Chapter 12

The Cell Cycle

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PowerPoint® Lecture Presentations for

Biology

Eighth Edition

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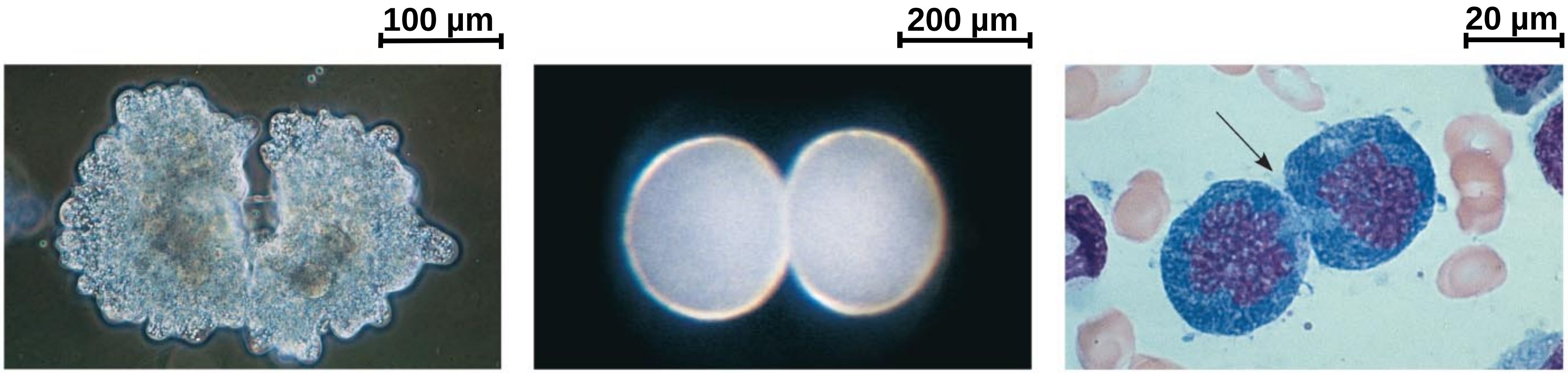
Overview: The Key Roles of Cell Division

- 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



(a) Reproduction **(b) Growth and development** **(c) Tissue renewal**

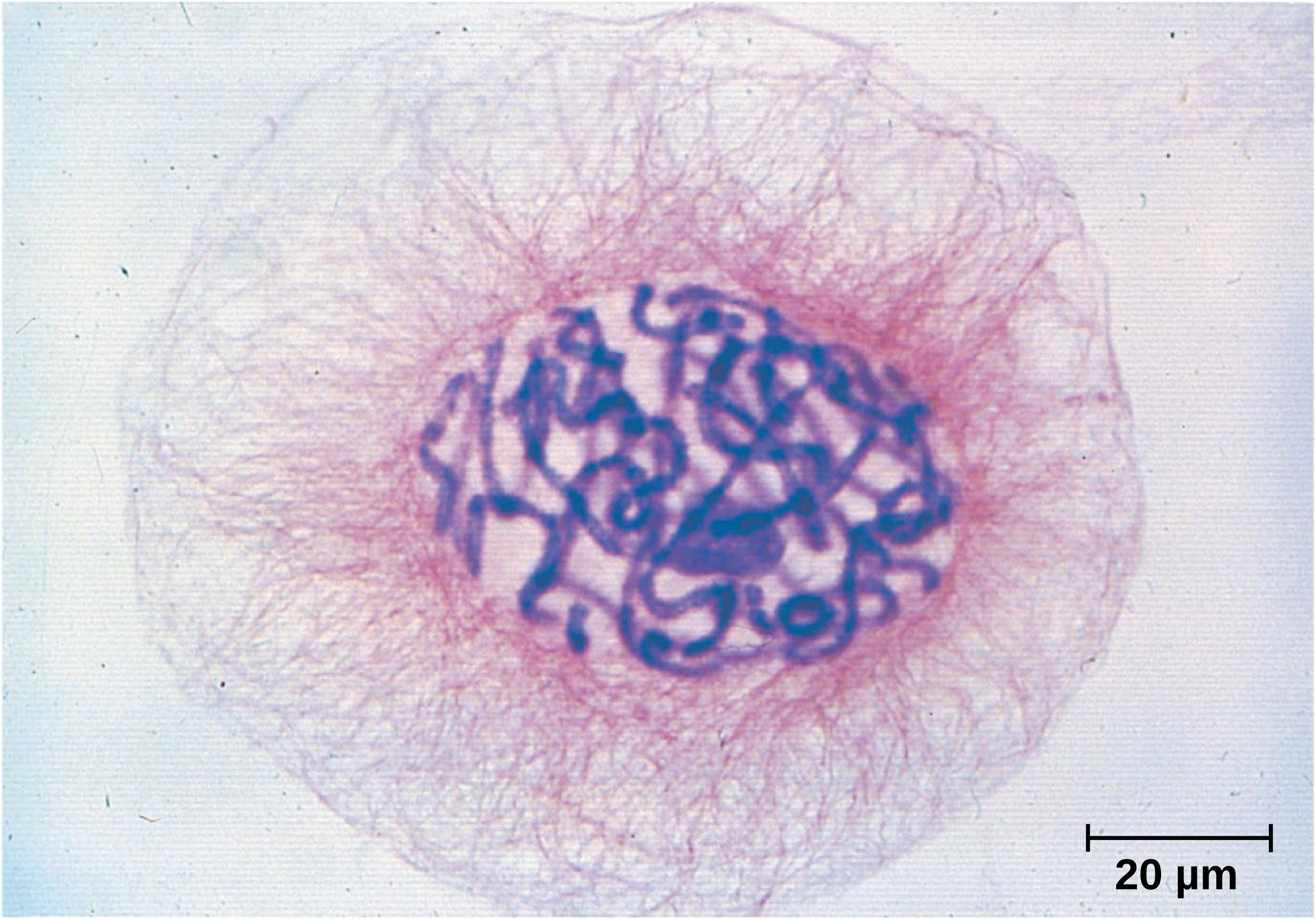
Concept 12.1: Cell division results in genetically identical daughter cells

- 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

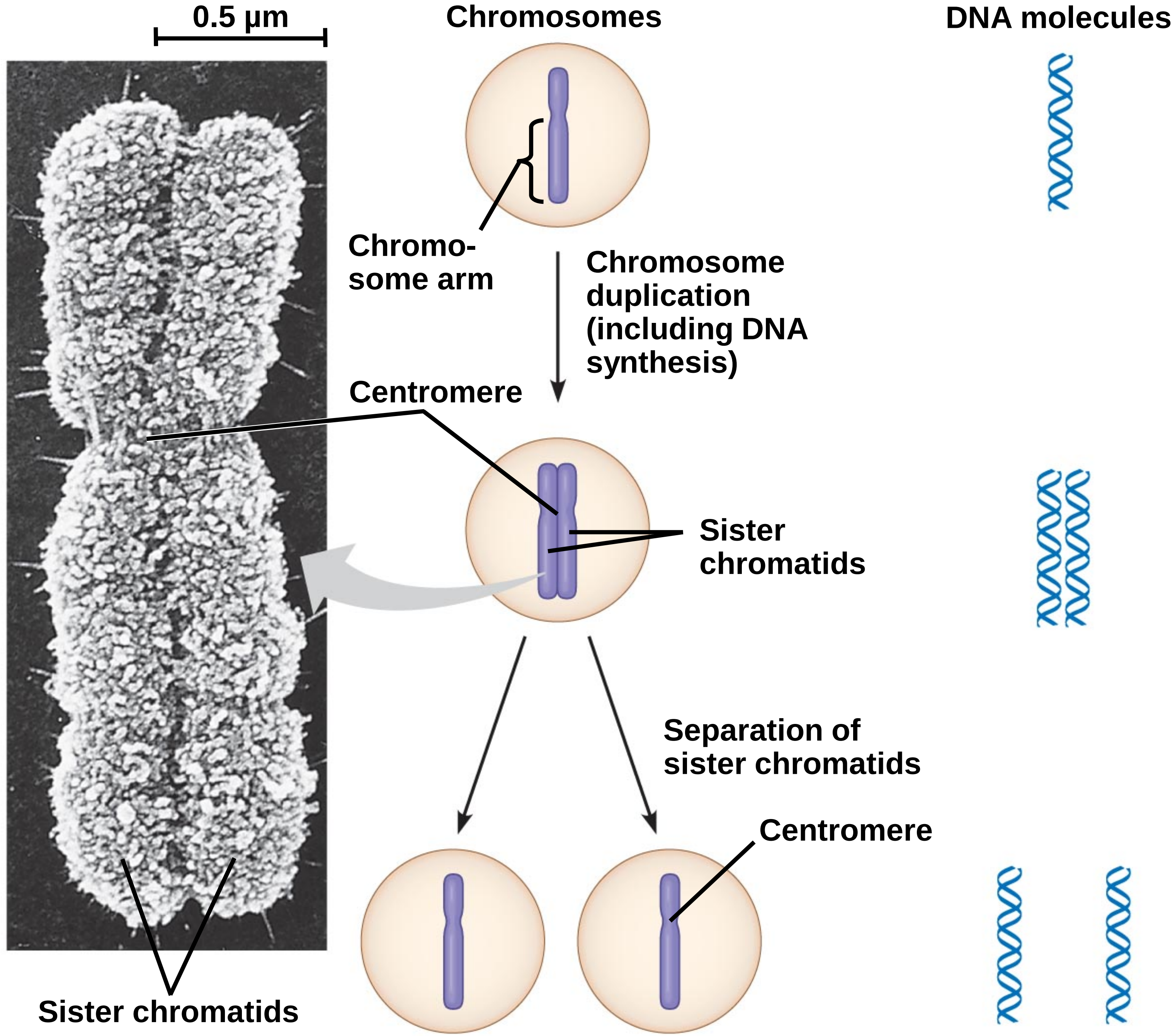


- Every eukaryotic species has a characteristic number of chromosomes in each cell nucleus
- **Somatic cells** (nonreproductive cells) have two sets of chromosomes
- **Gametes** (reproductive cells: sperm and eggs) have half as many chromosomes as somatic cells
- Eukaryotic chromosomes consist of **chromatin**,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


0.5 µm
Chromosomes
DNA molecules
Chromo-
some arm
Chromosome
duplication
(including DNA
synthesis)
Centromere
Sister
chromatids
Separation of
sister chromatids
Centromere
Sister chromatids

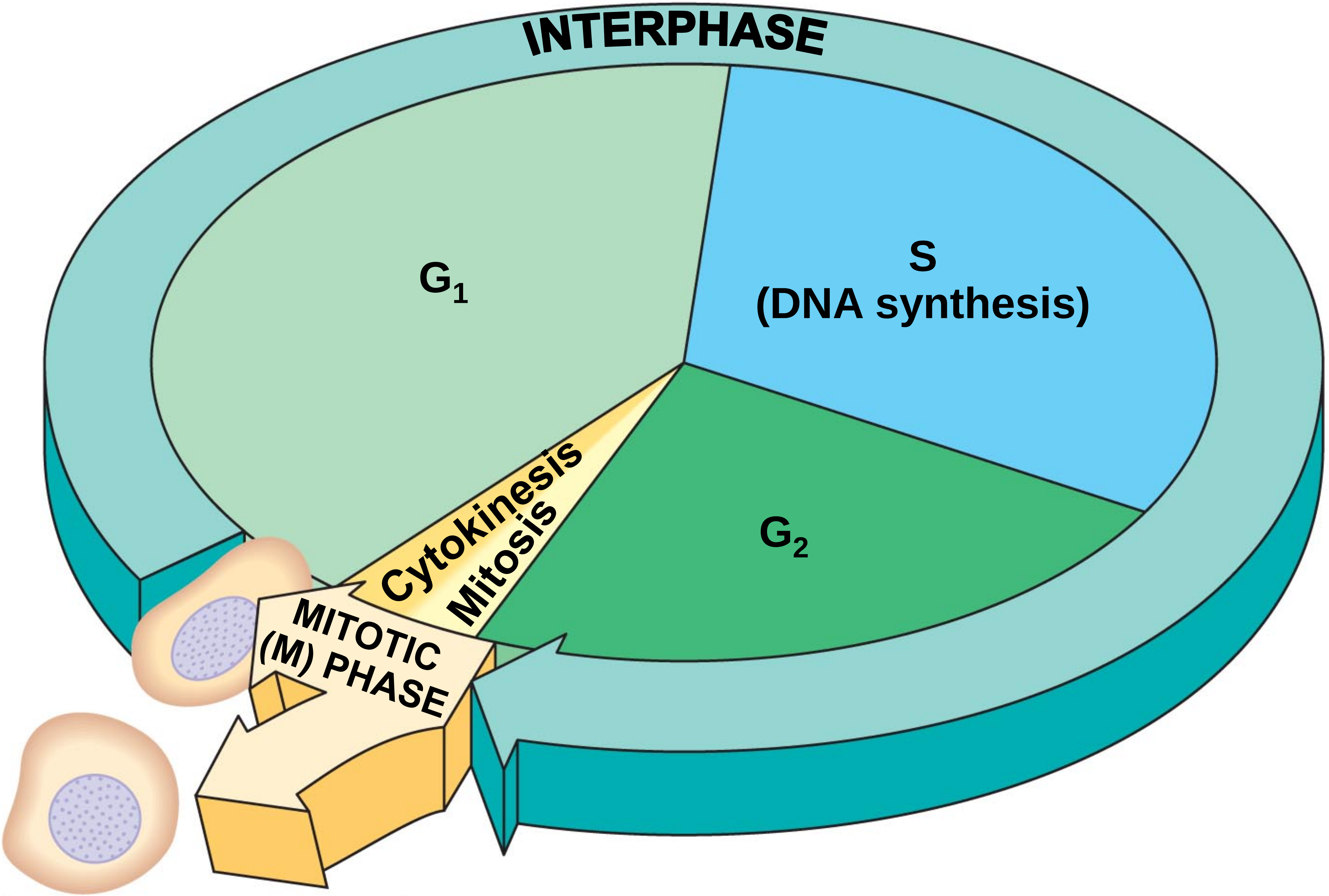
- Eukaryotic cell division consists of:
  - **Mitosis**, the division of the nucleus
  - **Cytokinesis**, the division of the cytoplasm
- Gametes are produced by a variation of cell division called **meiosis**
- Meiosis yields nonidentical daughter cells that have only one set of chromosomes, half as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

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

Fig. 12-5


INTERPHASE
G_1
S
(DNA synthesis)
G_2
Cytokinesis
Mitosis
MITOTIC
(M) PHASE

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

Fig. 12-6

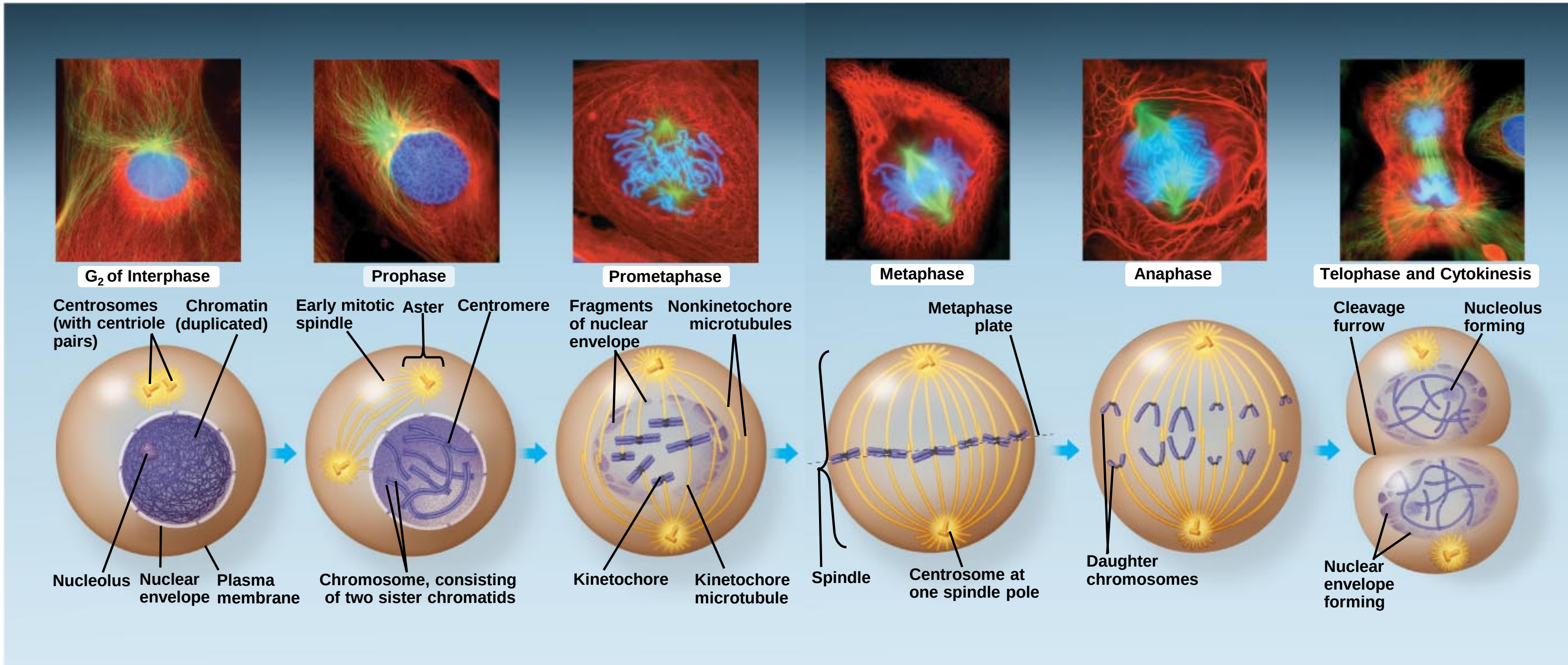

G2 of Interphase
Prophase
Prometaphase
Metaphase
Anaphase
Telophase and Cytokinesis
Centrosomes (with centriole pairs)
Chromatin (duplicated)
Early mitotic spindle
Aster
Centromere
Fragments of nuclear envelope
Nonkinetochore microtubules
Metaphase plate
Cleavage furrow
Nucleolus forming
Nucleolus
Nuclear envelope
Plasma membrane
Chromosome, consisting of two sister chromatids
Kinetochore
Kinetochore microtubule
Spindle
Centrosome at one spindle pole
Daughter chromosomes
Nuclear envelope forming

Fig. 12-6a

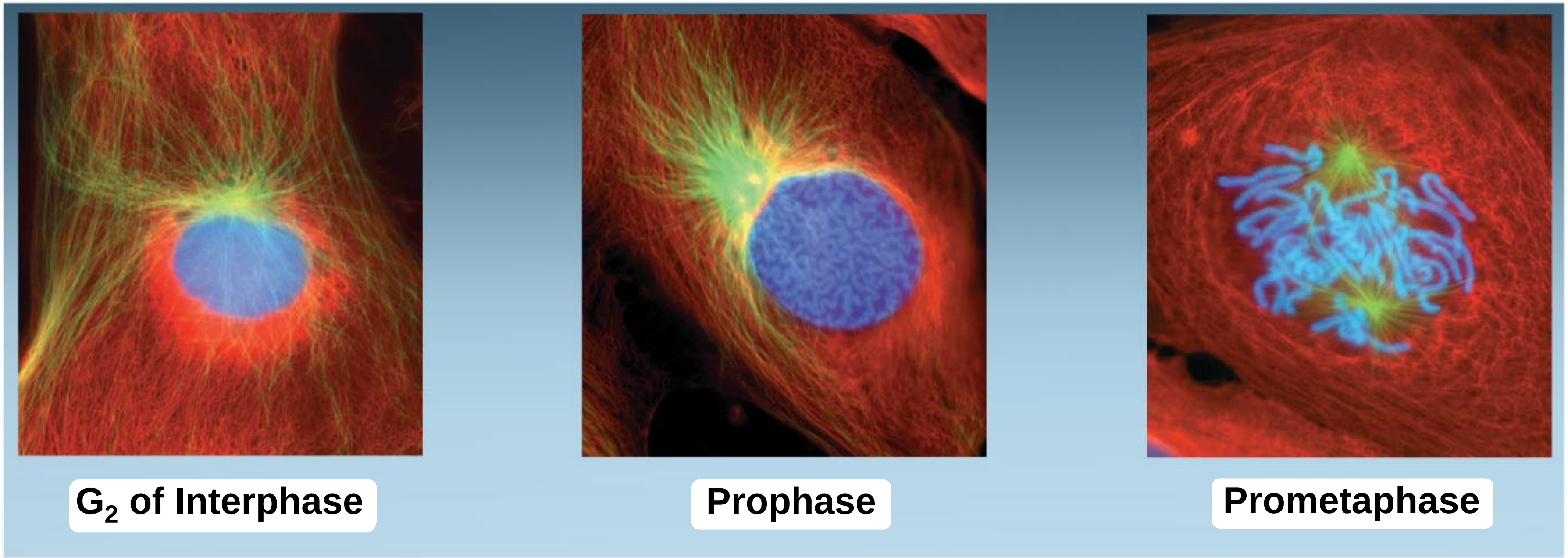
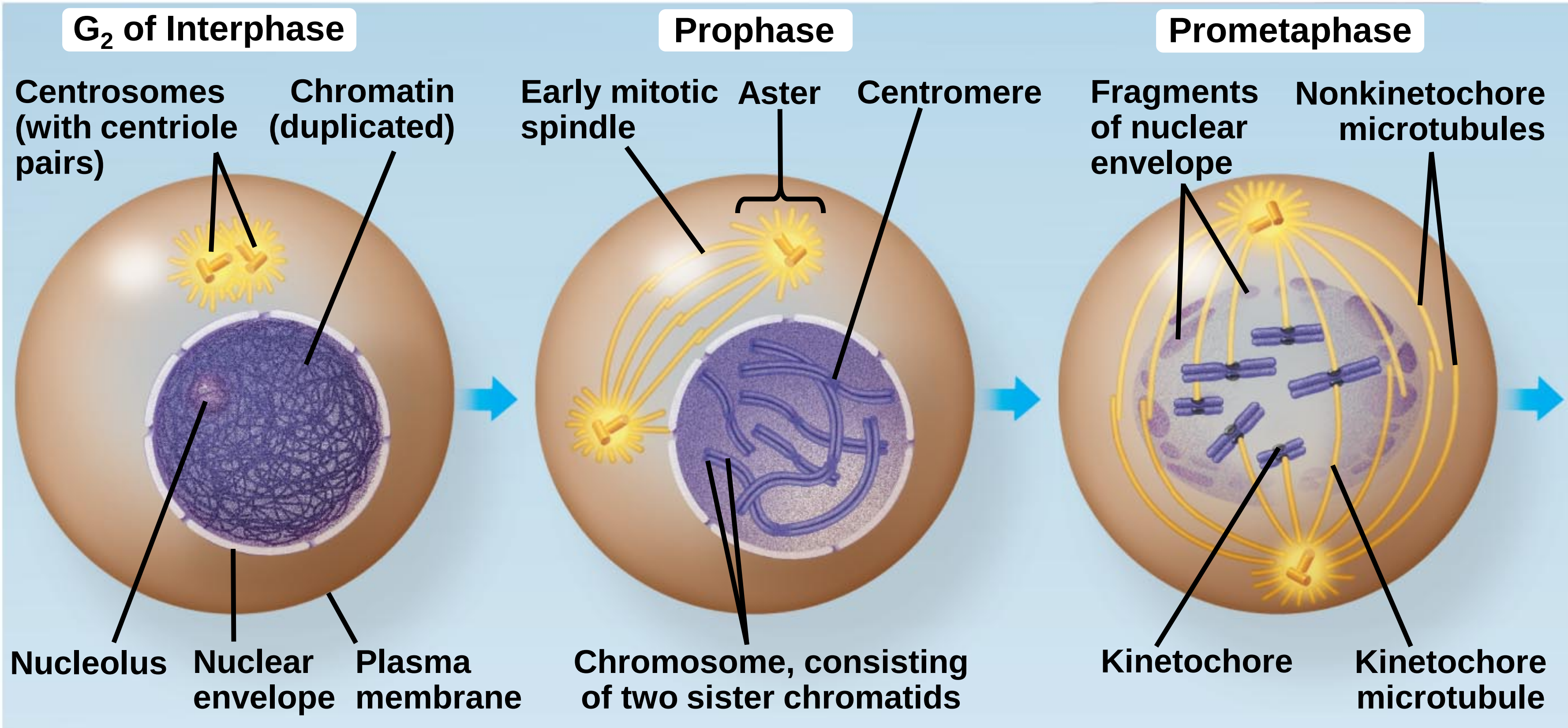


Fig. 12-6b



G_2 of Interphase
Prophase
Prometaphase
Centrosomes (with centriole pairs)
Chromatin (duplicated)
Early mitotic spindle
Aster
Centromere
Fragments of nuclear envelope
Nonkinetochore microtubules
Nucleolus
Nuclear envelope
Plasma membrane
Chromosome, consisting of two sister chromatids
Kinetochore
Kinetochore microtubule

Fig. 12-6c

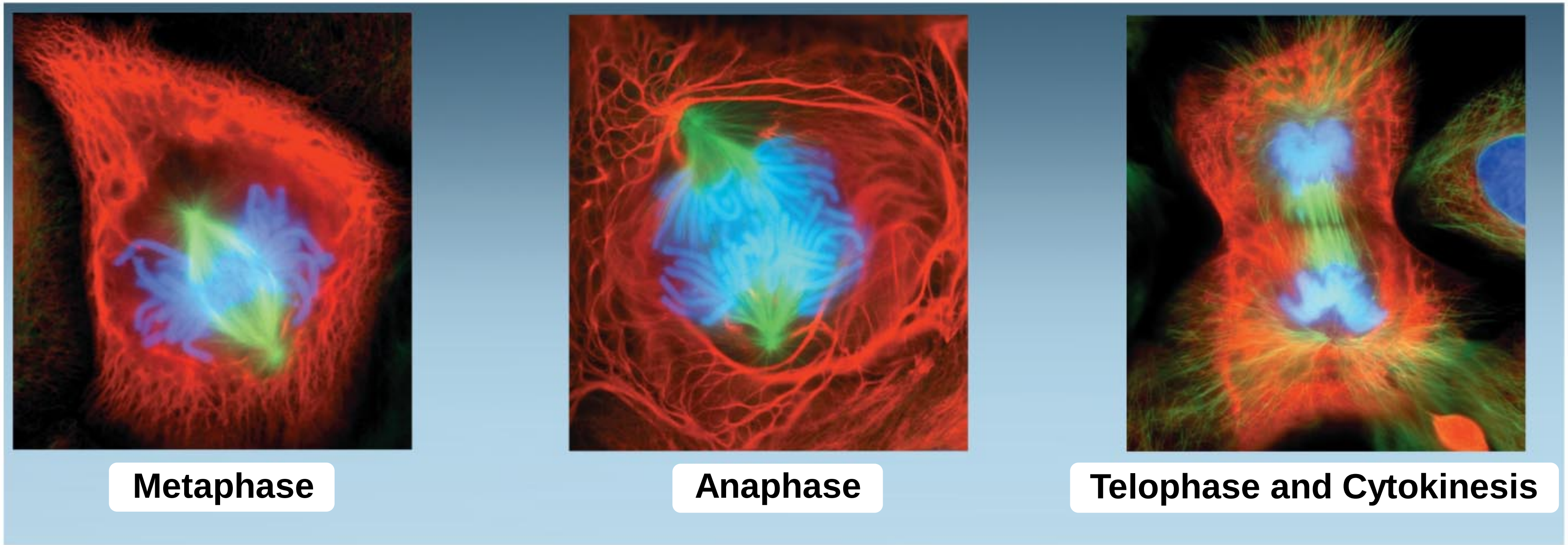
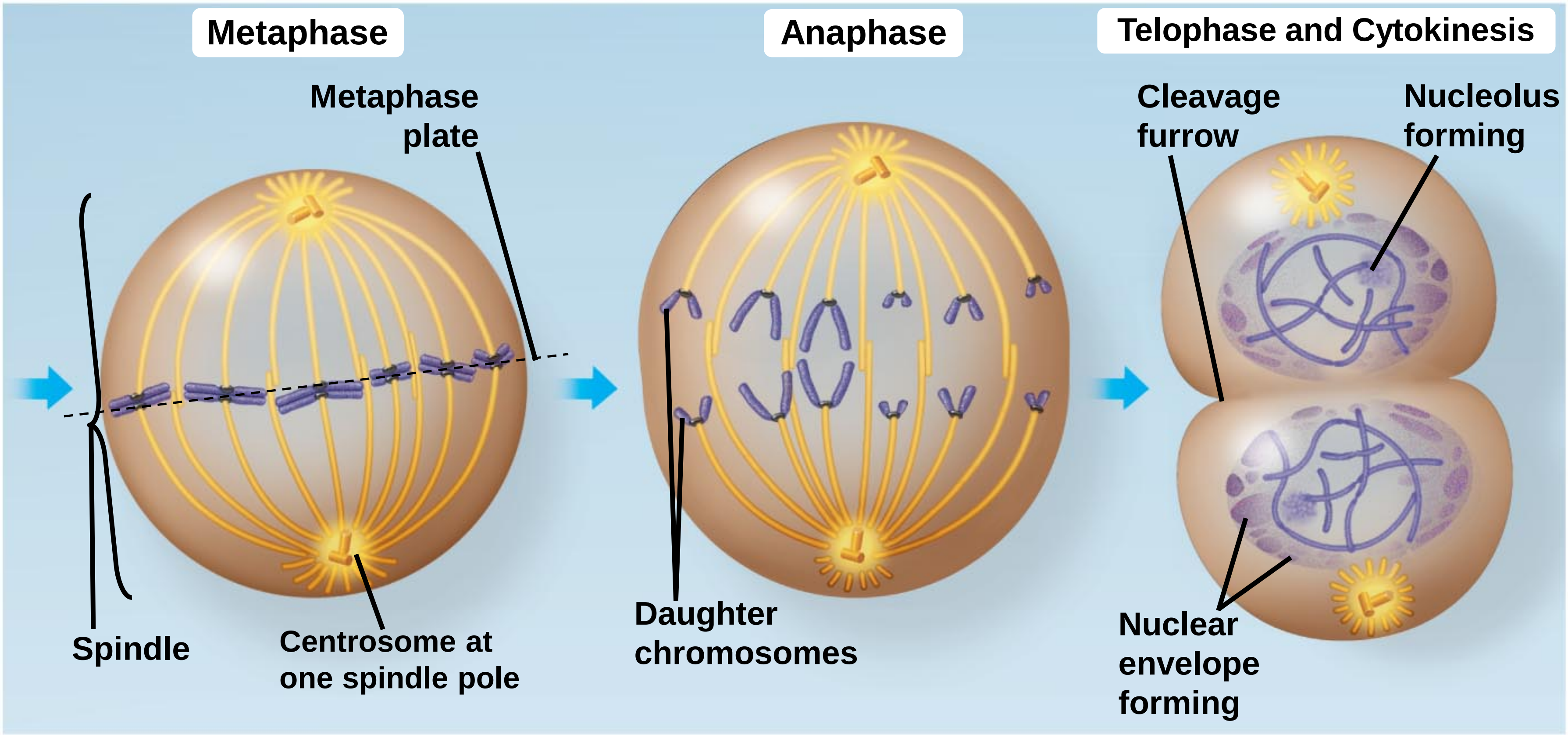


Fig. 12-6d



Metaphase
Anaphase
Telophase and Cytokinesis
Metaphase plate
Cleavage furrow
Nucleolus forming
Spindle
Centrosome at one spindle pole
Daughter chromosomes
Nuclear envelope forming

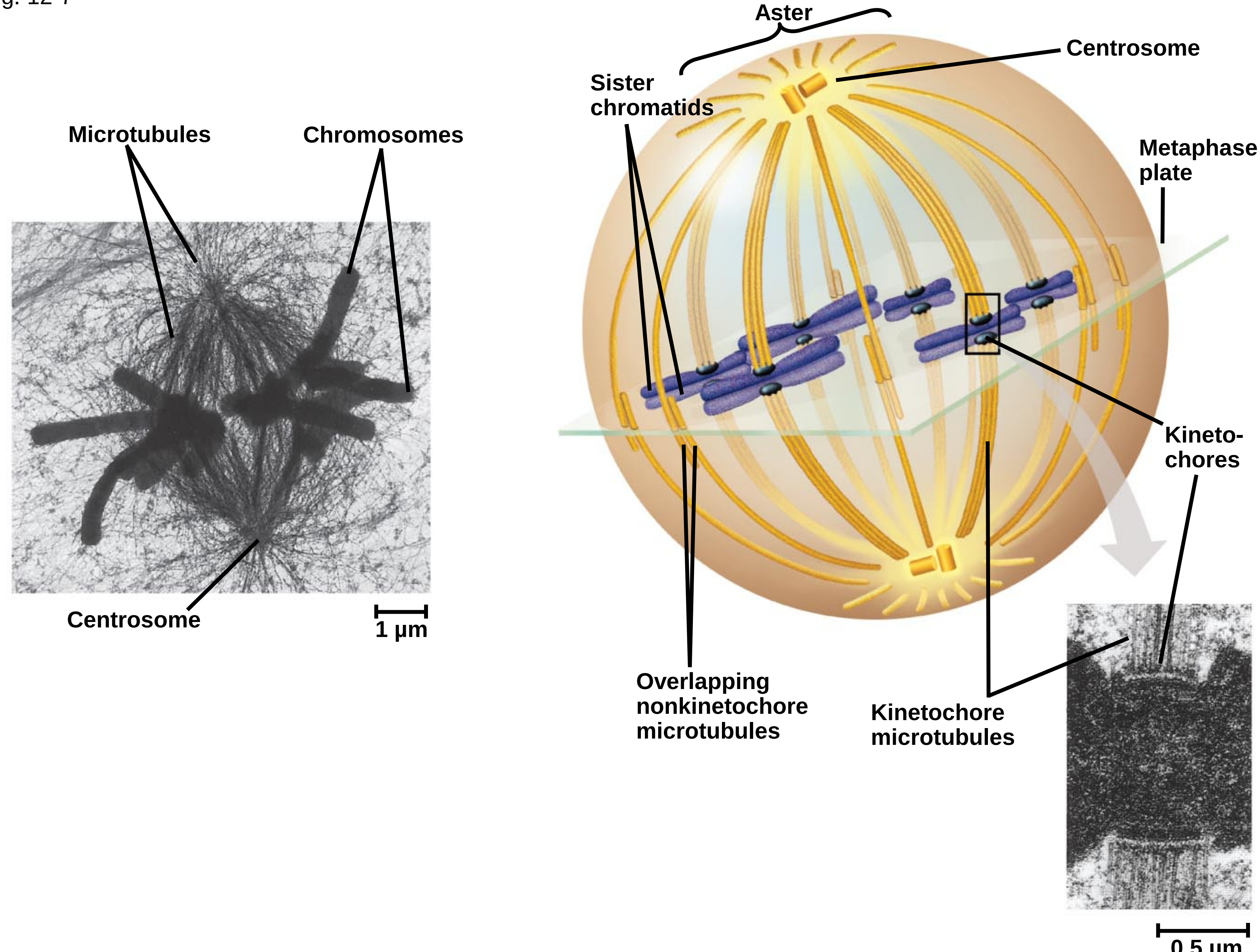
The Mitotic Spindle: *A Closer Look*

- 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

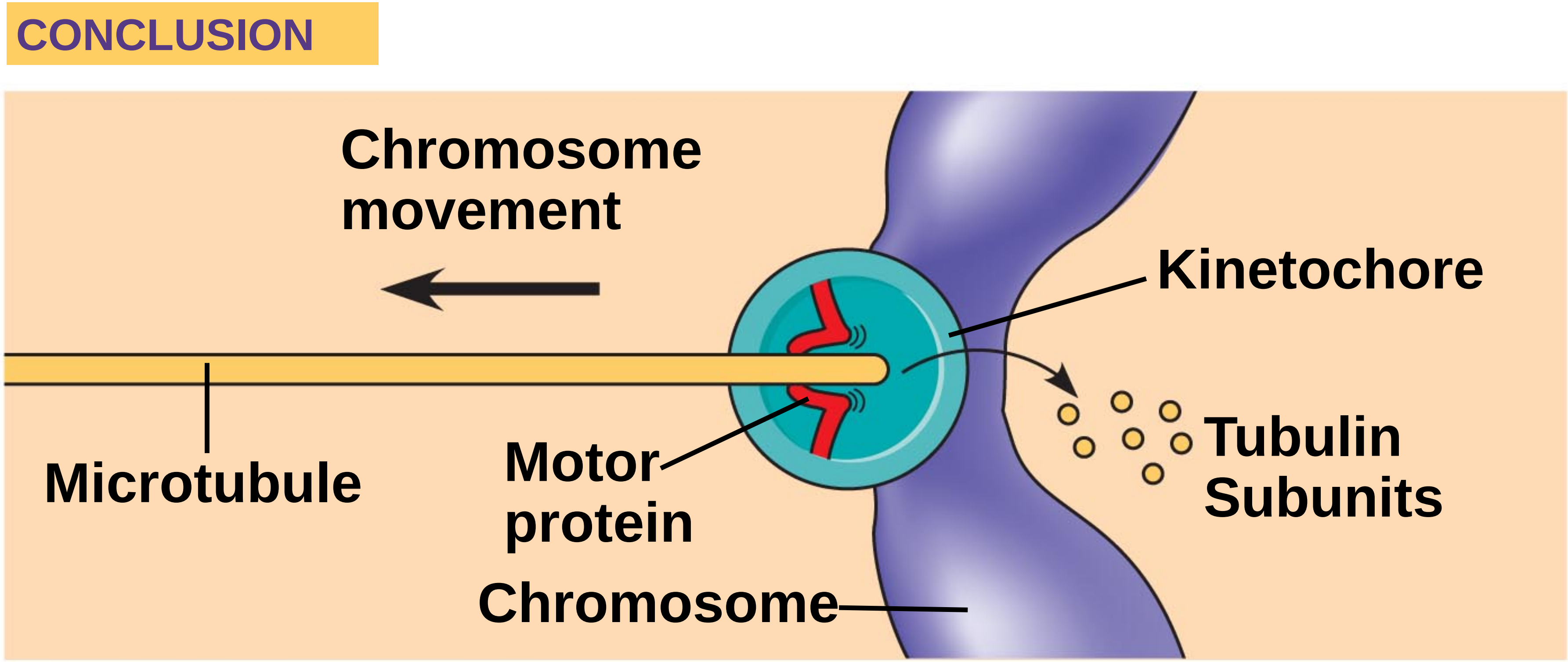
Fig. 12-7



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

- 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. 12-8b



Animation

- 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

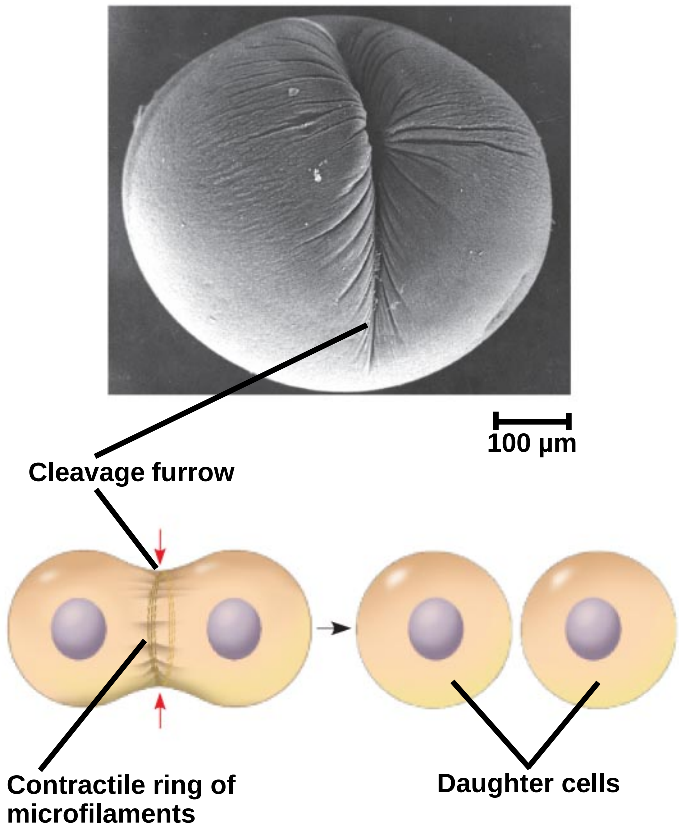
Cytokinesis: *A Closer Look*

- In animal cells, cytokinesis occurs by a process known as **cleavage**, forming a **cleavage furrow**

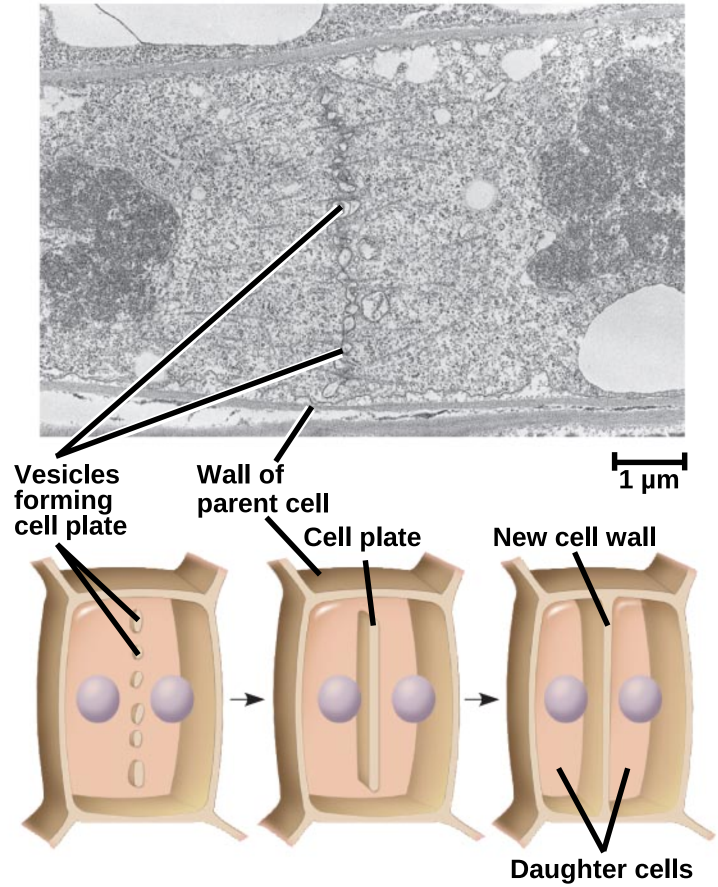
- In plant cells, a **cell plate** forms during cytokinesis

Fig. 12-9

Bioflix Mitosis



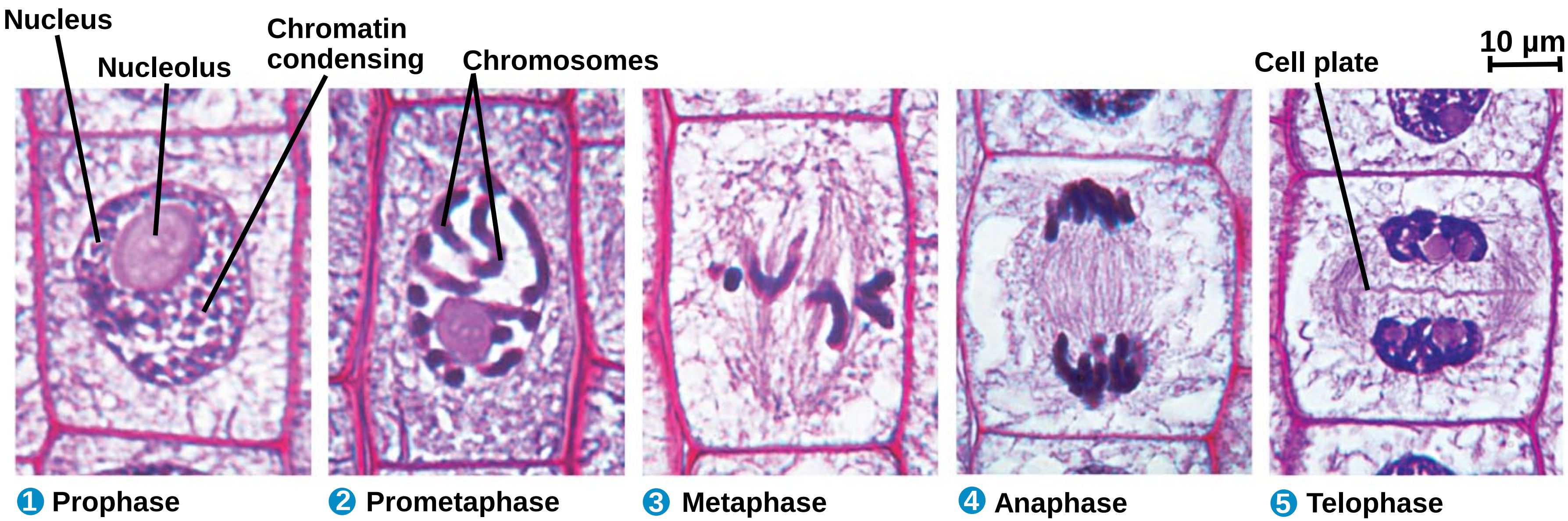
(a) Cleavage of an animal cell (SEM)



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

- Animal Cell Mitosis
- Plant Cell Mitosis

Fig. 12-10


Nucleus
Nucleolus
Chromatin condensing
Chromosomes
Cell plate
10 µm
1 Prophase
2 Prometaphase
3 Metaphase
4 Anaphase
5 Telophase

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
- Since prokaryotes evolved before eukaryotes, mitosis probably evolved from binary fission

Fig. 12-11-1

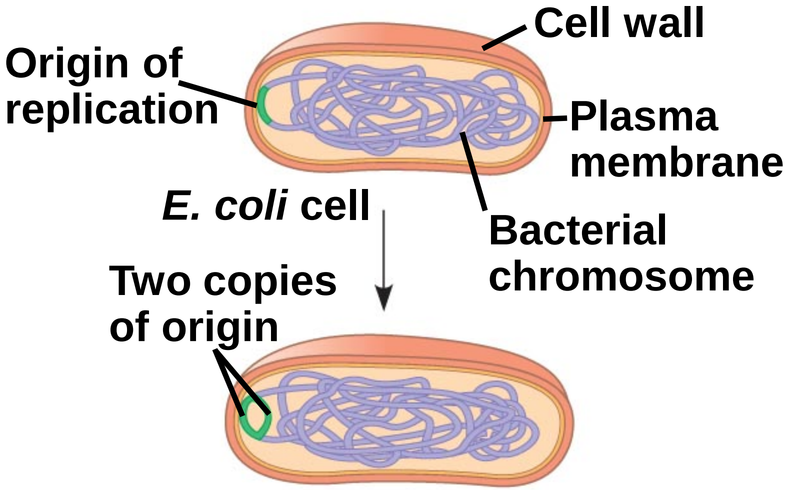

Cell wall
Origin of
replication
Plasma
membrane
E. coli cell
Bacterial
chromosome
Two copies
of origin

Fig. 12-11-2

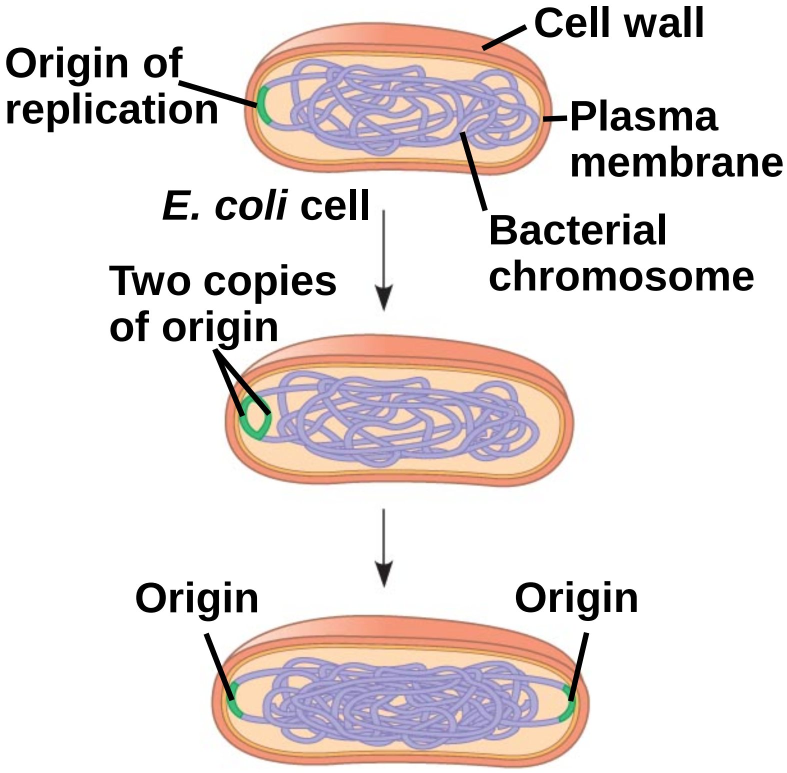

Cell wall
Origin of replication
Plasma membrane
E. coli cell
Bacterial chromosome
Two copies of origin
Origin
Origin

Fig. 12-11-3

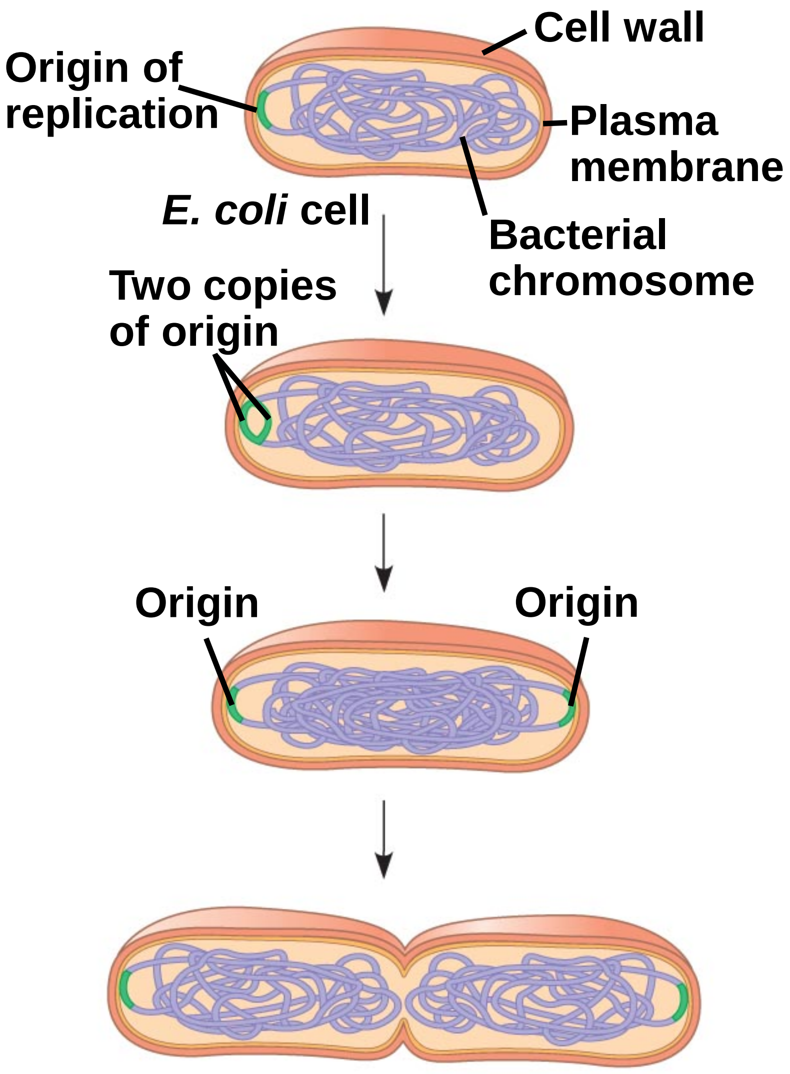
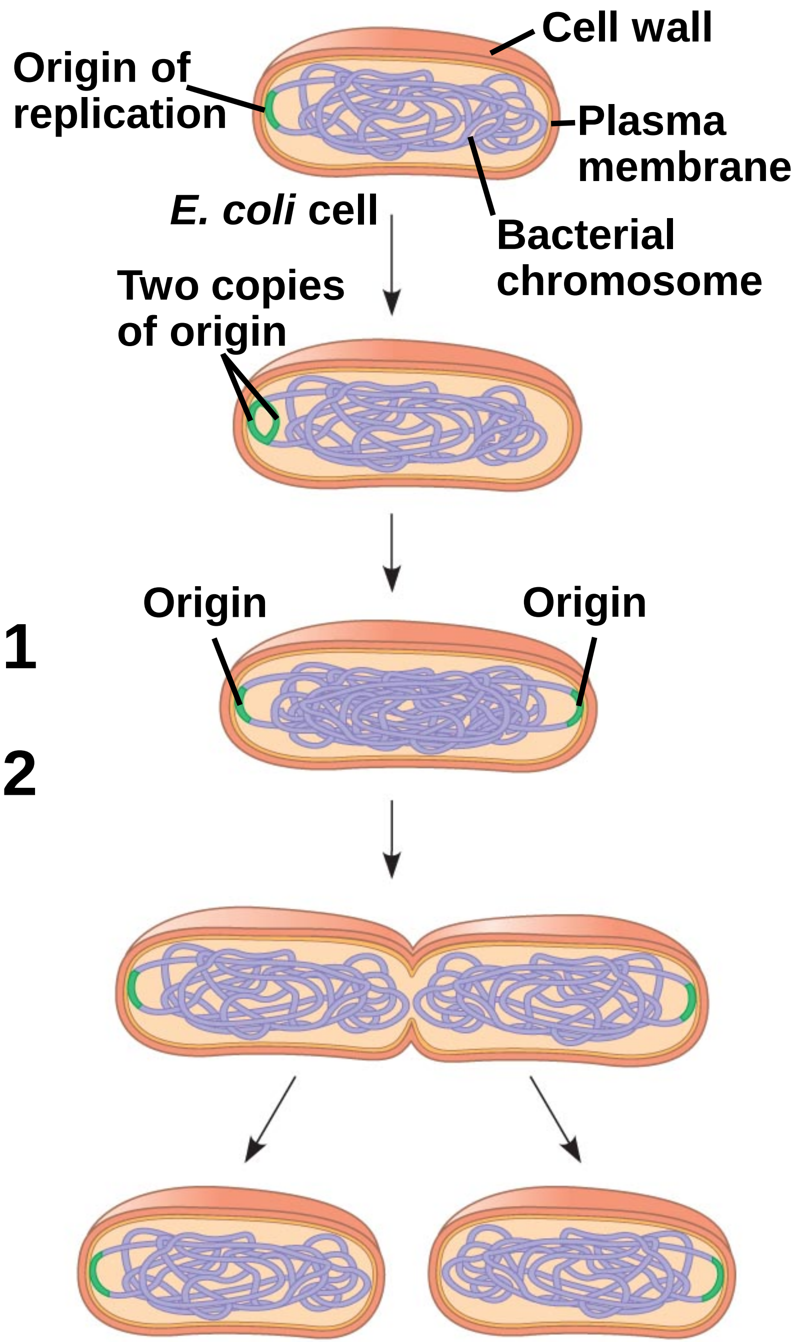

Cell wall
Origin of replication
Plasma membrane
E. coli cell
Bacterial chromosome
Two copies of origin
Origin
Origin

Fig. 12-11-4

- [Binary Fission](#) 1
- [Binary Fission](#) 2

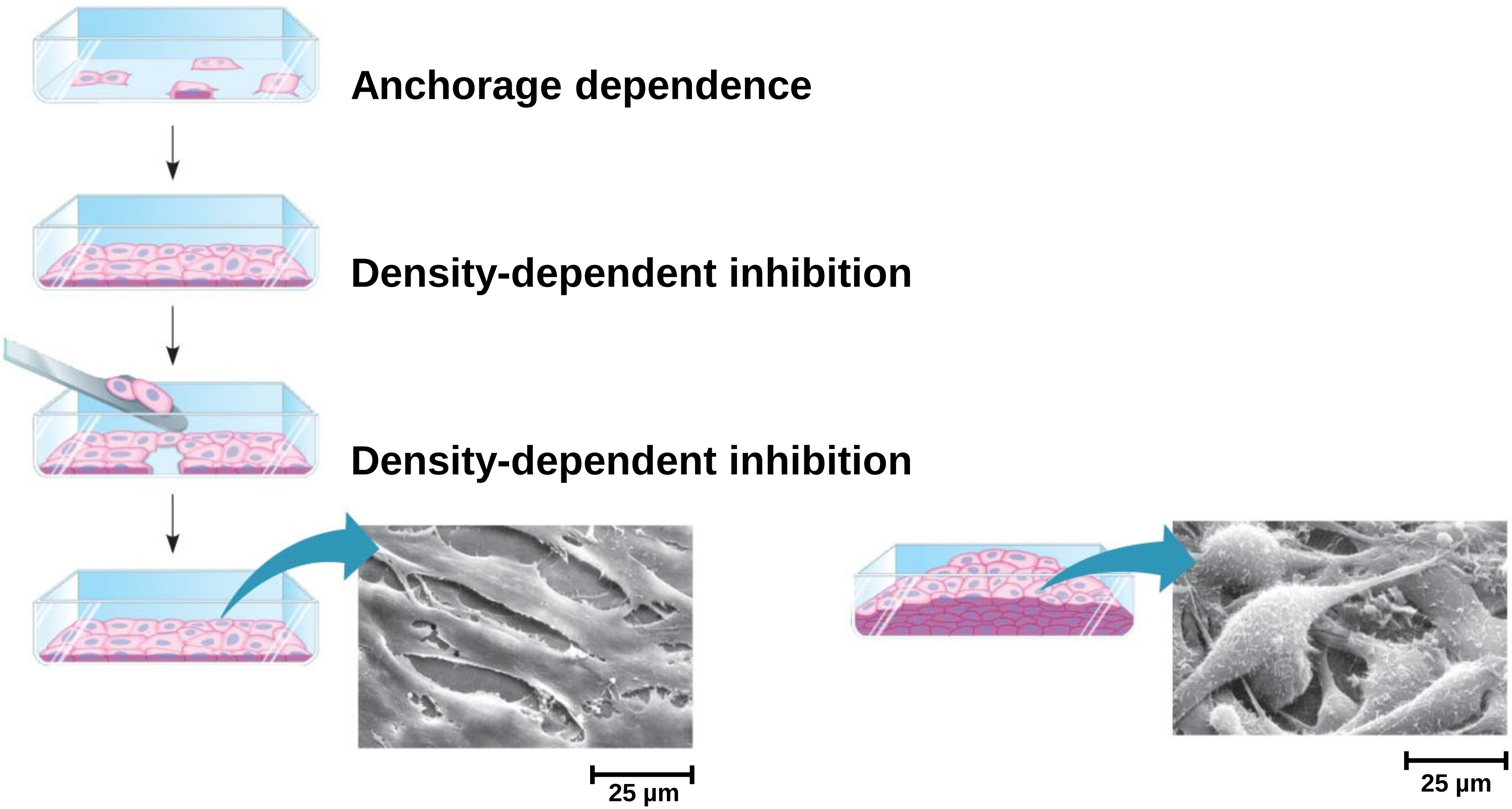


Concept 12.3: The eukaryotic cell cycle is regulated by a molecular control system

- The frequency of cell division varies with the type of cell
- These cell cycle differences result from regulation at the molecular level
- Many different chemical signals involved
  - - regulatory proteins, growth factors etc.

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

Fig. 12-19



(a) Normal mammalian cells **(b) Cancer cells**

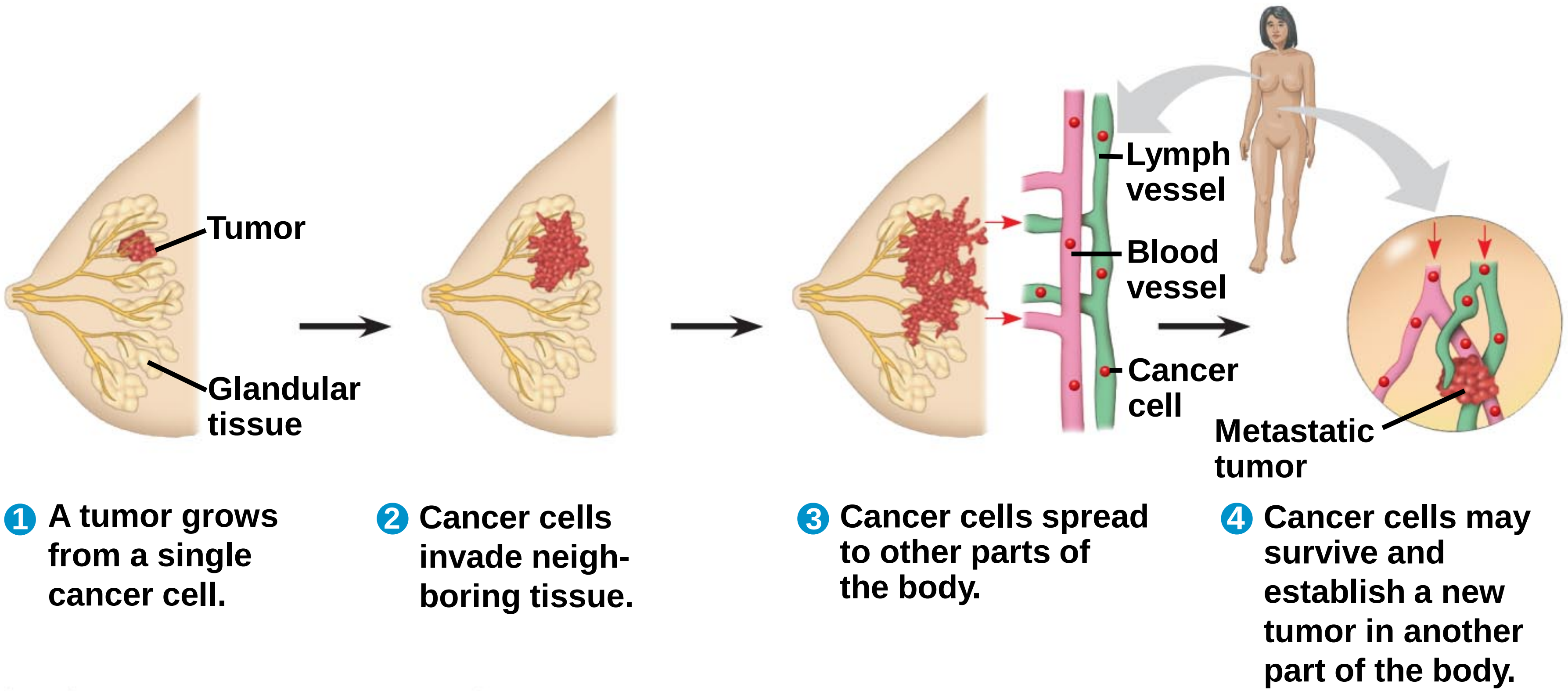
- Cancer cells exhibit neither density-dependent inhibition nor anchorage dependence (loss of contact inhibition)

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



- **Current research suggests that bacteria in breast tissue along with genetic mutations, increases risk for developing breast cancer.**

Fig. 12-UN1

• Summary

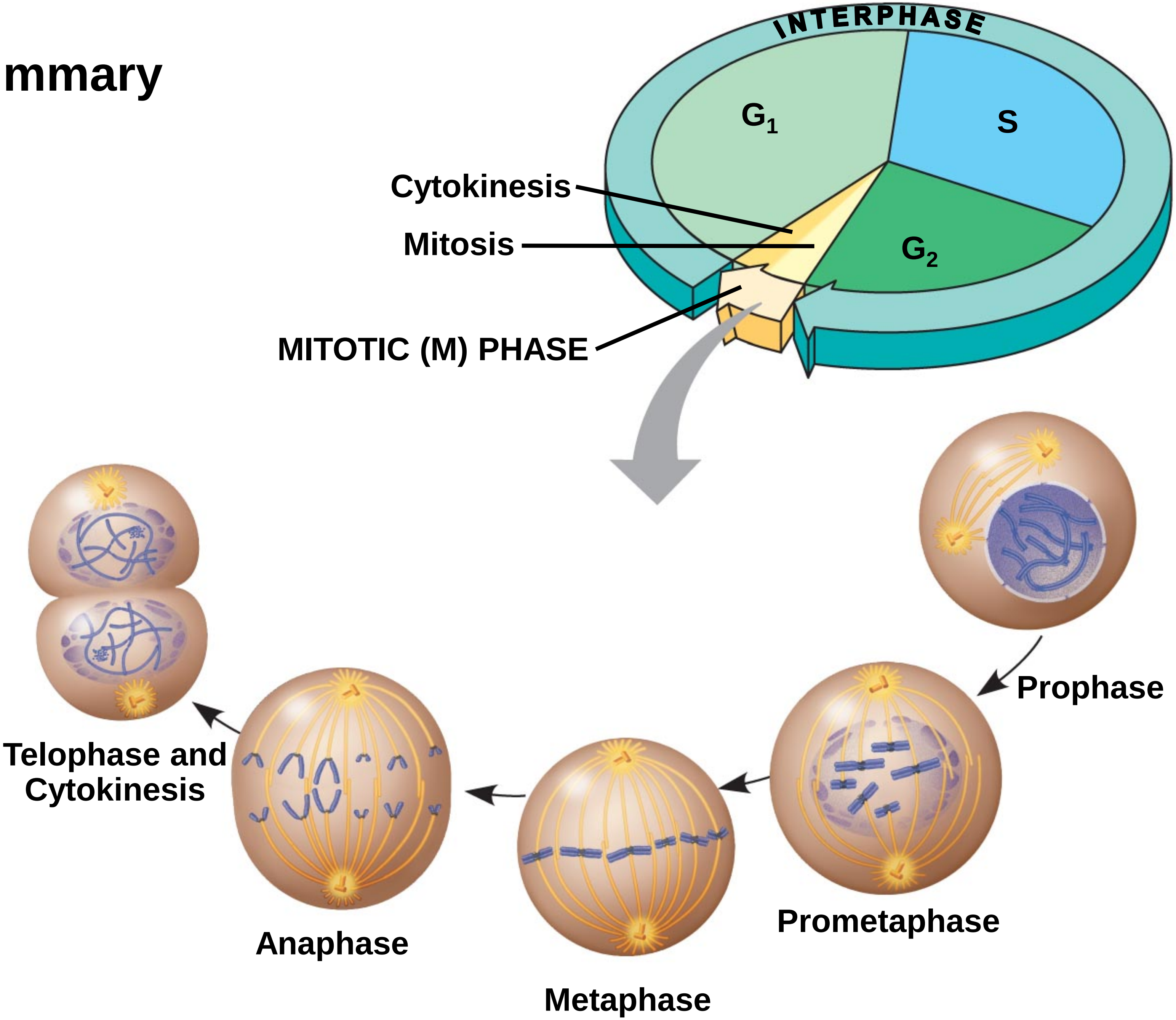
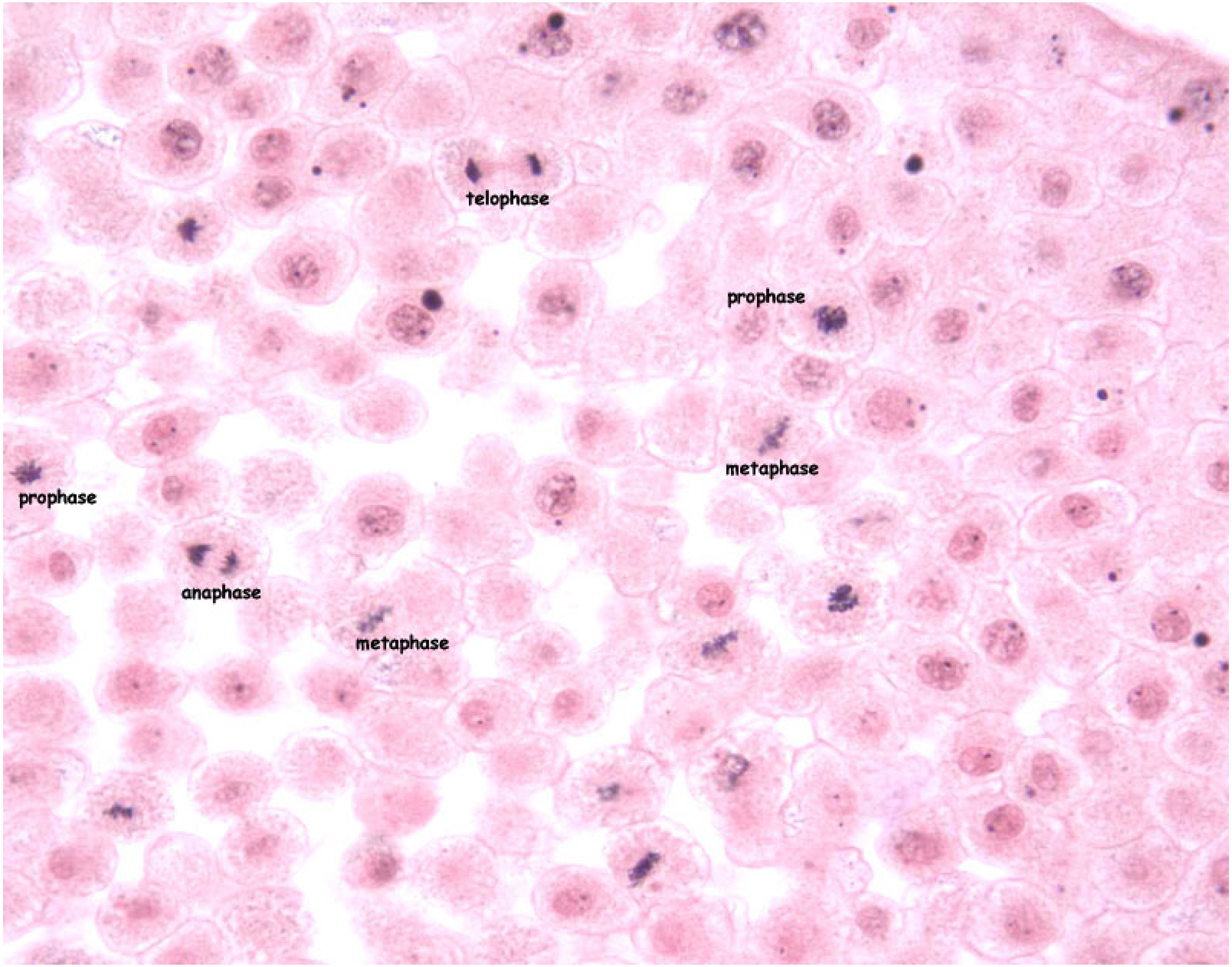
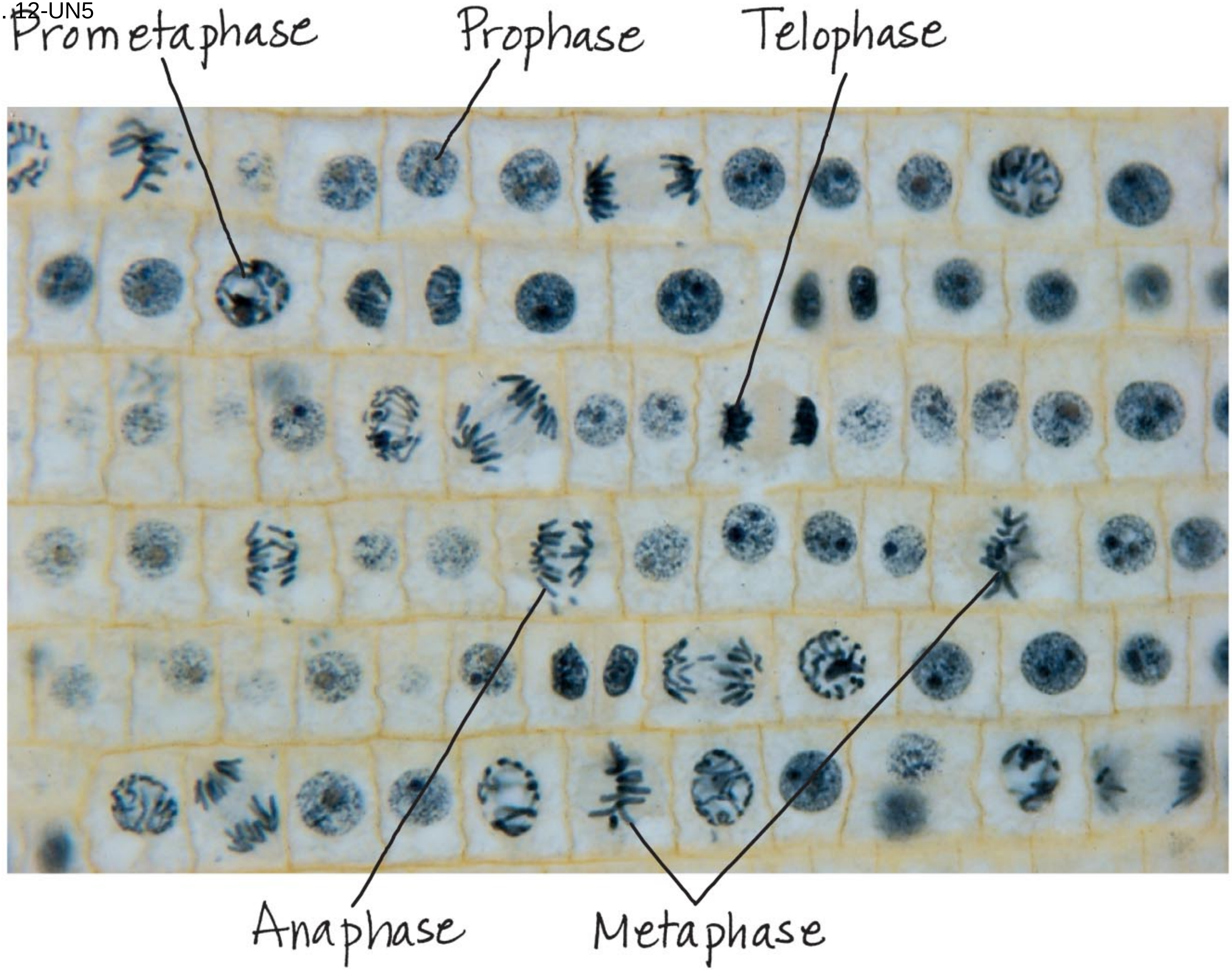


Fig. 12-UN2



telophase
prophase
metaphase
prophase
anaphase
metaphase

Fig. 12-UN5



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