LECTURE PRESENTATIONS

For CAMPBELL BIOLOGY, NINTH EDITION

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Chapter 12

The Cell Cycle 2020

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Mitosis


MITOSIS
SONG
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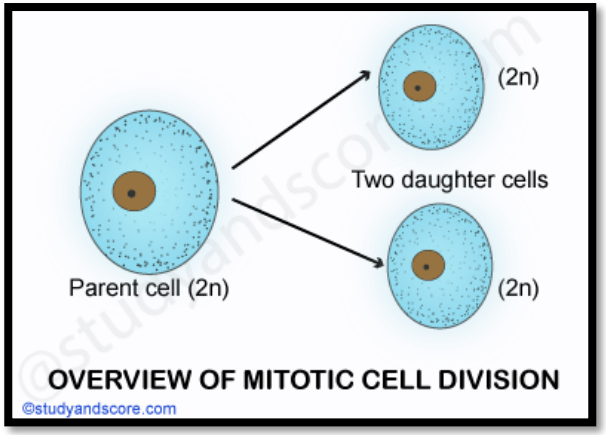
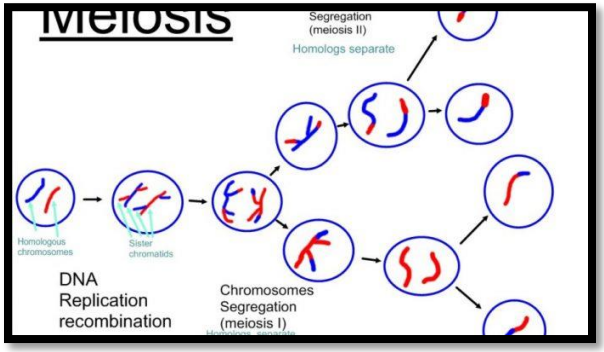
Overview: The Key Roles of Cell Division

- 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**



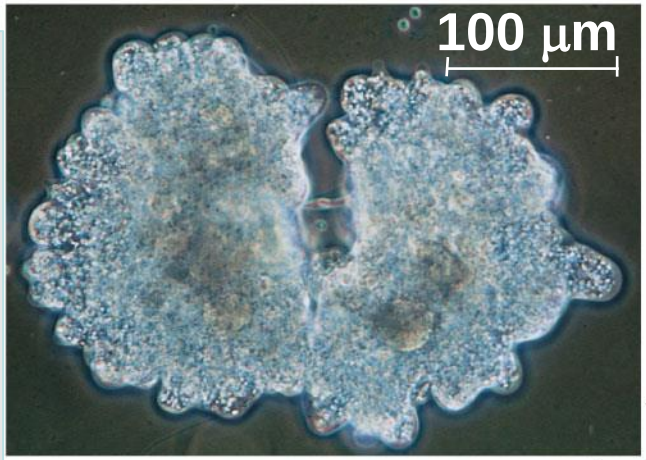


- In **unicellular** organisms, division of one cell reproduces the entire organism

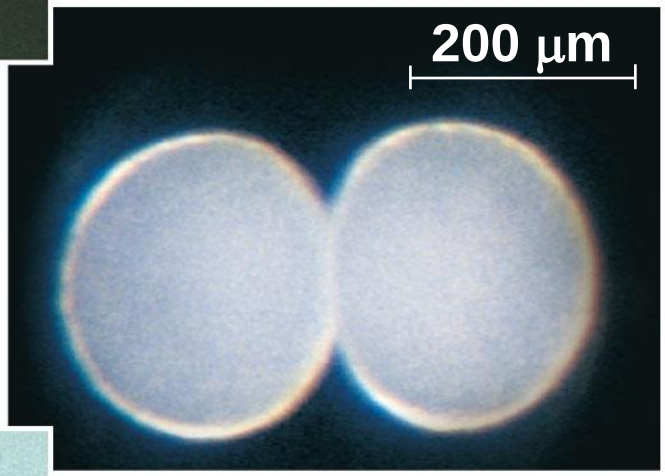
- **Multicellular** organisms depend on cell division for
  - **Development** from a fertilized cell
  - Growth
  - **Repair**

Figure 12.2

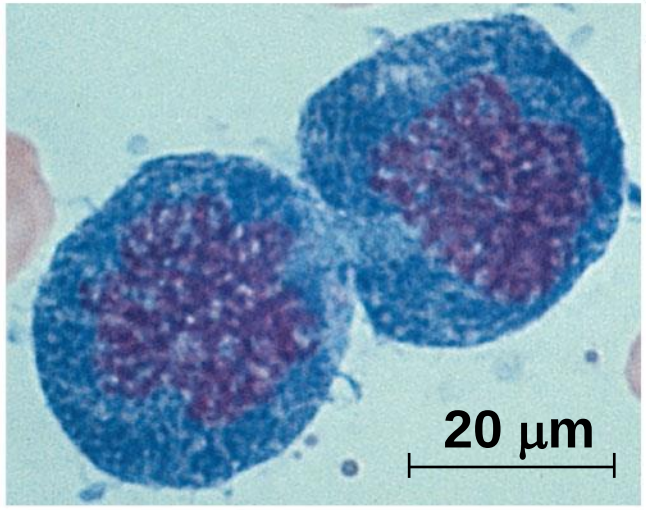
The functions of cell division



(a) Reproduction



(b) Growth and development



(c) Tissue renewal

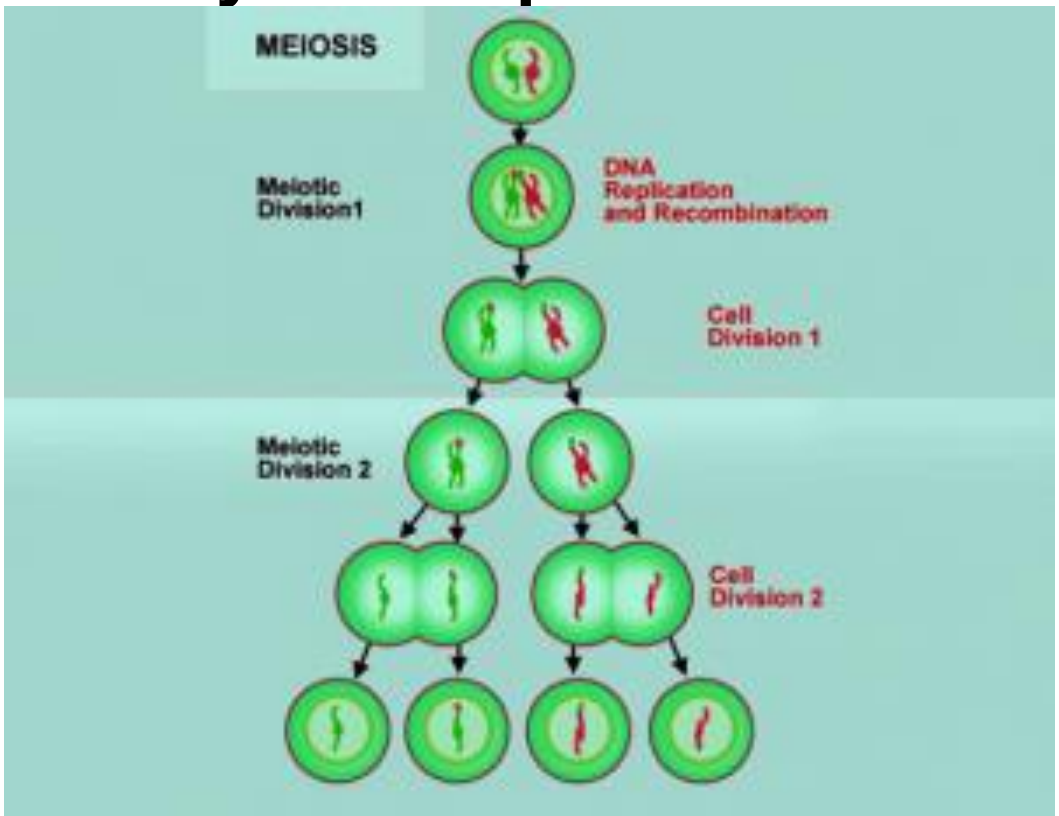
Concept 12.1: Most cell division results in genetically identical daughter cells

- 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

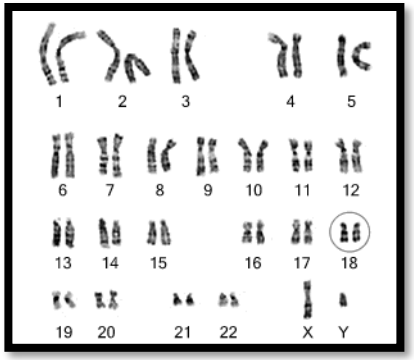
- **Gametes are produced by a variation of cell division called meiosis**

- **Meiosis yields nonidentical daughter cells that have only one set of chromosomes, half as many as the parent cell**



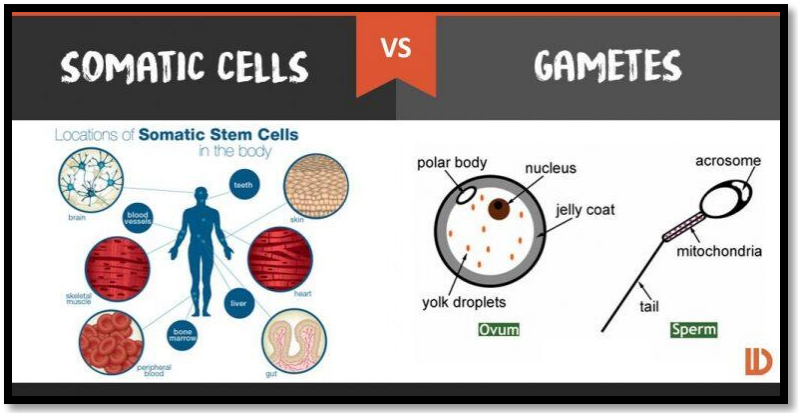
- **Eukaryotic chromosomes consist of chromatin, a complex of DNA and protein that condenses during cell division**

- **Every eukaryotic species has a characteristic number of chromosomes in each cell nucleus >> Karyotype**



- **Somatic cells** (**nonreproductive cells) have <u>two sets of chromosomes</u>**

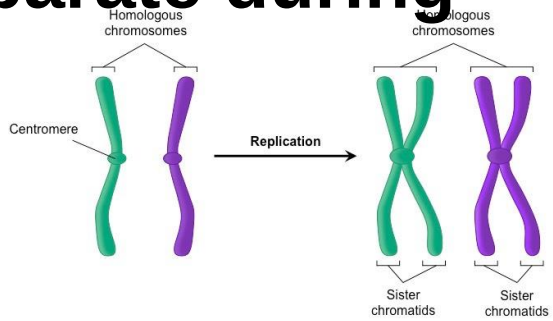
- **Gametes** (**reproductive cells: sperm and eggs) have <u>half</u> as many chromosomes as somatic cells**



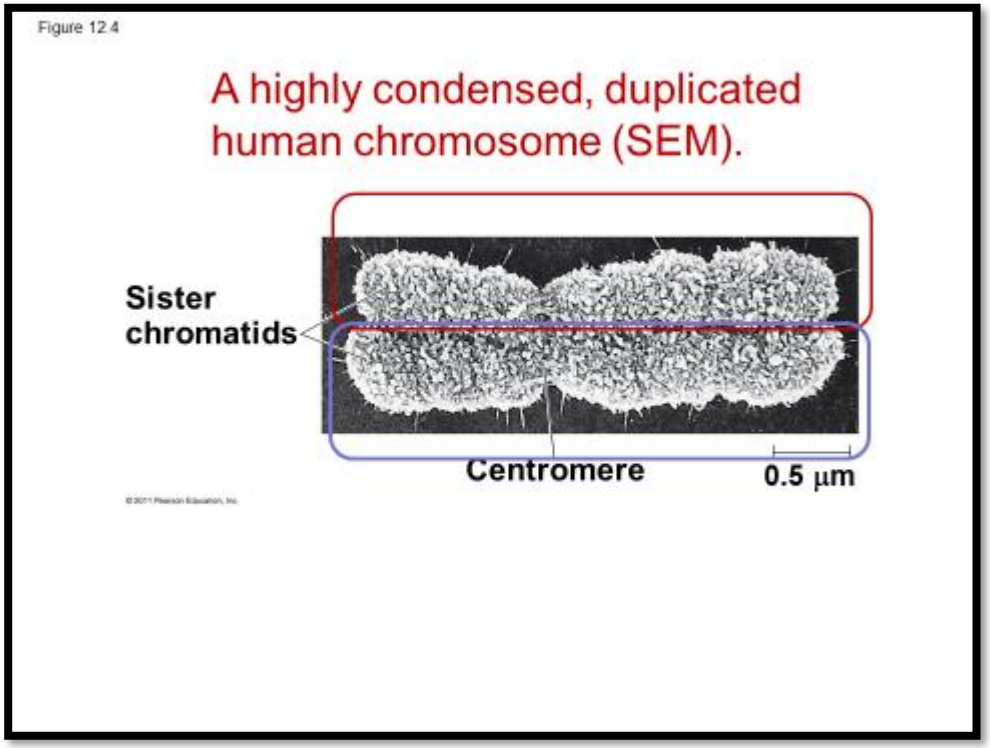
Distribution of Chromosomes During Eukaryotic Cell Division

- 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 خَاصِرَة" of the duplicated chromosome, where the two chromatids are most closely attached**



- During cell division, the two sister chromatids of each duplicated **chromosome separate and move into two nuclei**

- Once separate, **the chromatids are called chromosomes**

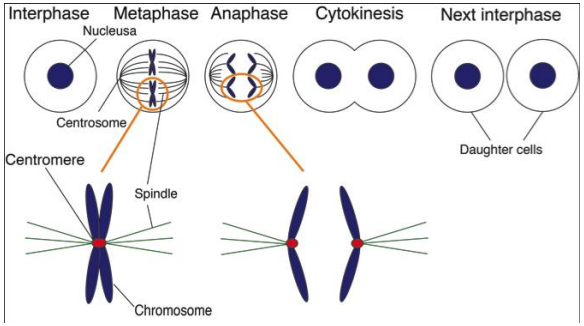
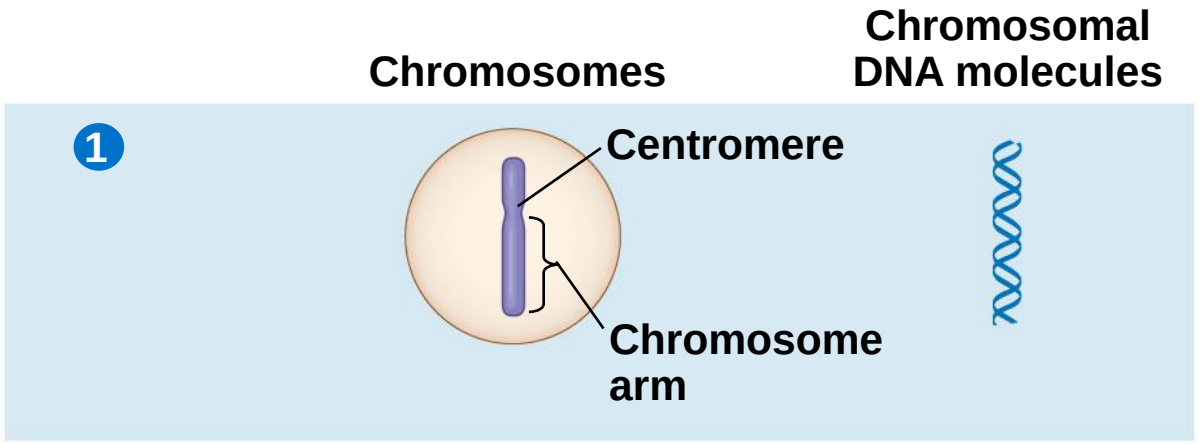


Figure 12.5-1



Chromosome duplication and distribution during cell division.

Figure 12.5-2

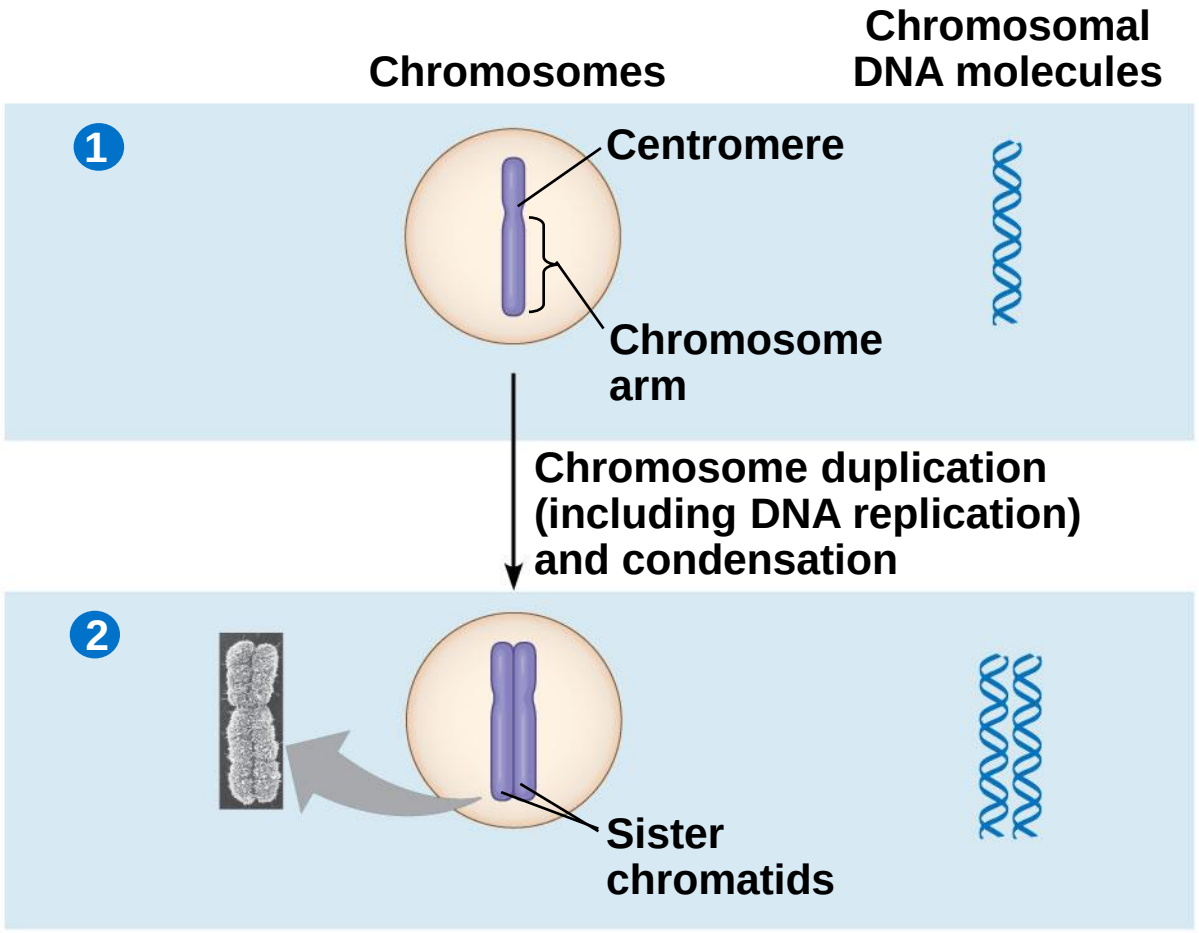
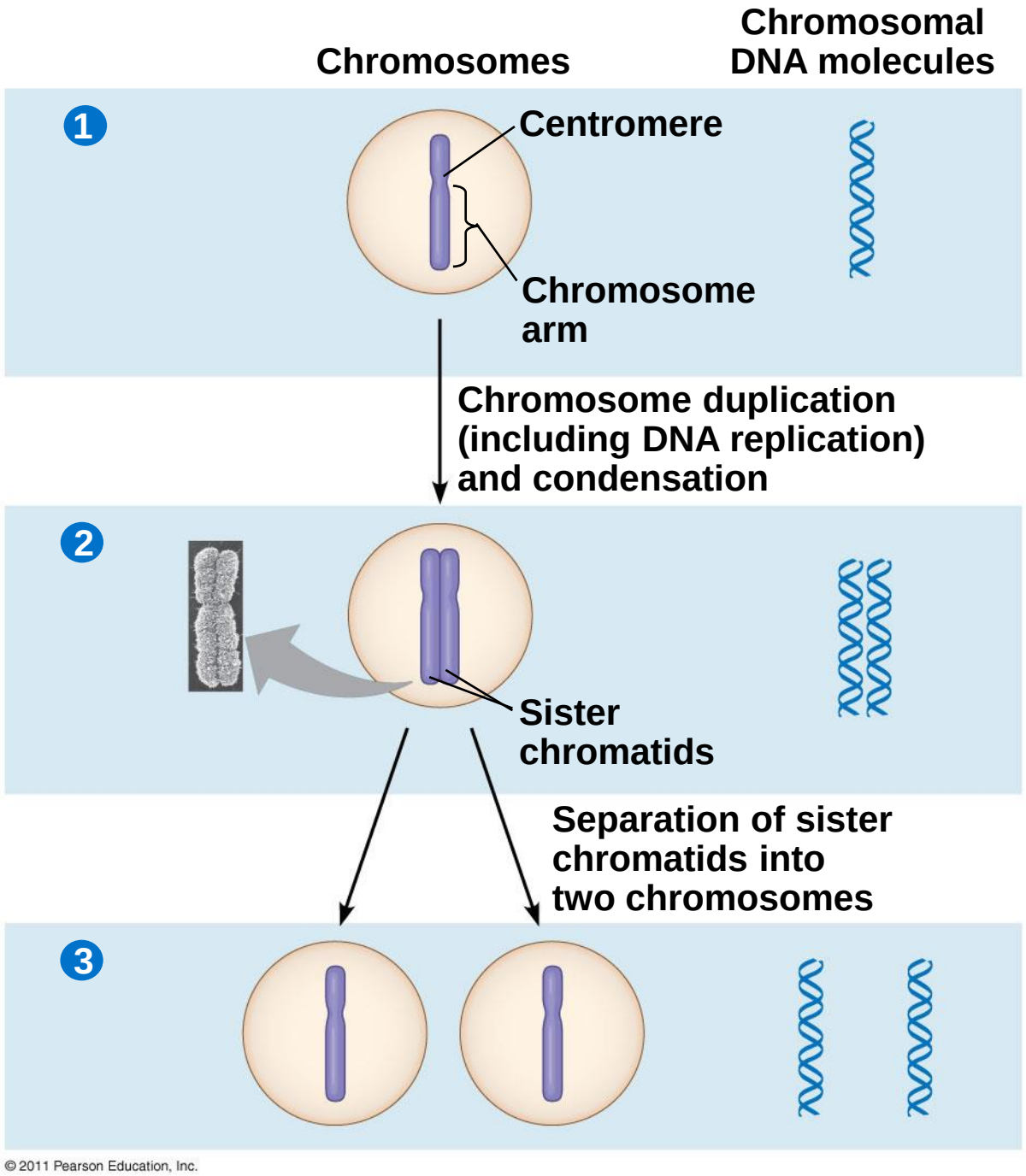


Figure 12.5-3


Chromosomes
Chromosomal DNA molecules
1
Centromere
Chromosome arm
Chromosome duplication (including DNA replication) and condensation
2
Sister chromatids
Separation of sister chromatids into two chromosomes
3
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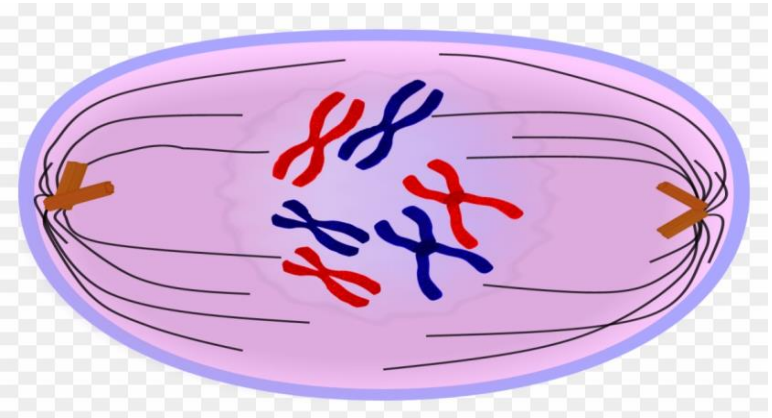
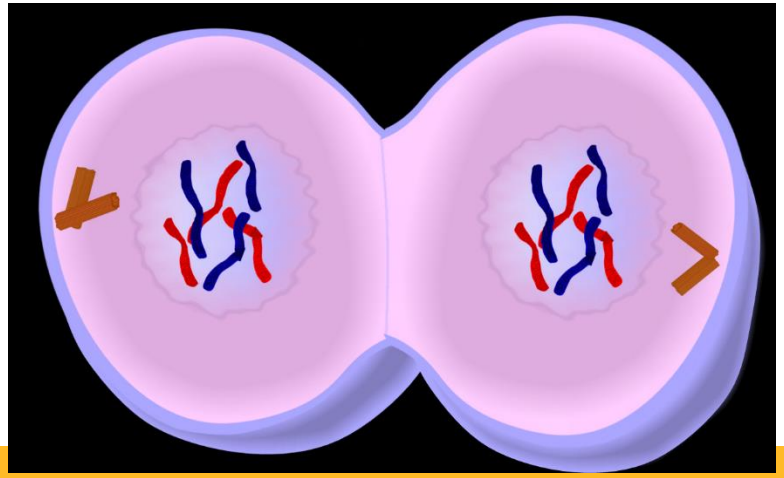
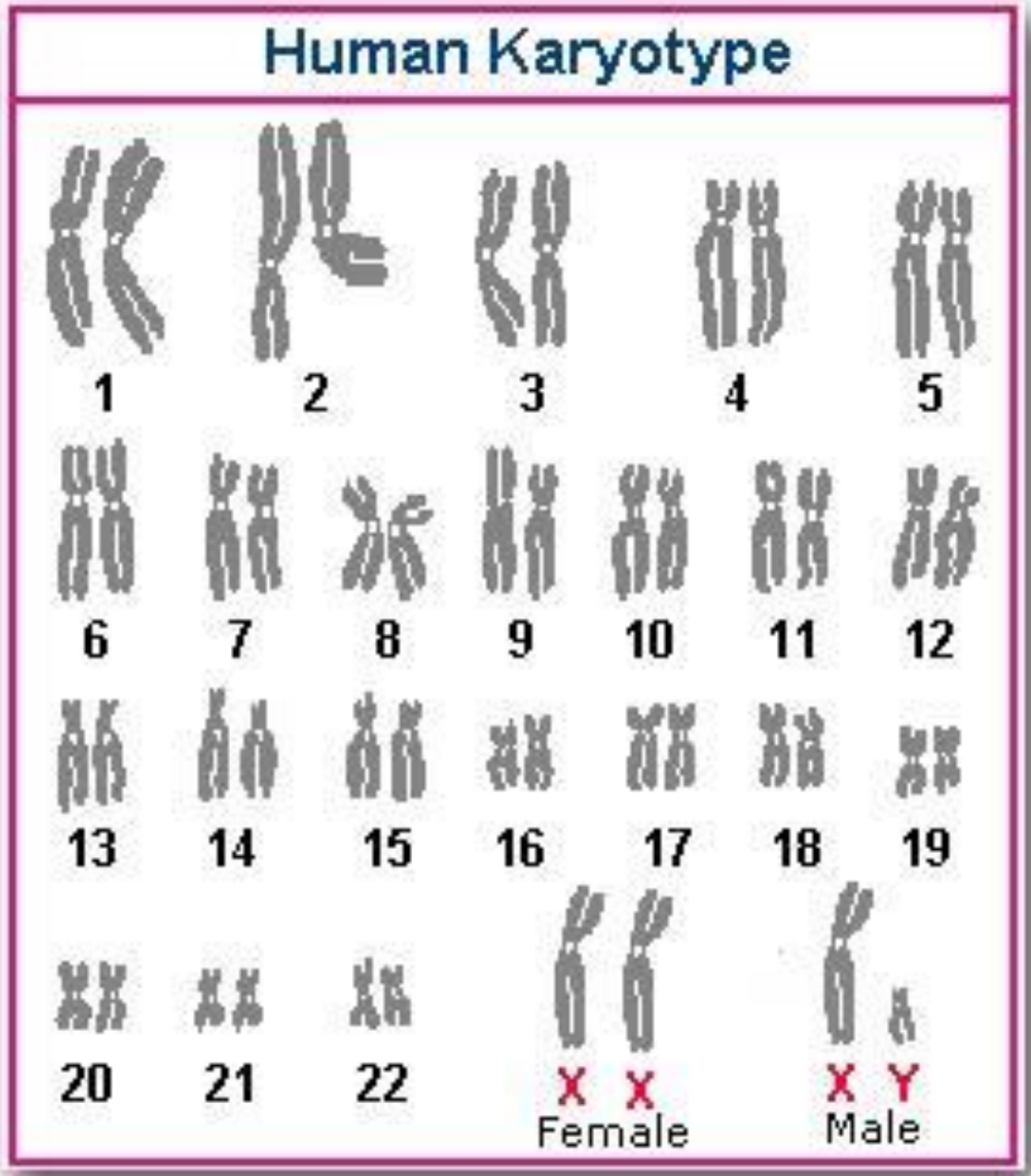
- **Eukaryotic cell division consists of**

  – **Mitosis, the division of the genetic material in the nucleus**

  – **Cytokinesis, the division of the cytoplasm**





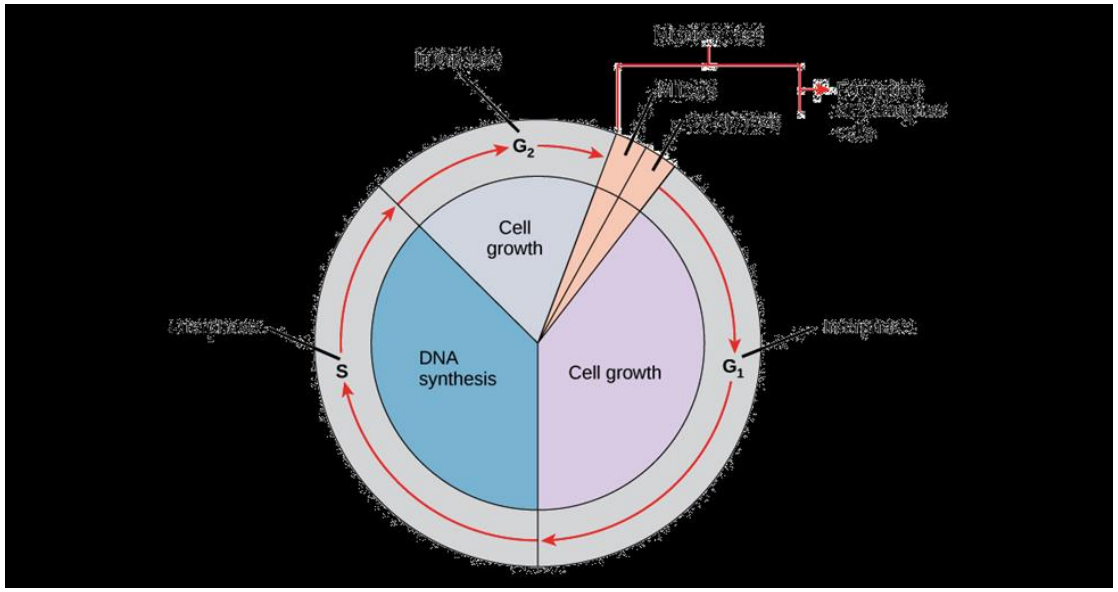

Human Karyotype
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
X X
Female
X Y
Male

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

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)



- **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**

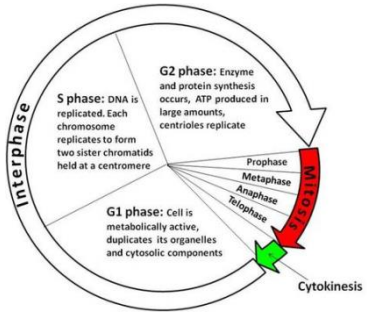
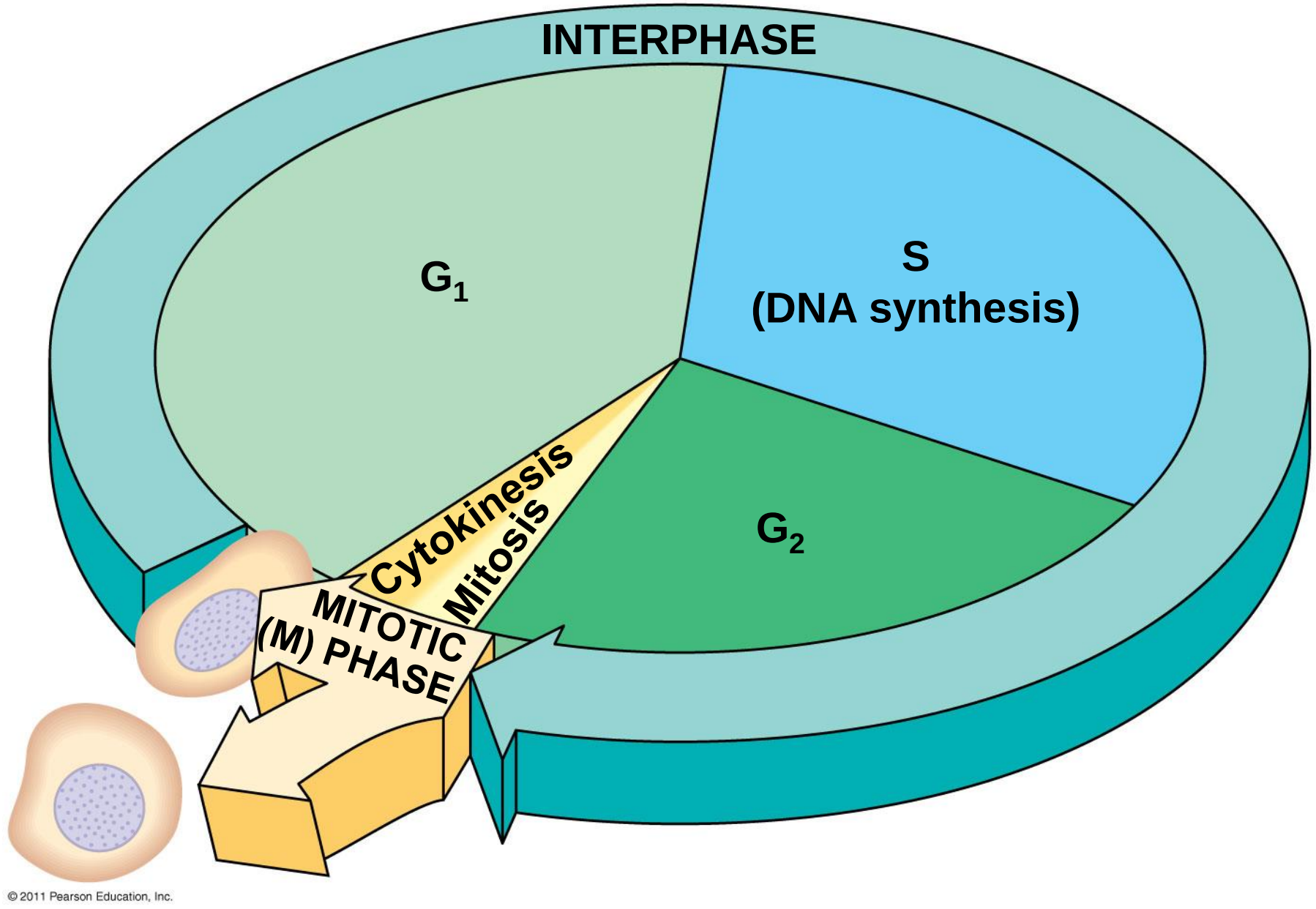


Figure 12.6


INTERPHASE
G1
S
(DNA synthesis)
G2
Cytokinesis
Mitosis
MITOTIC
(M) PHASE
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- **Mitosis is conventionally divided into five phases**
  - **Prophase (pro= ما قبل**
  - **Prometaphase**
  - **Metaphase (meta = وسطي**
  - **Anaphase (ana = انفصال**
  - **Telophase (telo= نِهايَة**

- **Cytokinesis overlaps the latter stages of mitosis**

Figure 12.7

Exploring: Mitosis in an Animal Cell

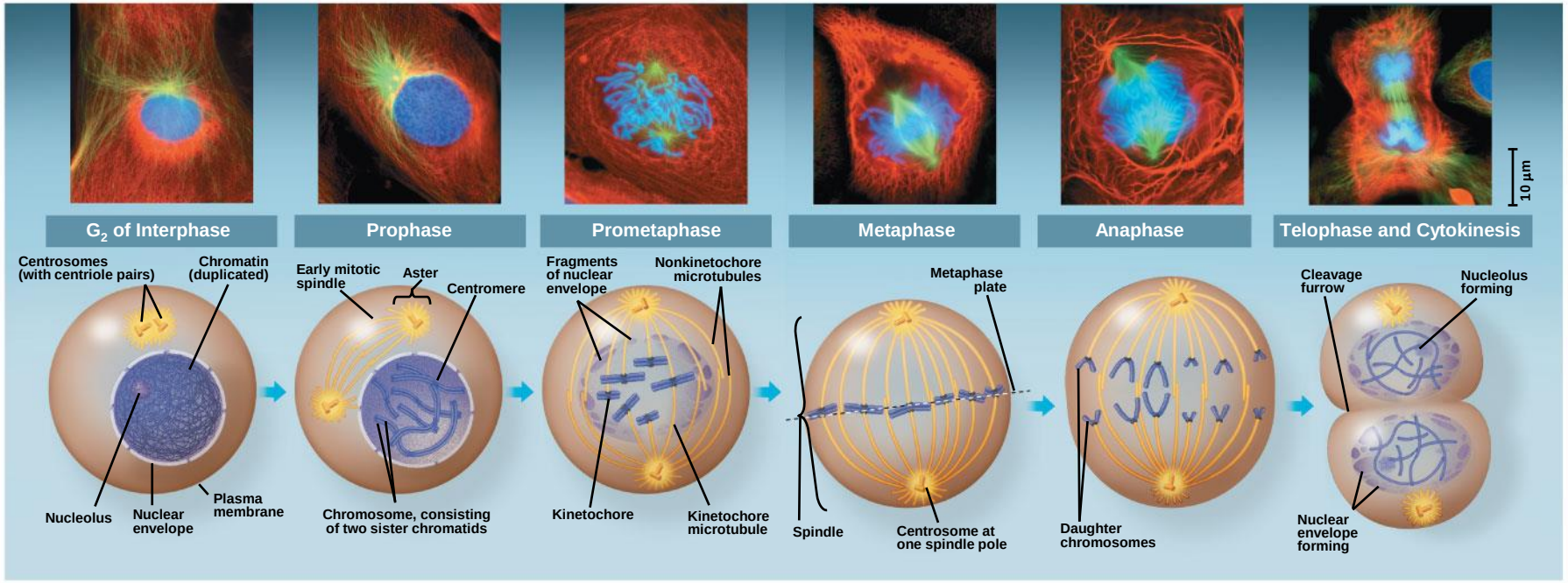


Figure 12.7a

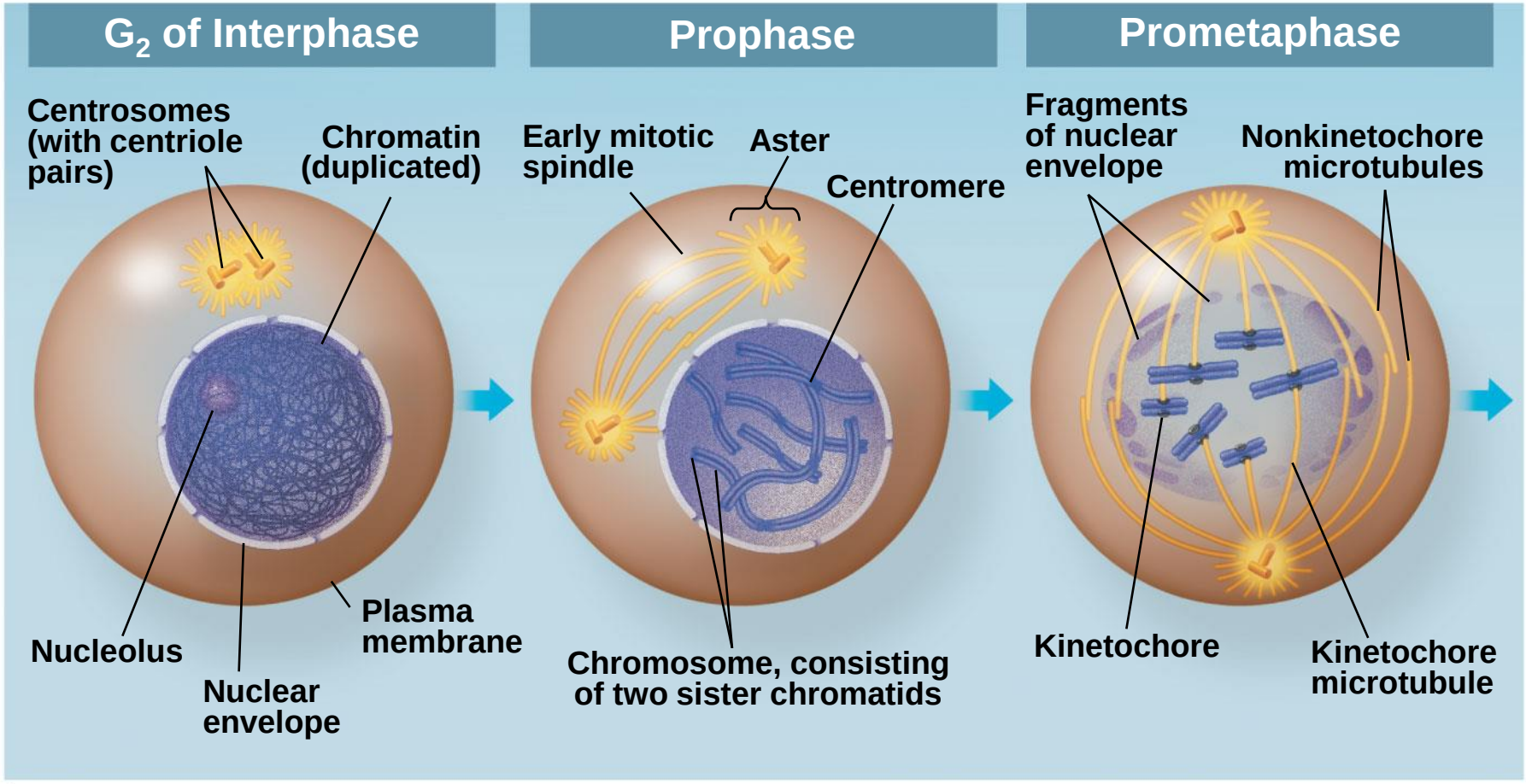
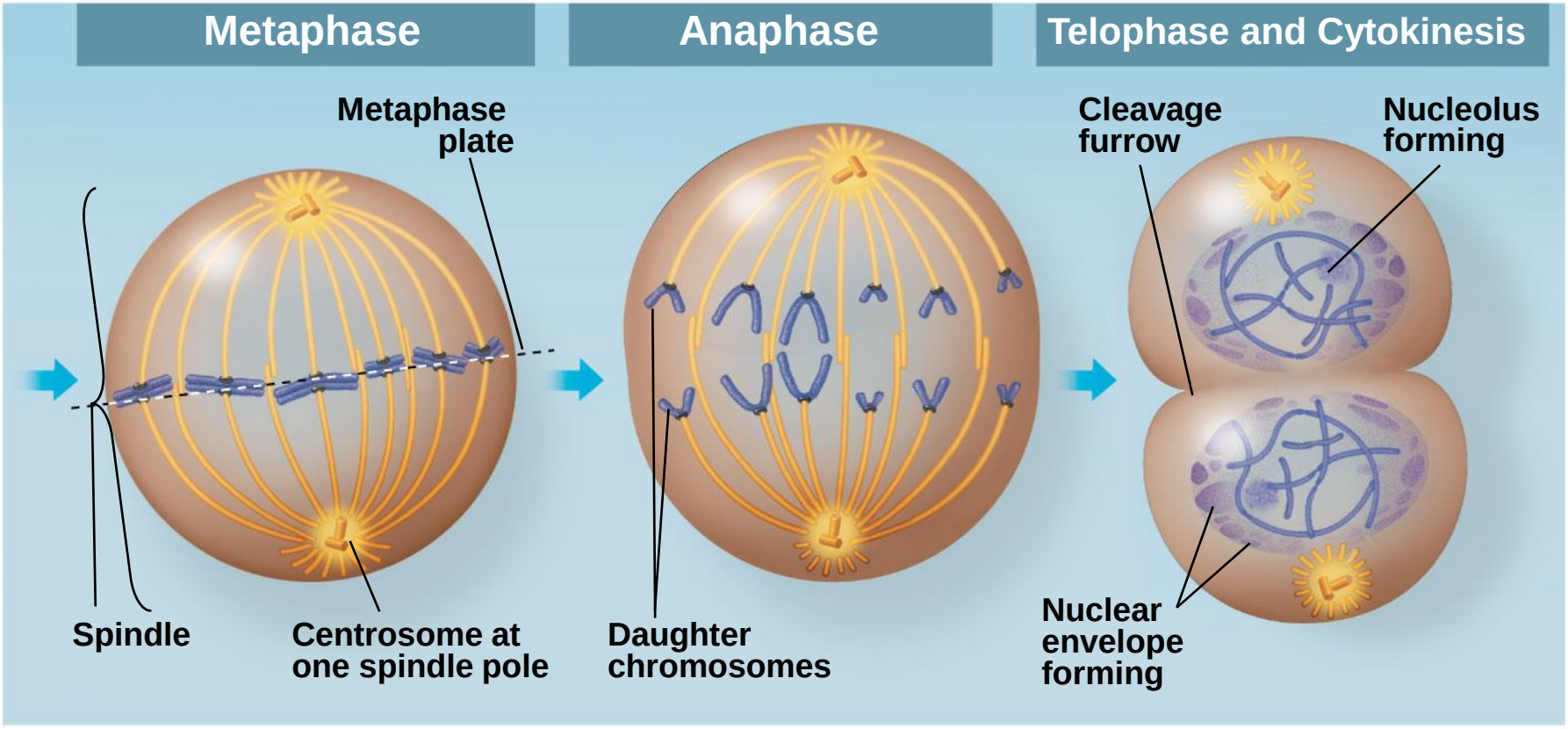
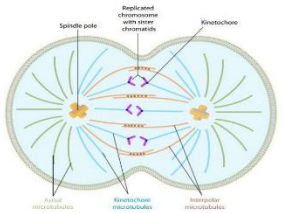


Figure 12.7b



The Mitotic Spindle: *A Closer Look*



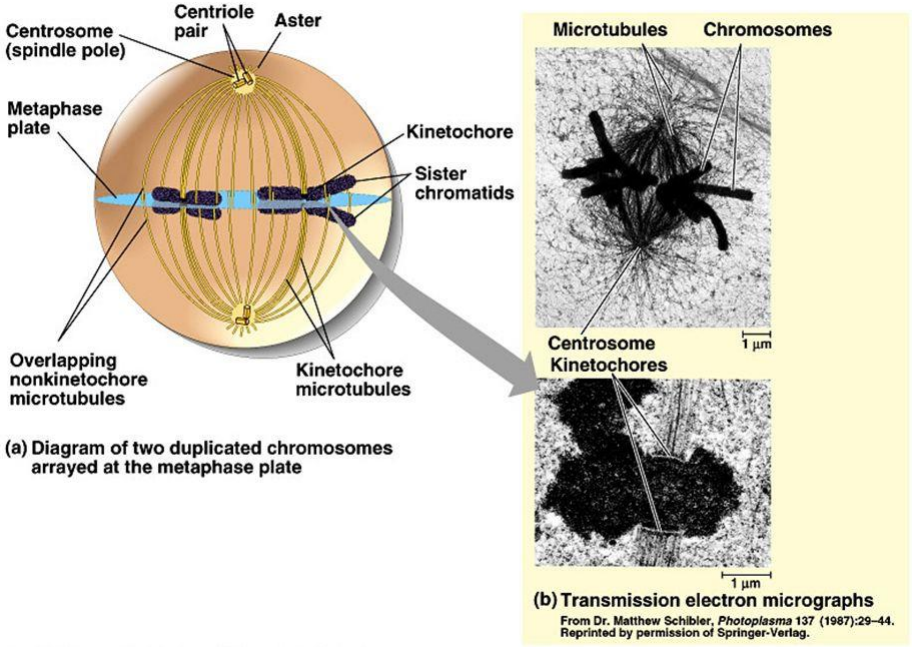
- The **mitotic spindle** is a structure made of **microtubules** that **controls chromosome movement** during mitosis

- 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**

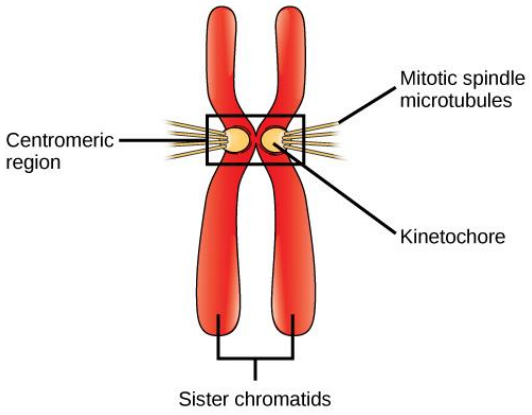
- An **aster** (*a radial array of short microtubules*) extends from each centrosome

- **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

- **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**

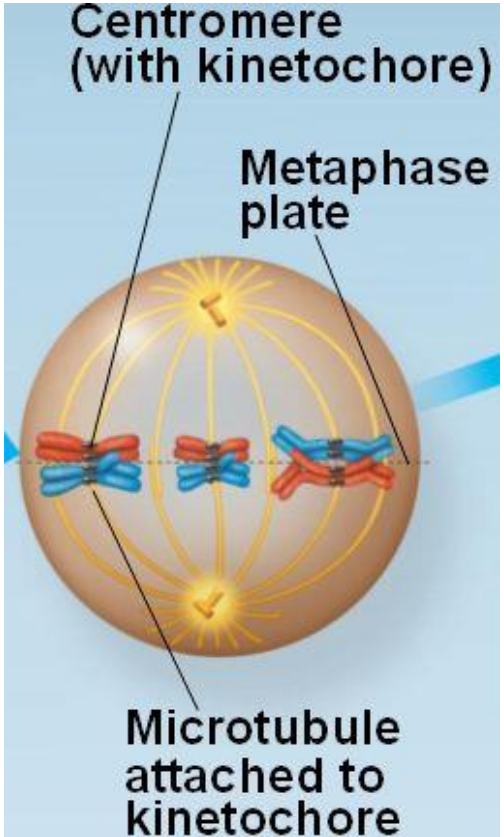
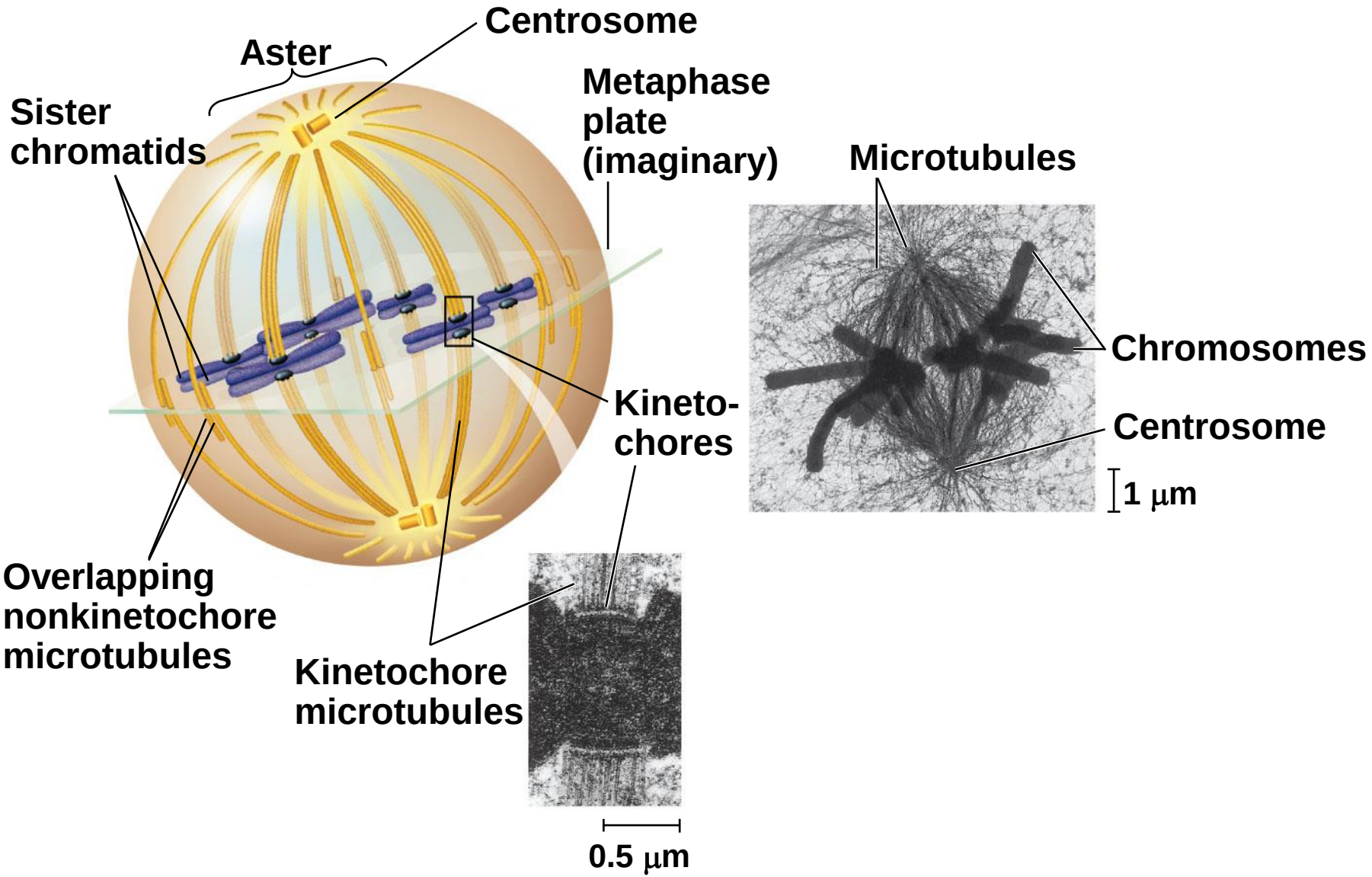


Figure 12.8

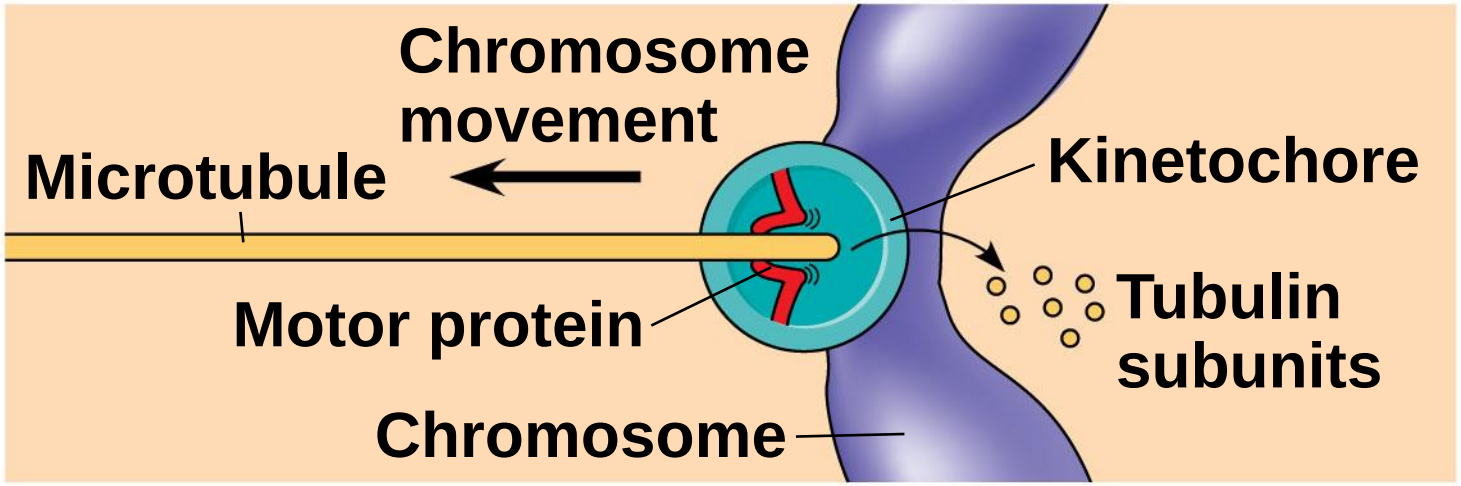


- In anaphase, **sister chromatids separate** and move along the kinetochore microtubules toward **opposite ends of the cell**

- Anaphase begins when the **Cohesins** holding together sister chromatids of each chromosome are **cleaved** by an enzyme called ***separase***

Figure 12.9b

CONCLUSION



- **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**

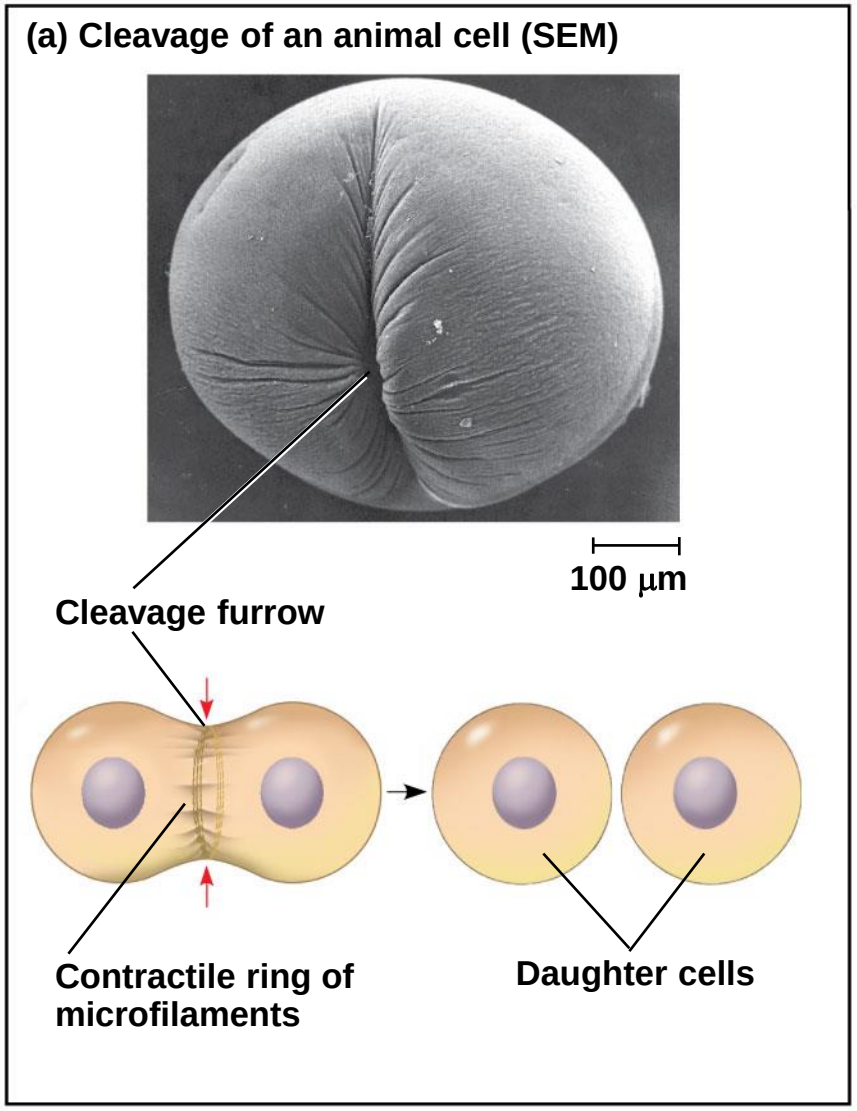
- **Cytokinesis begins during anaphase or telophase and the spindle eventually disassembles**

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

Figure 12.10



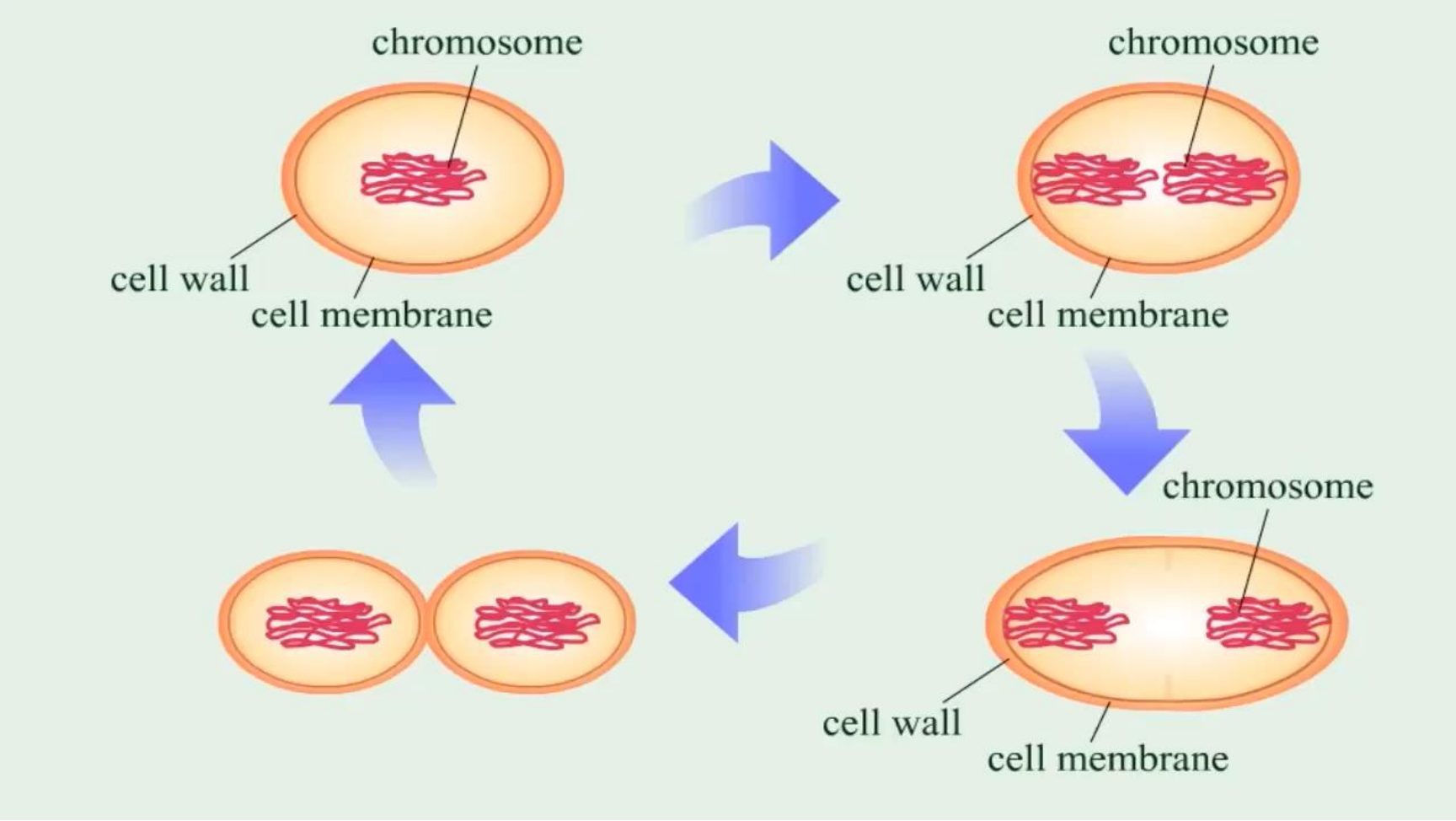
Binary Fission in Bacteria

- 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

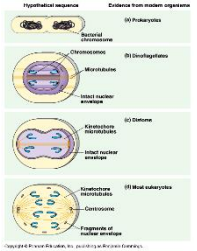
Binary Fission



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**



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

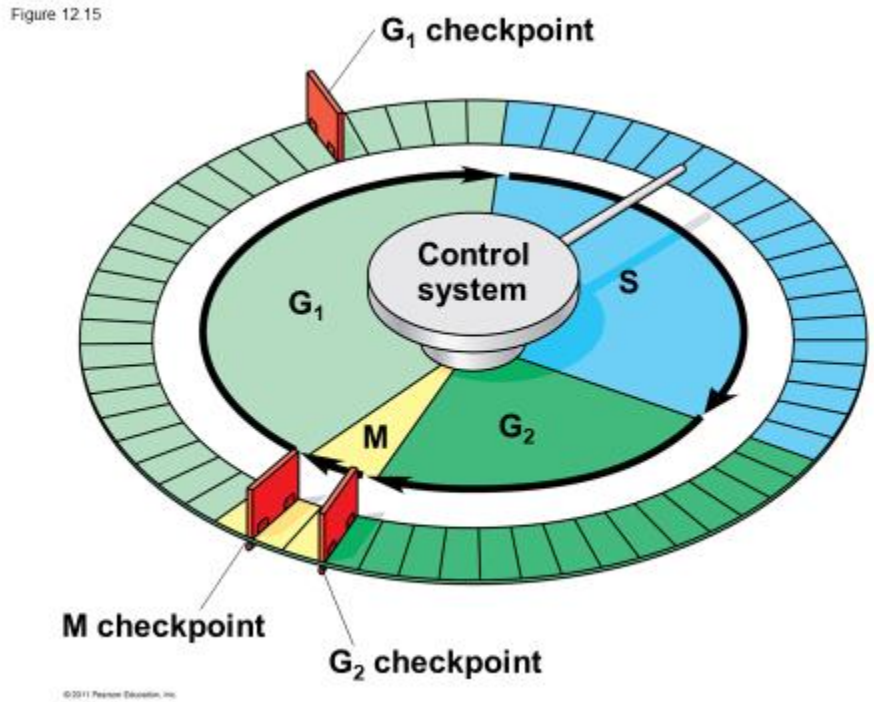
- The **frequency of cell division** varies with the type of cell
- These differences result from **regulation at the molecular level**
- **Cancer cells manage to escape** the usual controls on the cell cycle

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**

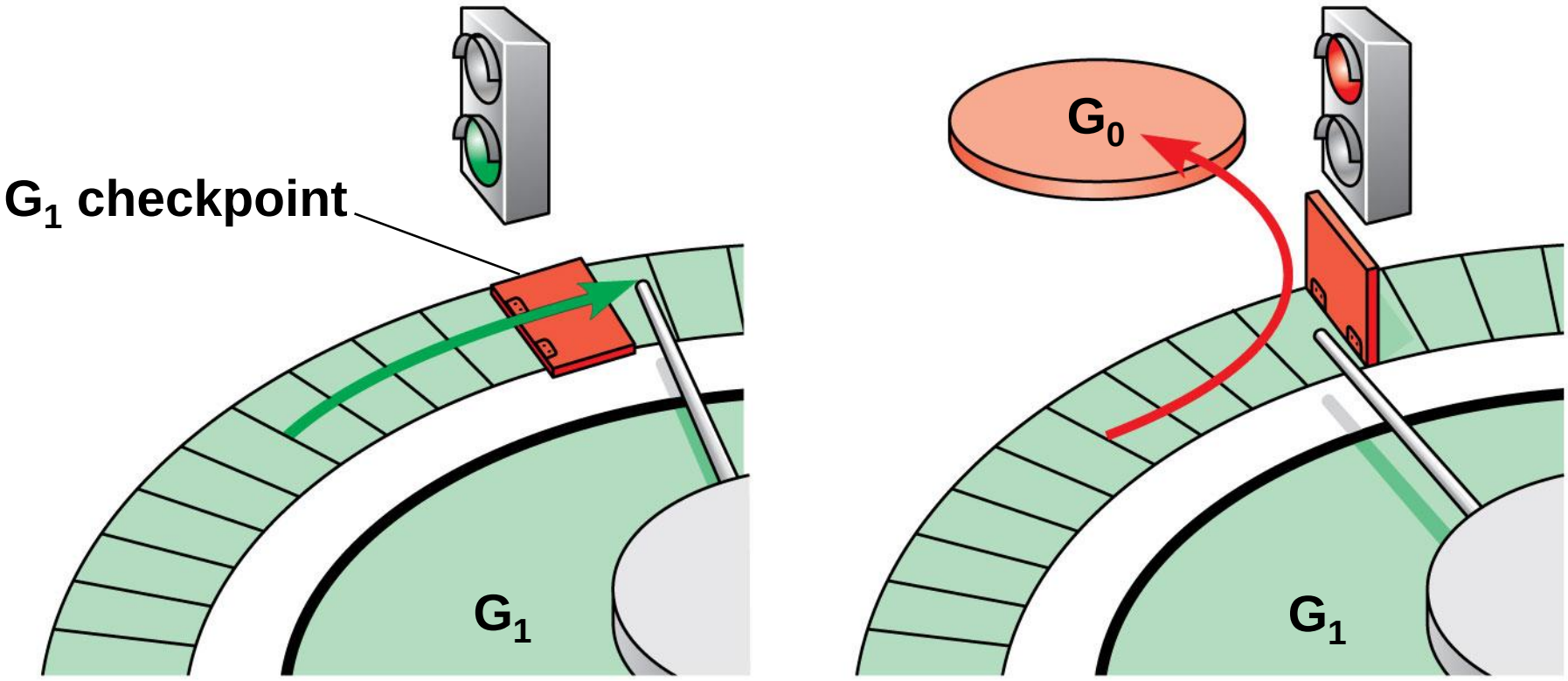
- **The clock has specific checkpoints where the cell cycle stops until a go-ahead signal is received**



- For many cells, the G_1 checkpoint seems to be the most important

- 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

Figure 12.16



(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)**

- ***Cdks* activity fluctuates during the cell cycle because it is controlled by cyclins, so named because their concentrations vary with the cell cycle**

- **An example of an internal signal is that kinetochores not attached to spindle microtubules send a molecular signal that delays anaphase**

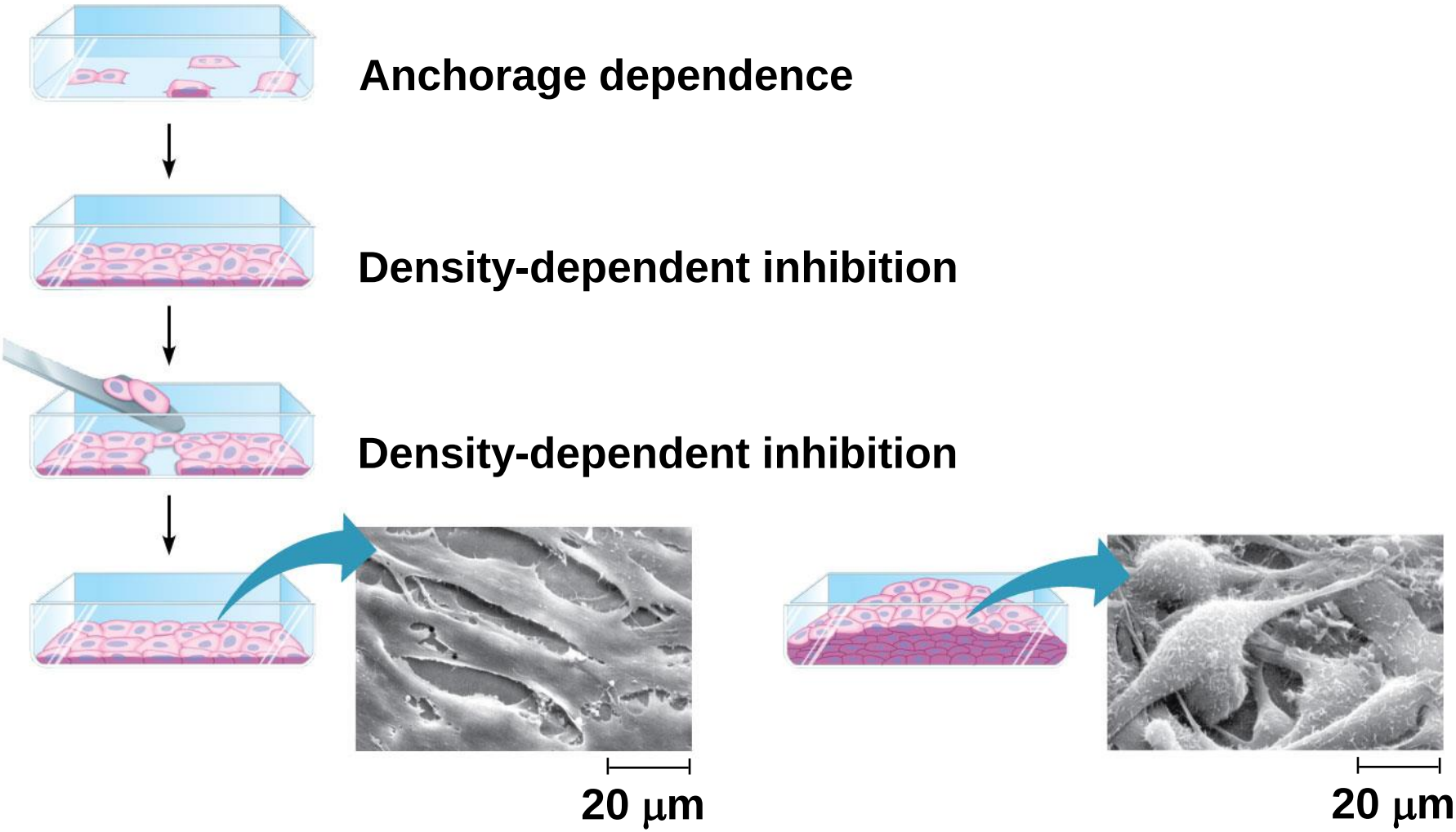
- **Some external signals are growth factors, proteins released by certain cells that stimulate other cells to divide**

- 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

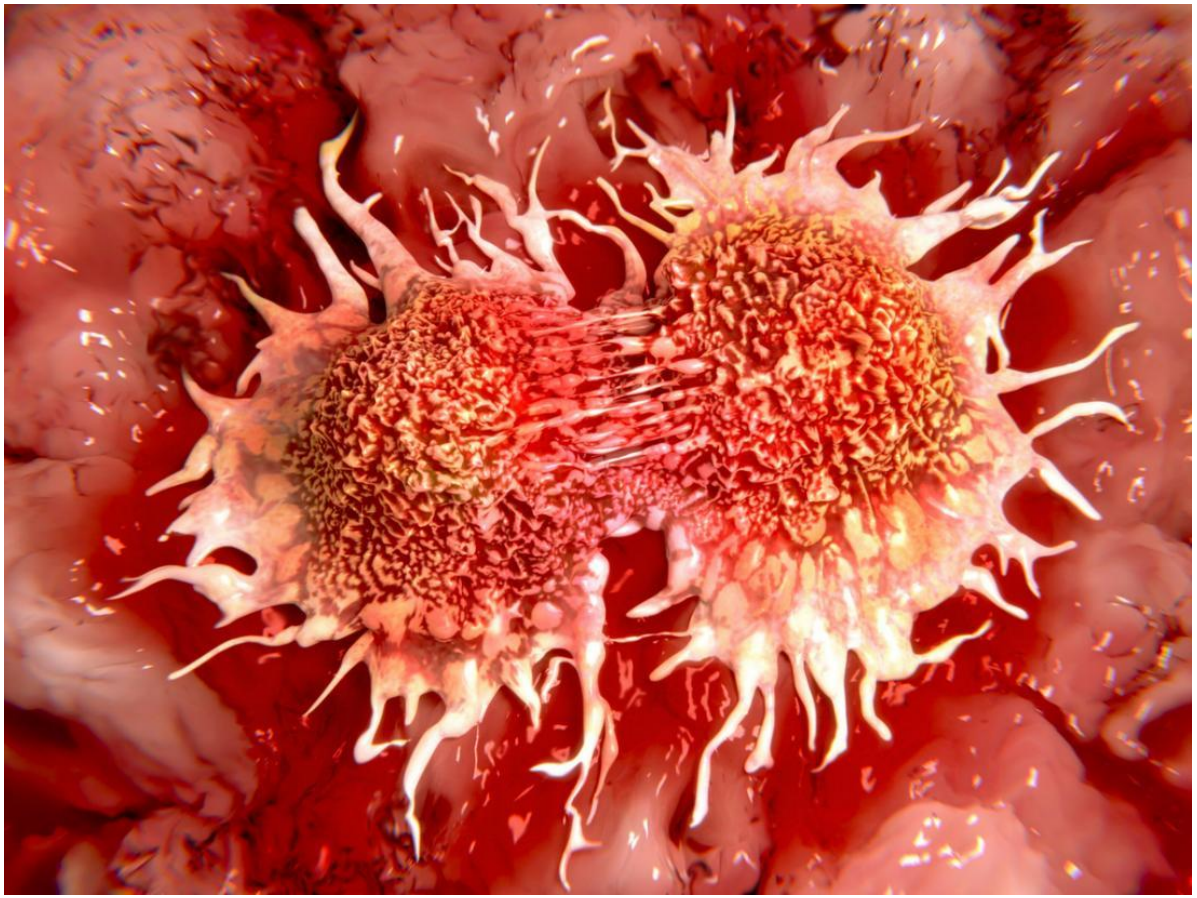
- Cancer cells exhibit **neither** density-dependent inhibition nor anchorage dependence

Figure 12.19



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

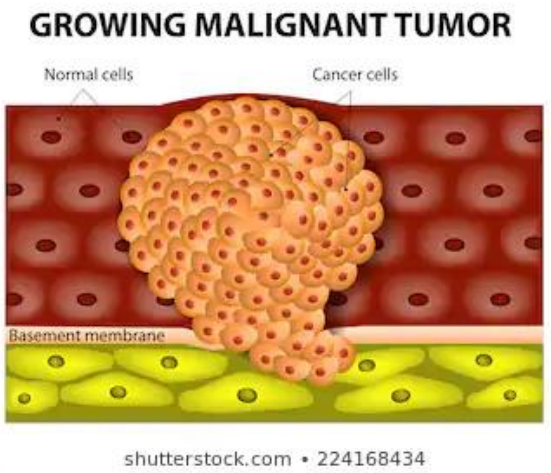
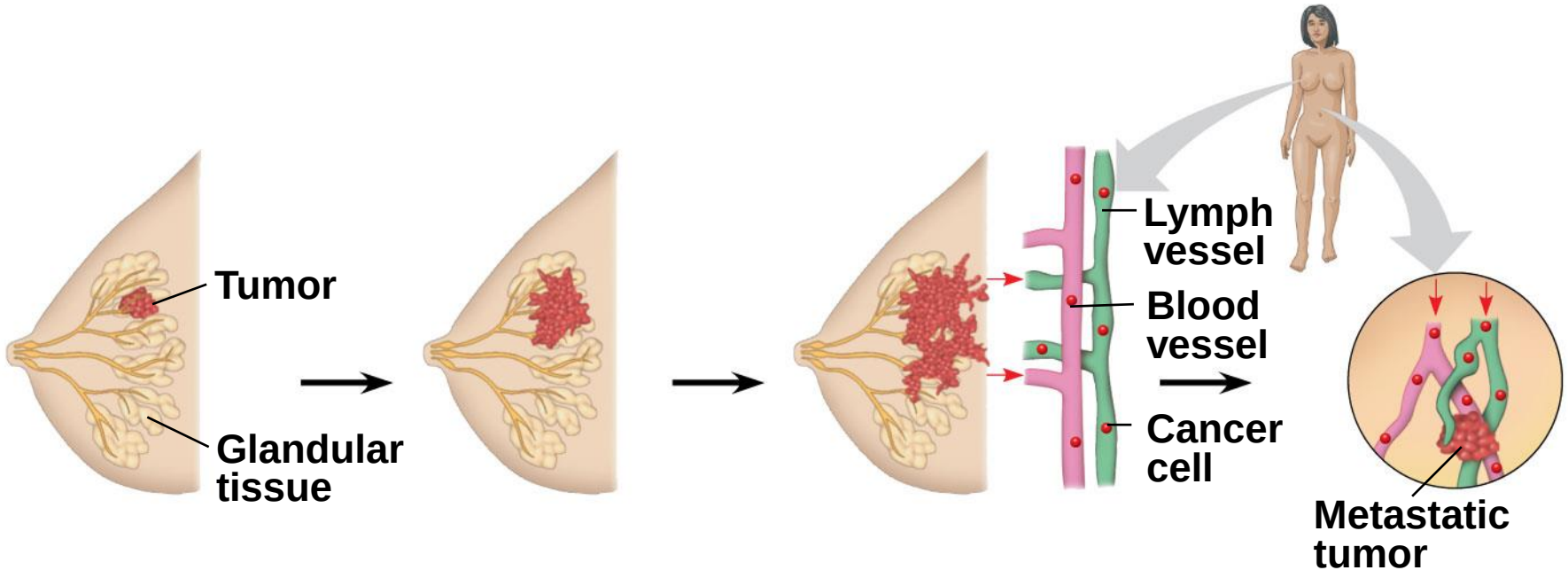


Figure 12.20



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

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