key Roles of Cell Division

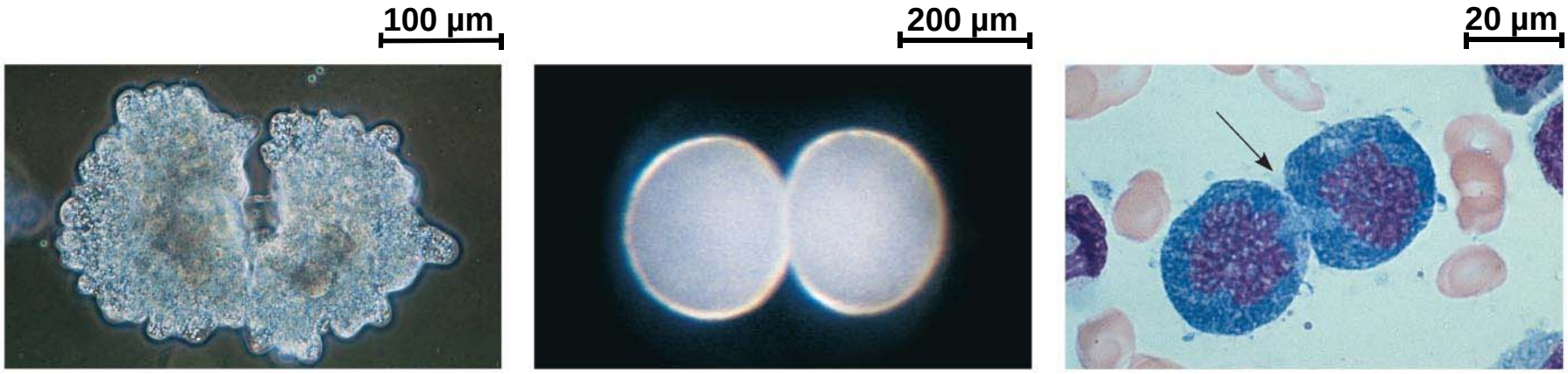
- The ability of organisms to reproduce best distinguishes living things from nonliving matter
- The continuity of life is based on the reproduction of cells, or **cell division**



- In unicellular organisms, division of one cell reproduces the entire organism
- Multicellular organisms 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

Fig. 12-2

The functions of cell division



(a) Reproduction

(b) Growth and development

(c) Tissue renewal

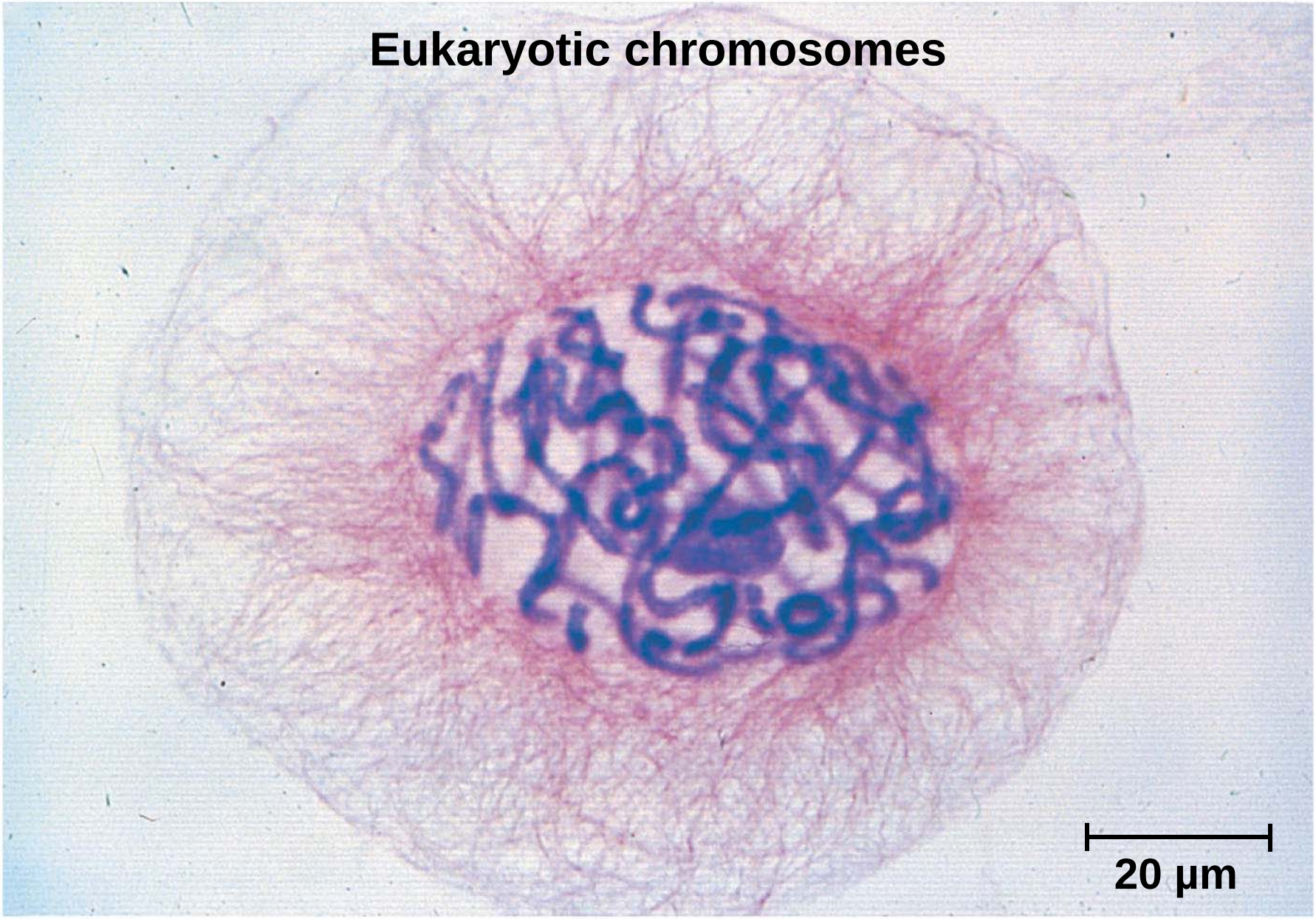
Concept 12.1: Cell division results in genetically identical daughter cells

- Most cell division results in daughter cells with identical genetic information, DNA
- A special type of division produces nonidentical daughter cells (gametes, or 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**

Fig. 12-3

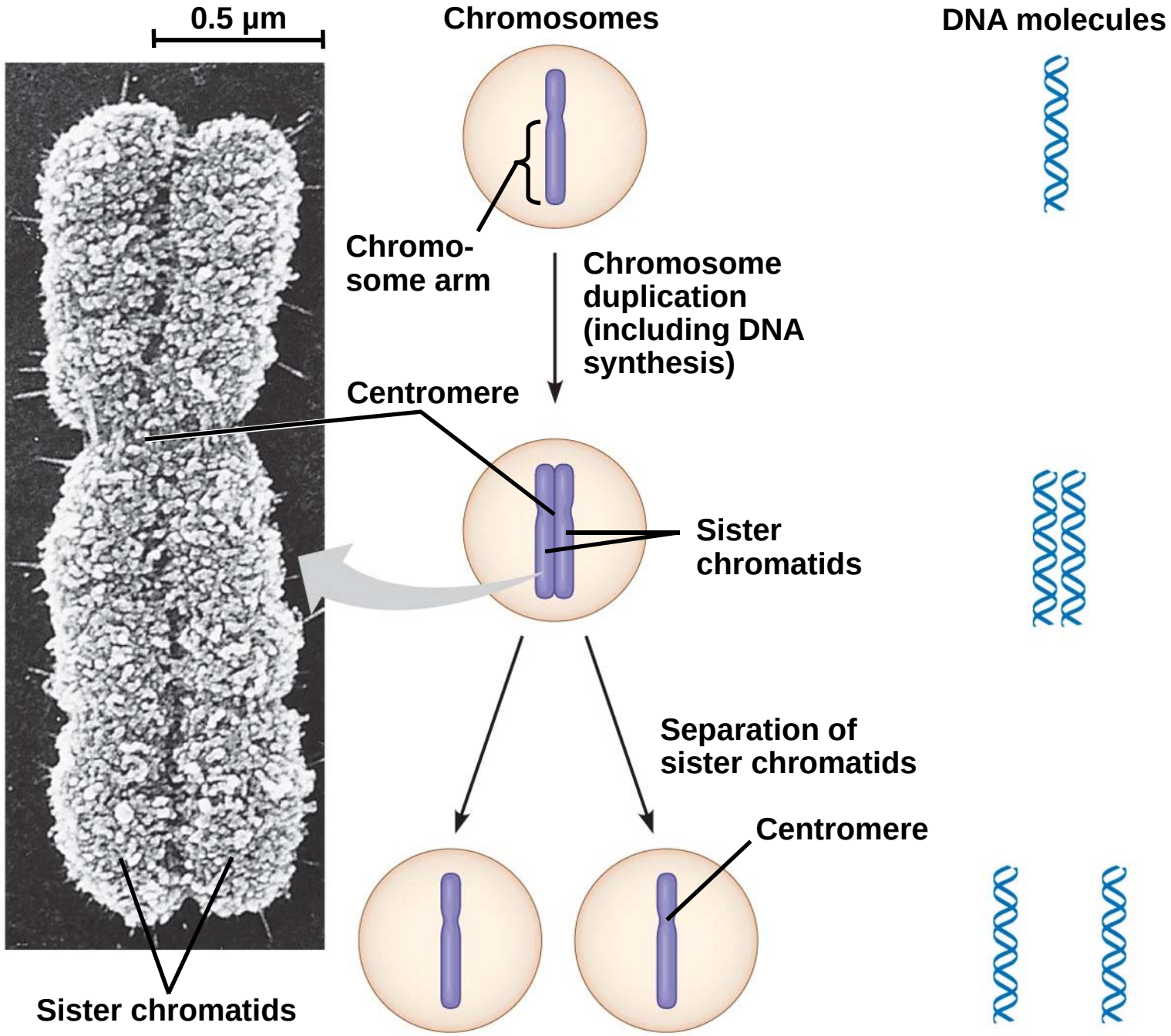


- Every eukaryotic species has a characteristic number of chromosomes in each cell nucleus
- **Somatic cells** (nonreproductive cells) have two sets of chromosomes
- **Gametes** (reproductive cells: sperm and eggs) have half as many chromosomes as somatic cells
- Eukaryotic chromosomes consist of **chromatin**,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

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**, which separate during cell division
- The **centromere** is the narrow "waist" of the duplicated chromosome, where the two chromatids are most closely attached

Fig. 12-4



- Eukaryotic cell division consists of:
  - **Mitosis**, the division of the nucleus
  - **Cytokinesis**, the division of the cytoplasm
- Gametes are produced by a variation of cell division called **meiosis**
- Meiosis yields nonidentical daughter cells that have only one set of chromosomes, half as many as the parent cell

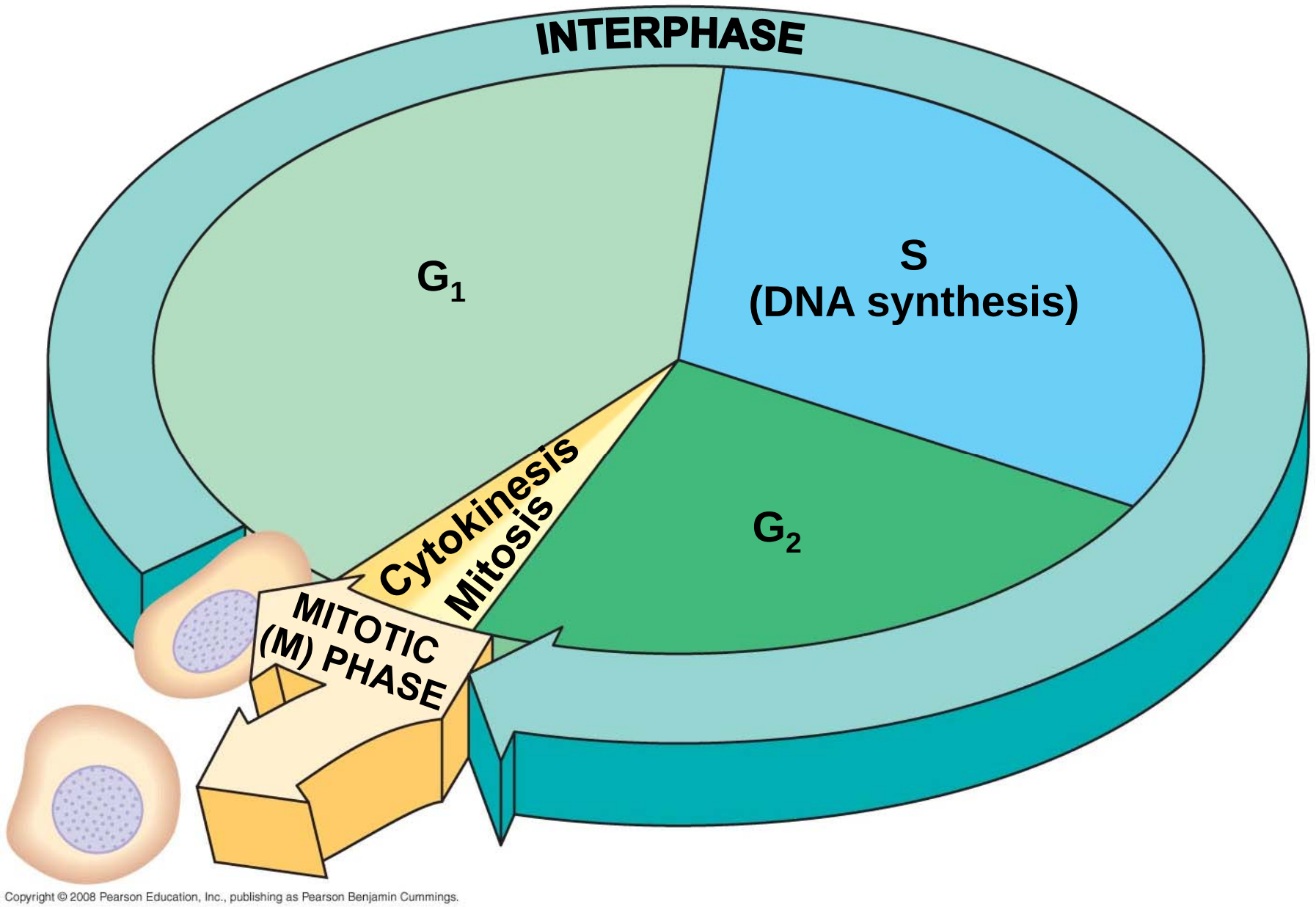
Concept 12.2: The mitotic phase alternates with interphase in the cell cycle

- In 1882, the German anatomist Walther Flemming developed dyes to observe chromosomes during mitosis and cytokinesis
- The cell cycle consists of
  - **Mitotic (M) phase** (mitosis and cytokinesis)
  - **Interphase** (cell growth and copying of chromosomes in preparation for cell division)

- Interphase (about 90% of the cell cycle) can be divided into subphases:
  - **G_1 phase** (“first gap”)
  - **S phase** (“synthesis”)
  - **G_2 phase** (“second gap”)
- The cell grows during all three phases, but chromosomes are duplicated only during the S phase

Fig. 12-5

The cell cycle



- Mitosis is conventionally divided into five phases:
  - **Prophase**
  - **Prometaphase**
  - **Metaphase**
  - **Anaphase**
  - **Telophase**
- Cytokinesis is well underway by late telophase

PLAY BioFlix: Mitosis

Fig. 12-6a

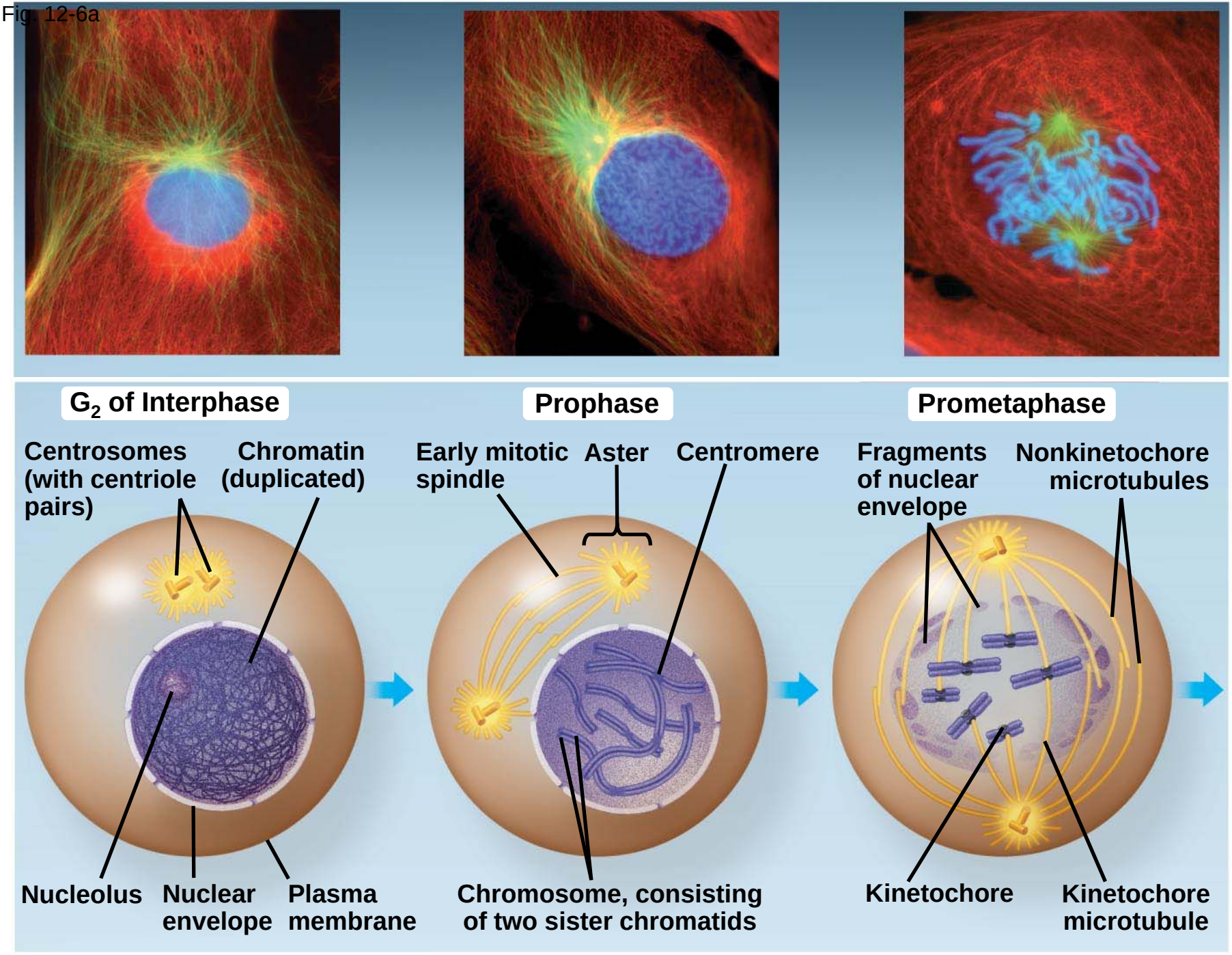
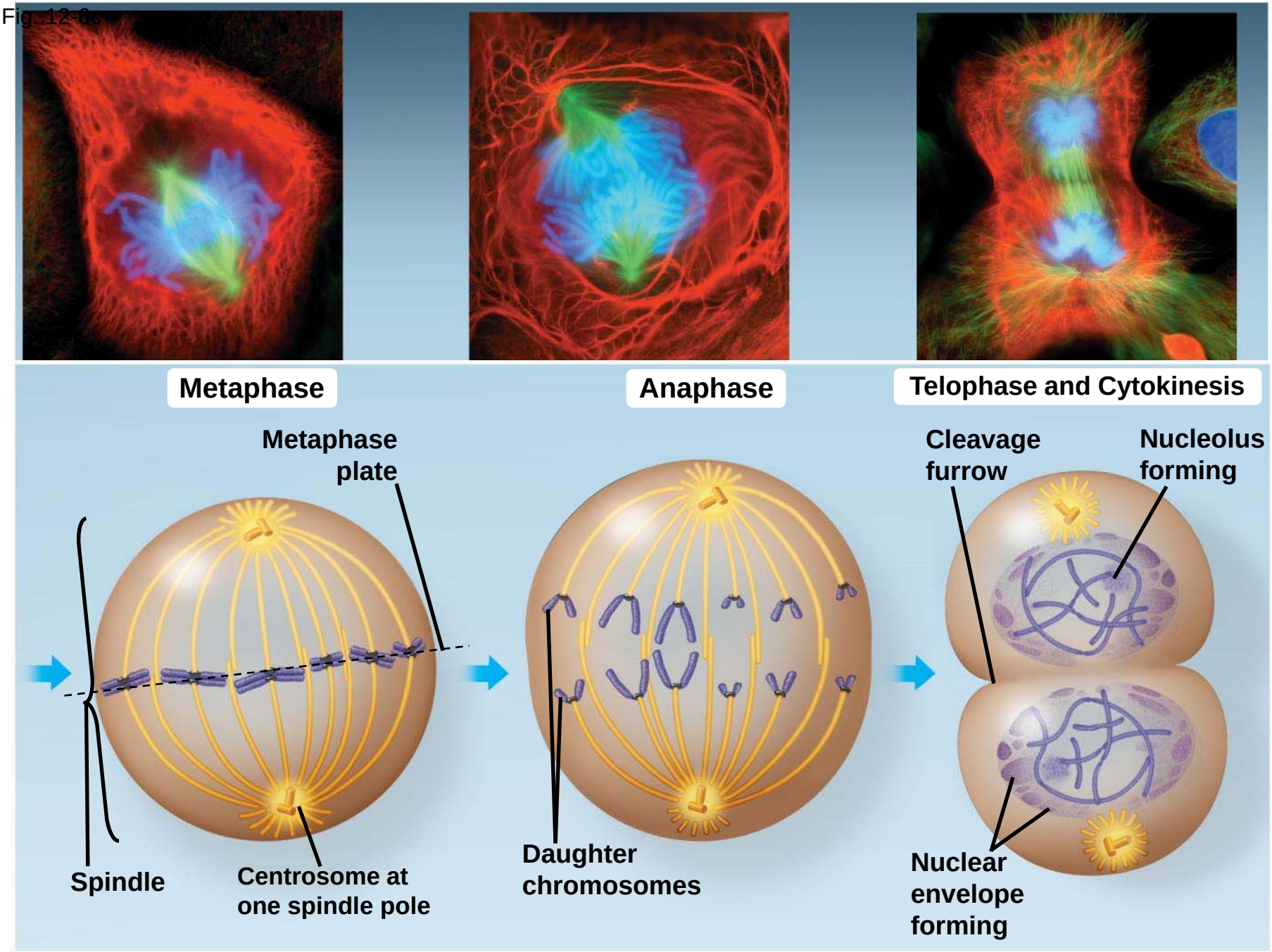


Fig. 12-6c



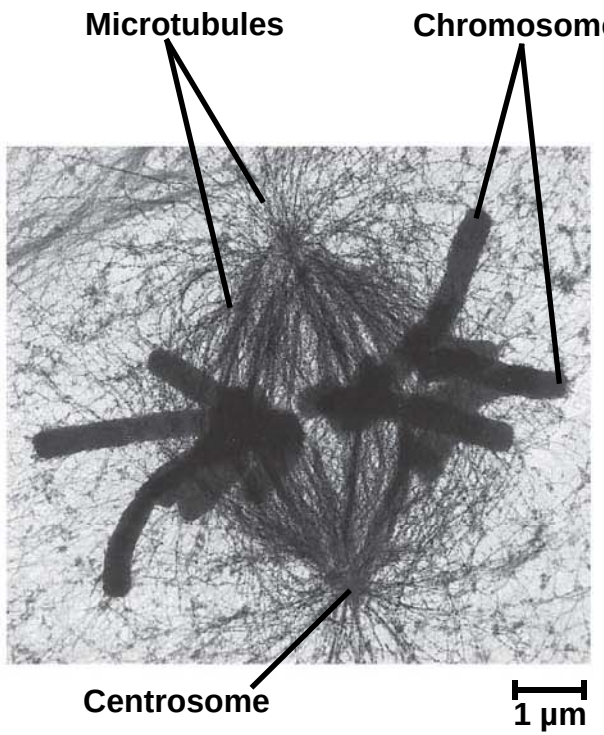
The Mitotic Spindle: *A Closer Look*

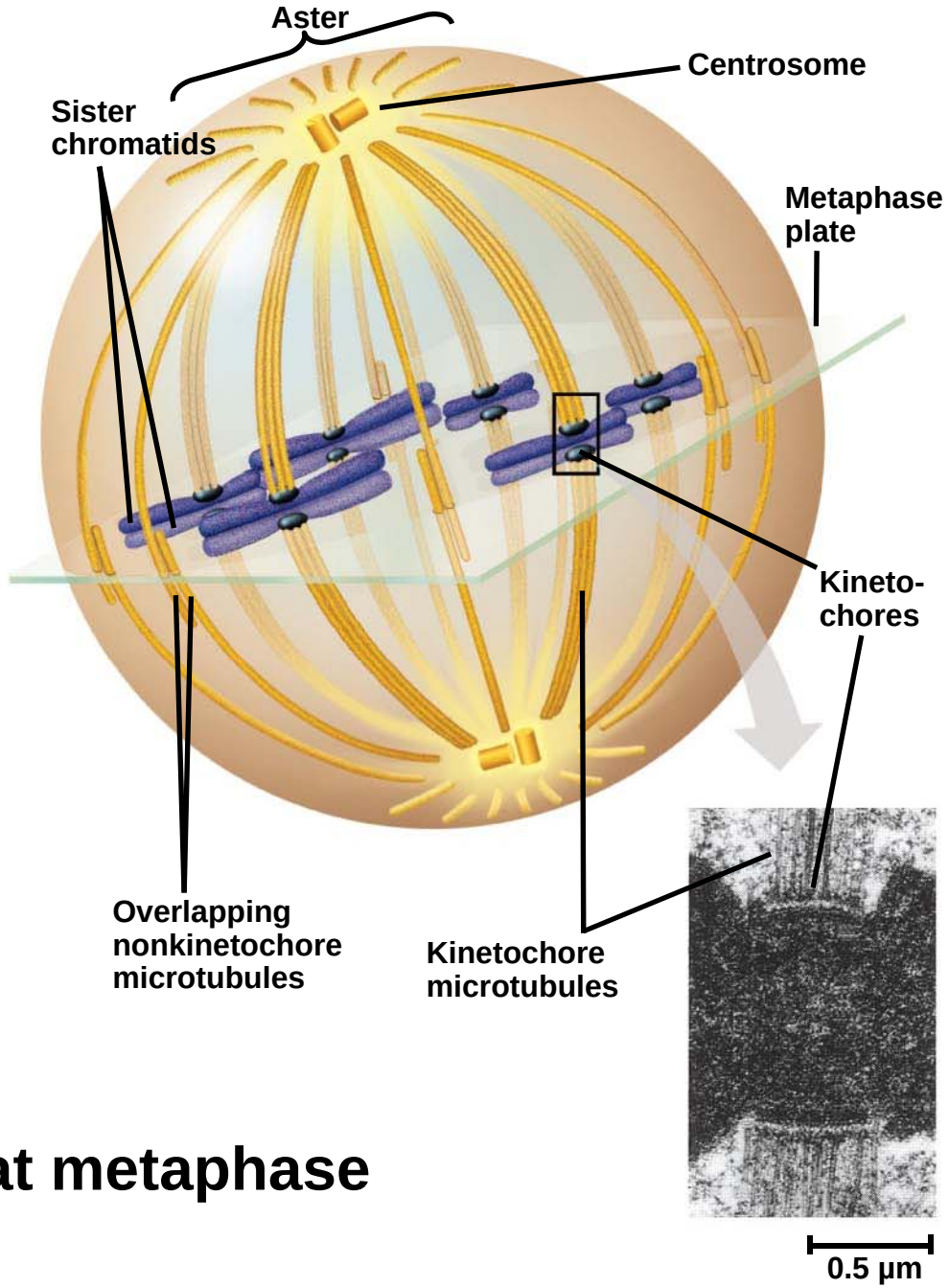
- The **mitotic spindle** is an apparatus of microtubules that controls chromosome movement during mitosis
- During prophase, assembly of spindle microtubules begins in the **centrosome**, the microtubule organizing center
- The centrosome replicates, forming two centrosomes that migrate to opposite ends of the cell, as spindle microtubules grow out from them

- An **aster** (a radial array of short microtubules) extends from each centrosome
- The spindle includes the centrosomes, the spindle microtubules, and the asters

- During prometaphase, some spindle microtubules attach to the **kinetochores** of chromosomes and begin to move the chromosomes
- At metaphase, the chromosomes are all lined up at the **metaphase plate**, the midway point between the spindle's two poles

Fig. 12-7

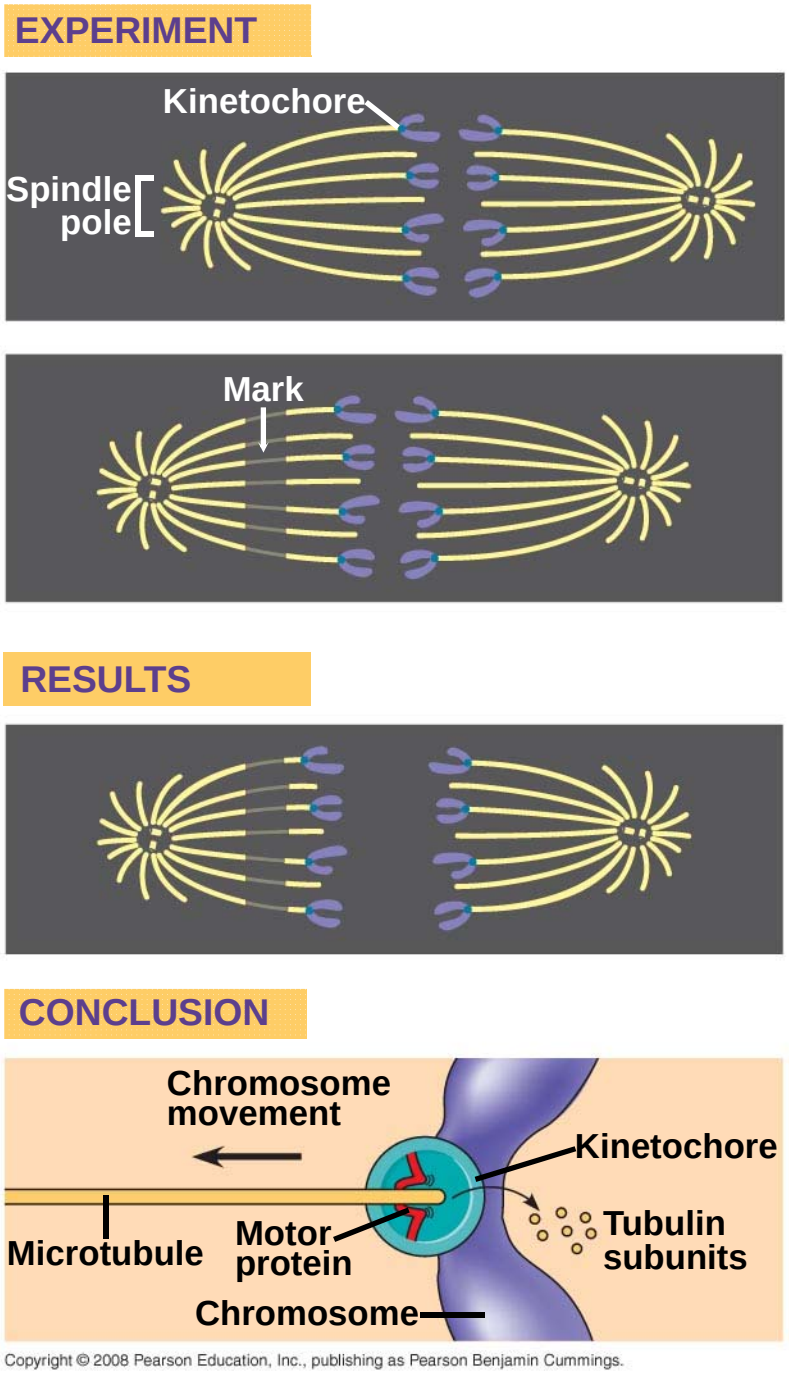




The mitotic spindle at metaphase

- In anaphase, sister chromatids separate and move along the kinetochore microtubules toward opposite ends of the cell
- The microtubules shorten by depolymerizing at their kinetochore ends

Fig. 12-8



- Nonkinetochore microtubules from opposite poles overlap and push against each other, elongating the cell
- In telophase, genetically identical daughter nuclei form at opposite ends of the cell

Cytokinesis: *A Closer Look*

- In animal cells, cytokinesis occurs by a process known as **cleavage**, forming a **cleavage furrow**
- In plant cells, a **cell plate** forms during cytokinesis

Fig. 12-9

Cytokinesis in animal and plant cells

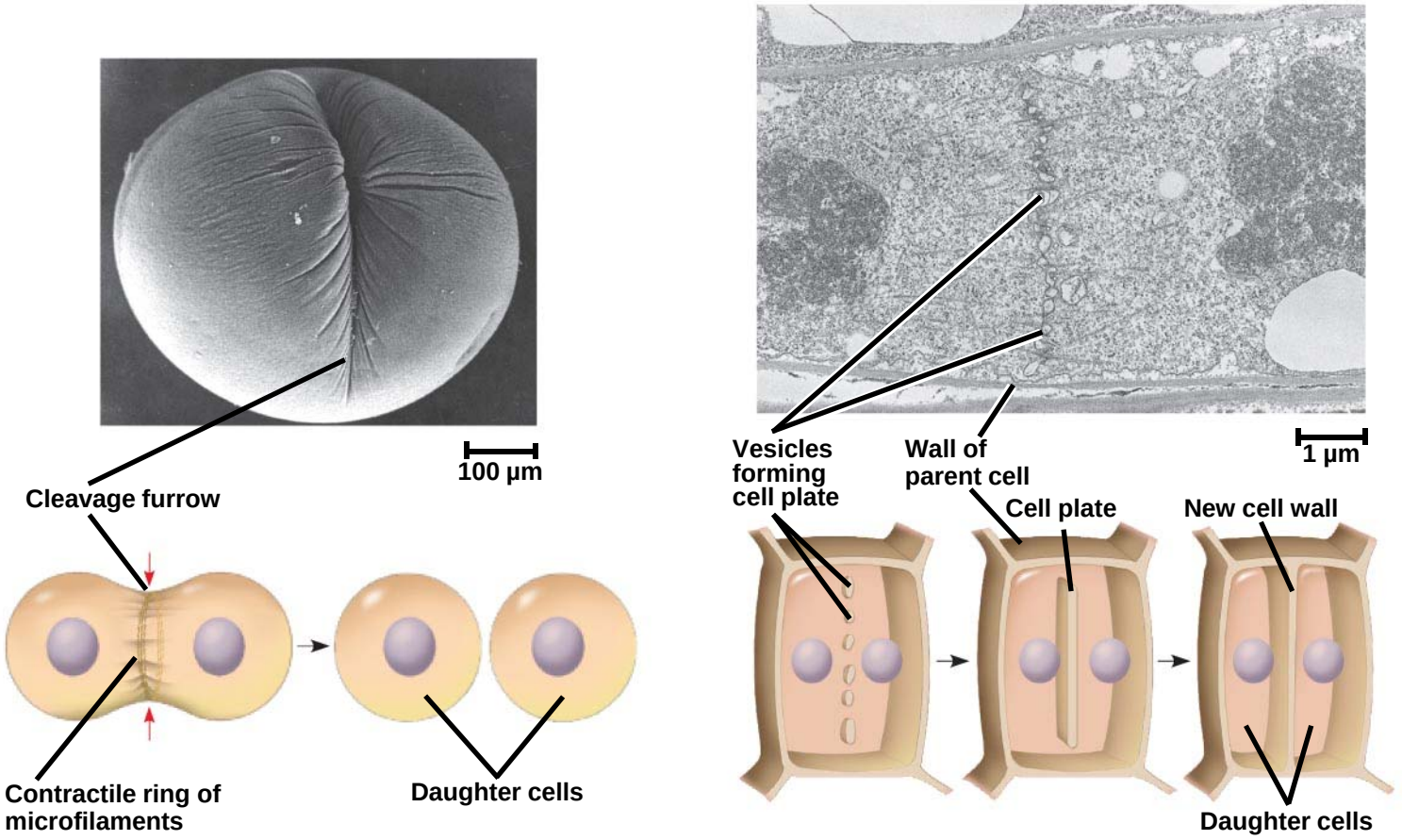
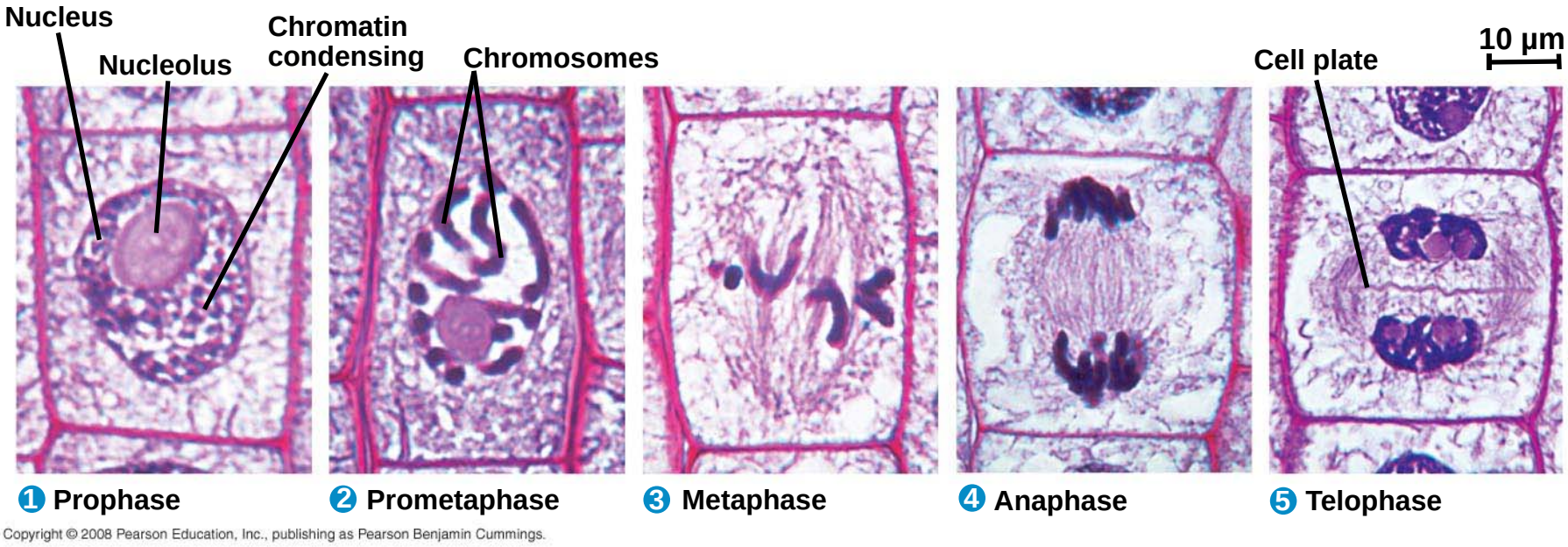


Fig. 12-10

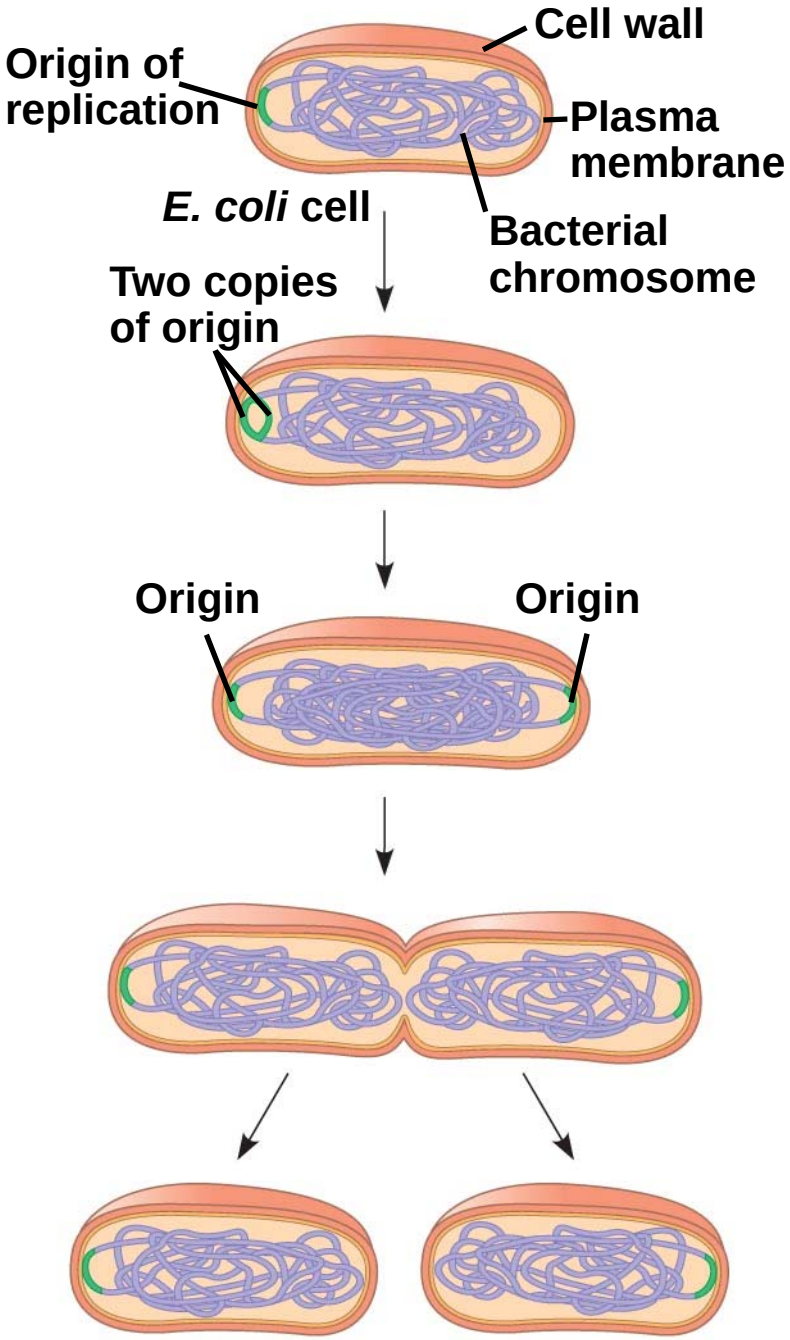
Mitosis in a plant cell



Binary Fission

- 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

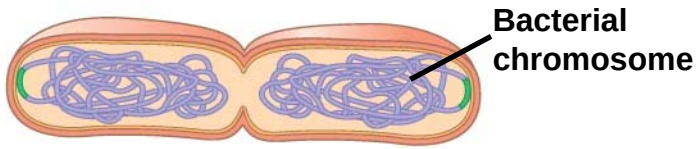
Fig. 12-11-4



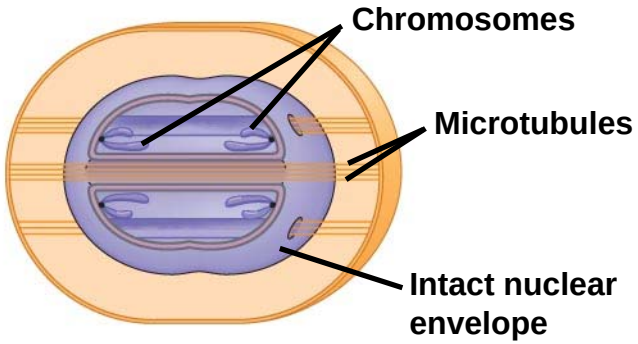
The Evolution of Mitosis

- Since prokaryotes evolved before eukaryotes, mitosis probably evolved from binary fission
- Certain protists exhibit types of cell division that seem intermediate between binary fission and mitosis

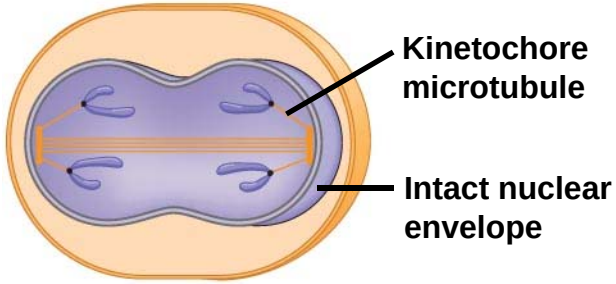
Fig. 12-12



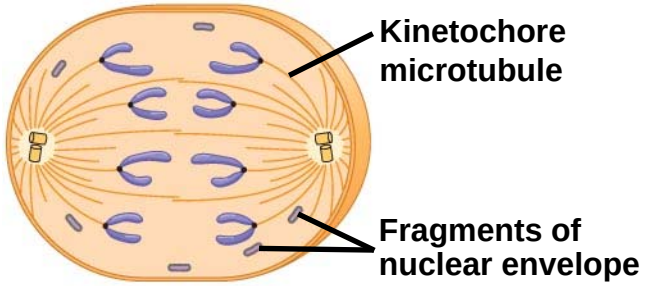
(a) Bacteria



(b) Dinoflagellates



(c) Diatoms and yeasts



(d) Most eukaryotes

Concept 12.3: The eukaryotic cell cycle is regulated by a molecular control system

- The frequency of cell division varies with the type of cell
- These cell cycle differences result from regulation at the molecular level

Evidence for Cytoplasmic Signals

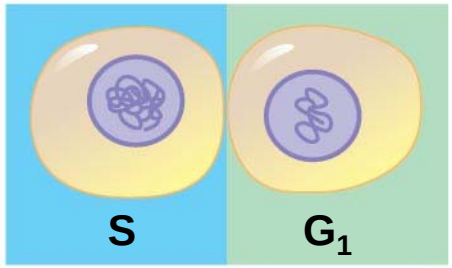
- The cell cycle appears to be driven by specific chemical signals present in the cytoplasm
- Some evidence for this hypothesis comes from experiments in which cultured mammalian cells at different phases of the cell cycle were fused to form a single cell with two nuclei

Fig. 12-13

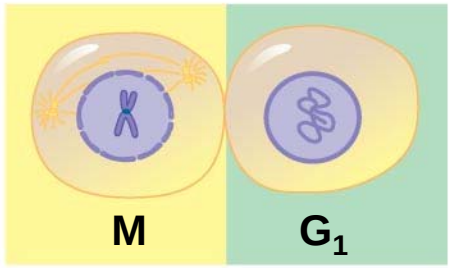
Molecular signals in the cytoplasm regulate the cell cycle

EXPERIMENT

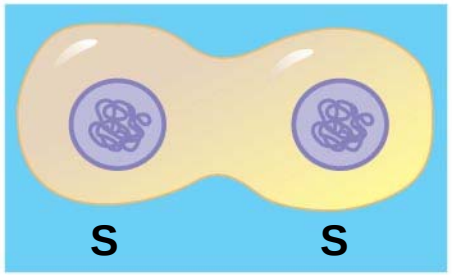
Experiment 1

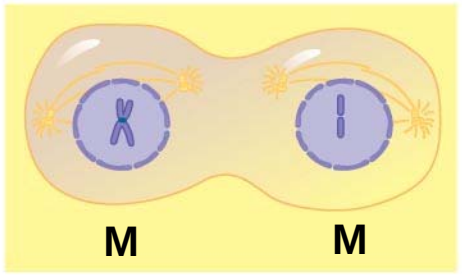


Experiment 2



RESULTS





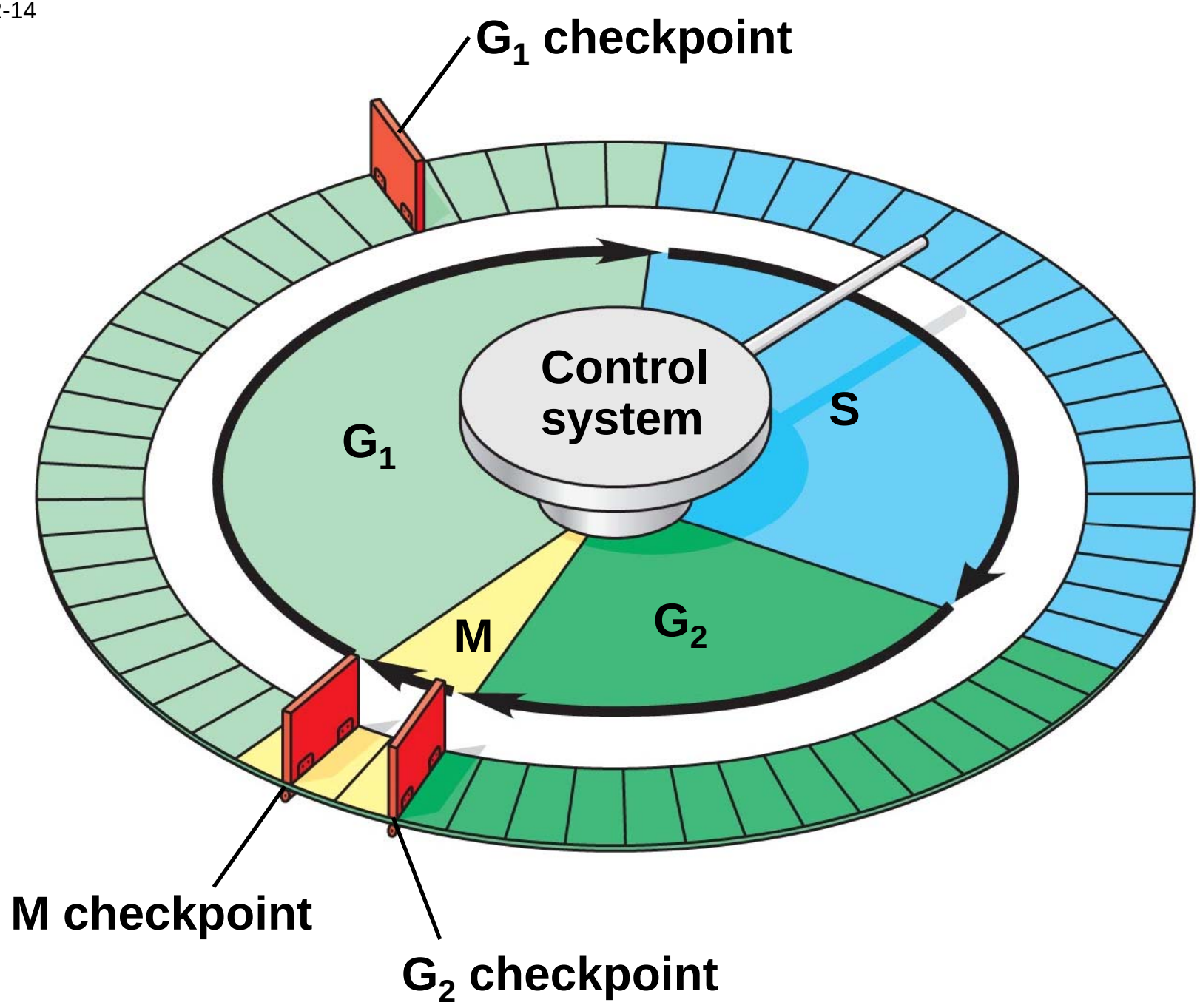
When a cell in the S phase was fused with a cell in G_1, the G_1 nucleus immediately entered the S phase—DNA was synthesized.

When a cell in the M phase was fused with a cell in G_1, the G_1 nucleus immediately began mitosis—a spindle formed and chromatin condensed, even though the chromosome had not been duplicated.

The Cell Cycle Control System

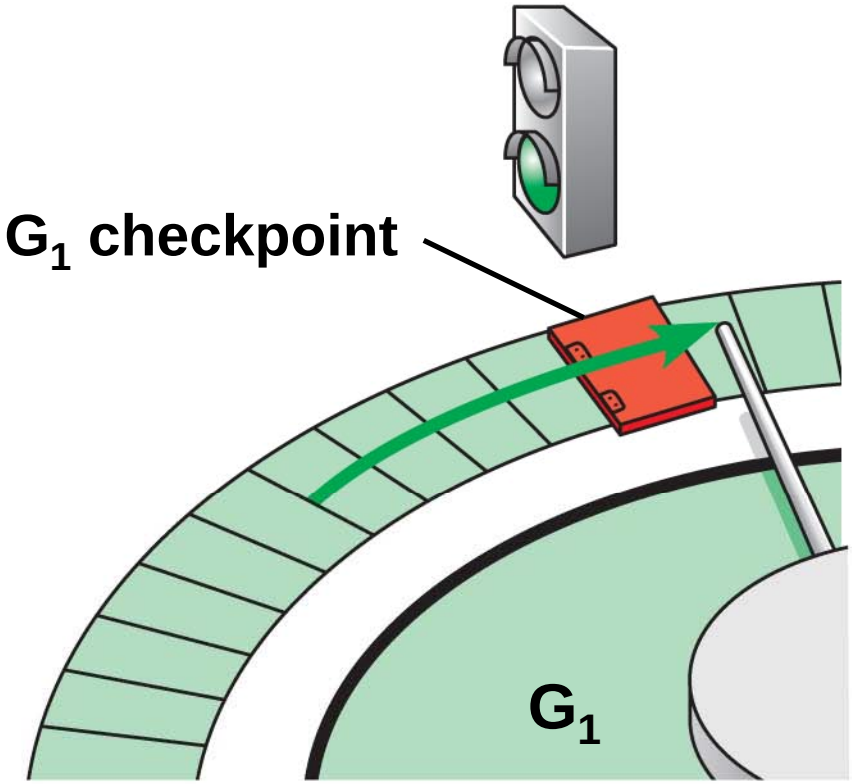
- The sequential events of the cell cycle are directed by a distinct **cell cycle control system**, which is similar to a clock
- The cell cycle control system is regulated by both internal and external controls
- The clock has specific **checkpoints** where the cell cycle stops until a go-ahead signal is received

Fig. 12-14

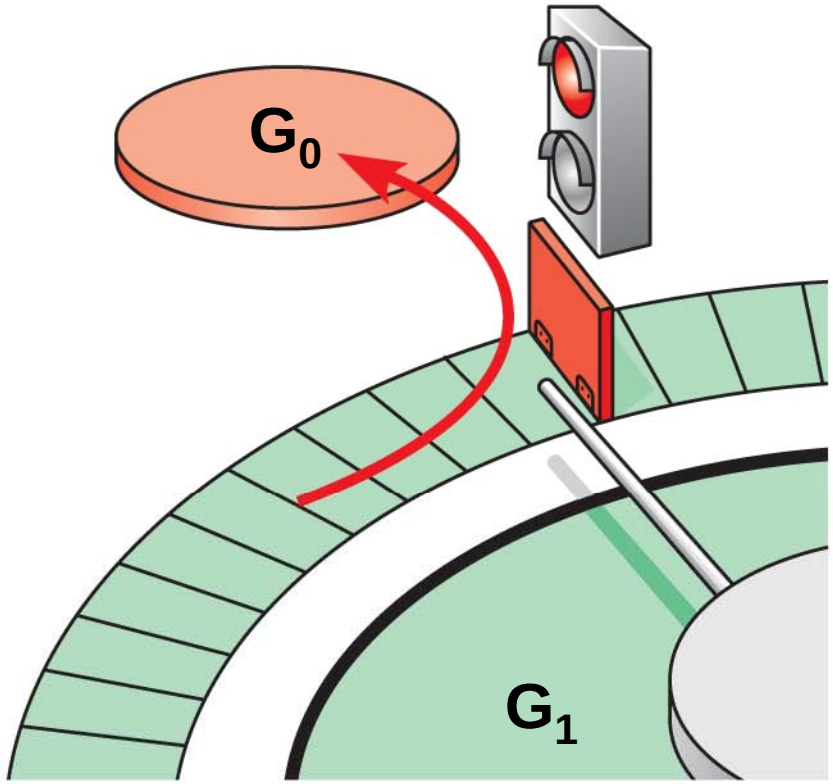


- For many cells, the G_1 checkpoint seems to be the most important one
- If a cell receives a go-ahead signal at the G_1 checkpoint, it will usually complete the S, G_2, and M phases and divide
- If the cell does not receive the go-ahead signal, it will exit the cycle, switching into a nondividing state called the **G_0 phase**

Fig. 12-15



(a) Cell receives a go-ahead signal



(b) Cell does not receive a go-ahead signal

The Cell Cycle Clock: Cyclins and Cyclin-Dependent Kinases

- Two types of regulatory proteins are involved in cell cycle control: **cyclins** and **cyclin-dependent kinases (Cdks)**
- The activity of cyclins and Cdks fluctuates during the cell cycle
- **MPF** (maturation-promoting factor) is a cyclin-Cdk complex that triggers a cell's passage past the G_2 checkpoint into the M phase

Fig. 12-16

RESULTS

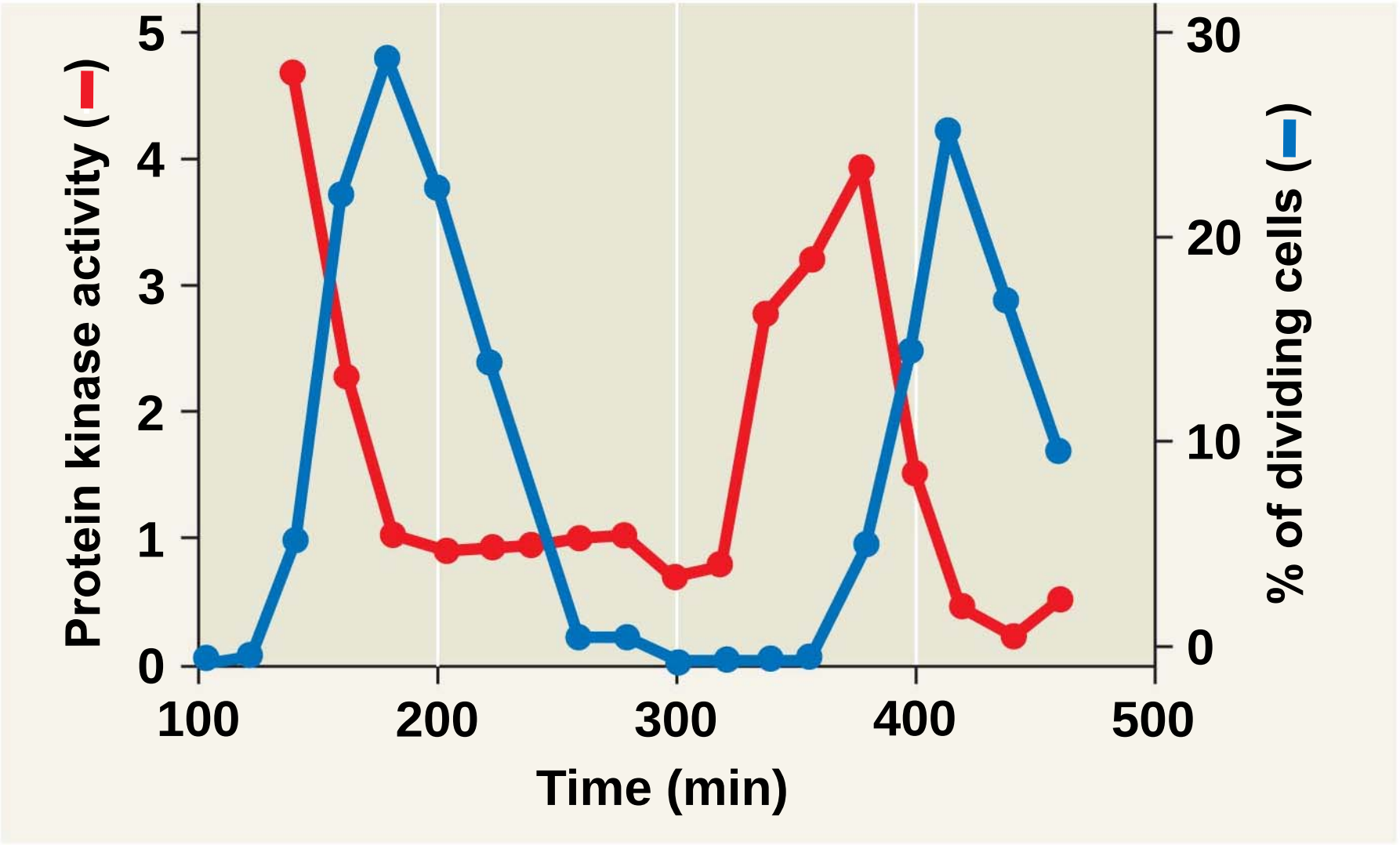
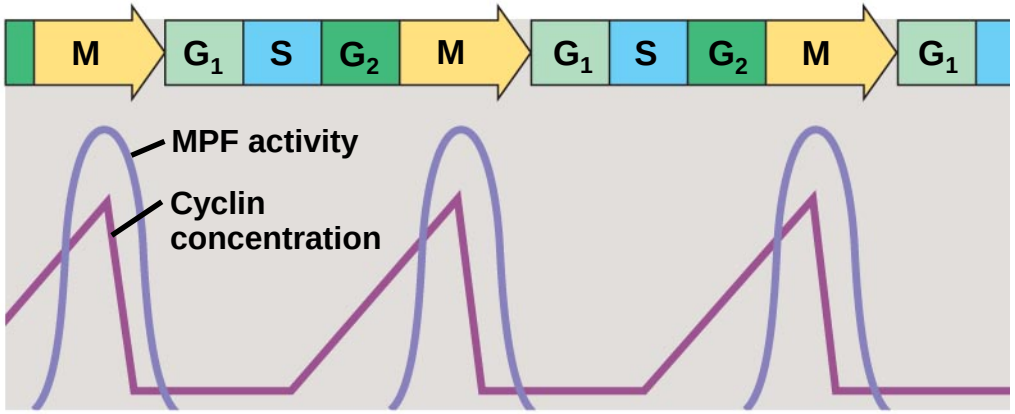
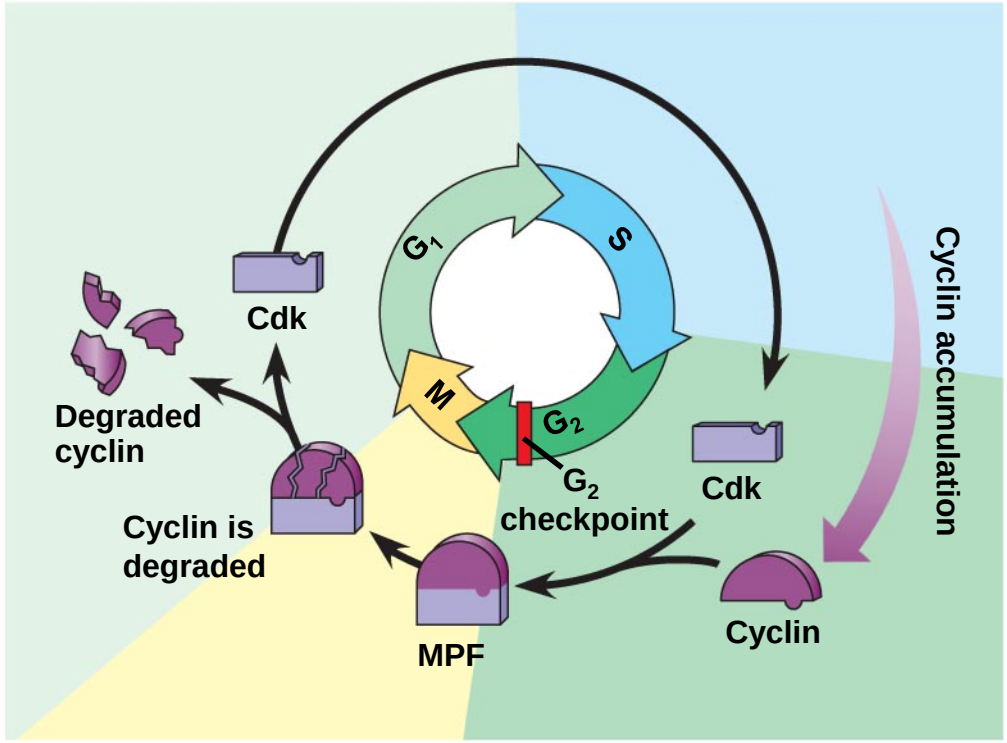


Fig. 12-17



(a) Fluctuation of MPF activity and cyclin concentration during the cell cycle



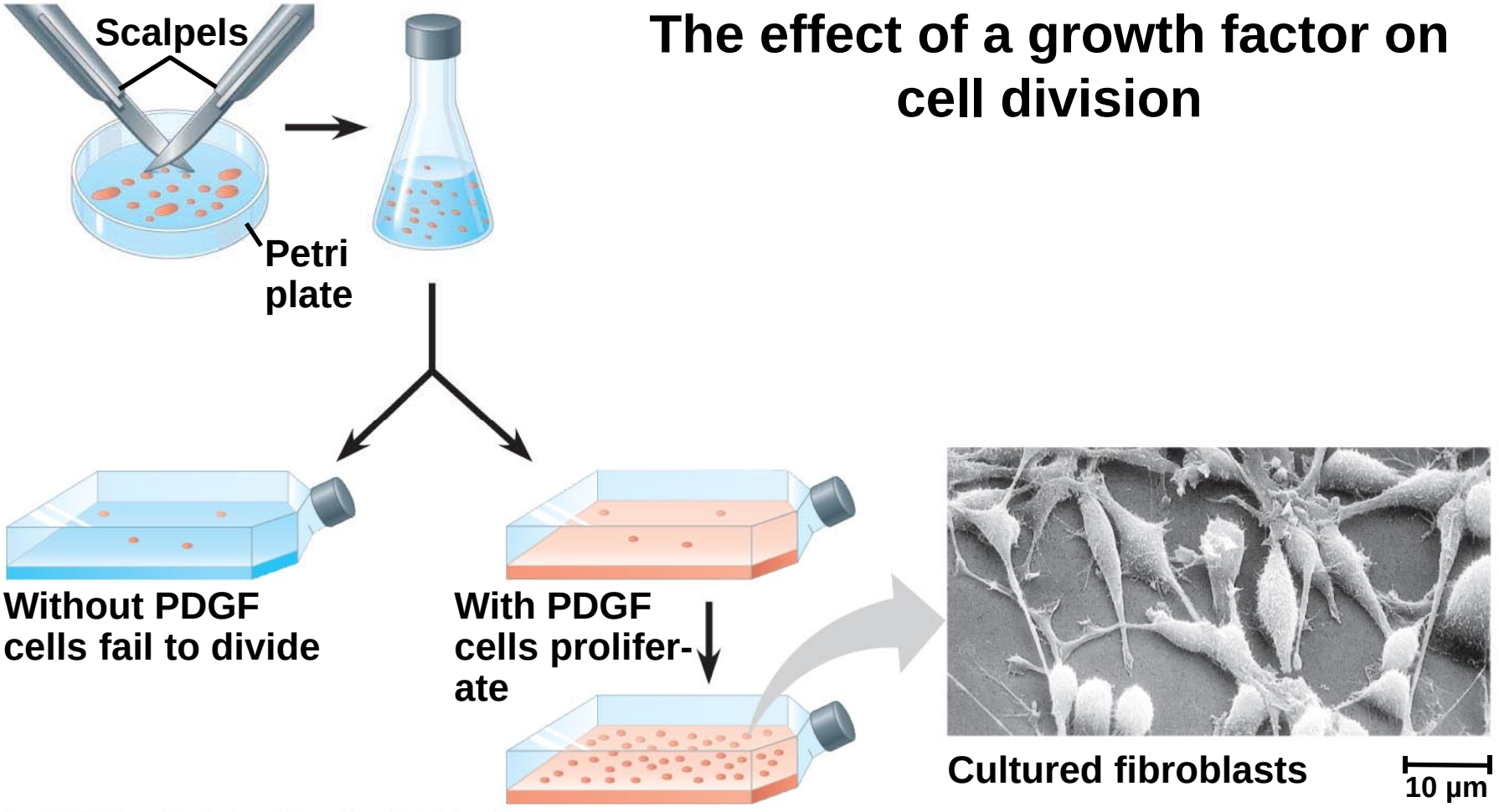
(b) Molecular mechanisms that help regulate the cell cycle

Stop and Go Signs: Internal and External Signals at the Checkpoints

- An example of an internal signal is that kinetochores not attached to spindle microtubules send a molecular signal that delays anaphase
- Some external signals are **growth factors**, proteins released by certain cells that stimulate other cells to divide
- For example, platelet-derived growth factor (PDGF) stimulates the division of human fibroblast cells in culture

Fig. 12-18

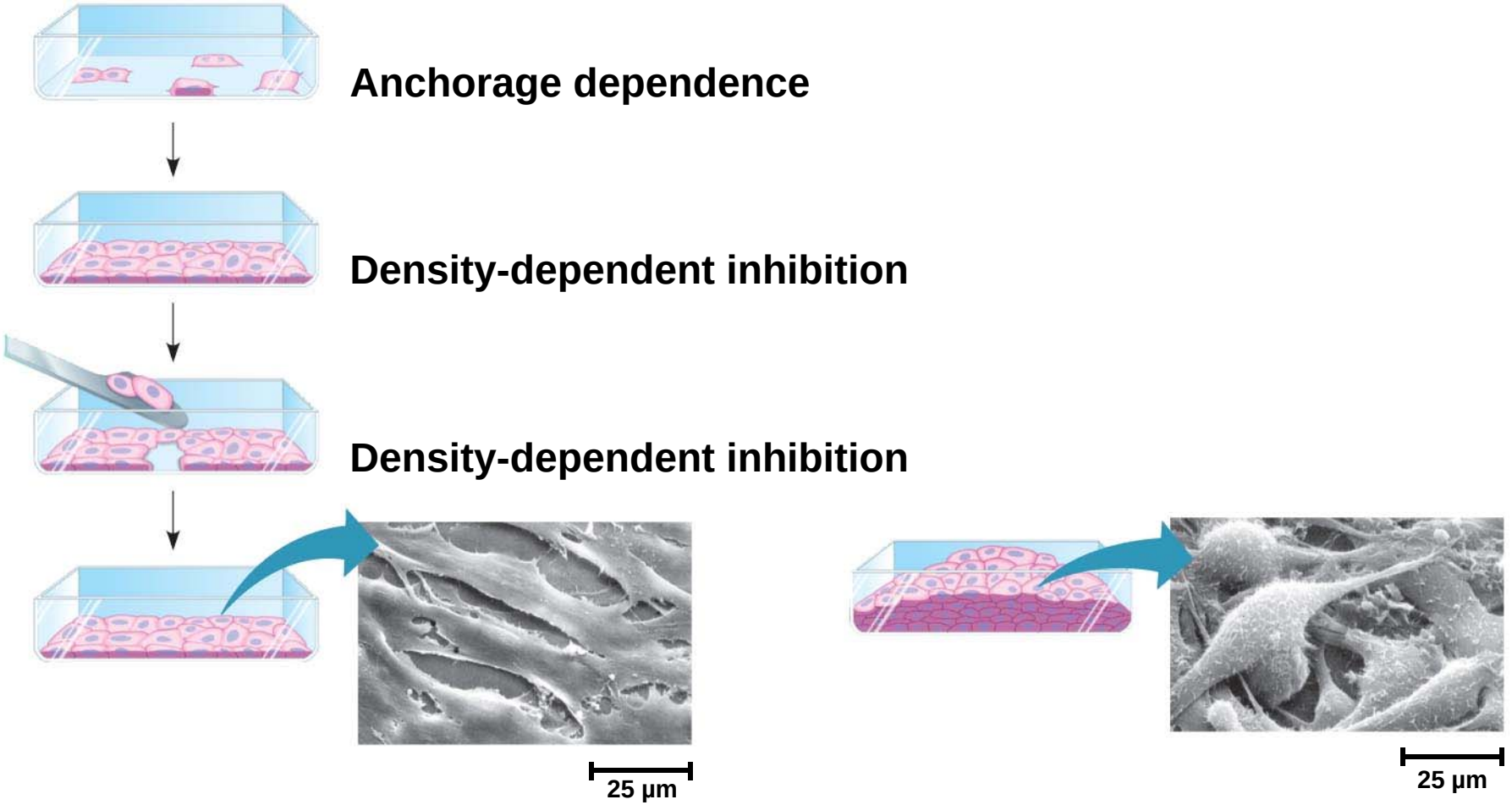
The effect of a growth factor on cell division



- Another example of external signals is **density-dependent inhibition**, in which crowded cells stop dividing
- Most animal cells also exhibit **anchorage dependence**, in which they must be attached to a substratum in order to divide

Fig. 12-19

Density-dependent inhibition and anchorage dependence of cell division



- Cancer cells exhibit neither density-dependent inhibition nor anchorage dependence

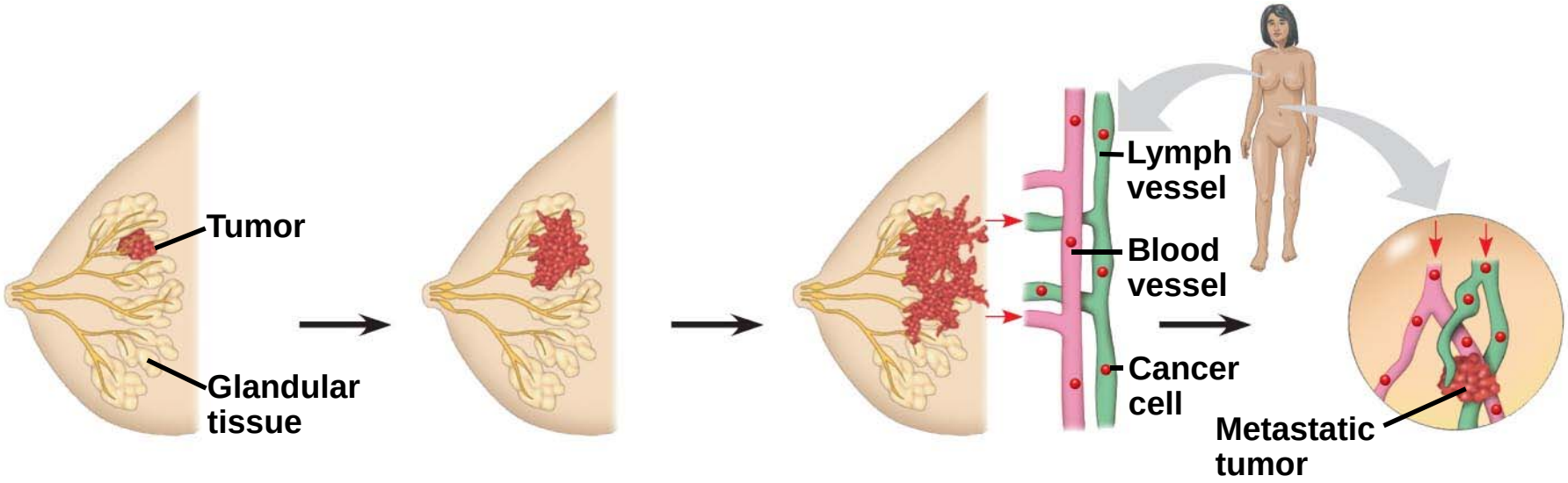
Loss of Cell Cycle Controls in Cancer Cells

- Cancer cells do not respond normally to the body's control mechanisms
- Cancer cells may not need growth factors to grow and divide:
  - They may make their own growth factor
  - They may convey a growth factor's signal without the presence of the growth factor
  - They may have an abnormal cell cycle control system

- A normal cell is converted to a cancerous cell by a process called **transformation**
- Cancer cells form tumors, masses of abnormal cells within otherwise normal tissue
- If abnormal cells remain at the original site, the lump is called a **benign tumor**
- **Malignant tumors** invade surrounding tissues and can **metastasize**, exporting cancer cells to other parts of the body, where they may form secondary tumors

Fig. 12-20

The growth and metastasis of a malignant breast tumor



1. A tumor grows from a single cancer cell.
2. Cancer cells invade neighboring tissue.
3. Cancer cells spread to other parts of the body.
4. Cancer cells may survive and establish a new tumor in another part of the body.

You should now be able to:

1. Describe the structural organization of the prokaryotic genome and the eukaryotic genome
2. List the phases of the cell cycle; describe the sequence of events during each phase
3. List the phases of mitosis and describe the events characteristic of each phase
4. Draw or describe the mitotic spindle, including centrosomes, kinetochore microtubules, nonkinetochore microtubules, and asters

5. Compare cytokinesis in animals and plants

6. Describe the process of binary fission in bacteria and explain how eukaryotic mitosis may have evolved from binary fission

7. Explain how the abnormal cell division of cancerous cells escapes normal cell cycle controls

8. Distinguish between benign, malignant, and metastatic tumors