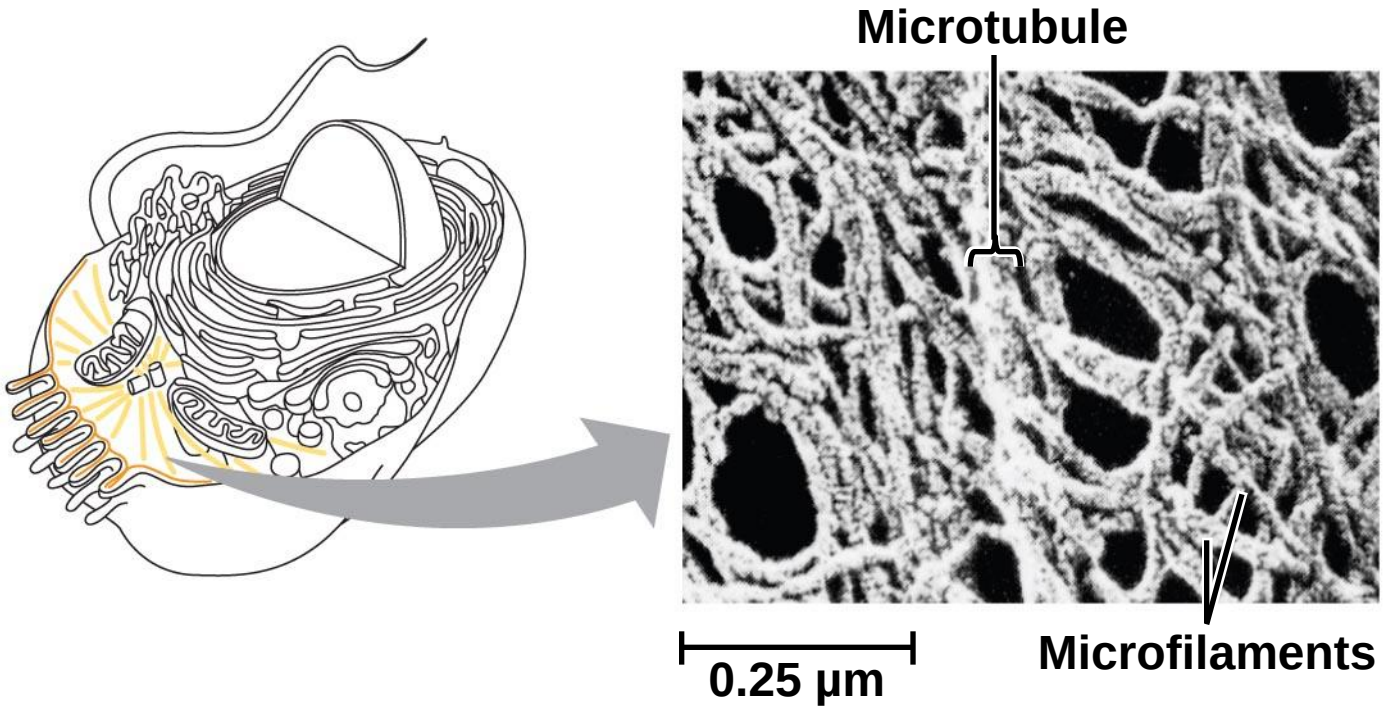
Concept 6.6: The cytoskeleton is a network of fibers that organizes structures and activities in the cell

- The **cytoskeleton** is a network of fibers extending throughout the cytoplasm
- It organizes the cell's structures and activities, anchoring many organelles
- It is composed of three types of molecular structures:
  - Microtubules
  - Microfilaments
  - Intermediate filaments

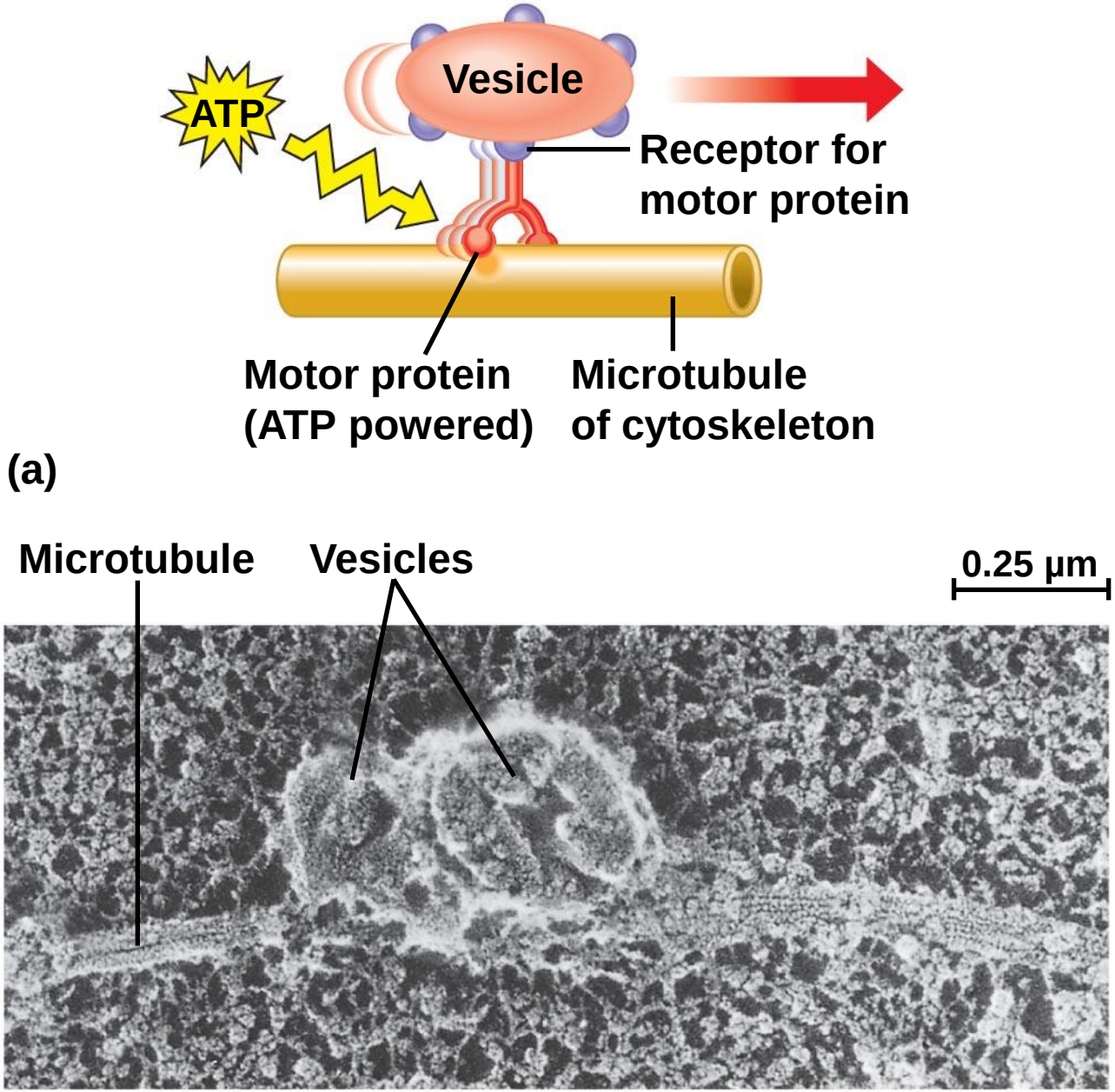
Fig. 6-20



Roles of the Cytoskeleton: Support, Motility, and Regulation

- The cytoskeleton helps to support the cell and maintain its shape
- It interacts with **motor proteins** to produce motility
- Inside the cell, vesicles can travel along "monorails" provided by the cytoskeleton
- Recent evidence suggests that the cytoskeleton may help regulate biochemical activities

Fig. 6-21



Components of the Cytoskeleton

- Three main types of fibers make up the cytoskeleton:
  - *Microtubules* are the thickest of the three components of the cytoskeleton
  - *Microfilaments*, also called actin filaments, are the thinnest components
  - *Intermediate filaments* are fibers with diameters in a middle range

Table 6-1

Table 6.1 The Structure and Function of the Cytoskeleton

Property	Microtubules (Tubulin Polymers)	Microfilaments (Actin Filaments)	Intermediate Filaments
Structure	Hollow tubes; wall consists of 13 columns of tubulin molecules	Two intertwined strands of actin, each a polymer of actin subunits	Fibrous proteins supercoiled into thicker cables
Diameter	25 nm with 15-nm lumen	7 nm	8–12 nm
Protein subunits	Tubulin, a dimer consisting of α-tubulin and β-tubulin	Actin	One of several different proteins of the keratin family, depending on cell type
Main functions	Maintenance of cell shape (compression-resisting "girders") Cell motility (as in cilia or flagella) Chromosome movements in cell division Organelle movements	Maintenance of cell shape (tension-bearing elements) Changes in cell shape Muscle contraction Cytoplasmic streaming Cell motility (as in pseudopodia) Cell division (cleavage furrow formation)	Maintenance of cell shape (tension-bearing elements) Anchorage of nucleus and certain other organelles Formation of nuclear lamina

Micrographs of fibroblasts, a favorite cell type for cell biology studies. Each has been experimentally treated to fluorescently tag the structure of interest.

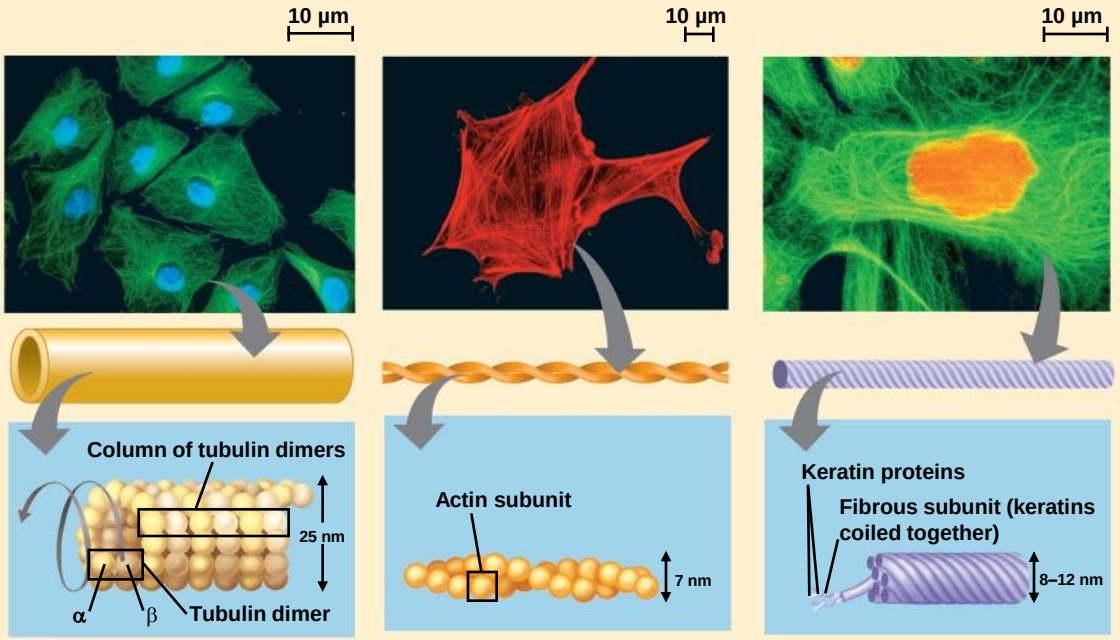


Table 6-1a

Property	Microtubules (Tubulin Polymers)
Structure	Hollow tubes; wall consists of 13 columns of tubulin molecules
Diameter	25 nm with 15-nm lumen
Protein subunits	Tubulin
Main functions	Maintenance of cell shape Cell motility Chromosome movements in cell division Organelle movements

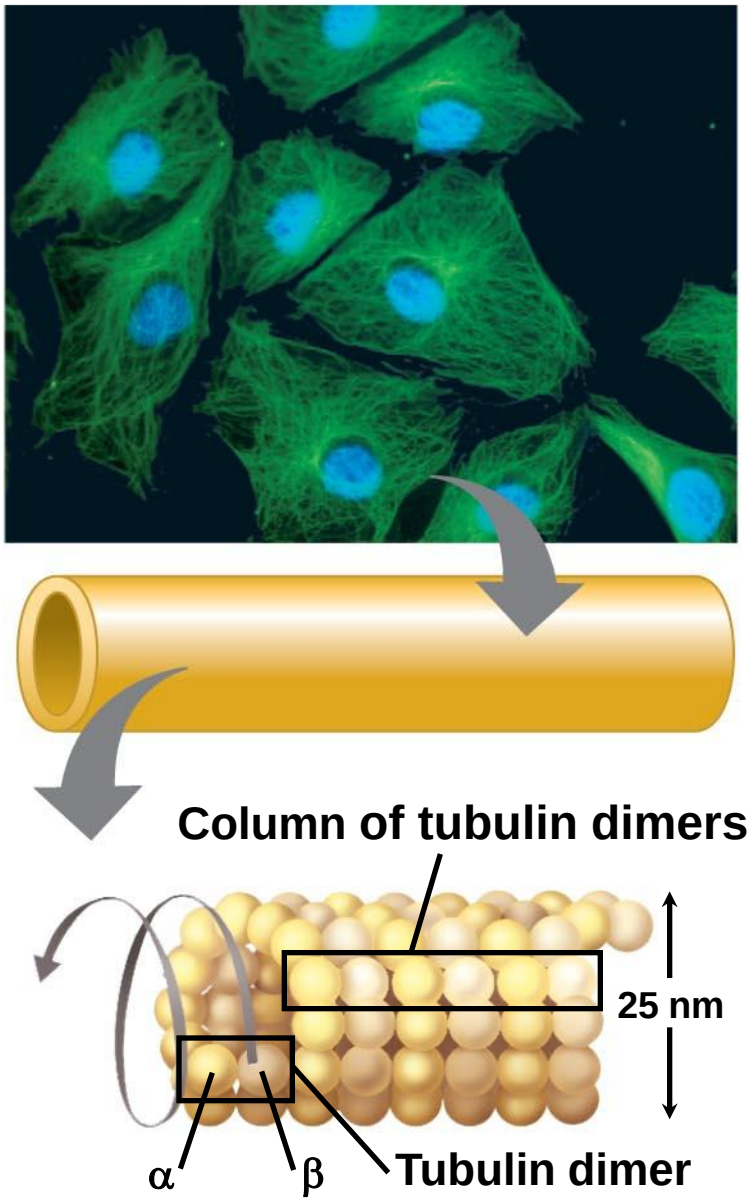


Table 6-1b

Property	Microfilaments (Actin Filaments)
Structure	Two intertwined strands of actin
Diameter	7 nm
Protein subunits	Actin
Main functions	Maintenance of cell shape Changes in cell shape Muscle contraction Cytoplasmic streaming Cell motility Cell division

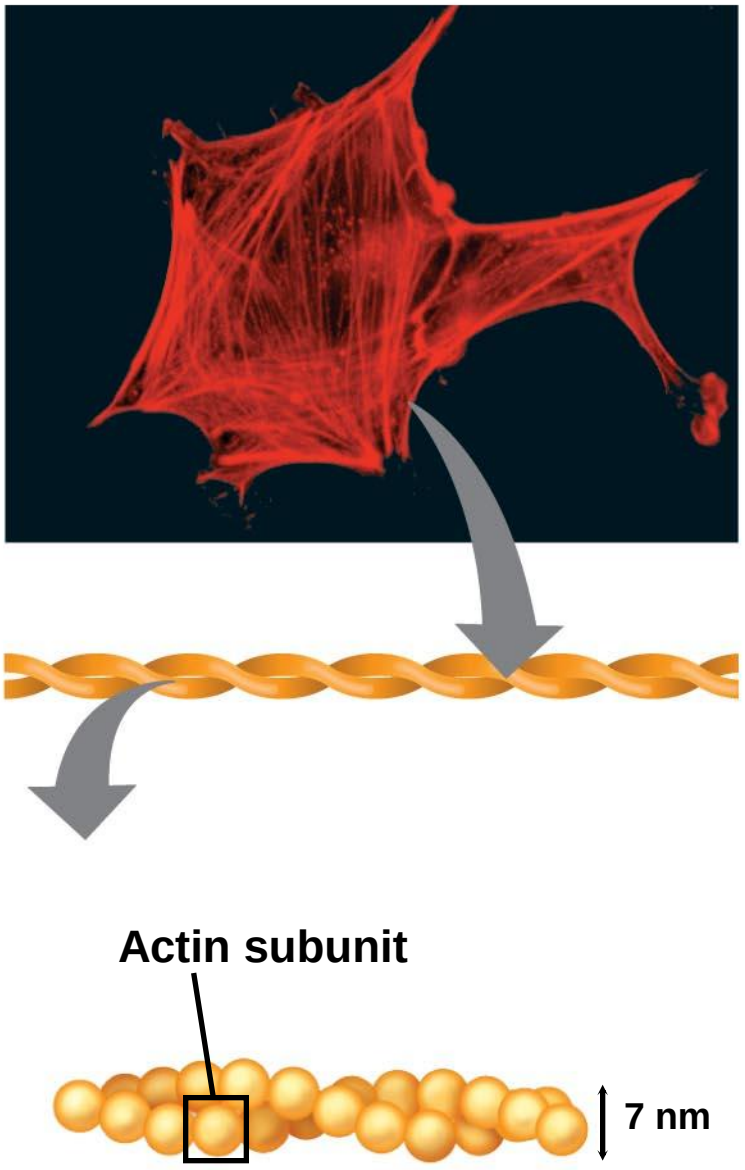
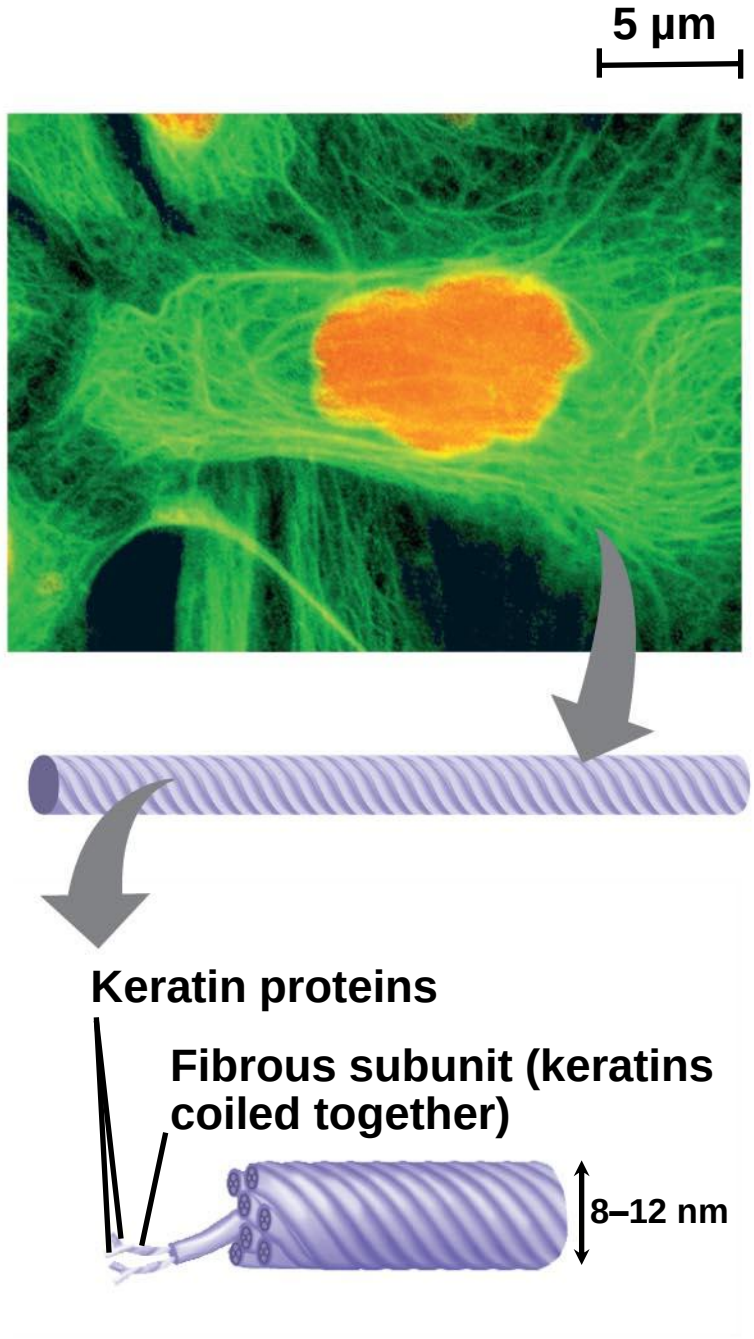


Table 6-1c

Property	Intermediate Filaments
Structure	Fibrous proteins supercoiled into thicker cables
Diameter	8–12 nm
Protein subunits	One of several different proteins of the keratin family
Main functions	Maintenance of cell shape Anchorage of nucleus and certain other organelles Formation of nuclear lamina



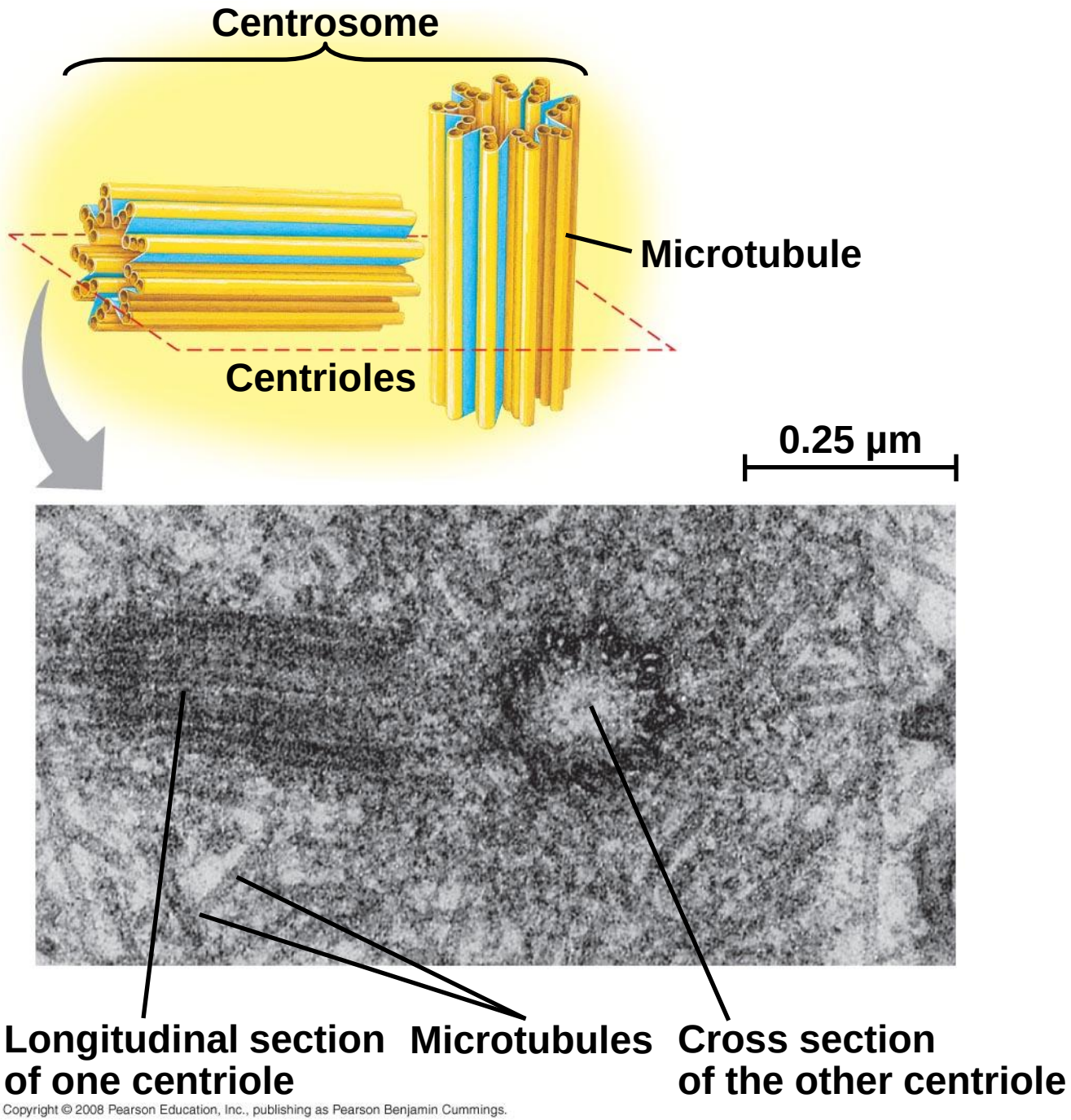
Microtubules

- **Microtubules** are hollow rods about 25 nm in diameter and about 200 nm to 25 microns long
- Functions of microtubules:
  - Shaping the cell
  - Guiding movement of organelles
  - Separating chromosomes during cell division

Centrosomes and Centrioles

- In many cells, microtubules grow out from a **centrosome** near the nucleus
- The centrosome is a "microtubule-organizing center"
- In animal cells, the centrosome has a pair of **centrioles**, each with nine triplets of microtubules arranged in a ring

Fig. 6-22



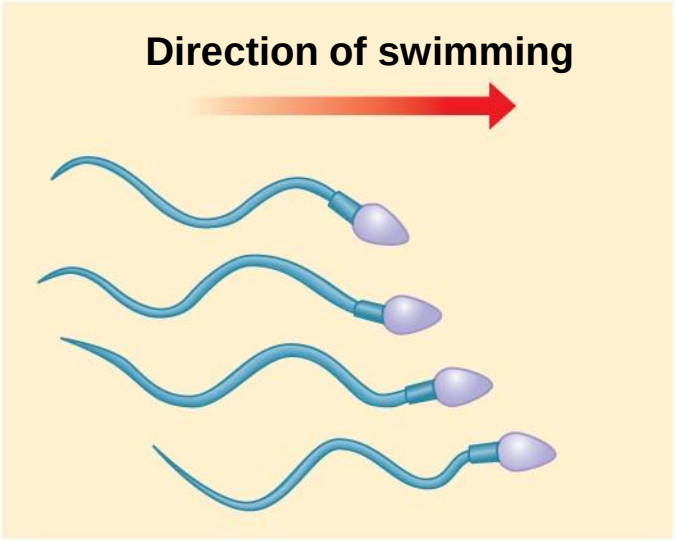
Cilia and Flagella

- Microtubules control the beating of **cilia** and **flagella**, locomotor appendages of some cells
- Cilia and flagella **differ in their beating patterns**

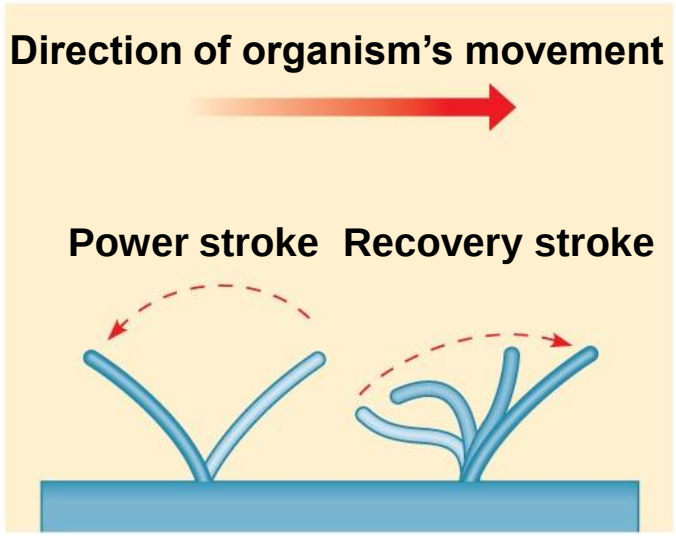
PLAY Video: *Chlamydomonas*

PLAY Video: *Paramecium* Cilia

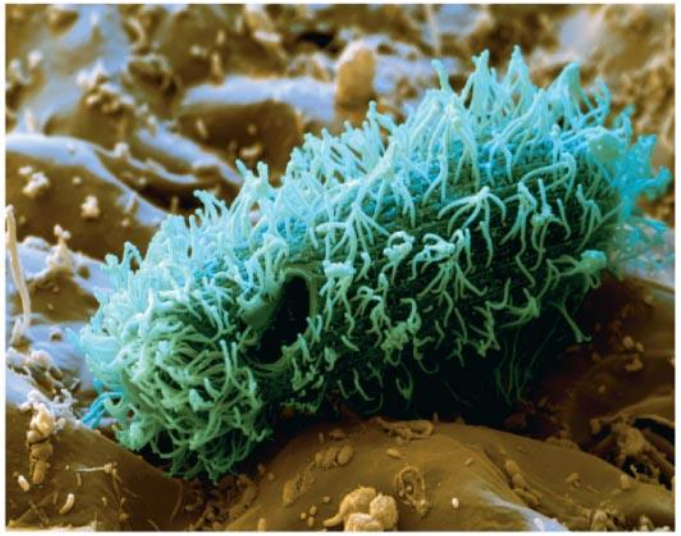
Fig. 6-23



(a) Motion of flagella



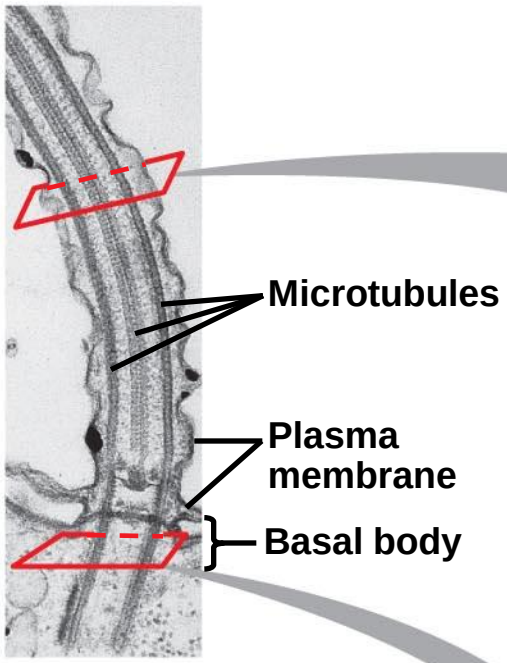
(b) Motion of cilia



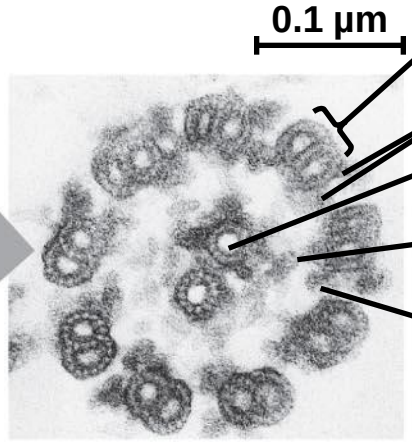
- Cilia and flagella share a common ultrastructure:
  - A core of microtubules sheathed by the plasma membrane
  - A **basal body** that anchors the cilium or flagellum
  - A motor protein called **dynein**, which drives the bending movements of a cilium or flagellum

PLAY Animation: Cilia and Flagella

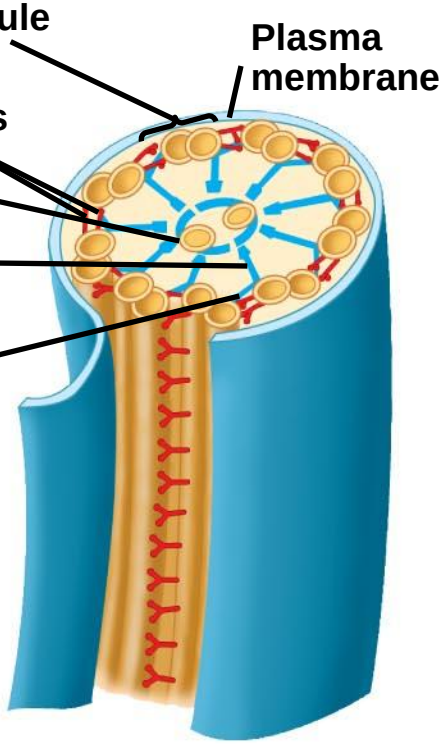
Fig. 6-24

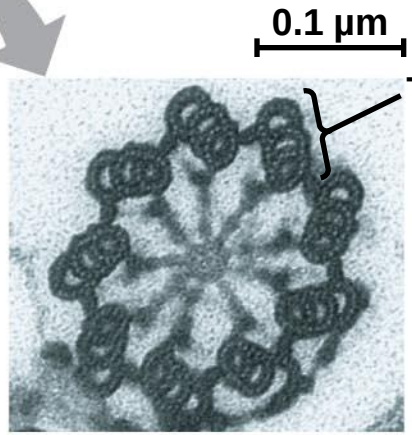


(a) Longitudinal section of cilium

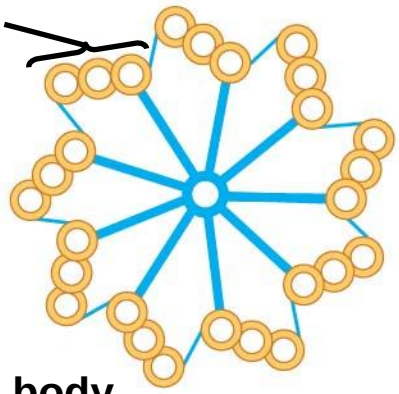


(b) Cross section of cilium



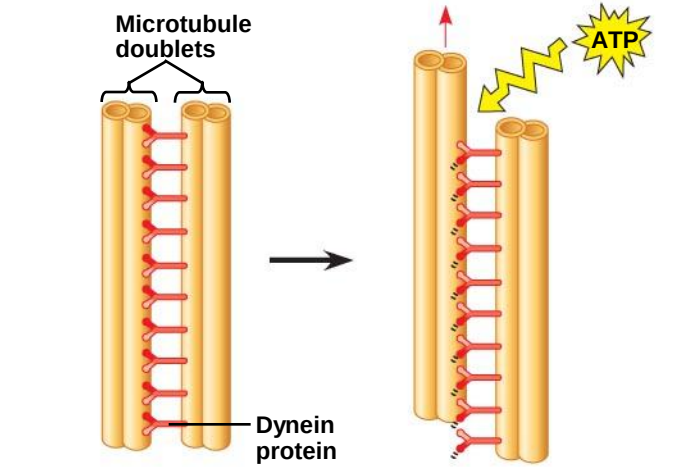


(c) Cross section of basal body

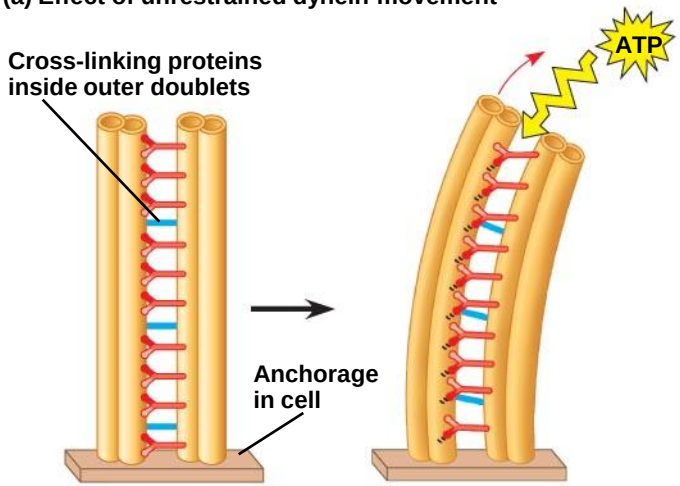


- How dynein “walking” moves flagella and cilia:
  - Dynein arms alternately grab, move, and release the outer microtubules
  - Protein cross-links limit sliding
  - Forces exerted by dynein arms cause doublets to curve, bending the cilium or flagellum

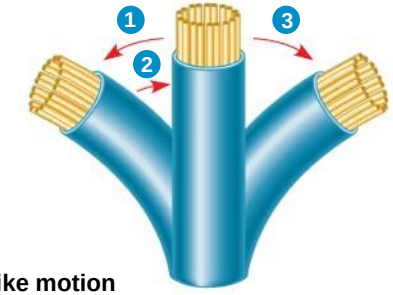
Fig. 6-25



(a) Effect of unrestrained dynein movement

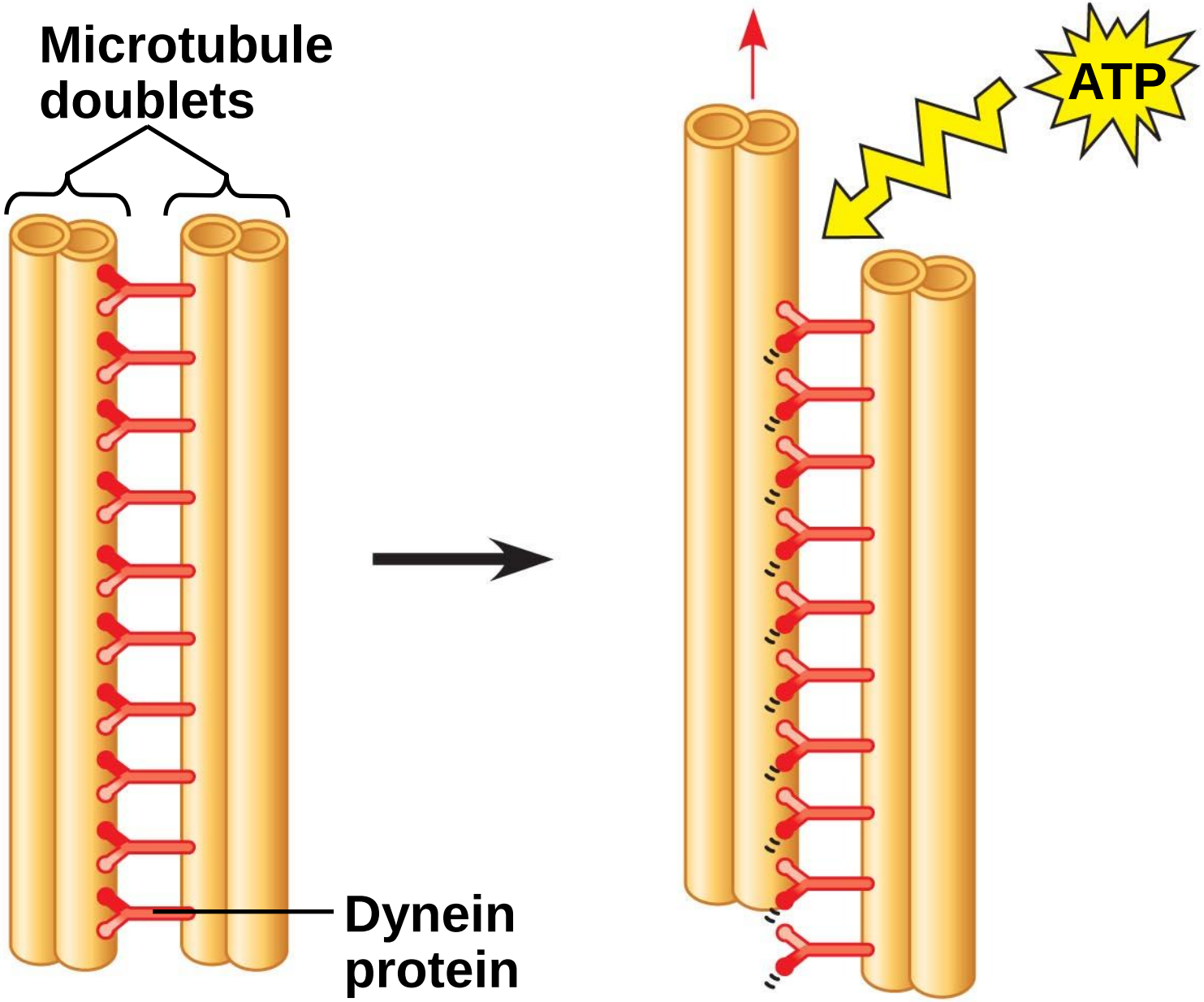


(b) Effect of cross-linking proteins



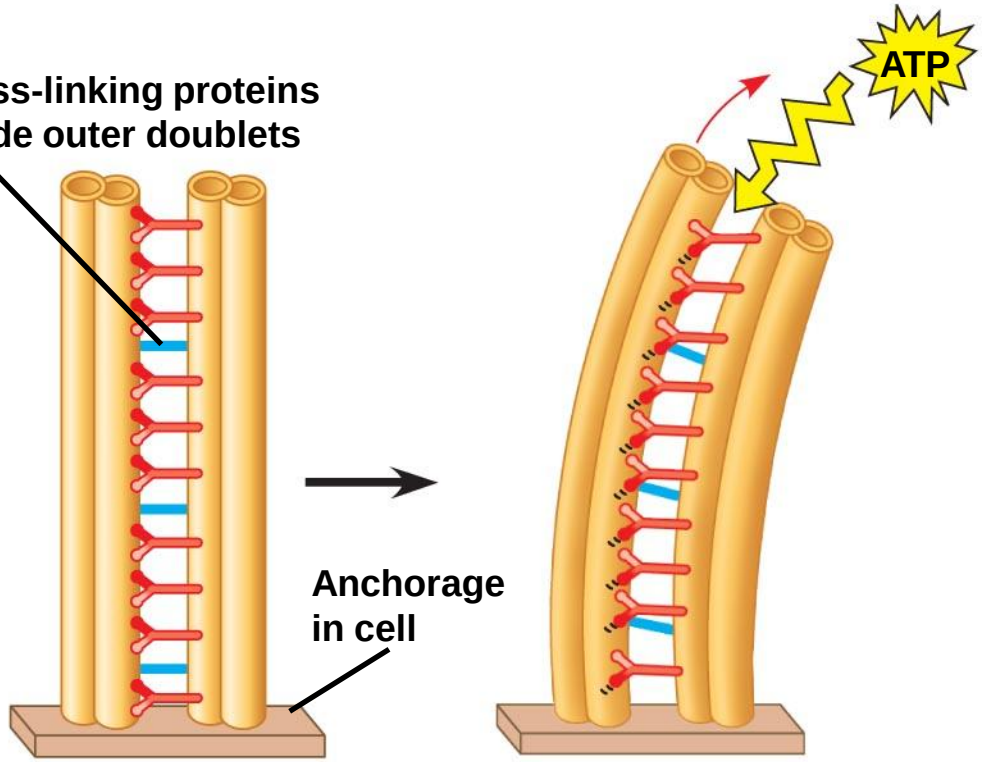
(c) Wavelike motion

Fig. 6-25a

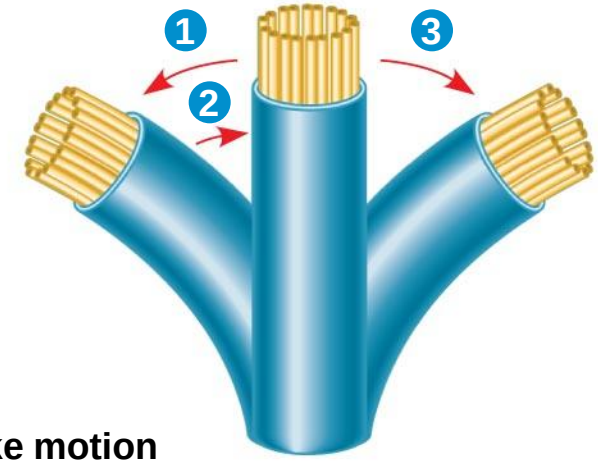


(a) Effect of unrestrained dynein movement

Fig. 6-25b



(b) Effect of cross-linking proteins

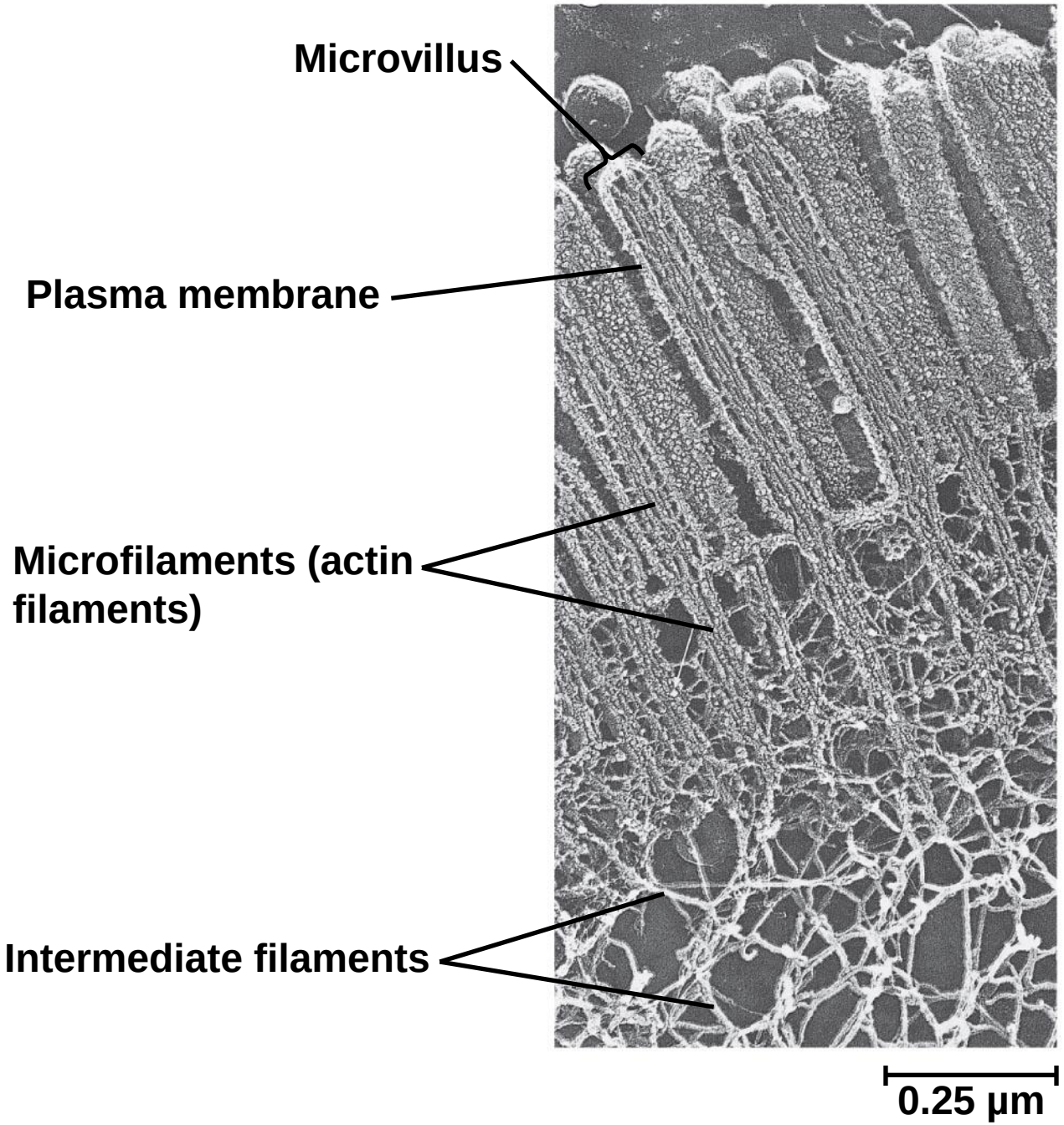


(c) Wavelike motion

Microfilaments (Actin Filaments)

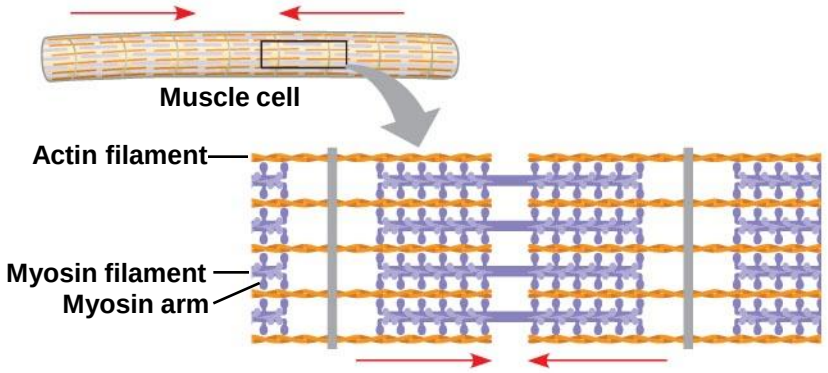
- **Microfilaments** are solid rods about 7 nm in diameter, built as a twisted double chain of **actin** subunits
- The structural role of microfilaments is to bear tension, resisting pulling forces within the cell
- They form a 3-D network called the **cortex** just inside the plasma membrane to help support the cell's shape
- Bundles of microfilaments make up the core of microvilli of intestinal cells

Fig. 6-26

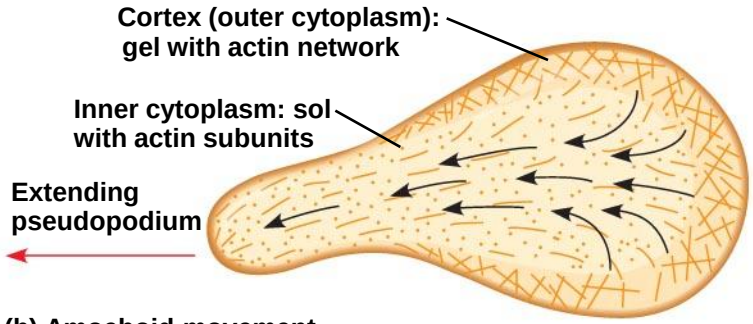


- Microfilaments that function in cellular motility contain the protein **myosin** in addition to actin
- In muscle cells, thousands of actin filaments are arranged parallel to one another
- Thicker filaments composed of myosin interdigitate with the thinner actin fibers

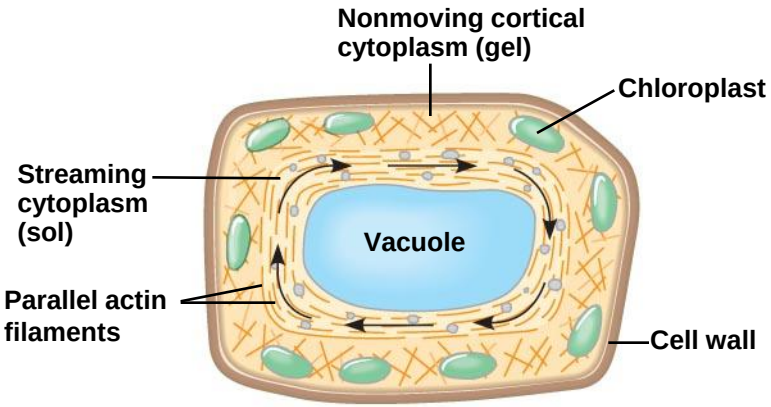
Fig. 6-27



(a) Myosin motors in muscle cell contraction

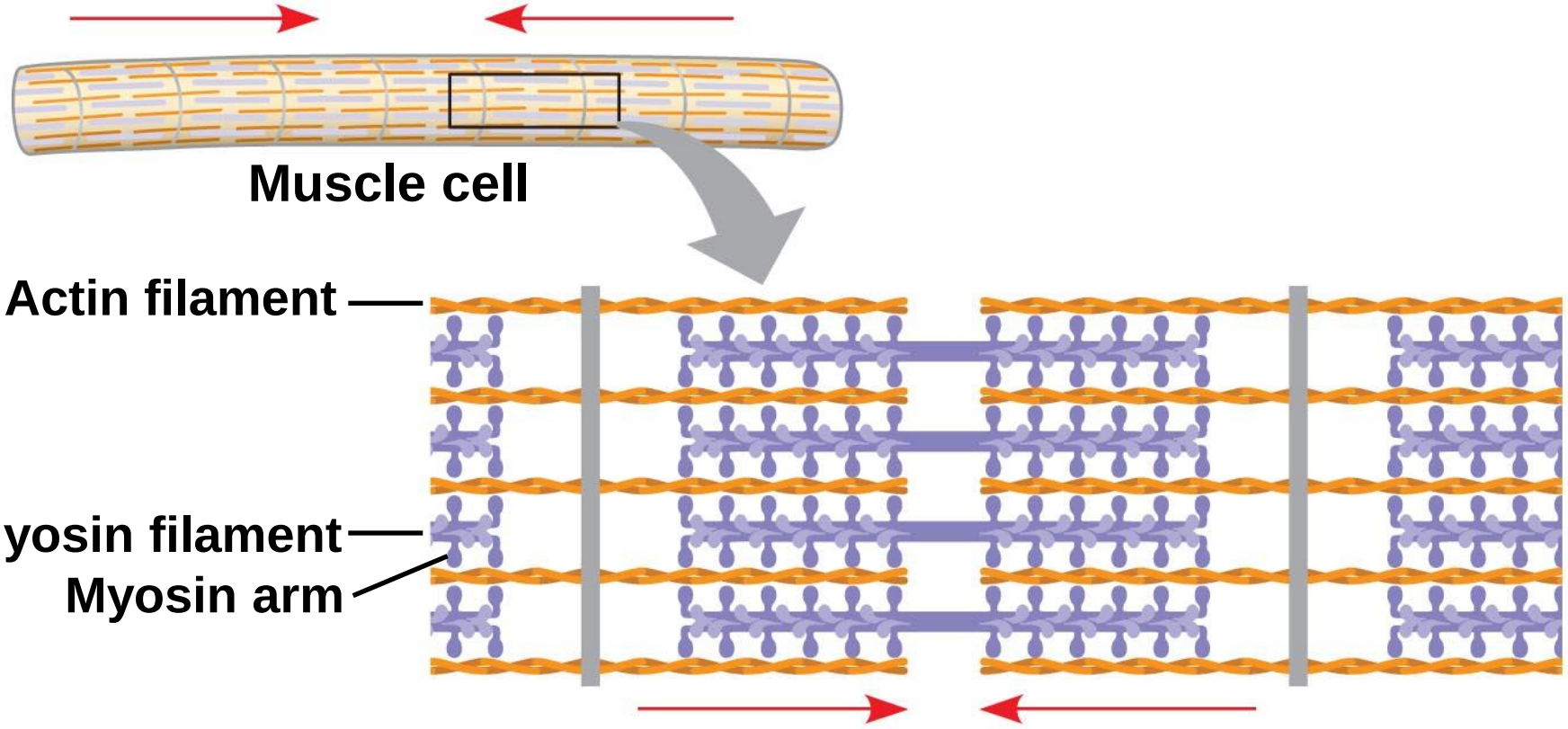


(b) Amoeboid movement



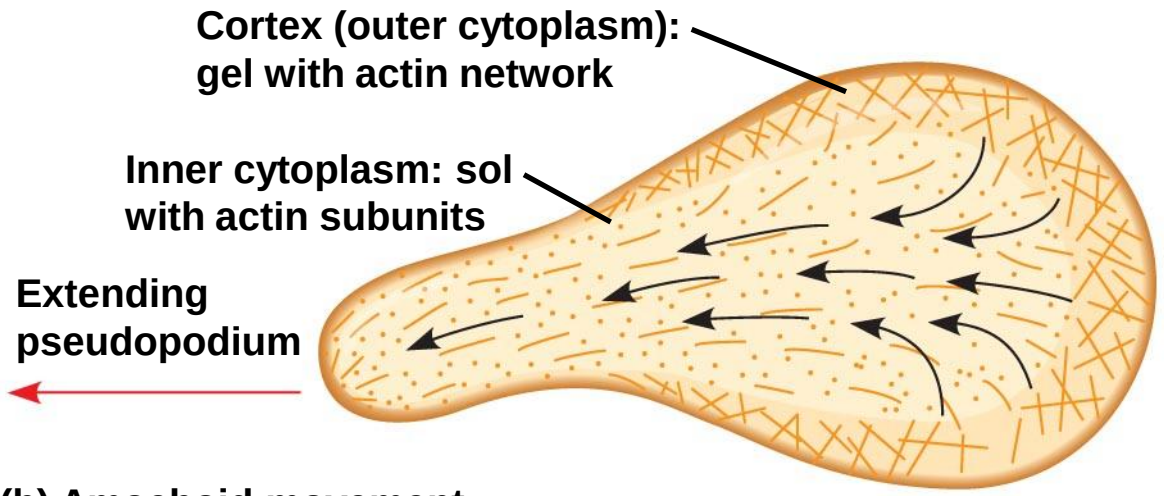
(c) Cytoplasmic streaming in plant cells

Fig, 6-27a

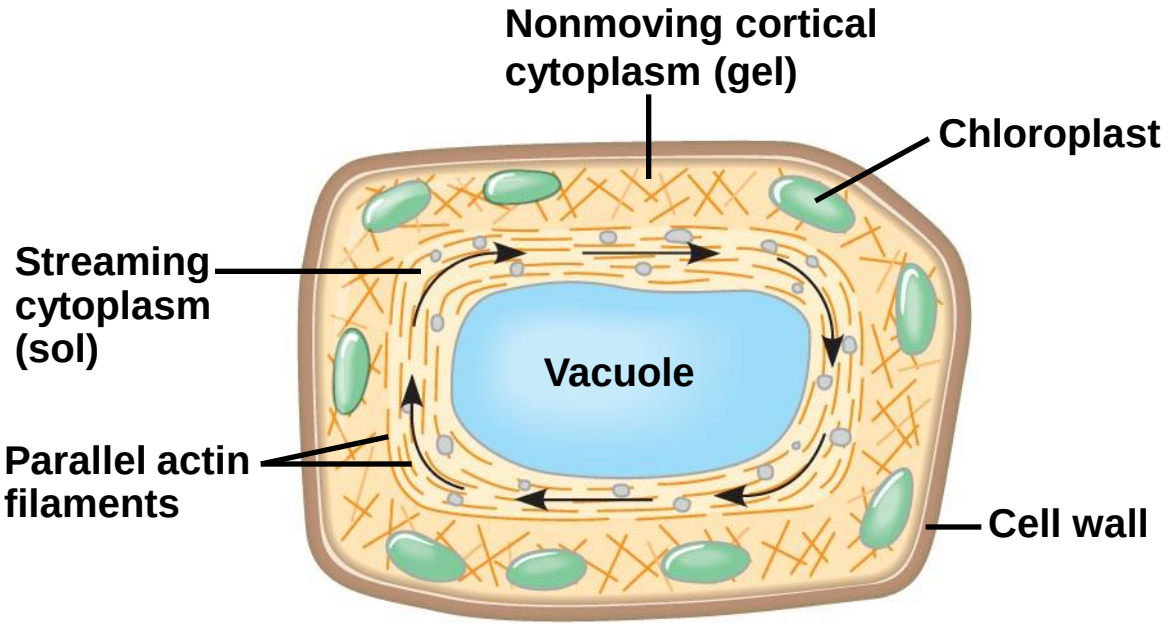


(a) Myosin motors in muscle cell contraction

Fig. 6-27bc



(b) Amoeboid movement



(c) Cytoplasmic streaming in plant cells

- Localized contraction brought about by actin and myosin also drives amoeboid movement
- **Pseudopodia** (cellular extensions) extend and contract through the reversible assembly and contraction of actin subunits into microfilaments

- **Cytoplasmic streaming** is a circular flow of cytoplasm within cells
- This streaming speeds distribution of materials within the cell
- In plant cells, actin-myosin interactions and sol-gel transformations drive cytoplasmic streaming

PLAY Video: Cytoplasmic Streaming

Intermediate Filaments

- **Intermediate filaments** range in diameter from 8–12 nanometers, larger than microfilaments but smaller than microtubules
- They support cell shape and fix organelles in place
- Intermediate filaments are more permanent cytoskeleton fixtures than the other two classes

Concept 6.7: Extracellular components and connections between cells help coordinate cellular activities

- Most cells synthesize and secrete materials that are external to the plasma membrane
- These extracellular structures include:
  - Cell walls of plants
  - The extracellular matrix (ECM) of animal cells
  - Intercellular junctions

Cell Walls of Plants

- The **cell wall** is an extracellular structure that distinguishes plant cells from animal cells
- Prokaryotes, fungi, and some protists also have cell walls
- The cell wall protects the plant cell, maintains its shape, and prevents excessive uptake of water
- Plant cell walls are made of **cellulose** fibers embedded in other polysaccharides and protein

- Plant cell walls may have multiple layers:
  - **Primary cell wall**: relatively thin and flexible
  - **Middle lamella**: thin layer between primary walls of adjacent cells
  - **Secondary cell wall** (in some cells): added between the plasma membrane and the primary cell wall
- Plasmodesmata are channels between adjacent plant cells

Fig. 6-28

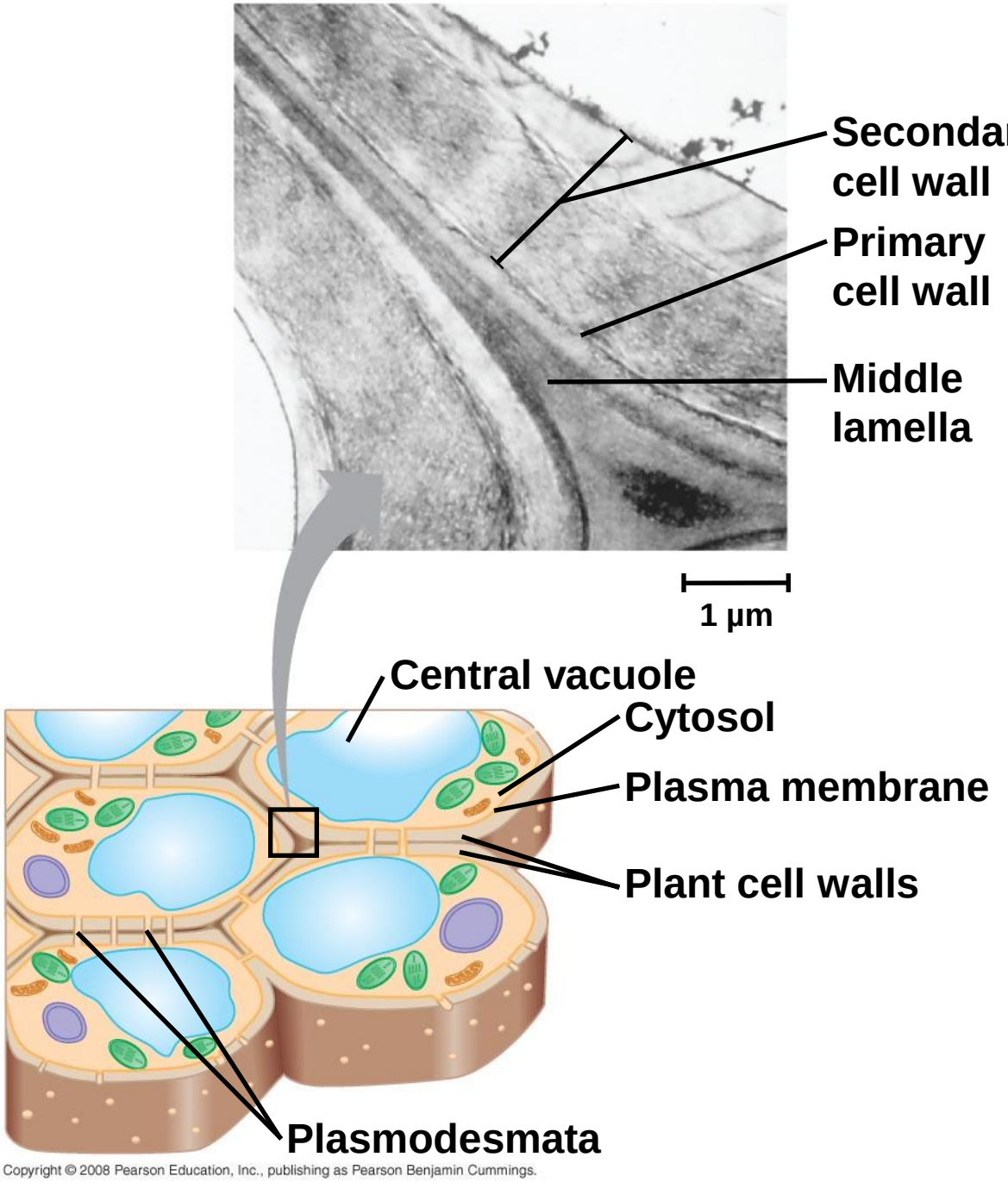
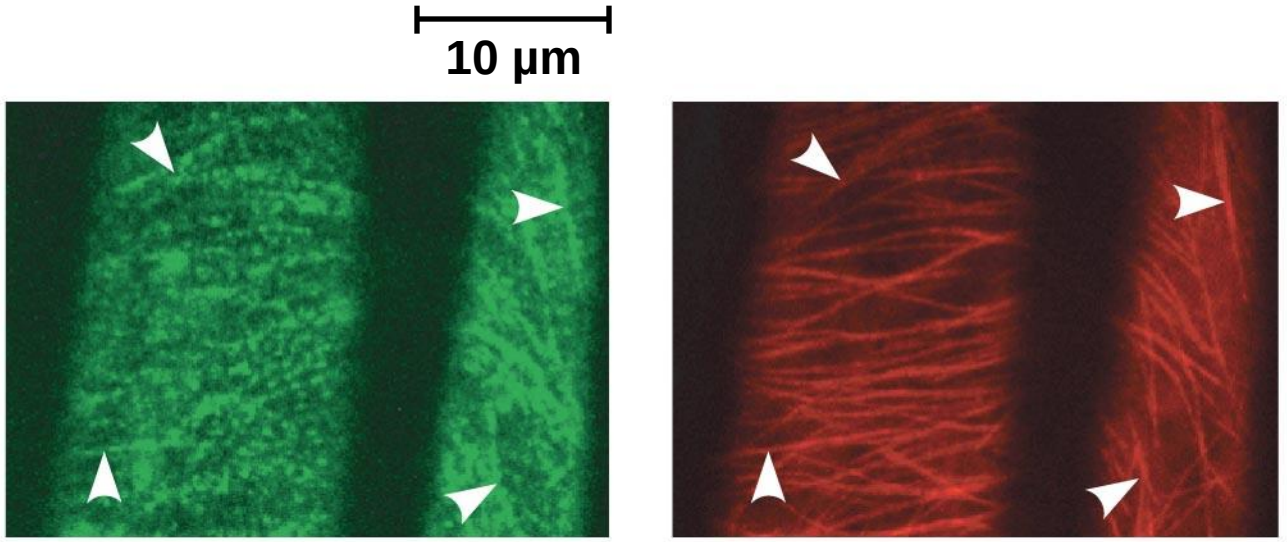


Fig. 6-29

RESULTS



Distribution of cellulose synthase over time

Distribution of microtubules over time

The Extracellular Matrix (ECM) of Animal Cells

- Animal cells lack cell walls but are covered by an elaborate **extracellular matrix (ECM)**
- The ECM is made up of glycoproteins such as **collagen**, **proteoglycans**, and **fibronectin**
- ECM proteins bind to receptor proteins in the plasma membrane called **integrins**

Fig. 6-30

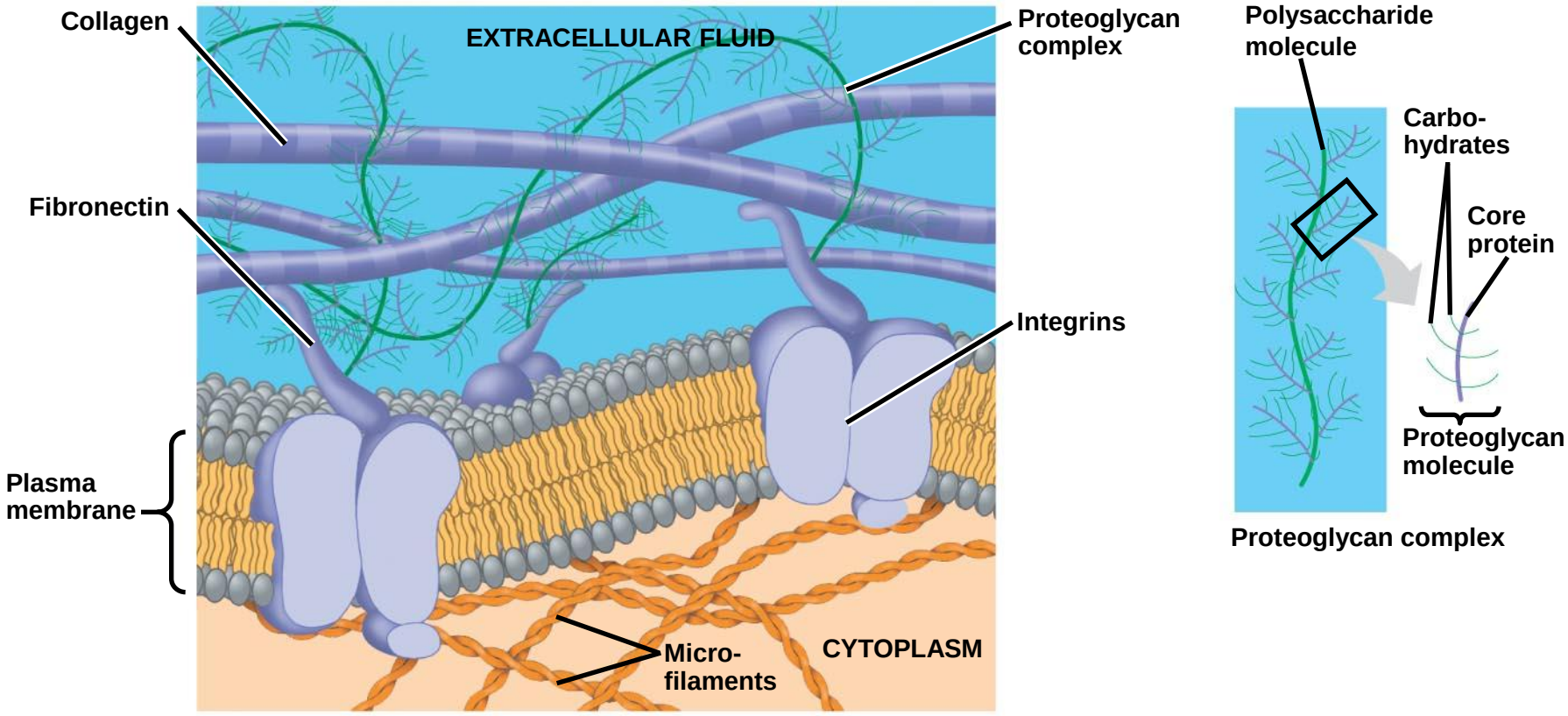


Fig. 6-30a

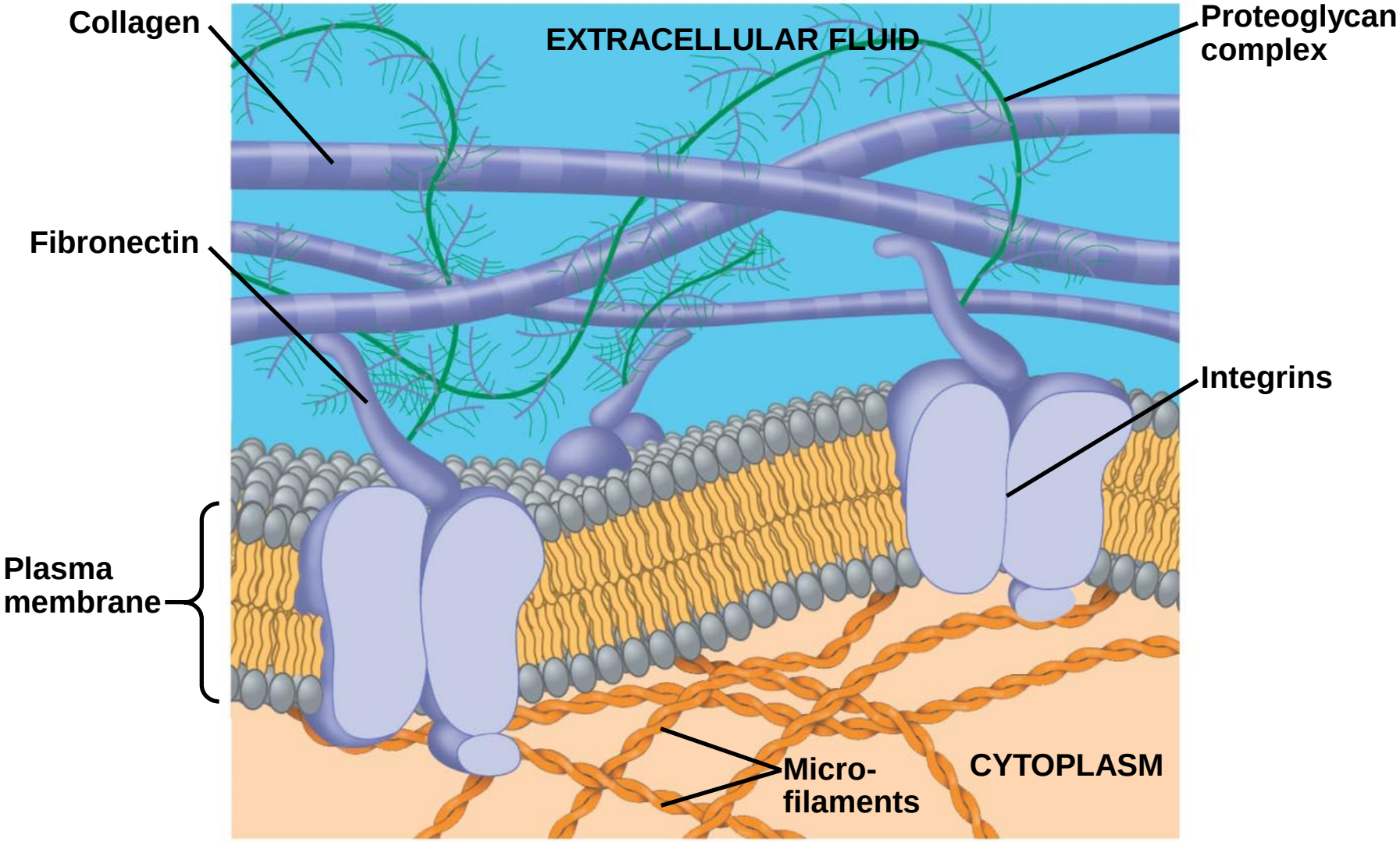
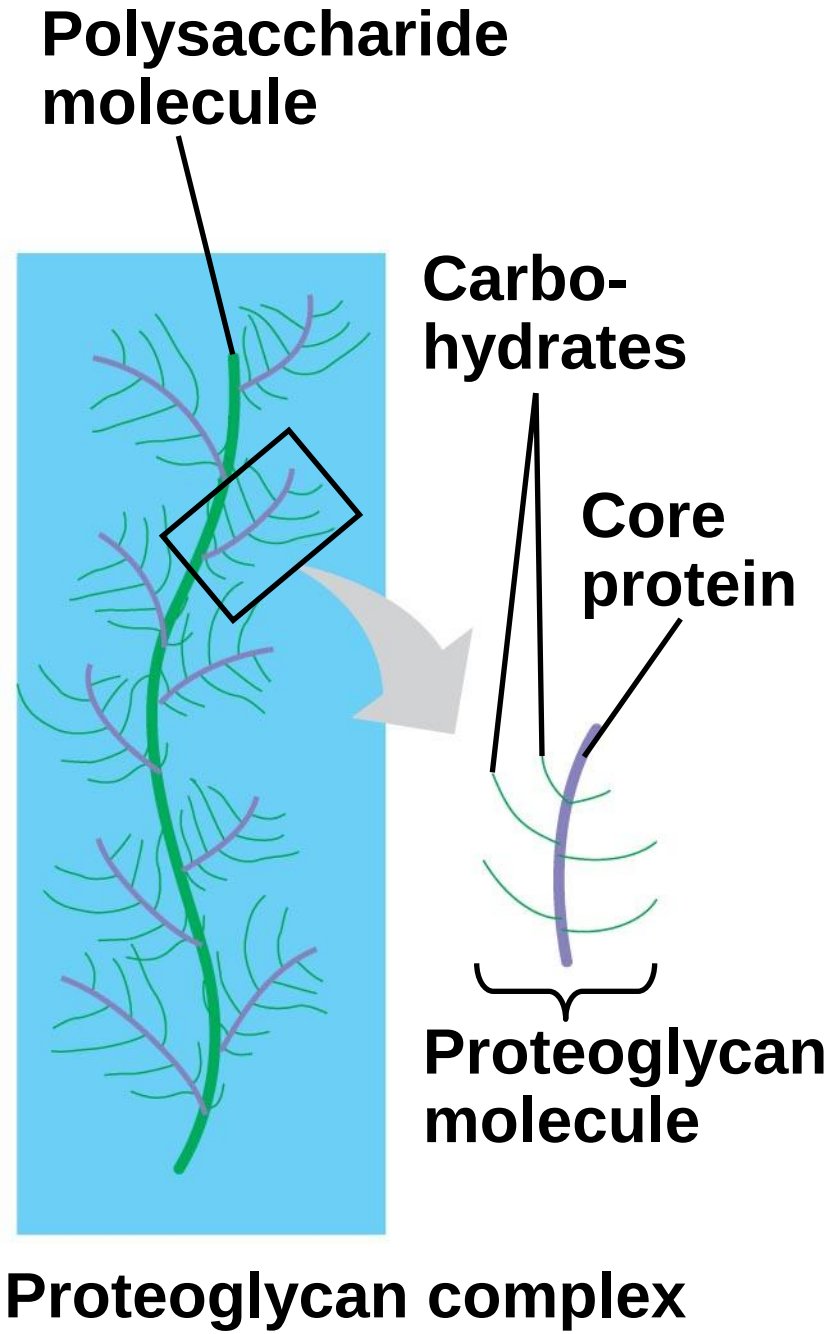


Fig. 6-30b



- Functions of the ECM:
  - Support
  - Adhesion
  - Movement
  - Regulation

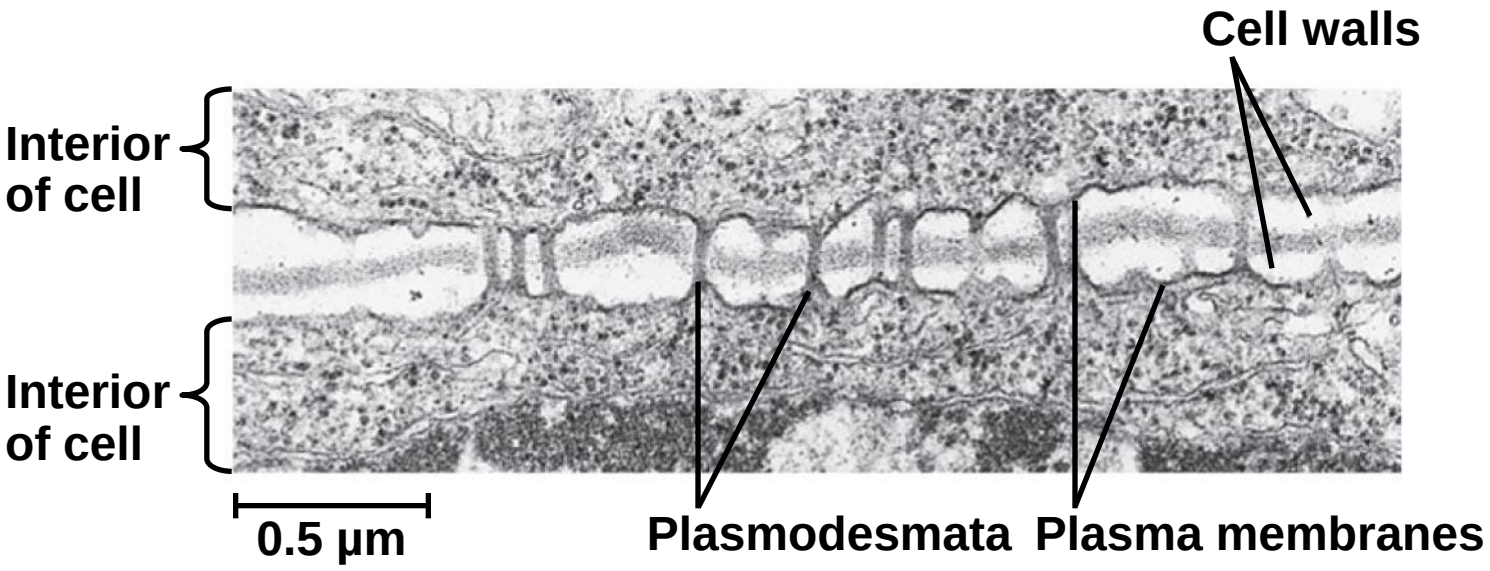
Intercellular Junctions

- Neighboring cells in tissues, organs, or organ systems often adhere, interact, and communicate through direct physical contact
- Intercellular junctions facilitate this contact
- There are several types of intercellular junctions
  - Plasmodesmata
  - Tight junctions
  - Desmosomes
  - Gap junctions

Plasmodesmata in Plant Cells

- **Plasmodesmata** are channels that perforate plant cell walls
- Through plasmodesmata, water and small solutes (and sometimes proteins and RNA) can pass from cell to cell

Fig. 6-31



Tight Junctions, Desmosomes, and Gap Junctions in Animal Cells

- At **tight junctions**, membranes of neighboring cells are pressed together, preventing leakage of extracellular fluid
- **Desmosomes** (anchoring junctions) fasten cells together into strong sheets
- **Gap junctions** (communicating junctions) provide cytoplasmic channels between adjacent cells

PLAY Animation: Tight Junctions

PLAY Animation: Desmosomes

PLAY Animation: Gap Junctions

Fig. 6-32

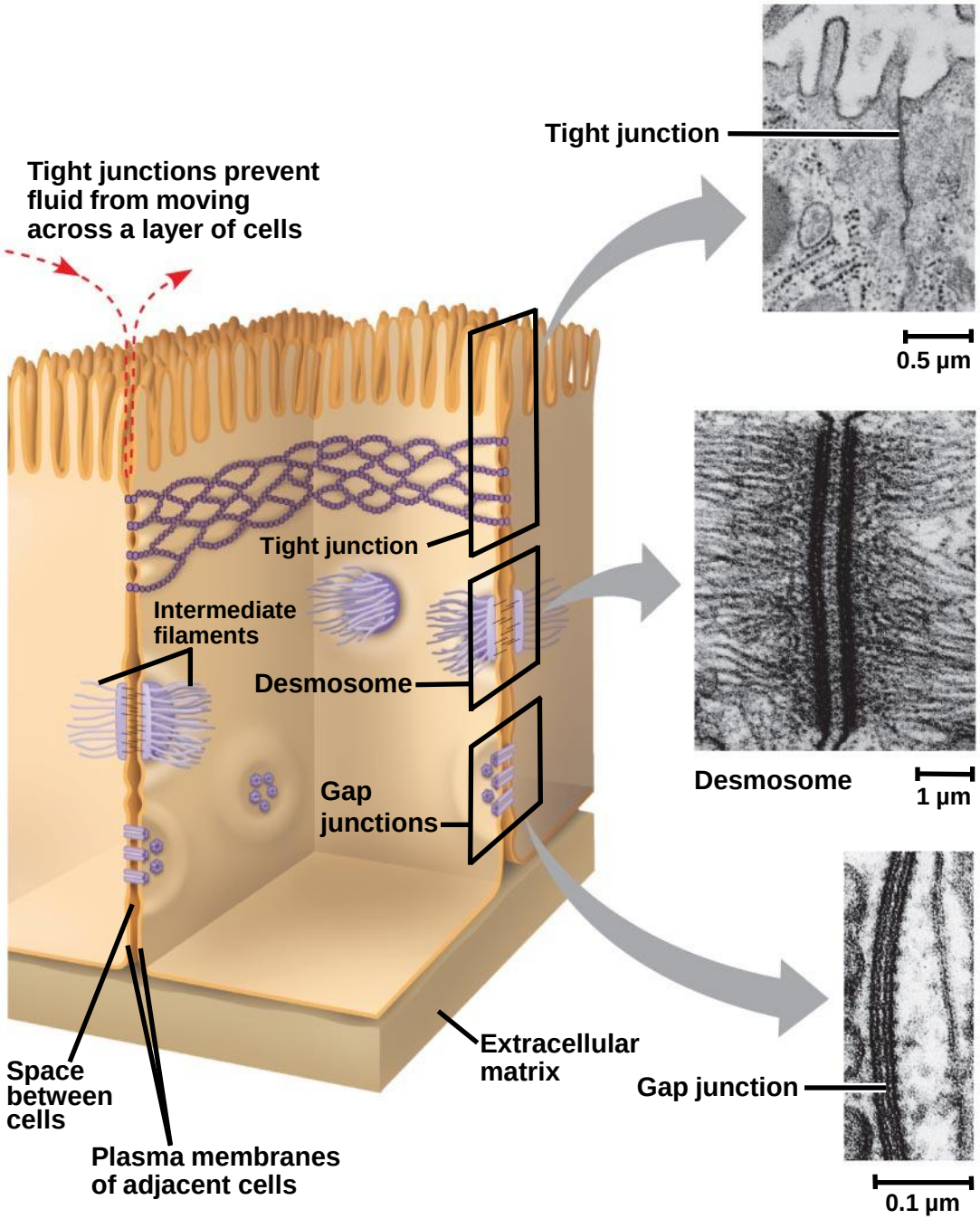


Fig. 6-32a

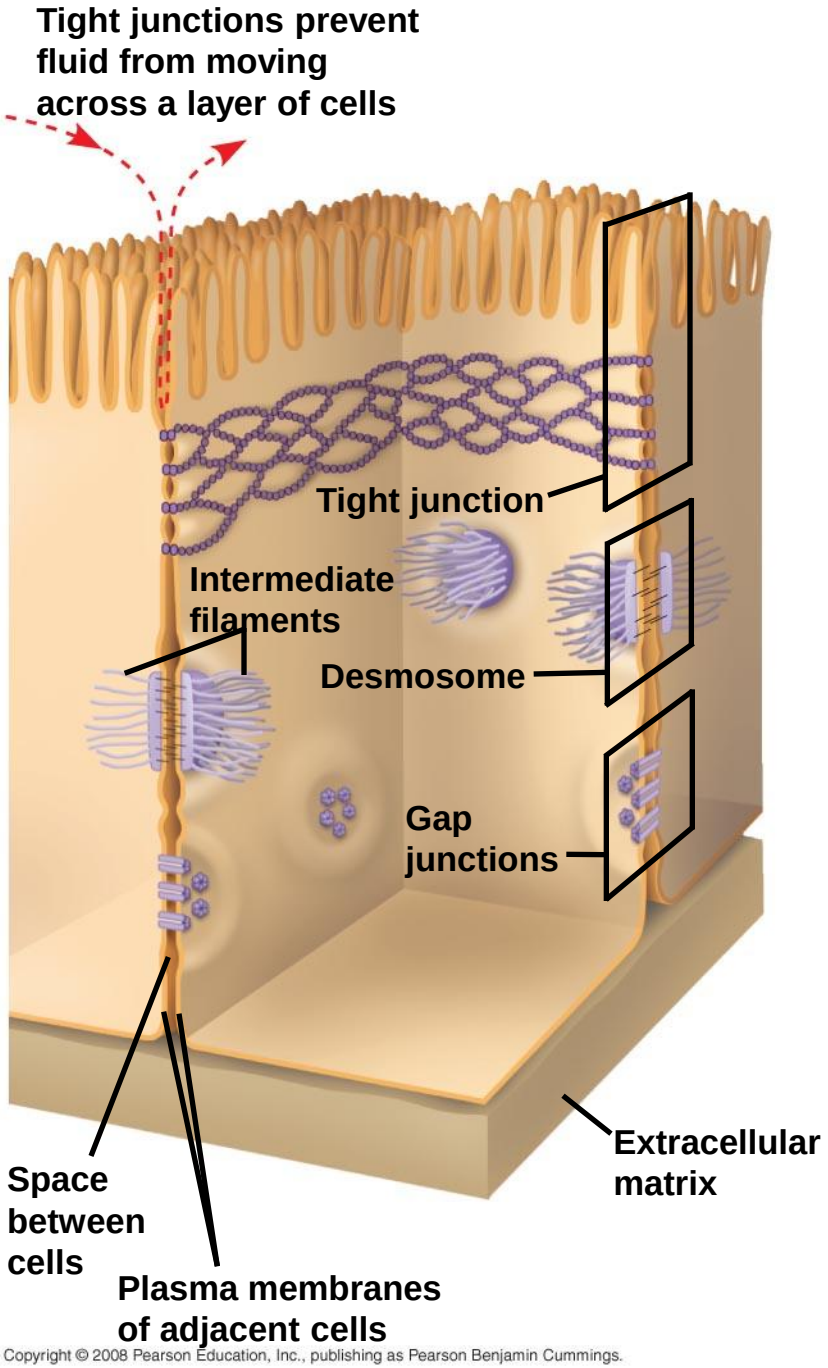
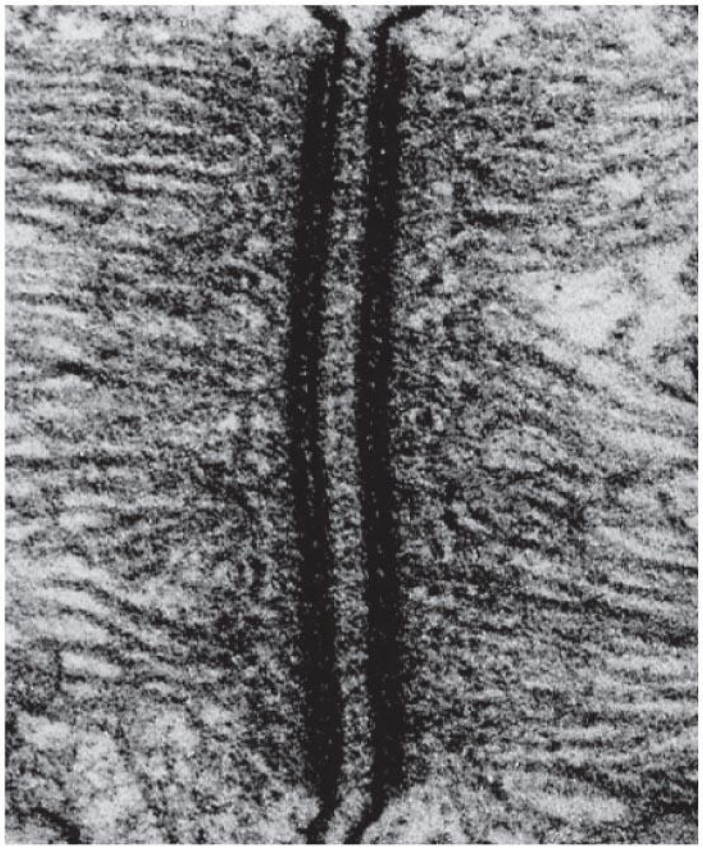


Fig. 6-32b

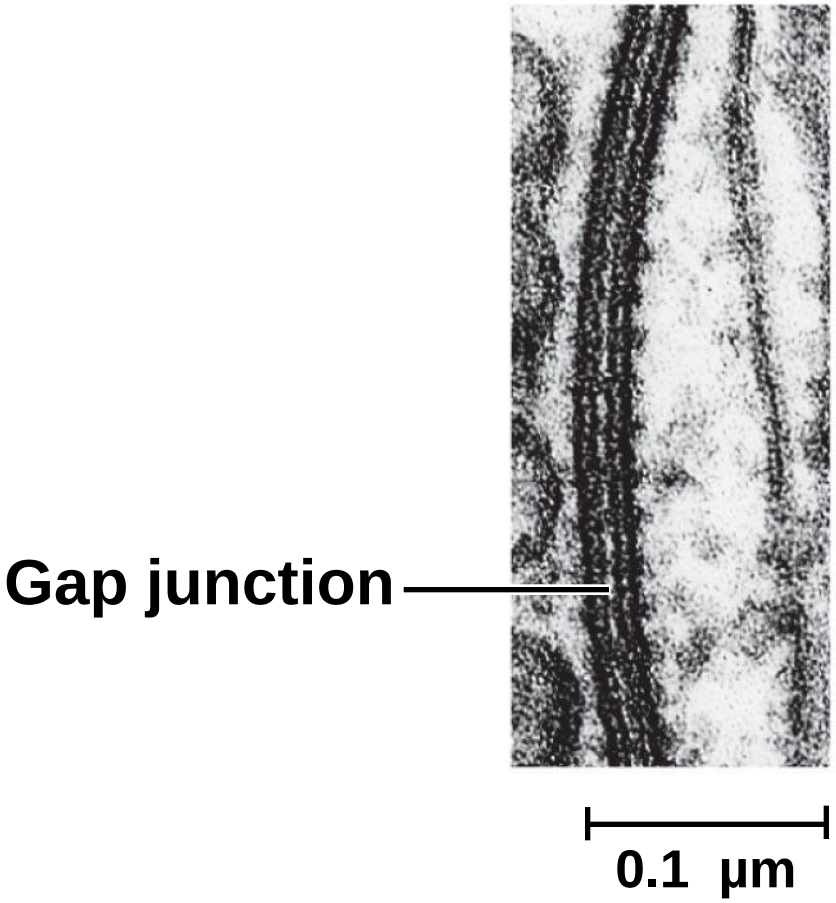
Fig. 6-32c



Desmosome

1 μm

Fig. 6-32d



The Cell: A Living Unit Greater Than the Sum of Its Parts

- Cells rely on the integration of structures and organelles in order to function
- For example, a macrophage's ability to destroy bacteria involves the whole cell, coordinating components such as the cytoskeleton, lysosomes, and plasma membrane

Fig. 6-33

Fig. 6-UN1

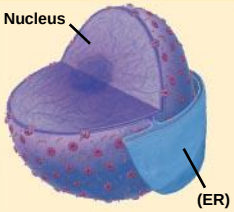
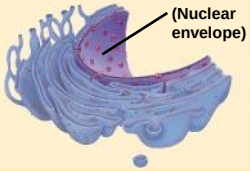
	Cell Component	Structure	Function
Concept 6.3 The eukaryotic cell's genetic instructions are housed in the nucleus and carried out by the ribosomes	Nucleus 	Surrounded by nuclear envelope (double membrane) perforated by nuclear pores. The nuclear envelope is continuous with the endoplasmic reticulum (ER).	Houses chromosomes, made of chromatin (DNA, the genetic material, and proteins); contains nucleoli, where ribosomal subunits are made. Pores regulate entry and exit of materials.
	Ribosome 	Two subunits made of ribosomal RNA and proteins; can be free in cytosol or bound to ER	Protein synthesis
Concept 6.4 The endomembrane system regulates protein traffic and performs metabolic functions in the cell	Endoplasmic reticulum 	Extensive network of membrane-bound tubules and sacs; membrane separates lumen from cytosol; continuous with the nuclear envelope.	Smooth ER: synthesis of lipids, metabolism of carbohydrates, Ca^{2+} storage, detoxification of drugs and poisons Rough ER: Aids in synthesis of secretory and other proteins from bound ribosomes; adds carbohydrates to glycoproteins; produces new membrane
	Golgi apparatus 	Stacks of flattened membranous sacs; has polarity (*cis* and *trans* faces)	Modification of proteins, carbohydrates on proteins, and phospholipids; synthesis of many polysaccharides; sorting of Golgi products, which are then released in vesicles.
	Lysosome 	Membranous sac of hydrolytic enzymes (in animal cells)	Breakdown of ingested substances, cell macromolecules, and damaged organelles for recycling
	Vacuole 	Large membrane-bounded vesicle in plants	Digestion, storage, waste disposal, water balance, cell growth, and protection
Concept 6.5 Mitochondria and chloroplasts change energy from one form to another	Mitochondrion 	Bounded by double membrane; inner membrane has infoldings (cristae)	Cellular respiration
	Chloroplast 	Typically two membranes around fluid stroma, which contains membranous thylakoids stacked into grana (in plants)	Photosynthesis
	Peroxisome 	Specialized metabolic compartment bounded by a single membrane	Contains enzymes that transfer hydrogen to water, producing hydrogen peroxide (H_2O_2) as a by-product, which is converted to water by other enzymes in the peroxisome

Fig. 6-UN1a

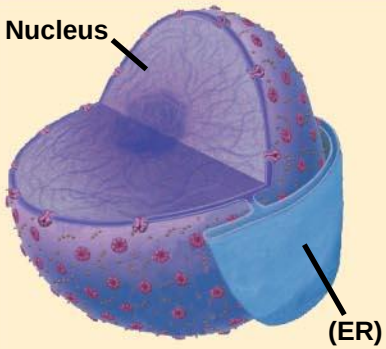
	Cell Component	Structure	Function
Concept 6.3 **The eukaryotic cell's genetic instructions are housed in the nucleus and carried out by the ribosomes**	**Nucleus**  **(ER)**	**Surrounded by nuclear envelope (double membrane) perforated by nuclear pores. The nuclear envelope is continuous with the endoplasmic reticulum (ER).**	**Houses chromosomes, made of chromatin (DNA, the genetic material, and proteins); contains nucleoli, where ribosomal subunits are made. Pores regulate entry and exit os materials.**
	Ribosome 	**Two subunits made of ribo-somal RNA and proteins; can be free in cytosol or bound to ER**	**Protein synthesis**

Fig. 6-UN1b

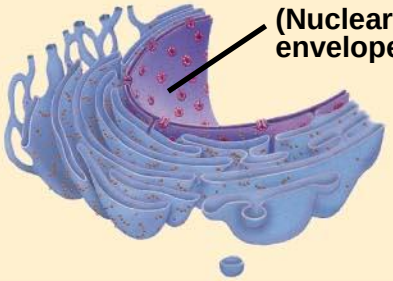
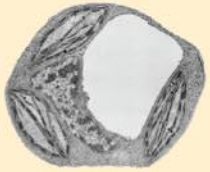
	Cell Component	Structure	Function
Concept 6.4 **The endomembrane system regulates protein traffic and performs metabolic functions in the cell**	**Endoplasmic reticulum**  	**Extensive network of membrane-bound tubules and sacs; membrane separates lumen from cytosol; continuous with the nuclear envelope.**	**Smooth ER: synthesis of lipids, metabolism of carbohydrates, Ca^{2+} storage, detoxification of drugs and poisons** **Rough ER: Aids in sythesis of secretory and other proteins from bound ribosomes; adds carbohydrates to glycoproteins; produces new membrane**
	Golgi apparatus 	**Stacks of flattened membranous sacs; has polarity (*cis* and *trans* faces)**	**Modification of proteins, carbohydrates on proteins, and phospholipids; synthesis of many polysaccharides; sorting of Golgi products, which are then released in vesicles.**
	Lysosome 	**Membranous sac of hydrolytic enzymes (in animal cells)**	**Breakdown of ingested substances cell macromolecules, and damaged organelles for recycling**
	Vacuole 	**Large membrane-bounded vesicle in plants**	**Digestion, storage, waste disposal, water balance, cell growth, and protection**

Fig. 6-UN1c

	Cell Component	Structure	Function
Concept 6.5 **Mitochondria and chloroplasts change energy from one form to another**	**Mitochondrion** 	**Bounded by double membrane; inner membrane has infoldings (cristae)**	**Cellular respiration**
	Chloroplast 	**Typically two membranes around fluid stroma, which contains membranous thylakoids stacked into grana (in plants)**	**Photosynthesis**
	Peroxisome 	**Specialized metabolic compartment bounded by a single membrane**	**Contains enzymes that transfer hydrogen to water, producing hydrogen peroxide (H_2O_2) as a by-product, which is converted to water by other enzymes in the peroxisome**

Fig. 6-UN2

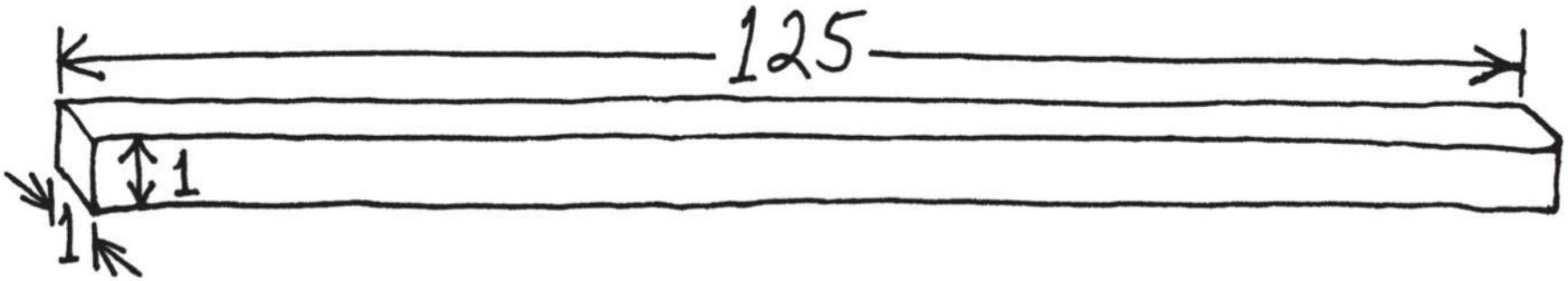
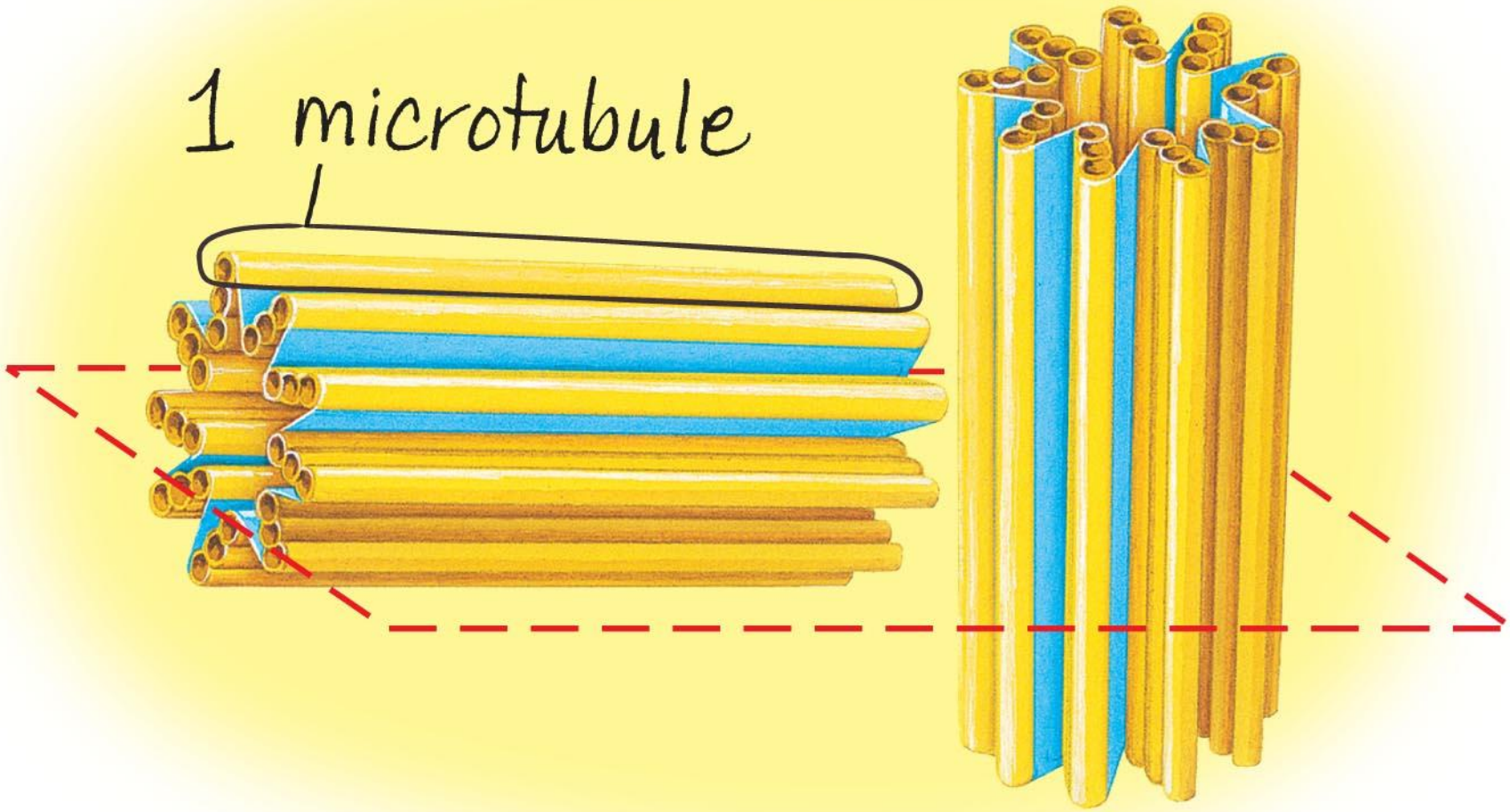


Fig. 6-UN3



You should now be able to:

1. Distinguish between the following pairs of terms: magnification and resolution; prokaryotic and eukaryotic cell; free and bound ribosomes; smooth and rough ER
2. Describe the structure and function of the components of the endomembrane system
3. Briefly explain the role of mitochondria, chloroplasts, and peroxisomes
4. Describe the functions of the cytoskeleton

5. Compare the structure and functions of microtubules, microfilaments, and intermediate filaments

6. Explain how the ultrastructure of cilia and flagella relate to their functions

7. Describe the structure of a plant cell wall

8. Describe the structure and roles of the extracellular matrix in animal cells

9. Describe four different intercellular junctions