Chapter 6

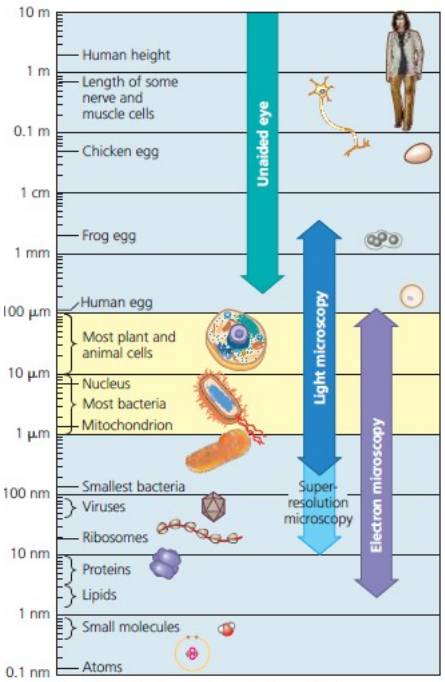
A Tour of the Cell

Contents, figures, and tables of slides are based on and/or adapted from Campbell Biology, 12th ed., unless otherwise specified.

CONCEPT 6.1

Studying Cells: Microscopy

- Magnification: image size vs. real size; resolution: minimum distance two points are distinguishable; contrast: differences in parts of the sample
- Light microscope (LM): visible light and glass lenses; resolution ~0.2 µm; live cells; stains, fluorescence, confocal, deconvolution, super-resolution
- Electron microscopes (EM): resolution ~2 nm; SEM images surface; TEM images internal ultrastructure; sample fixed (dead)
- Cryo-EM: flash-frozen samples, no stain



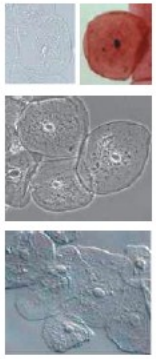
1 centimeter (cm) = 10^{-2} meter (m) = 0.4 inch
1 millimeter (mm) = 10^{-3} m
1 micrometer (µm) = 10^{-3} mm = 10^{-6} m
1 nanometer (nm) = 10^{-3} µm = 10^{-9} m

Light Microscopy (LM)

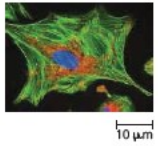
Brightfield. Light passes directly through the specimen. Unstained (left), the image has little contrast. Staining with dyes (right) enhances contrast. Most stains require cells to be preserved, which kills them.

Phase-contrast. Variations in density within the specimen are amplified to enhance contrast in unstained cells; this is especially useful for examining living, unstained cells.

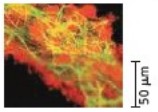
Differential interference contrast (Nomarski). As in phase-contrast microscopy, optical modifications are used to exaggerate differences in density; the image appears almost 3-D.



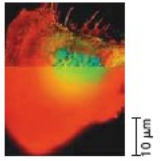
Fluorescence. Locations of specific molecules are revealed by labeling the molecules with fluorescent dyes or antibodies, which absorb ultraviolet radiation and emit visible light. In this fluorescently labeled uterine cell, DNA is blue, organelles called mitochondria are orange, and part of the cell's "skeleton" (called the *cytoskeleton*) is green.



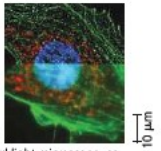
Confocal. This image shows two types of fluorescence micrographs: confocal (top) and standard (bottom). (Nerve cells are green, support cells orange, areas of overlap yellow.) In confocal microscopy, a laser is used to create a single plane of fluorescence; out-of-focus light from other planes is eliminated. By capturing sharp images at many different planes, a 3-D reconstruction can be created. A standard fluorescence micrograph is blurry because out-of-focus light is not excluded.



Deconvolution. The top of this image of a white blood cell was reconstructed from many blurry fluorescence images at different planes, each processed using deconvolution software. This process digitally removes out-of-focus light and reassigns it to its source, creating a much sharper 3-D image. The bottom is a compilation of standard fluorescent micrographs through the same cell.

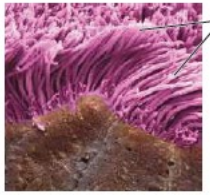


Super-resolution. To make this super-resolution image of a cow aorta cell (top), individual fluorescent molecules were excited by UV light and their position recorded. (DNA is blue, mitochondria red, and part of the cytoskeleton green.) Combining information from many molecules in different places "breaks" the resolution limit, resulting in the sharp image on top. The size of each dot is well below the 200-nm resolution of a standard light microscope, as seen in the confocal image (bottom) of the same cell.

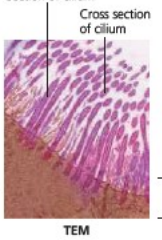


Electron Microscopy (EM)

Scanning electron microscopy (SEM). Micrographs taken with a scanning electron microscope show a 3-D image of the surface of a specimen. This SEM shows the surface of a cell from a trachea (windpipe) covered with cell projections called cilia. Electron micrographs are black and white but are often artificially colorized to highlight particular structures, as has been done with all three electron micrographs shown here.



Transmission electron microscopy (TEM). A transmission electron microscope profiles a thin section of a specimen. This TEM shows a section through a tracheal cell, revealing its internal structure. In preparing the specimen, some cilia were cut along their lengths, creating longitudinal sections, while other cilia were cut straight across, creating cross sections.



Cryo-electron microscopy (cryo-EM). Specimens of tissue or aqueous solutions of proteins are frozen rapidly at temperatures less than –160°C, locking the molecules into a rigid state. A beam of electrons is passed through the sample to visualize the molecules by electron microscopy, and software is used to merge a series of such micrographs, creating a 3-D image like the one below.



Computer-generated image of the bacterial enzyme β-galactosidase, which breaks down lactose. This image was compiled from more than 90,000 cryo-EM images.

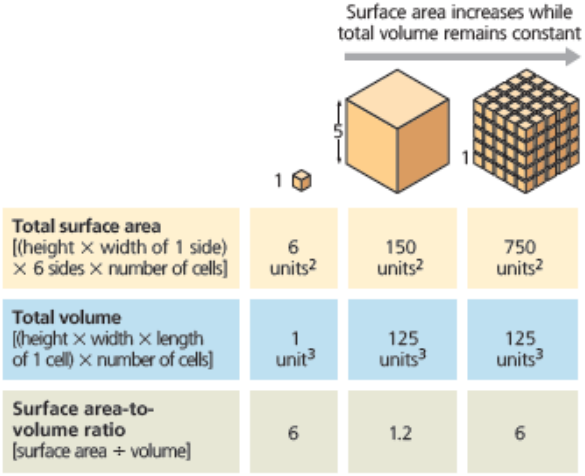
Abbreviations used in figure legends in this text:
LM = Light Micrograph
SEM = Scanning Electron Micrograph
TEM = Transmission Electron Micrograph

VISUAL SKILLS *When the tissue was sliced, what was the orientation of the cilia in the lower portion of the TEM? The upper portion? Explain how the orientation of the cilia determined the type of sections we see.*

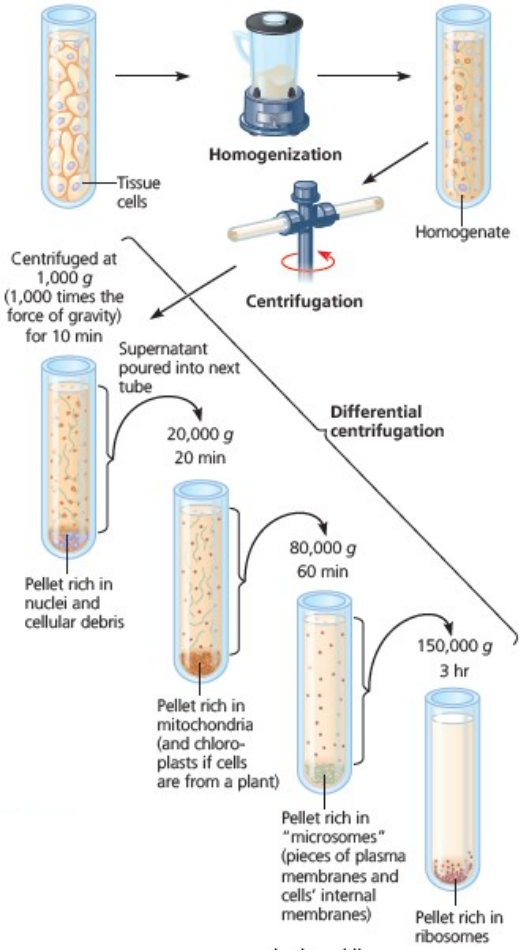
CONCEPT 6.1

Cell Fractionation and Cell Size

- Cell fractionation: homogenize cells, then differential centrifugation separates organelles by size and density
- Pellet vs. supernatant; speeds increase stepwise; used to link function to organelle
- Small cells: high surface area-to-volume ratio, efficient exchange with surroundings
- Volume grows faster than surface area as a cell enlarges
- Specialized shapes (microvilli, flattening) raise surface area



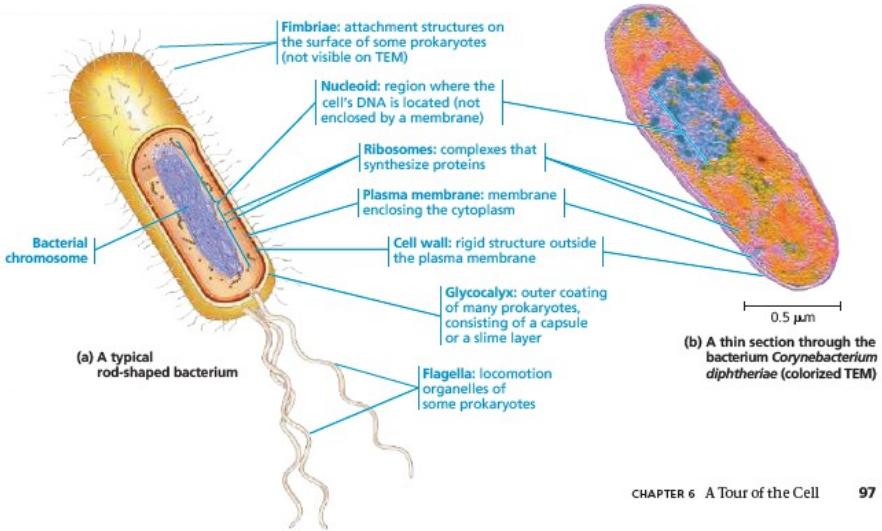
Total surface area [(height × width of 1 side) × 6 sides × number of cells]	6 units^2	150 units^2	750 units^2
Total volume [(height × width × length of 1 cell) × number of cells]	1 unit^3	125 units^3	125 units^3
Surface area-to-volume ratio [surface area ÷ volume]	6	1.2	6



CONCEPT 6.2

Prokaryotic vs. Eukaryotic Cells

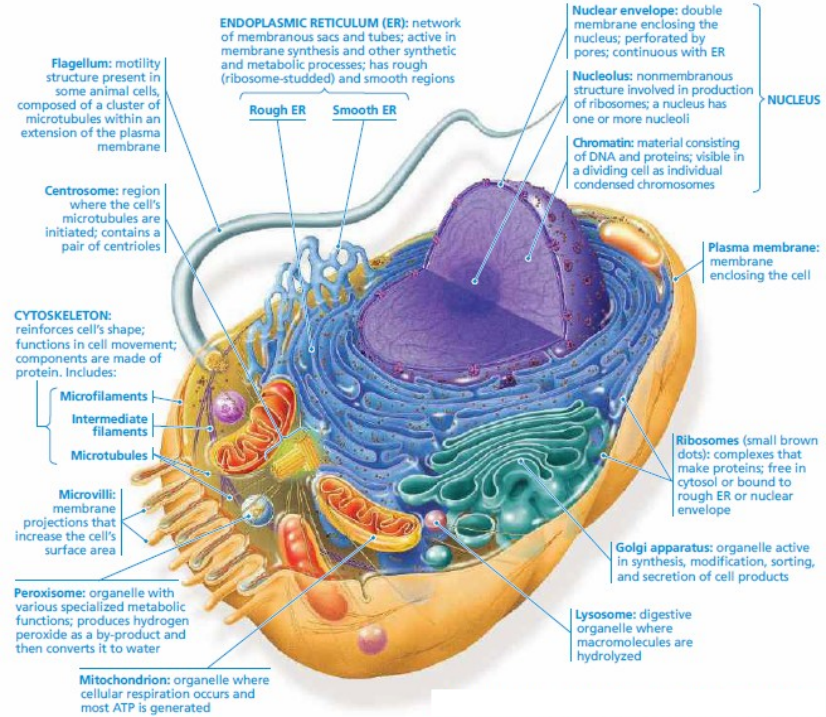
- Basic features of all cells: plasma membrane, cytosol, chromosomes, ribosomes
- Prokaryotic: DNA in nucleoid, no membrane-bound nucleus or organelles; cell wall, capsule, pili, flagella
- Eukaryotic: DNA in nucleus; membrane-bound organelles; generally larger
- Plasma membrane: selective barrier, phospholipid bilayer with proteins
- Internal membranes compartmentalize metabolism



CONCEPT 6.2

Animal Cell Overview

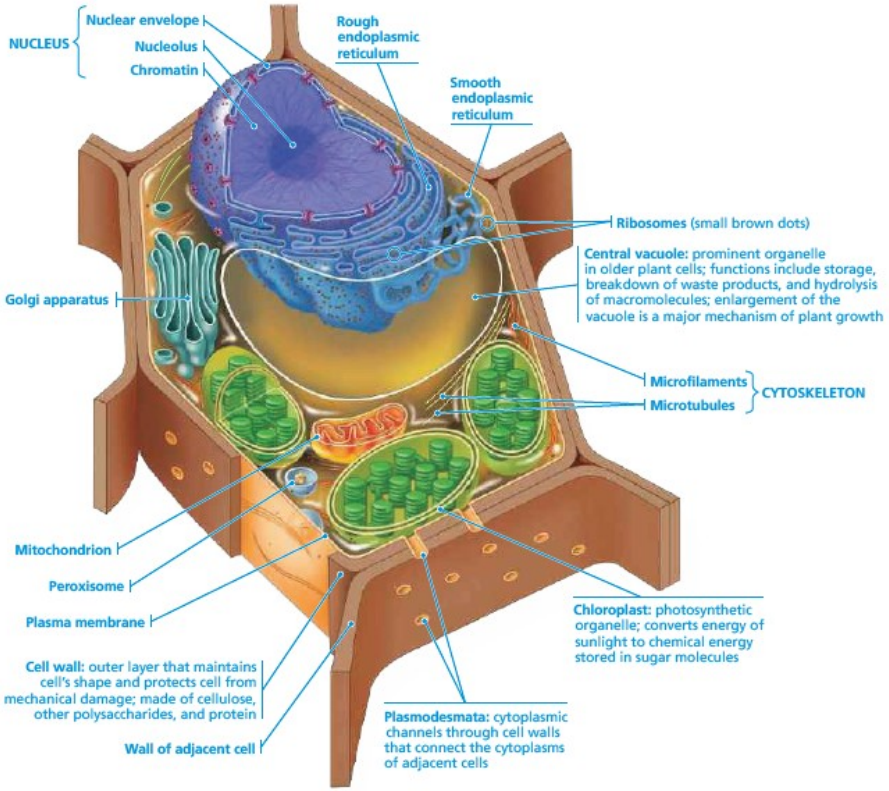
- Organelles: nucleus, nucleolus, rough and smooth ER, Golgi, lyso mitochondria, peroxisomes
- Cytoskeleton, centrosome with centrioles, ribosomes, plasma membrane
- Extracellular matrix outside the plasma membrane
- Flagella in some cells (sperm); cilia in many



CONCEPT 6.2

Plant Cell Overview

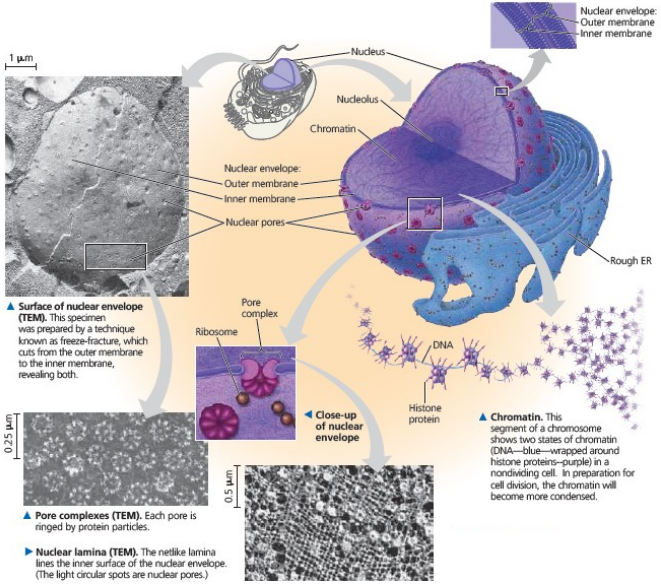
- Shares most organelles with animal cells
- Unique: chloroplasts, large central vacuole, cell wall, plasmodesmata
- No lysosomes (typically), no centrioles, no flagella in most species

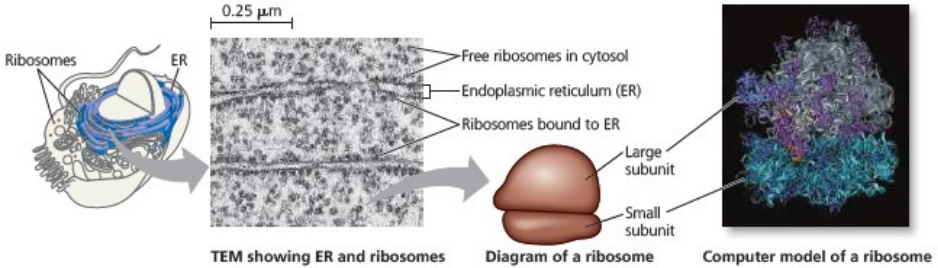


CONCEPT 6.3

Nucleus and Ribosomes

- Nucleus: nuclear envelope (double membrane) with pores; pore complex regulates transport
- Nuclear lamina: protein network supporting envelope
- Chromosomes: DNA + proteins = chromatin; condensed during division
- Nucleolus: rRNA synthesis, ribosomal subunit assembly
- Ribosomes: rRNA and protein; free (cytosolic proteins) vs. bound (secreted, membrane, lysosomal proteins)

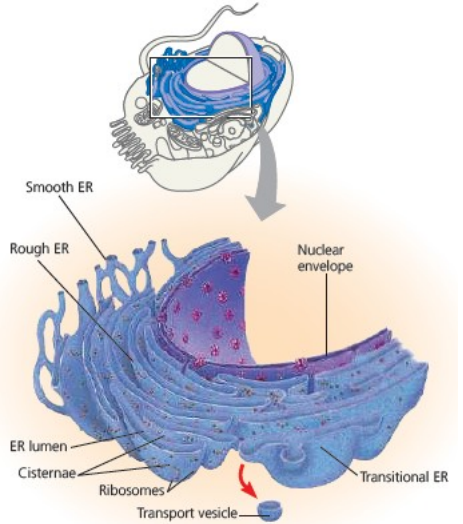


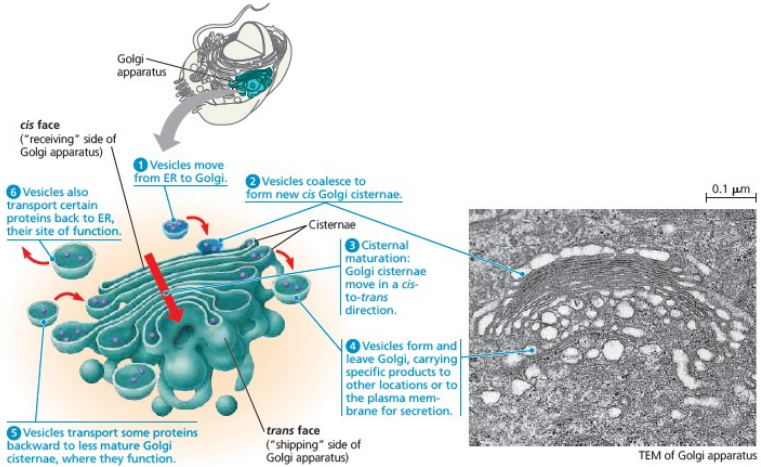


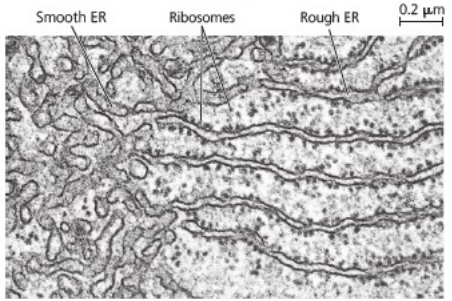
CONCEPT 6.4

Endoplasmic Reticulum and Golgi

- ER: over half of membrane in many cells; lumen and cisternae; continuous with nuclear envelope
- Smooth ER: lipid synthesis, carbohydrate metabolism, detoxification, Ca^{2+} storage
- Rough ER: bound ribosomes; glycoproteins made; transport vesicles bud off
- Golgi: cis face receives, trans face ships; modifies, sorts, makes polysaccharides
- Cisternal maturation model



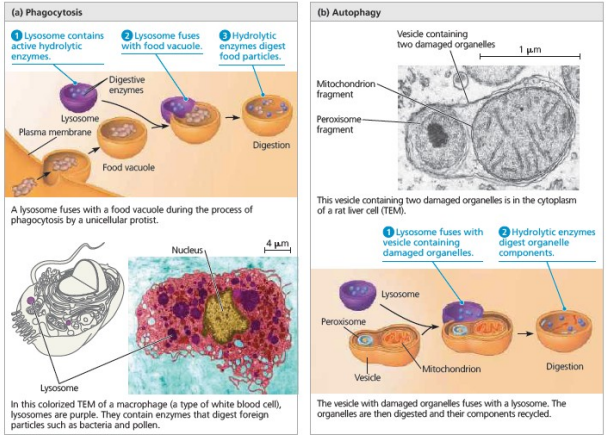


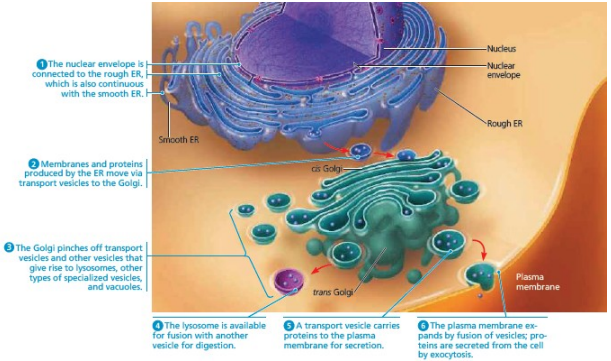


CONCEPT 6.4

Lysosomes, Vacuoles, and the Endomembrane System

- Lysosome: hydrolytic enzymes, acidic pH ~5
- Phagocytosis, autophagy; lysosomal storage diseases (e.g., Tay-Sachs)
- Food, contractile, and central vacuoles; tonoplast
- Endomembrane system: nuclear envelope, ER, Golgi, lysosomes, vacuoles, plasma membrane, linked directly or by vesicles

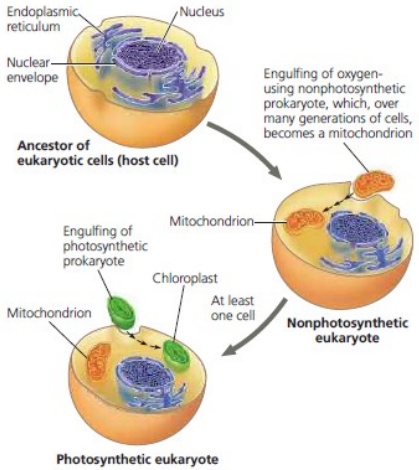


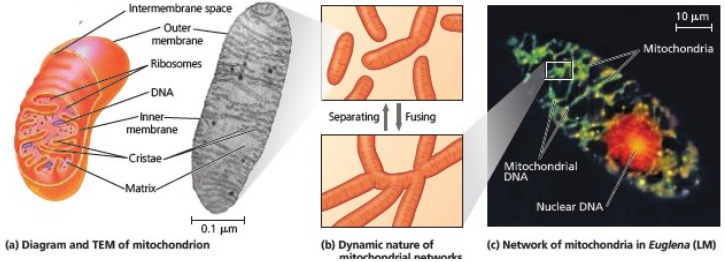


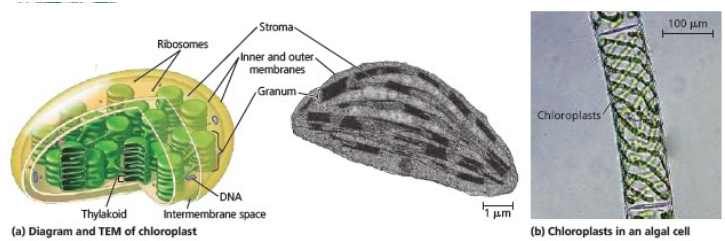
CONCEPT 6.5

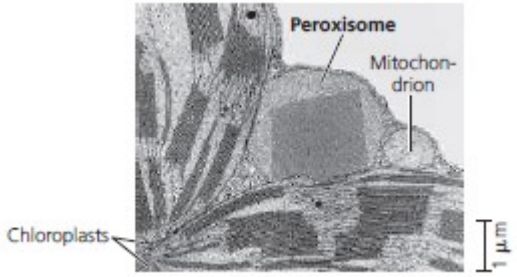
Mitochondria, Chloroplasts, and Peroxisomes

- Endosymbiont theory: ancestors were engulfed prokaryotes; own DNA, ribosomes, double membrane
- Mitochondria: outer and inner membranes, cristae, intermembrane space, matrix; cellular respiration
- Chloroplasts: thylakoids, grana, stroma; photosynthesis; plastids
- Peroxisomes: oxidative reactions, H_2O_2 made and broken down









CONCEPT 6.6

The Cytoskeleton

- Network of fibers: support, motility, regulation
- Microtubules (25 nm, tubulin dimers): shape, organelle and chromosome movement, cilia/flagella
- Microfilaments (7 nm, actin): shape, muscle contraction, cell motility, cytoplasmic streaming
- Intermediate filaments (8–12 nm, keratins etc.): tension, anchor nucleus
- Centrosome and centrioles

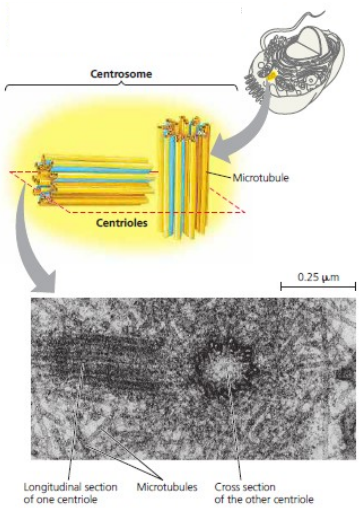
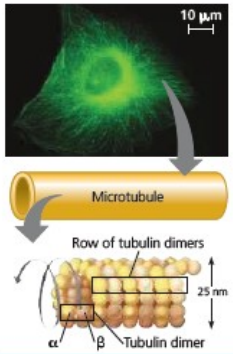
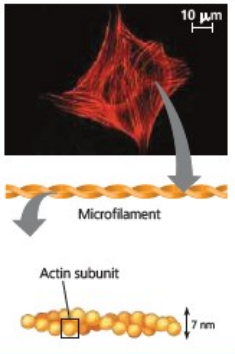
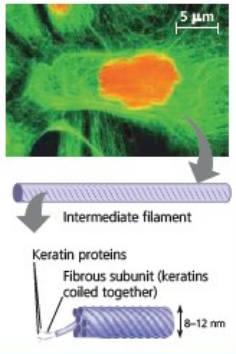


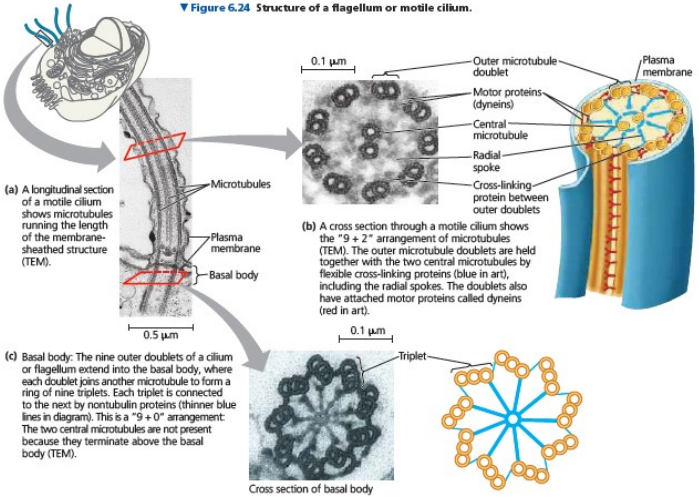
Table 6.1 The Structure and Function of the Cytoskeleton

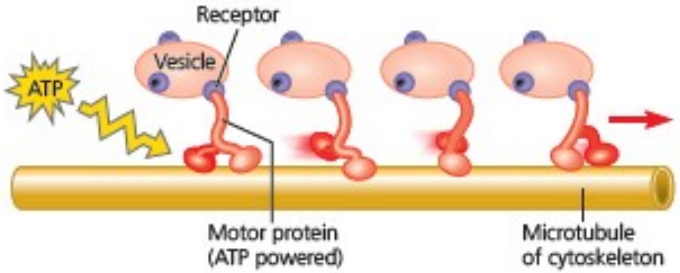
Property	Microtubules (Tubulin Polymers)	Microfilaments (Actin Filaments)	Intermediate Filaments
Structure	Hollow tubes	Two intertwined strands of actin	Fibrous proteins coiled into cables
Diameter	25 nm with 15-nm lumen	7 nm	8–12 nm
Protein subunits	Tubulin, a dimer consisting of an α-tubulin and a β-tubulin	Actin	One of several different proteins (including keratins)
Main functions	Maintenance of cell shape; cell motility; chromosome movements in cell division; organelle movements	Maintenance of cell shape; changes in cell shape; muscle contraction; cytoplasmic streaming (plant cells); cell motility; cell division (animal cells)	Maintenance of cell shape; anchorage of nucleus and certain other organelles; formation of nuclear lamina
Fluorescence micrographs of fibroblasts. Connective tissue cells called fibroblasts are a favorite cell type for cell biology studies because they spread out flat and their internal structures are easy to see. In each fibroblast shown here, the structure of interest has been tagged with fluorescent molecules. In the third micrograph, the DNA in the nucleus has also been tagged (orange).			

CONCEPT 6.6

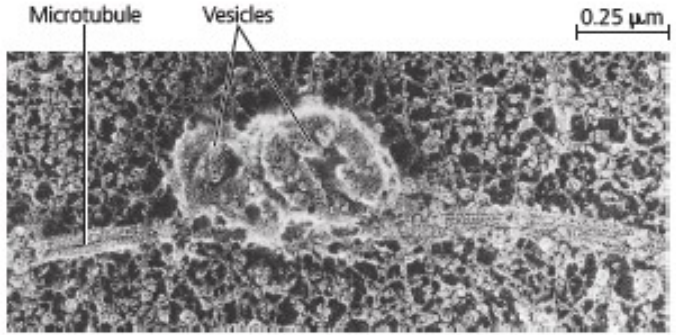
Motor Proteins, Cilia, and Flagella

- Motor proteins (kinesin, dynein) move vesicles along microtubules
- Cilia and flagella: 9 + 2 arrangement, basal body
- Dynein arms cause bending
- Actin and myosin drive muscle contraction and pseudopodia





(a) A motor protein that attaches to a receptor on a vesicle can "walk" the vesicle along a microtubule or microfilament.

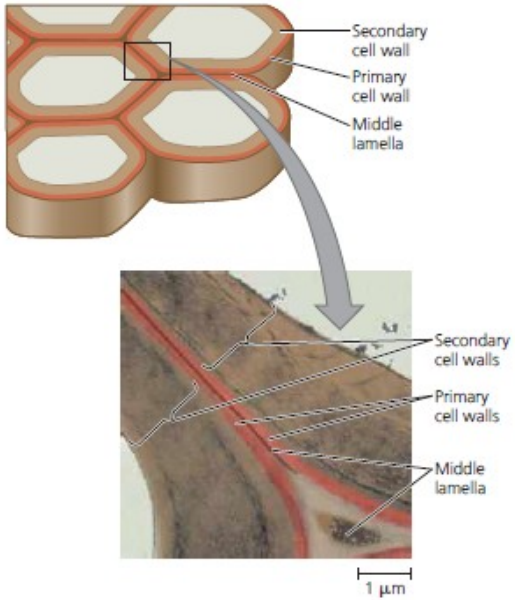


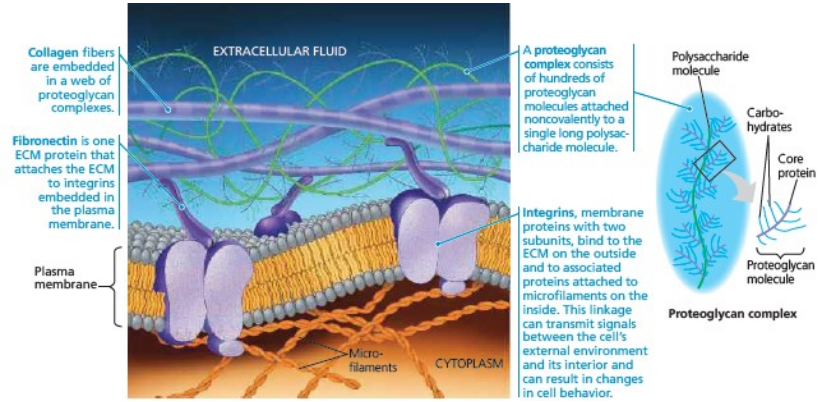
(b) Two vesicles containing neurotransmitters move along a microtubule toward the tip of a nerve cell extension called an axon (SEM).

CONCEPT 6.7

Cell Wall and Extracellular Matrix

- Plant cell wall: cellulose fibers, primary and secondary walls, middle lamella
- ECM of animals: collagen, proteoglycans, fibronectin
- Integrins link ECM to cytoskeleton; signaling

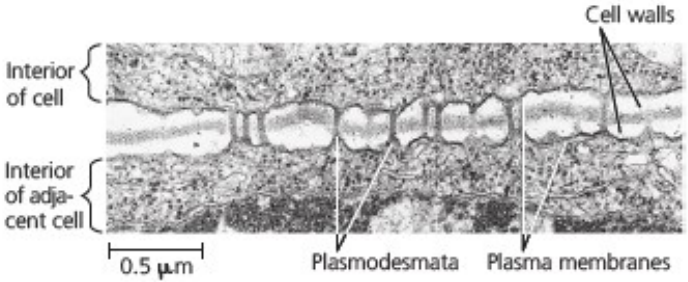


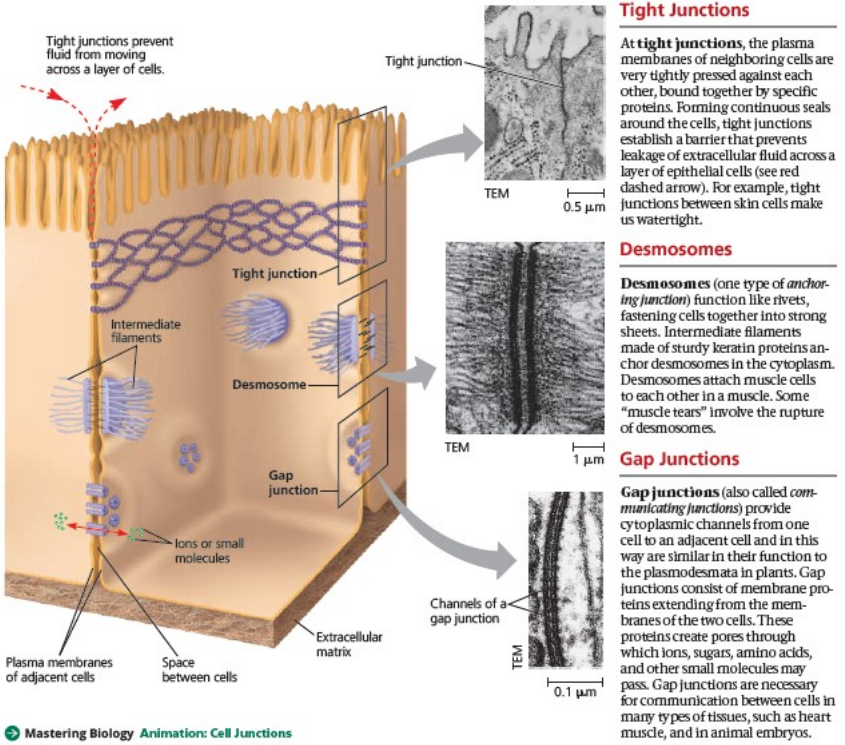


CONCEPT 6.7

Cell Junctions

- Plasmodesmata: channels in plant cell walls
- Tight junctions: seal cells, prevent leakage
- Desmosomes: anchor cells like rivets
- Gap junctions: cytoplasmic channels between animal cells





CONCEPT 6.8

The Cell as an Integrated Whole

- Cell is more than the sum of its parts
- Example: macrophage phagocytosis engages cytoskeleton, ribosomes, ER, Golgi, lysosomes
- Review: Key concepts and self-check questions

