

LECTURE PRESENTATIONS

For CAMPBELL BIOLOGY, NINTH EDITION

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Chapter 12

The Cell Cycle



Lectures by
Erin Barley
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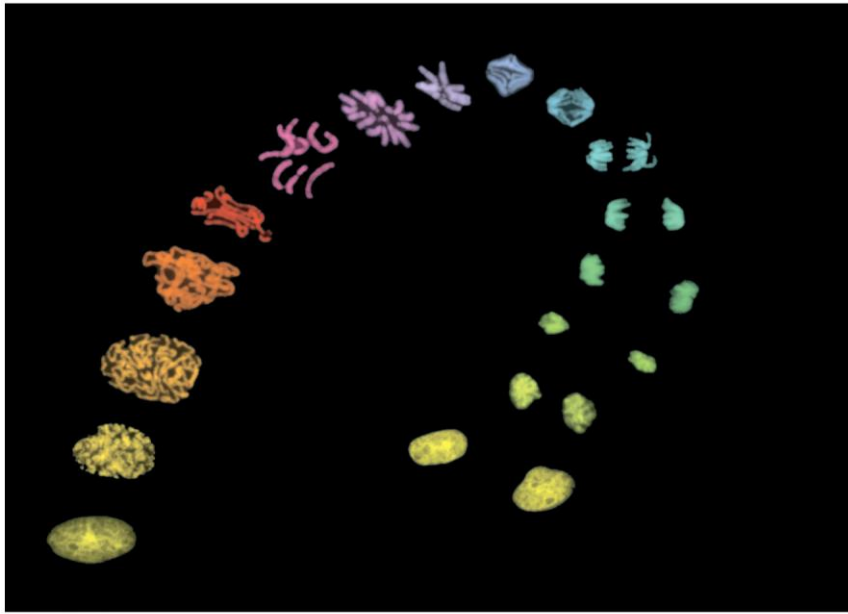
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Overview: The Key Roles of Cell Division

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

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Figure 12.1



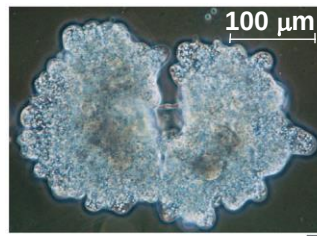
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- In unicellular organisms, division of one cell reproduces the entire organism
- Multicellular organisms depend on cell division for
 - Development from a fertilized cell
 - Growth
 - Repair
- Cell division is an integral part of the **cell cycle**,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

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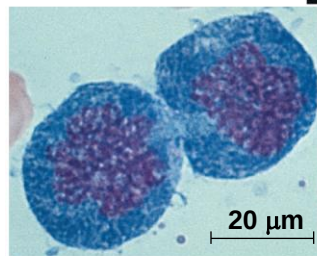
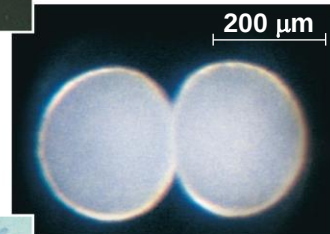
Figure 12.2

The
functions of
cell division



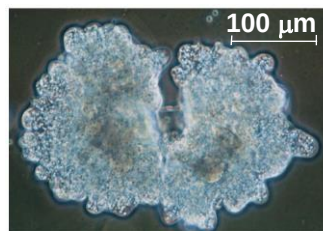
◀ (a) Reproduction

▶ (b) Growth and development



◀ (c) Tissue renewal

Figure 12.2a

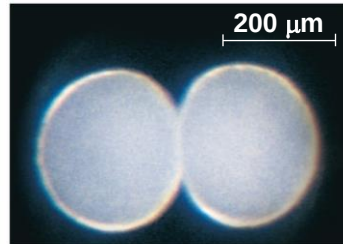


◀ (a) Reproduction: Amoeba

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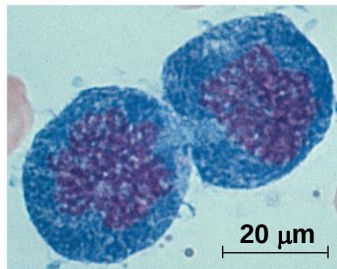
Figure 12.2b

► (b) Growth and development: an embryo shortly after fertilization



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Figure 12.2c



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► (c) Tissue renewal: Dividing bone marrow cells,

Concept 12.1: Most cell division results in genetically identical daughter cells

- 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

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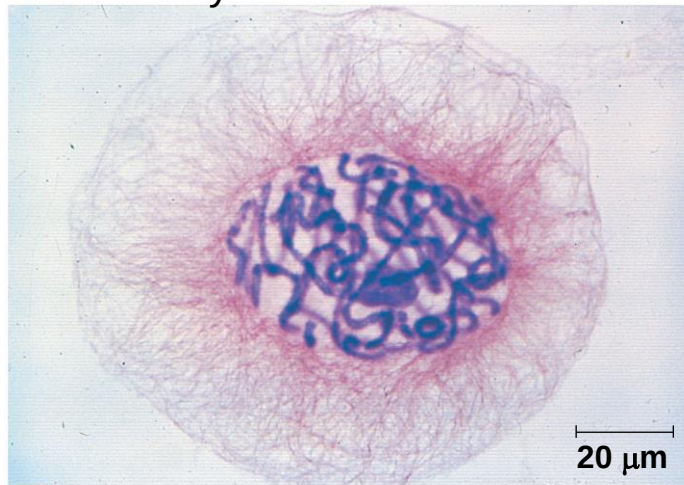
Cellular Organization of the Genetic Material

- 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**

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Figure 12.3

Eukaryotic 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 >> Karyotype
- **Somatic cells** (nonreproductive cells) have two sets of chromosomes
- **Gametes** (reproductive cells: sperm and eggs) have half as many chromosomes as somatic cells

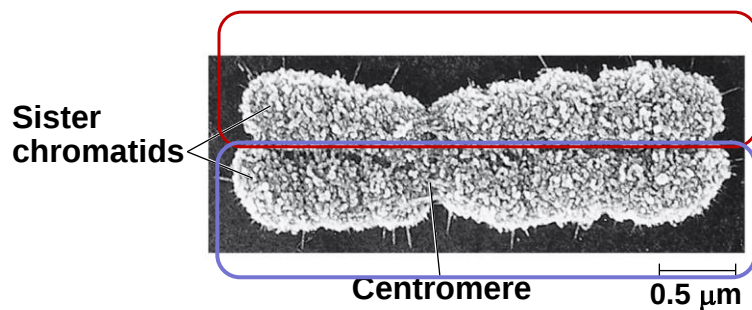
Distribution of Chromosomes During Eukaryotic Cell Division

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

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Figure 12.4

A highly condensed, duplicated human chromosome (SEM).

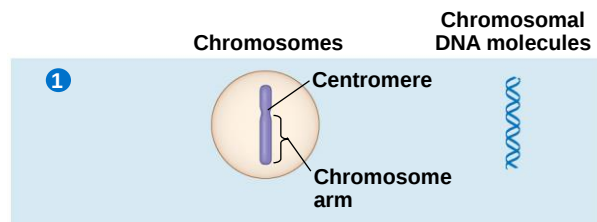


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- During cell division, the two sister chromatids of each duplicated chromosome separate and move into two nuclei
- Once separate, the chromatids are called chromosomes

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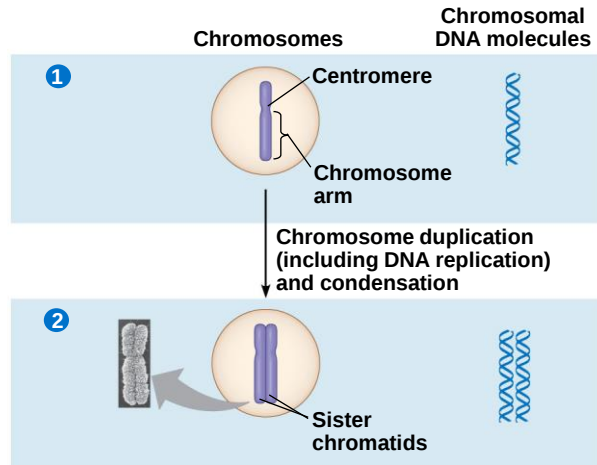
Figure 12.5-1



Chromosome duplication and distribution during cell division.

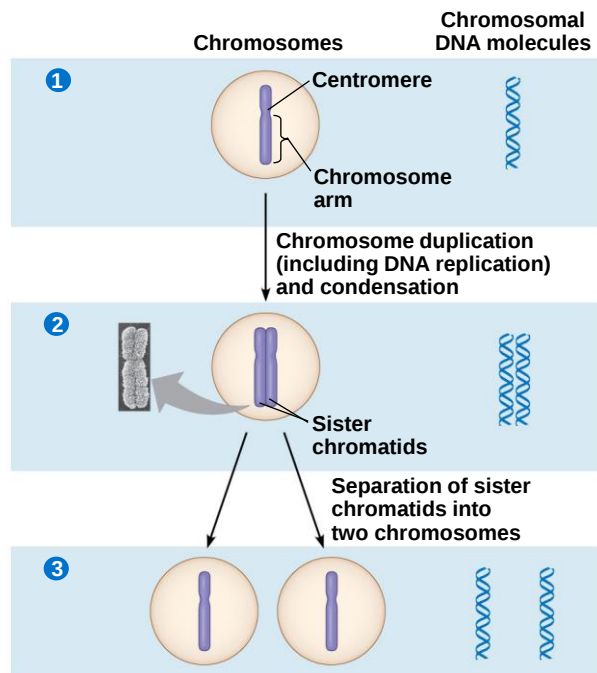
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Figure 12.5-2



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Figure 12.5-3



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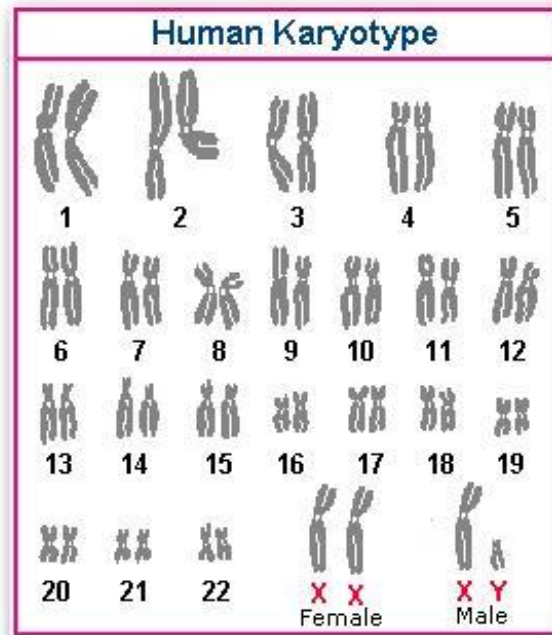
Class activity!

- How many chromosomes are drawn in each part of Figure 12.5 (ignore the micrograph in part 2)? (previous slide)

-
- Eukaryotic cell division consists of
 - **Mitosis**, the division of the genetic material in 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

Class activity!

- A chicken has 78 chromosomes in its somatic cells.
- How many chromosomes did the chicken inherit from each parent?
- How many chromosomes are in each of the chicken's gametes?
- How many chromosomes will be in each somatic cell of the chicken's offspring?



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

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Phases of the Cell Cycle

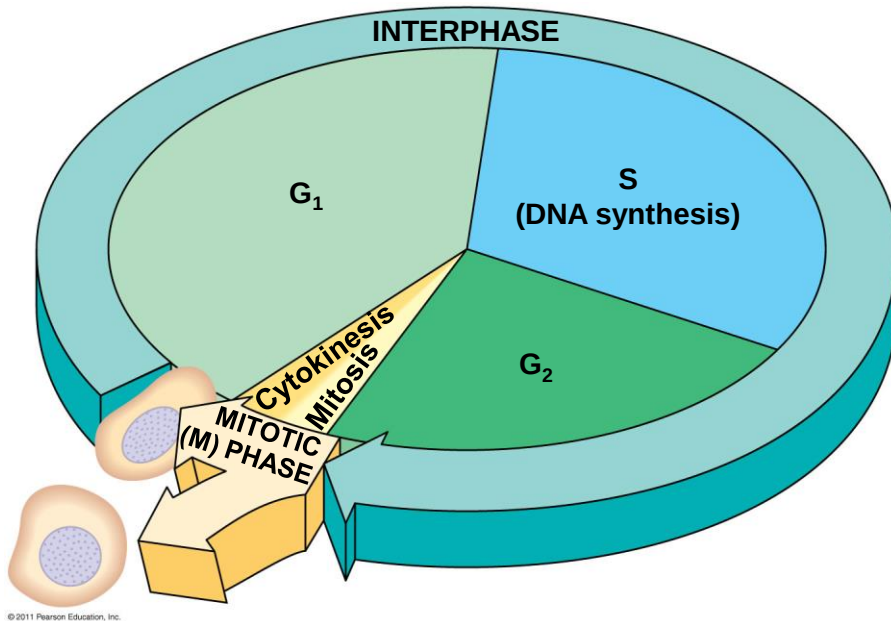
- The cell cycle consists of
 - **Mitotic (M) phase** (mitosis and cytokinesis)
 - **Interphase** (cell growth and copying of chromosomes in preparation for cell division)

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- Interphase (about 90% of the cell cycle) can be divided into subphases
 - **G₁ phase** (“first gap”)
 - **S phase** (“synthesis”)
 - **G₂ phase** (“second gap”)
- The cell grows during all three phases, but chromosomes are duplicated only during the S phase

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Figure 12.6



- Mitosis is conventionally divided into five phases
 - **Prophase**
 - **Prometaphase**
 - **Metaphase**
 - **Anaphase**
 - **Telophase**
- Cytokinesis overlaps the latter stages of mitosis

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Figure 12.7

Exploring: Mitosis in an Animal Cell

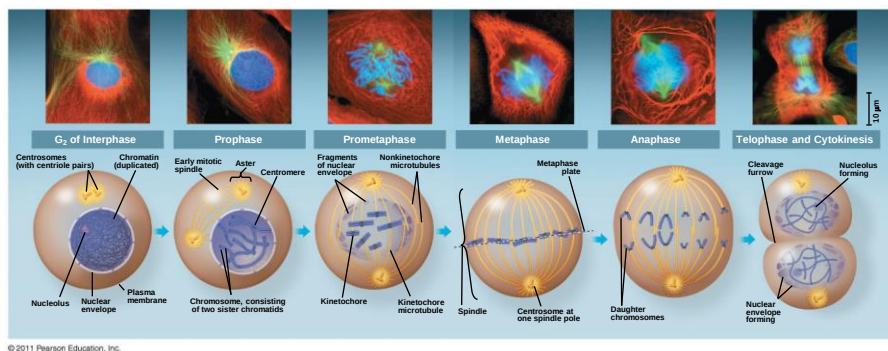


Figure 12.7a

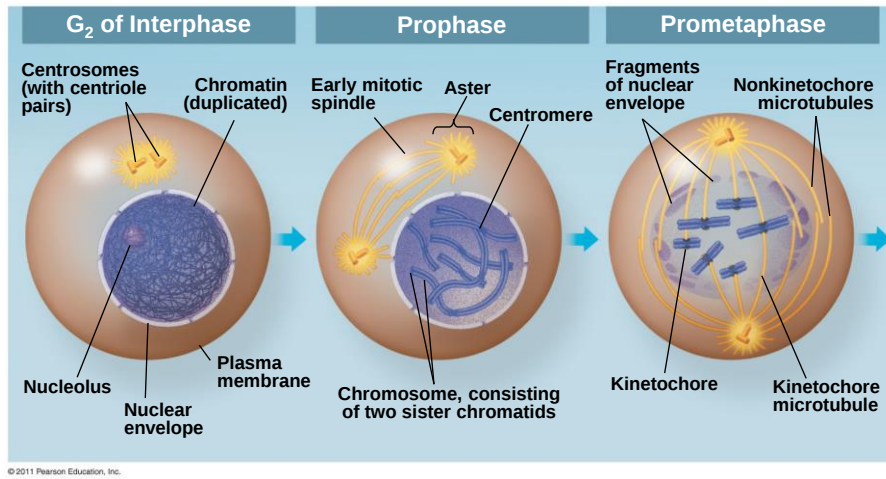


Figure 12.7b

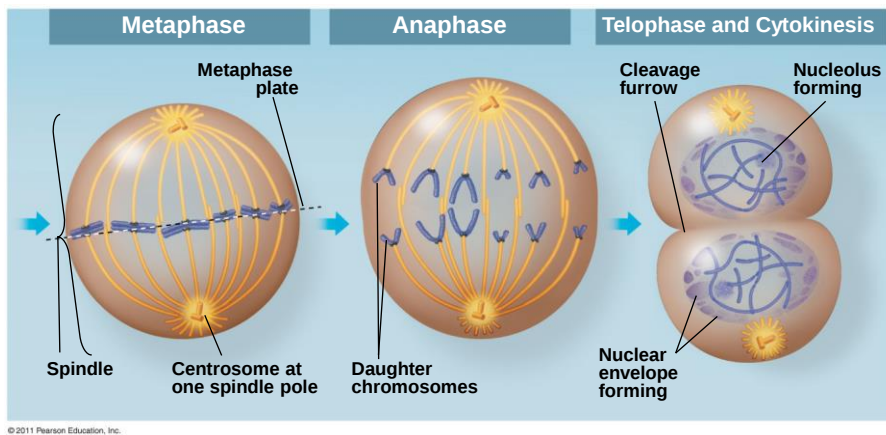


Figure 12.7c



Figure 12.7d

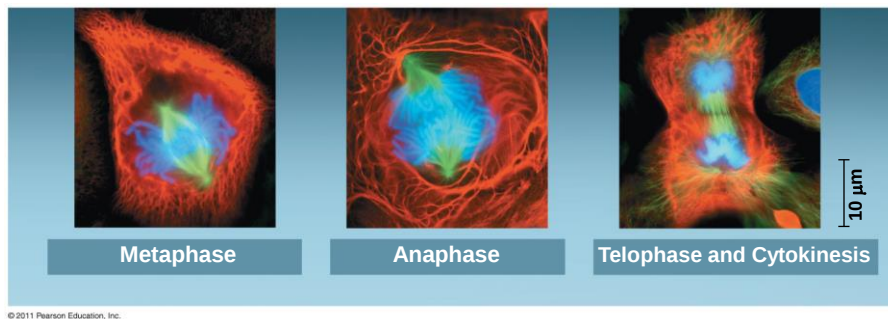
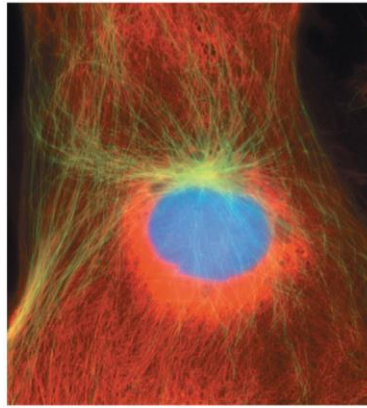
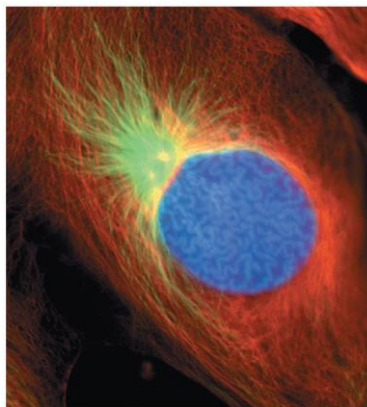


Figure 12.7e



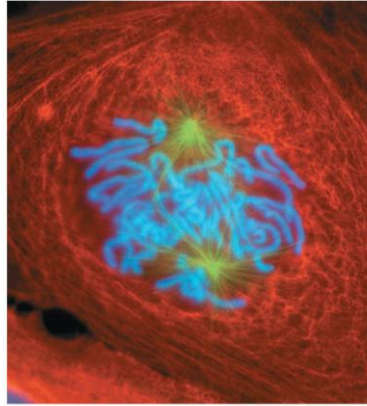
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Figure 12.7f



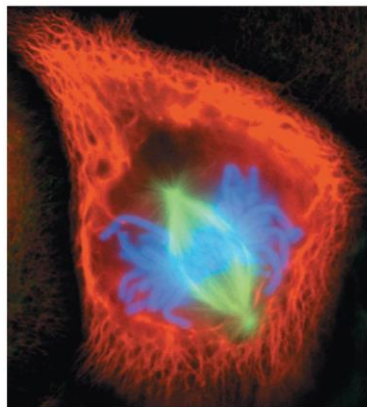
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Figure 12.7g



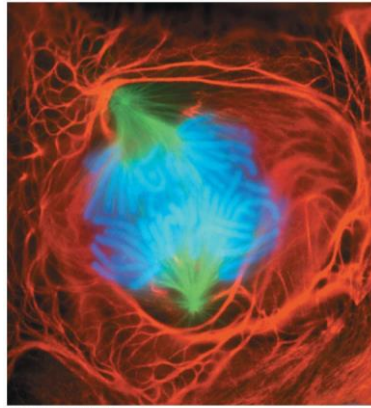
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Figure 12.7h



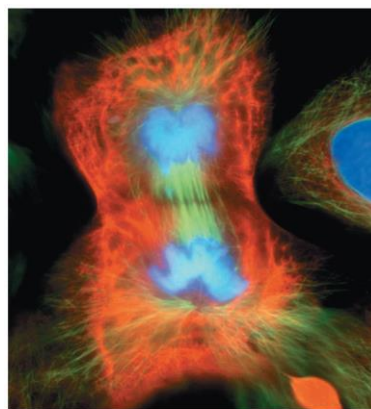
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Figure 12.7i



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Figure 12.7j



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The Mitotic Spindle: A Closer Look

- The **mitotic spindle** is a structure made of microtubules that controls chromosome movement during mitosis
- In animal cells, assembly of spindle microtubules begins in the **centrosome**, the microtubule organizing center
- The centrosome replicates during interphase, forming two centrosomes that migrate to opposite ends of the cell during prophase and prometaphase

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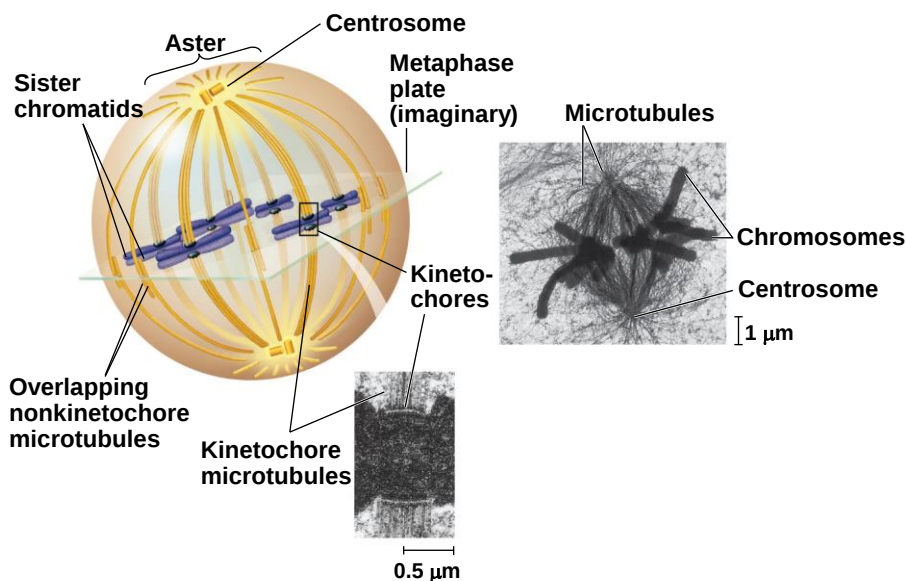
- An **aster** (a radial array of short microtubules) extends from each centrosome
- The spindle includes the centrosomes, the spindle microtubules, and the asters

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- During prometaphase, some spindle microtubules attach to the kinetochores of chromosomes and begin to move the chromosomes
- **Kinetochores** are protein complexes associated with centromeres
- At metaphase, the chromosomes are all lined up at the **metaphase plate**, an imaginary structure at the midway point between the spindle's two poles

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Figure 12.8



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Figure 12.8a

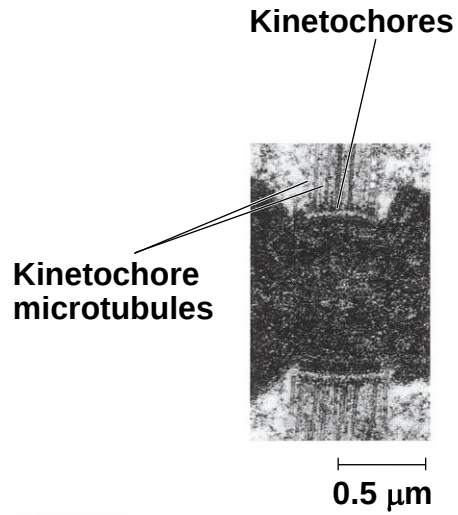
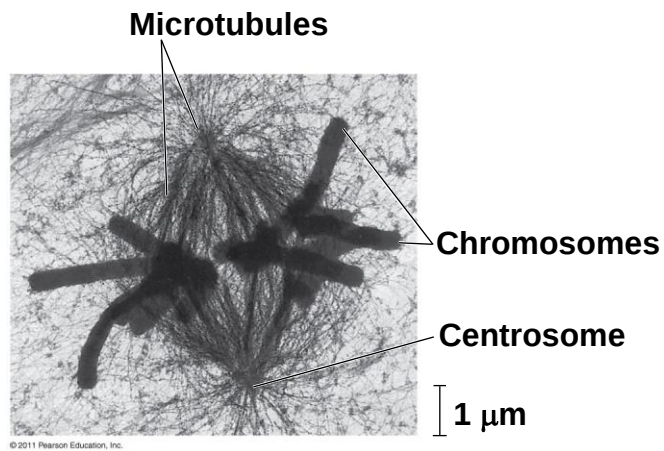


Figure 12.8b

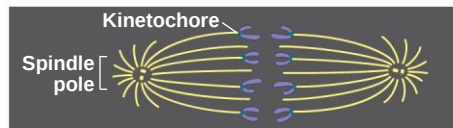


- In anaphase, sister chromatids separate and move along the kinetochore microtubules toward opposite ends of the cell
- Anaphase begins when the **Cohesins** holding together sister chromatids of each chromosome are cleaved by an enzyme called **separase**
- The microtubules shorten by depolymerizing at their kinetochore ends

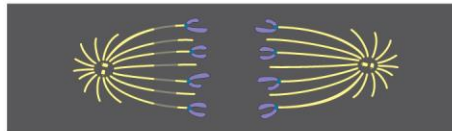
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Figure 12.9

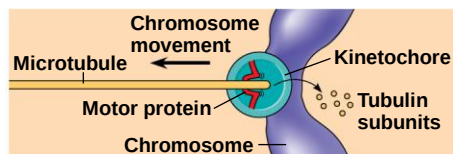
EXPERIMENT



RESULTS



CONCLUSION



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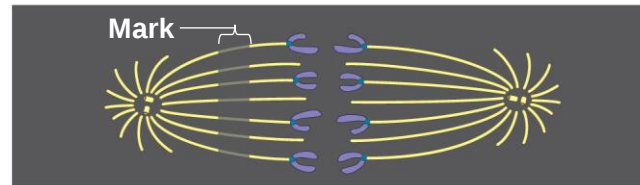
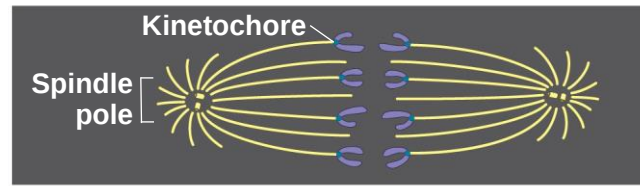
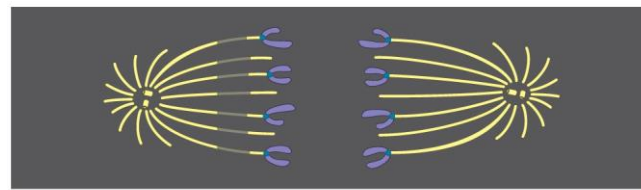
Inquiry!

- How do the kinetochore microtubules function in the poleward movement of chromosomes?
- Two mechanisms: Pac-man mechanism & “reeled in” by motor proteins

Inquiry!

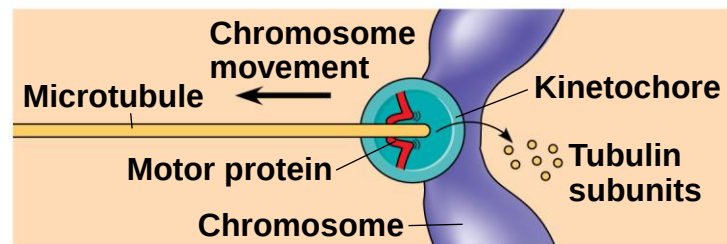
- At which end do kinetochore microtubules shorten during anaphase?

Figure 12.9a

EXPERIMENT**RESULTS**

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Figure 12.9b

CONCLUSION

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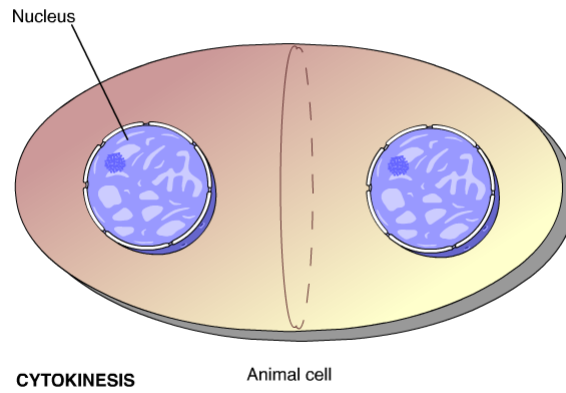
- Nonkinetochore microtubules from opposite poles overlap and push against each other, elongating the cell
- In telophase, genetically identical daughter nuclei form at opposite ends of the cell
- Cytokinesis begins during anaphase or telophase and the spindle eventually disassembles

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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

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Animation: Cytokinesis
Right-click slide / select "Play"

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Figure 12.10

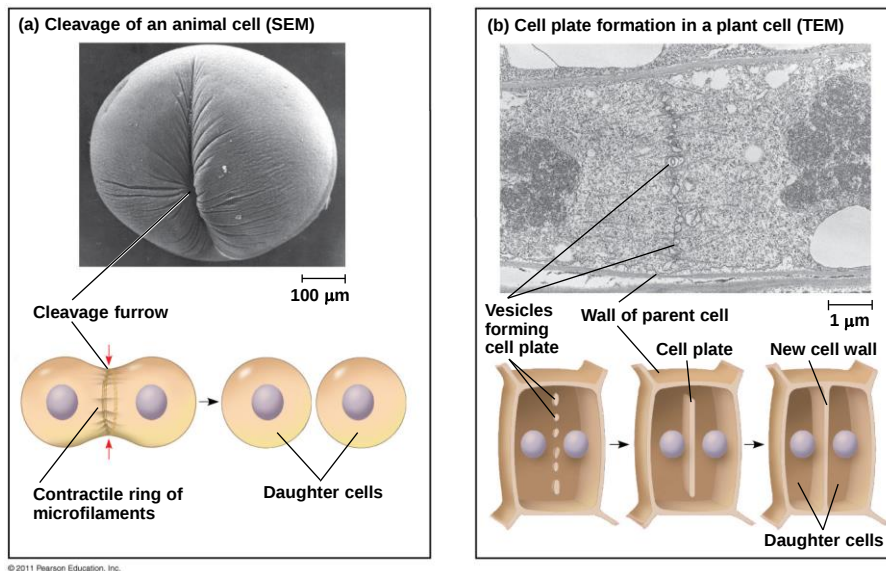


Figure 12.10a

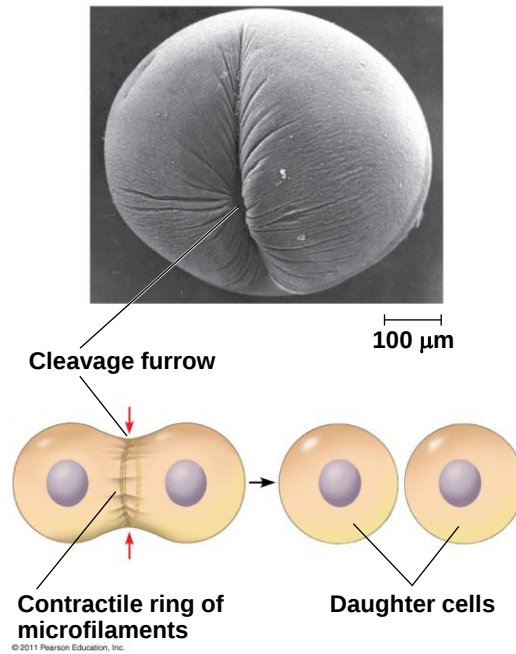
(a) Cleavage of an animal cell (SEM)

Figure 12.10b

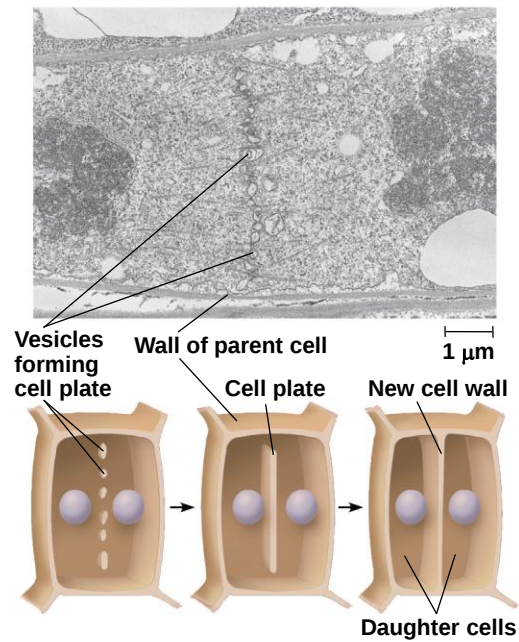
(b) Cell plate formation in a plant cell (TEM)

Figure 12.10c

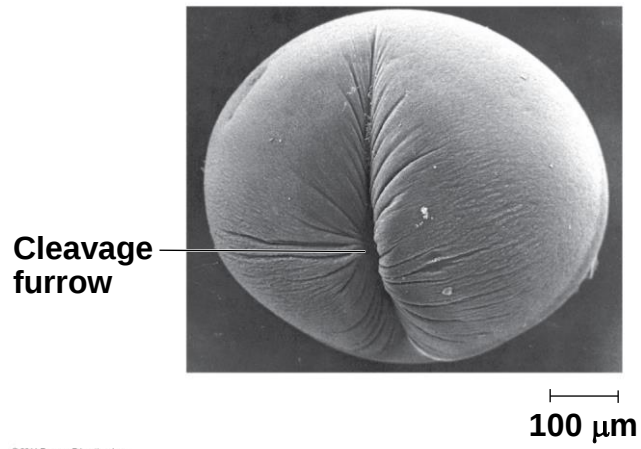


Figure 12.10d

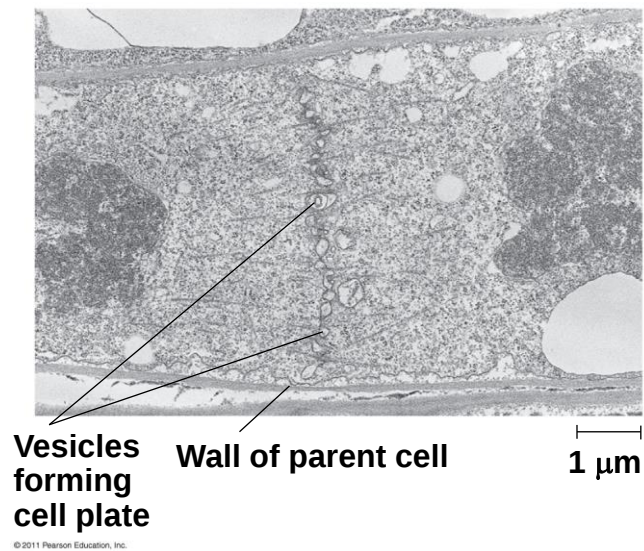


Figure 12.11

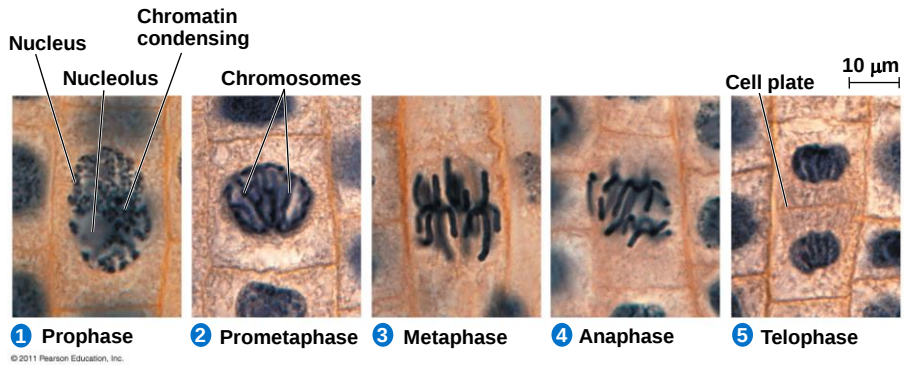


Figure 12.11a

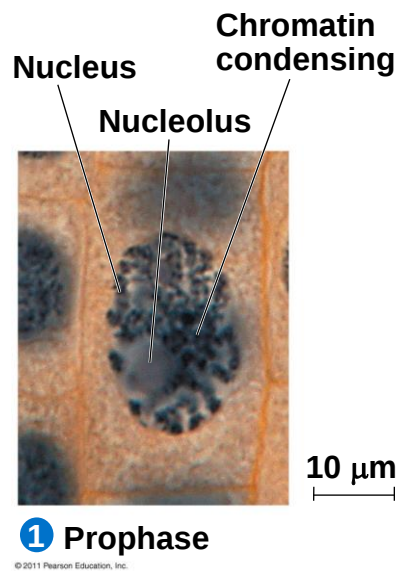


Figure 12.11b

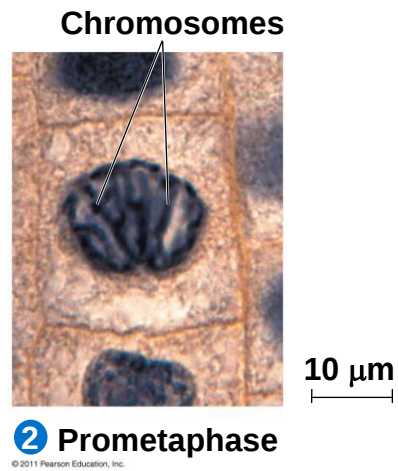


Figure 12.11c



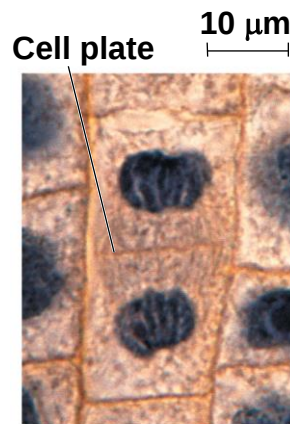
Figure 12.11d



4 Anaphase

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Figure 12.11e



5 Telophase

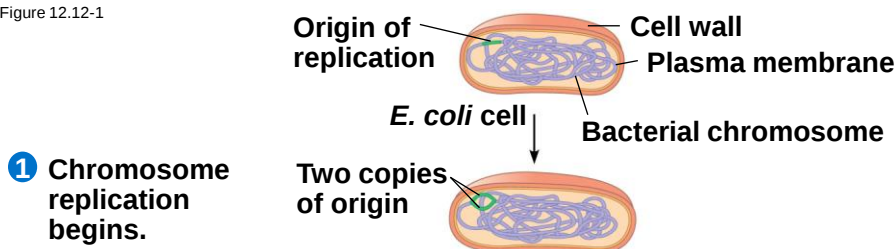
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Binary Fission in Bacteria

- 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

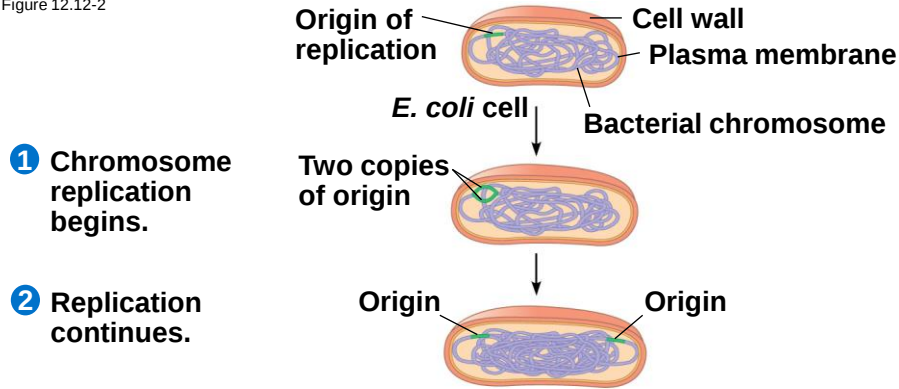
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Figure 12.12-1



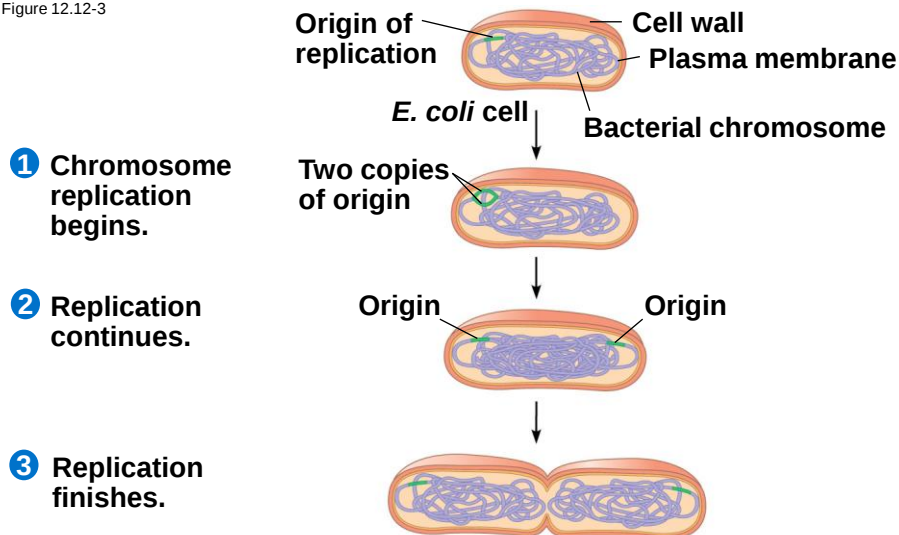
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Figure 12.12-2



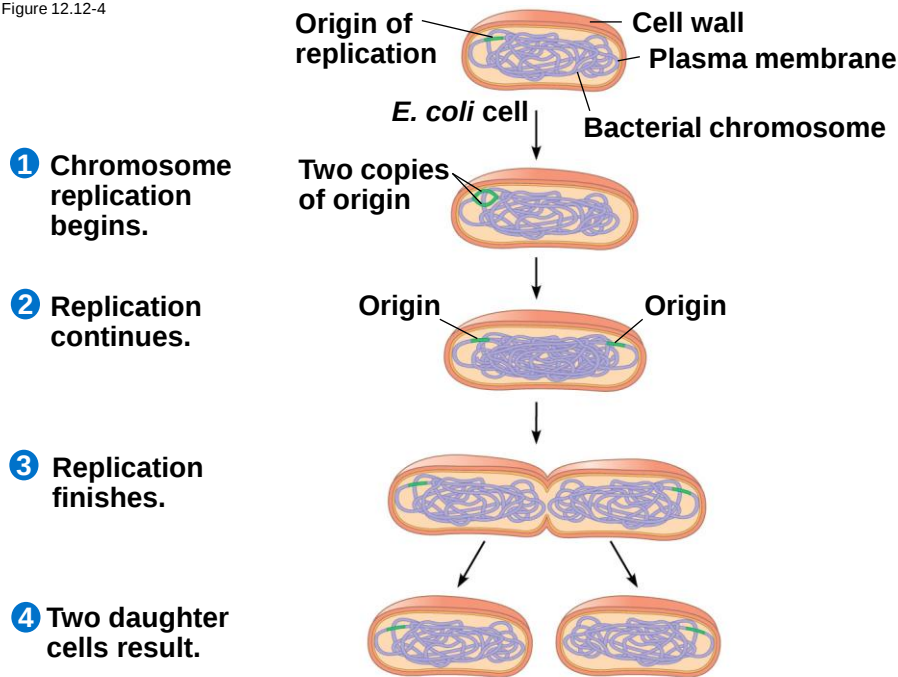
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Figure 12.12-3



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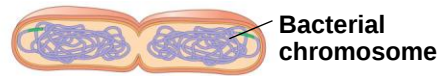
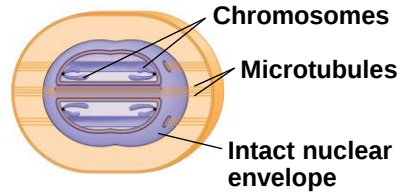
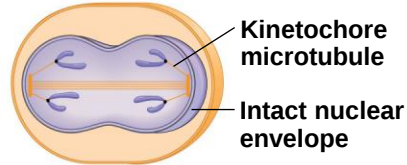
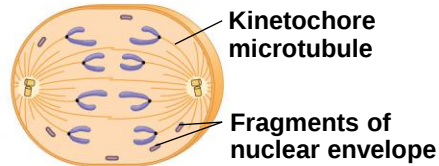
Figure 12.12-4



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

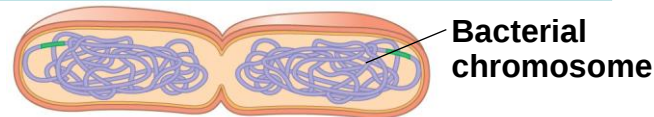
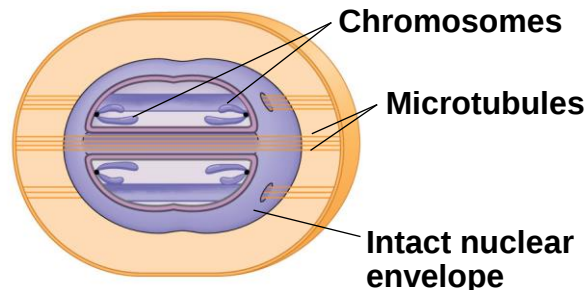
Figure 12.13

(a) Bacteria**(b) Dinoflagellates****(c) Diatoms and some yeasts****(d) Most eukaryotes**

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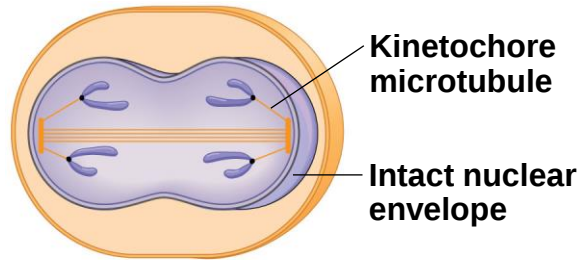
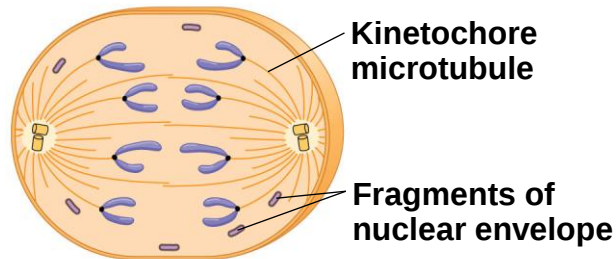
Figure 12.13a

Mechanisms of cell division in several groups of organisms.

**(a) Bacteria****(b) Dinoflagellates**

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Figure 12.13b

**(c) Diatoms and some yeasts****(d) Most eukaryotes**

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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 differences result from regulation at the molecular level
- Cancer cells manage to escape the usual controls on the cell cycle

Evidence for Cytoplasmic Signals

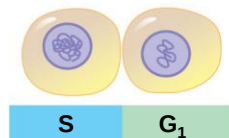
- The cell cycle appears to be driven by specific chemical signals present in the cytoplasm
- Some evidence for this hypothesis comes from experiments in which cultured mammalian cells at different phases of the cell cycle were fused to form a single cell with two nuclei

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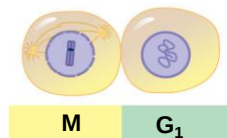
Figure 12.14

EXPERIMENT

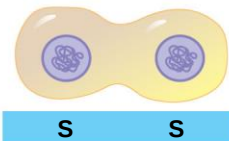
Experiment 1



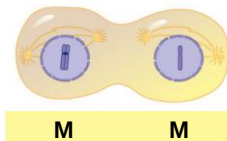
Experiment 2



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.

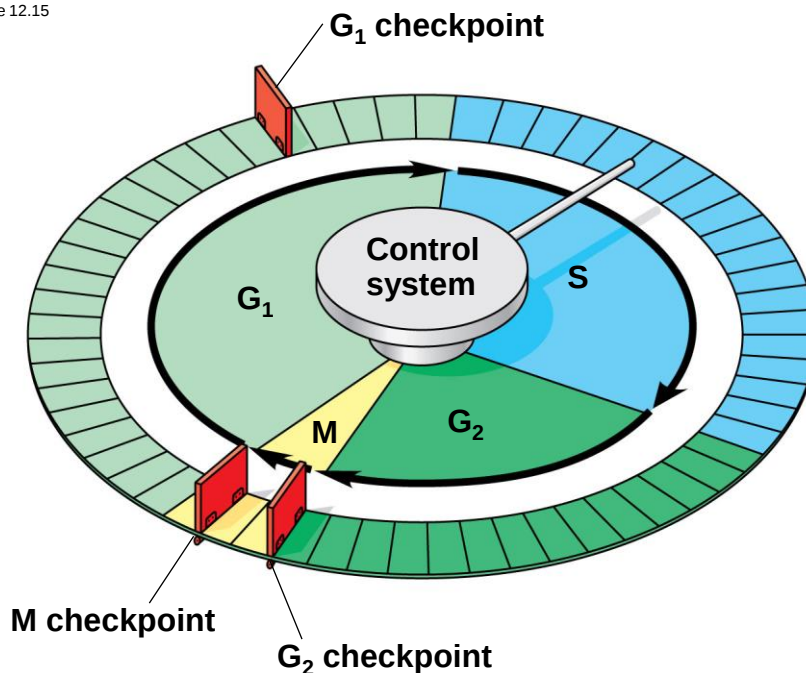
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The Cell Cycle Control System

- 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

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Figure 12.15

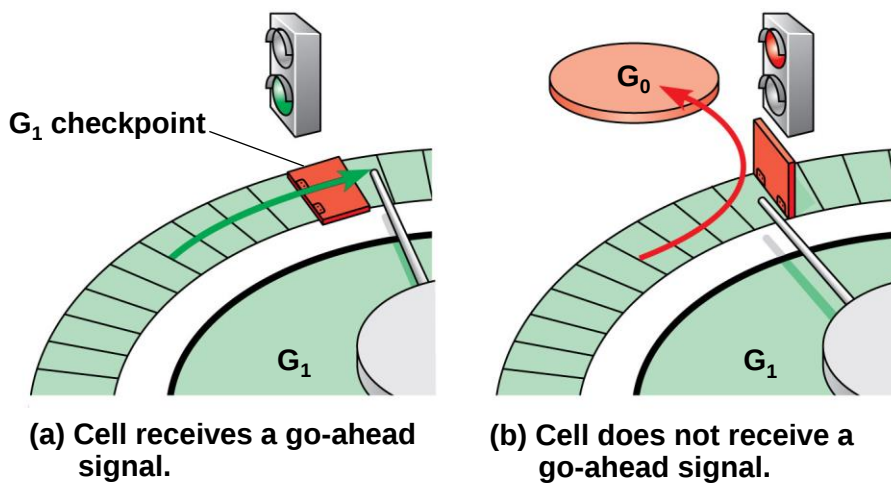


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- For many cells, the G_1 checkpoint seems to be the most important
- If a cell receives a go-ahead signal at the G_1 checkpoint, it will usually complete the S, G_2 , and M phases and divide
- If the cell does not receive the go-ahead signal, it will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

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Figure 12.16

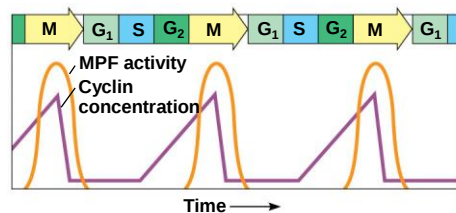


The Cell Cycle Clock: Cyclins and Cyclin-Dependent Kinases

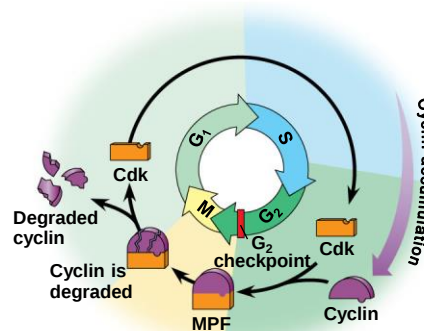
- Two types of regulatory proteins are involved in cell cycle control: **cyclins** and **cyclin-dependent kinases (Cdks)**
- Cdks activity fluctuates during the cell cycle because it is controlled by cyclins, so named because their concentrations vary with the cell cycle
- **MPF** (maturation-promoting factor) is a cyclin-Cdk complex that triggers a cell's passage past the G_2 checkpoint into the M phase

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Figure 12.17



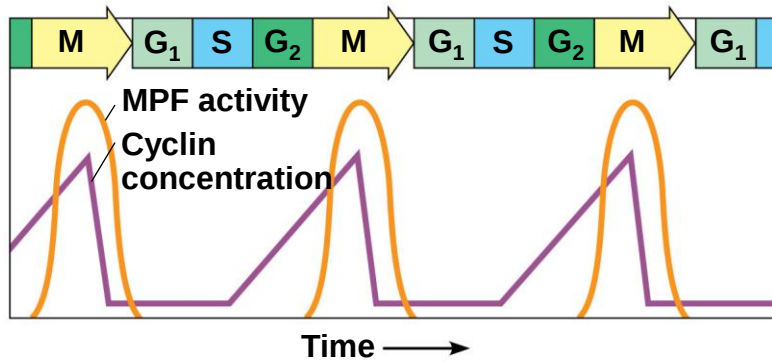
(a) Fluctuation of MPF activity and cyclin concentration during the cell cycle



(b) Molecular mechanisms that help regulate the cell cycle

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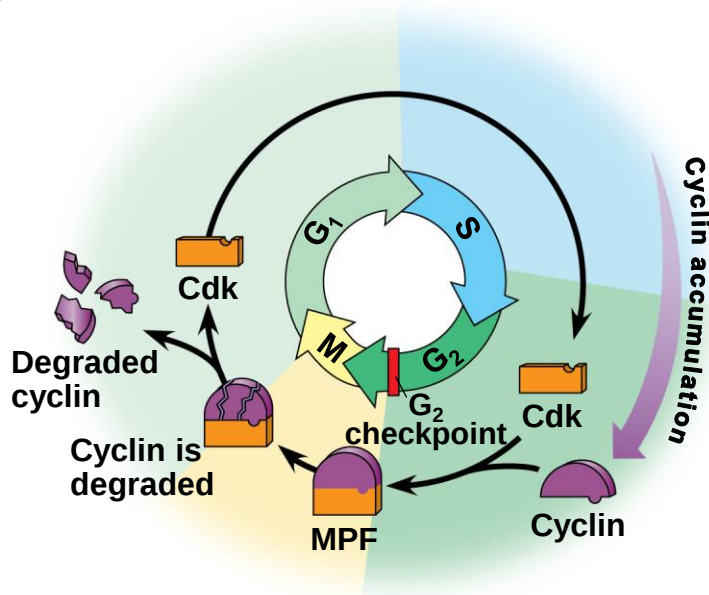
Figure 12.17a



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

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Figure 12.17b



(b) Molecular mechanisms that help regulate the cell cycle

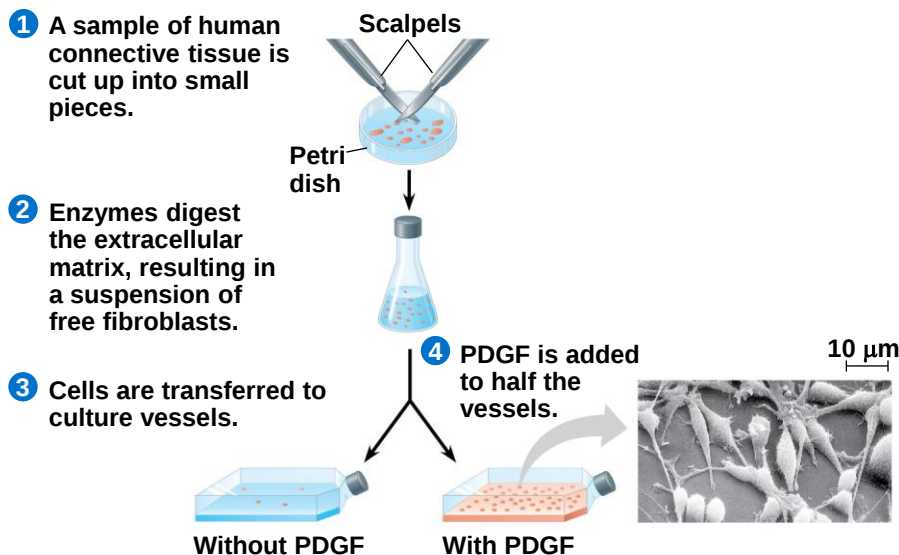
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Stop and Go Signs: Internal and External Signals at the Checkpoints

- 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

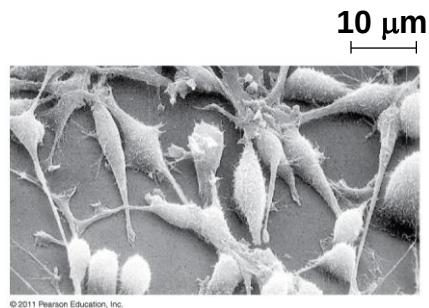
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Figure 12.18



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Figure 12.18a



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

Figure 12.19

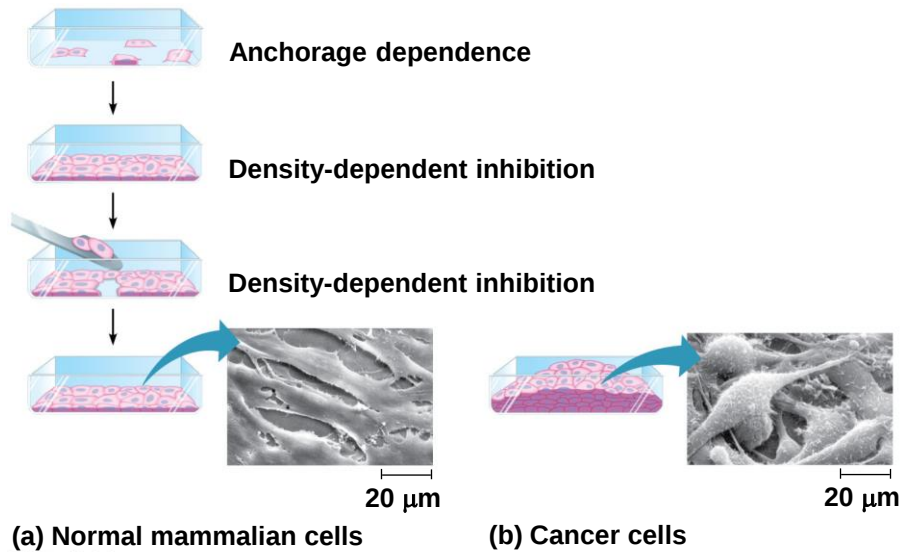


Figure 12.19a

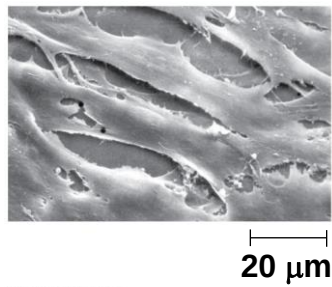
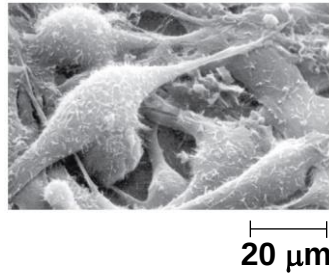


Figure 12.19b



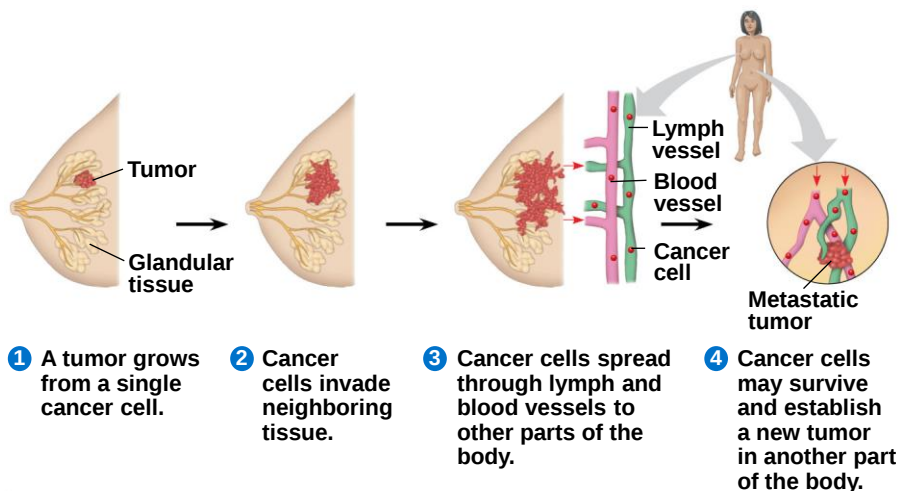
Loss of Cell Cycle Controls in Cancer Cells

- 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 that are not eliminated by the immune system, 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 additional tumors

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Figure 12.20

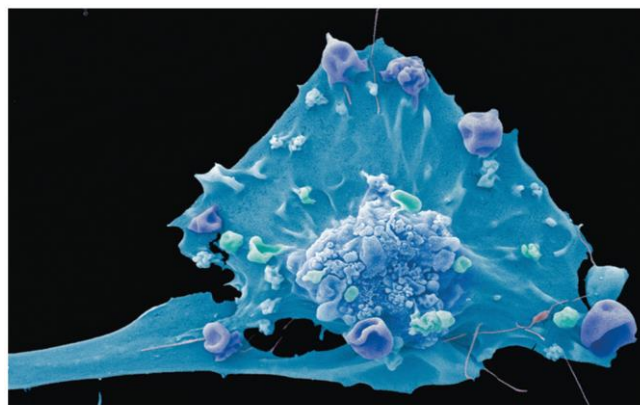


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- Recent advances in understanding the cell cycle and cell cycle signaling have led to advances in cancer treatment

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Figure 12.21



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Figure 12.UN01

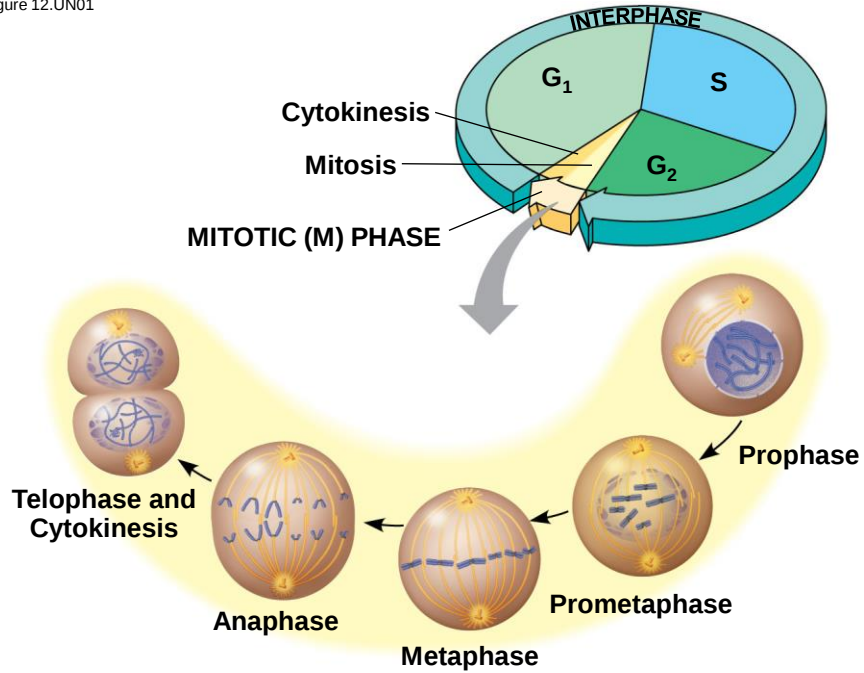


Figure 12.UN02

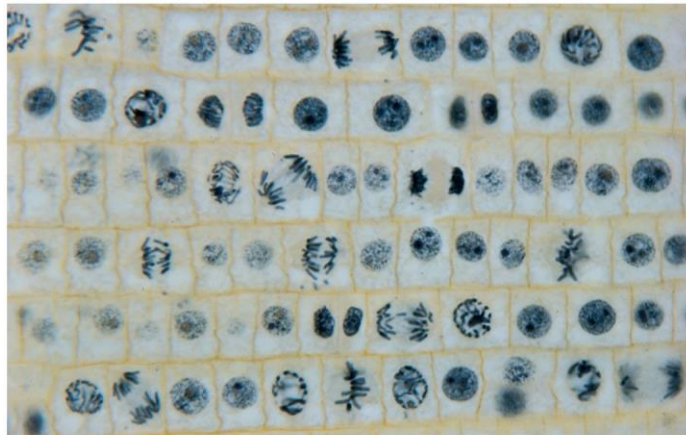


Figure 12.UN03

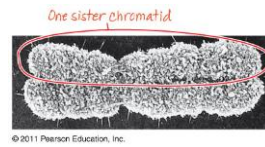


Figure 12.UN04

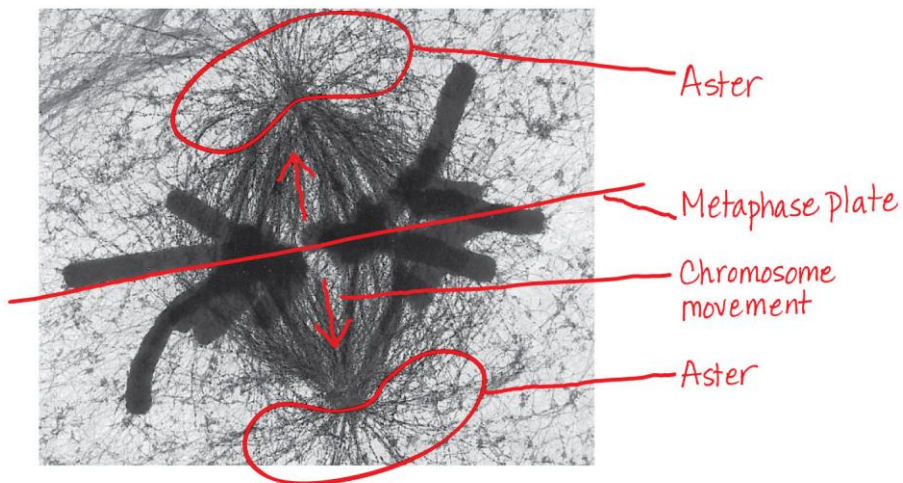


Figure 12.UN05

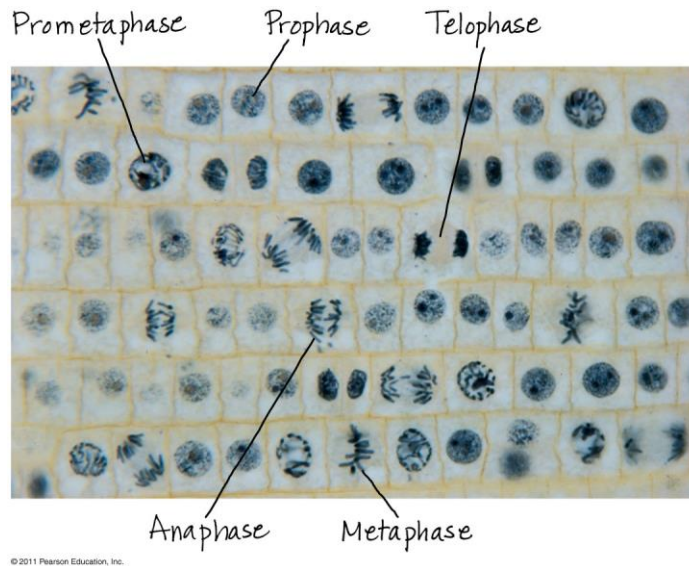


Figure 12.UN06

