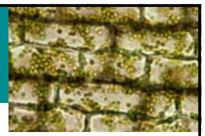
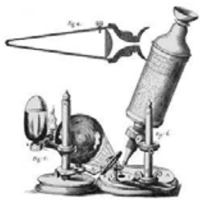
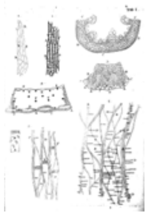
Chapter 6

A Tour of the Cell







Lectures by Chris Romero Modified by Prof. Maria Morlin

Cell word scramble

Unscramble the words below:

1. clle_______________
2. luunecs_______________
3. rebmmane_______________
4. dpliphpoohis_______________
5. alnami_______________
6. ntpla_______________
7. ipostrt_______________
8. ratbacie_______________
9. osseymlo_______________
10. sirebomo_______________

The Importance of Cells

- All organisms are made of cells
- The cell is the simplest collection of matter that can live
- Concept 6.1: To study cells, biologists use microscopes and the tools of biochemistry
- Scientists use microscopes to visualize cells too small to see with the naked eye

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Introduction

- The cell theory is one of the great triumphs in biology
- The introduction of the microscope made the study of the cell possible
- Earliest microscopes invented around 1590 by an unknown Dutch spectacle maker

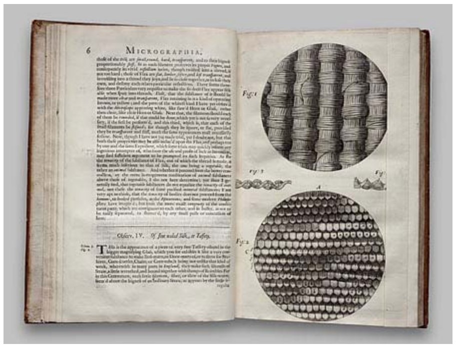
What are the characteristics of life?

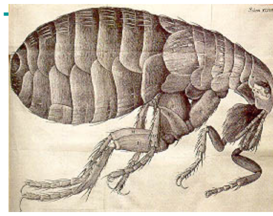
All living things:

1. are composed of one or more cells.
2. require energy.
3. carryout metabolic processes (anabolic and catabolic).
4. undergo growth and development.
5. respond to their environment.
6. maintain homeostasis (a state of internal balance).
7. reproduce.
8. can pass on their traits to their offspring (heredity).

The two characteristics most unique to living things are characteristics seven and eight.

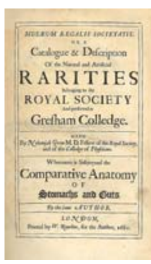
Robert Hook
(1635-1703)






- Between 1672 and 1682 observed "bladders"
- Botanist, physician, and microscopist, who, with the Italian microscopist Marcello Malpighi, is considered to be among the founders of plant anatomy

Nehemiah Grew
(English, 1641-1712)

Catalogue & Description
RARITIES
ROYAL SOCIETY
Gresham Colledge.
Comparative Anatomy
OF
Stomachs and Guts.
LONDON,

Marcello
Malpighi
(Italian, 1628-1694)


MARCELLI MALPIGHII
ANATOME
PLANTARUM
APPENDIX,
OVO INCUBATO

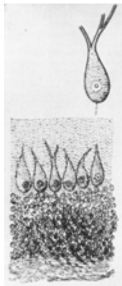
- Professor of medicine and personal physician to Pope Innocent XII
- Between 1675 and 1679 published more and better illustrations

Anton van Leeuwenhoek
(Dutch, 1632-1723)

Precursors Without Theories

- None of them made any conceptual assessment
- In 1800 the "tissue theory" (all organs are made out of tissues) became popular

Better microscopes



Unresolved Questions

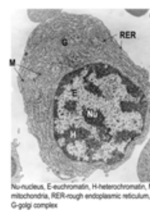
- By the end of the 1830s there were two major questions:

  a) What was the role of the cell in the organism

  b) How do new cells originate?

The Schwann-Schleiden Cell Theory

Plant & animal cells



Conclusions

- The evolution of the cell theory is one of the best examples of progress of science based on mounting number of observations
- Although the object had been observed, many failed to realize its importance
- Many of the initial ideas were totally incorrect; yet, they stimulated a great deal of scientific research
- It required the development of better and better instruments (microscopes)

5. The entire theory was based on a simple observation. Almost no experimentation was needed
6. It is a good example that great generalizations escape from the mind of most people
7. This generalization is only comparable to the theory of evolution in its repercussions of the understanding of biological phenomena

Cell theory

- The cell is the basic unit of structure and function of all living things.
- All living things are composed of one or more cells.
- All cells come from pre-existing cells.

Light microscope

- Enables us to see the overall shape and structure of a cell

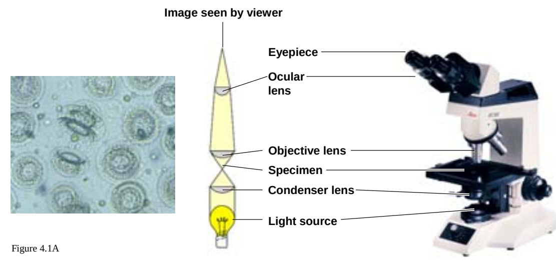


Figure 4.1A

- Use different methods for enhancing visualization of cellular structures

TECHNIQUE | RESULT

(a) Brightfield (unstained specimen). Passes light directly through specimen. Unless cell is naturally pigmented or artificially stained, image has little contrast. [Parts (a)–(d) show a human cheek epithelial cell.]

(b) Brightfield (stained specimen). Staining with various dyes enhances contrast, but most staining procedures require that cells be fixed (preserved).

(c) Phase-contrast. Enhances contrast in unstained cells by amplifying variations in density within specimen; especially useful for examining living, unpigmented cells.

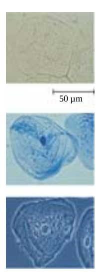
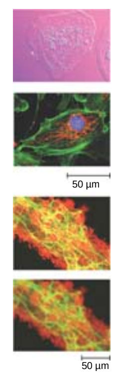


Figure 6.3

(d) Differential-interference-contrast (Nomarski). Like phase-contrast microscopy, it uses optical modifications to exaggerate differences in density, making the image appear almost 3D.

(e) Fluorescence. Shows the locations of specific molecules in the cell by tagging the molecules with fluorescent dyes or antibodies. These fluorescent substances absorb ultraviolet radiation and emit visible light, as shown here in a cell from an artery.

(f) Confocal. Uses lasers and special optics for "optical sectioning" of fluorescently stained specimens. Only a single plane of focus is illuminated; out-of-focus fluorescence above and below the plane is subtracted by a computer. A sharp image results, as seen in stained nervous tissue (top), where nerve cells are green, support cells are red, and regions of overlap are yellow. A standard fluorescence micrograph (bottom) of this relatively thick tissue is blurry.



- Electron microscopes (EMs)
  - Focus a beam of electrons through a specimen (TEM) or onto its surface (SEM)

- The scanning electron microscope (SEM)
  - Provides for detailed study of the surface of a specimen

TECHNIQUE | RESULTS

(a) Scanning electron microscopy (SEM). Micrographs taken with a scanning electron microscope show a 3D image of the surface of a specimen. This SEM shows the surface of a cell from a rabbit trachea (windpipe) covered with motile organelles called cilia. Beating of the cilia helps move inhaled debris upward toward the throat.

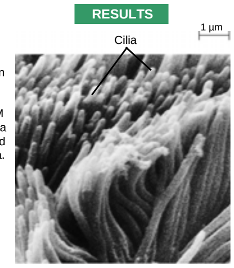
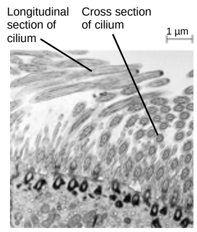


Figure 6.4 (a)

- The transmission electron microscope (TEM)
  - Provides for detailed study of the internal ultrastructure of cells



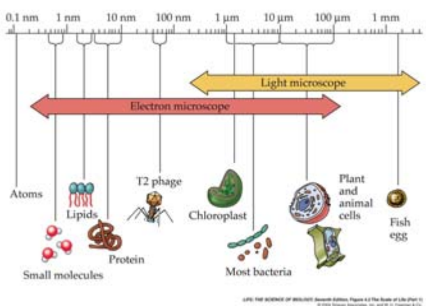
(b) Transmission electron microscopy (TEM). A transmission electron microscope profiles a thin section of a specimen. Here we see a section through a tracheal cell, revealing its ultrastructure. In preparing the TEM, some cilia were cut along their lengths, creating longitudinal sections, while other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

Figure 6.4 (b)

MEASUREMENT EQUIVALENTS

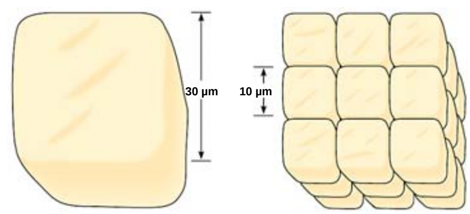
1 centimeter (cm) = 10^{-2} meter (m) = 1/100 m = about 0.4 inch
1 millimeter (mm) = 10^{-3} m = 1/1,000 m = 1/10 cm
1 micrometer (µm) = 10^{-6} m = 1/1,000,000 m = 1/10,000 cm
1 nanometer (nm) = 10^{-9} m = 1/1,000,000,000 m = 1/10,000,000 cm
1 meter = 10^{2} cm = 10^{3} mm = 10^{6} µm = 10^{9} nm

Table 4.2



Surface area to volume ratio

- A smaller cell has a higher surface to volume ratio, which facilitates the exchange of materials into and out of the cell



Surface area of one large cube = 5,400 µm²

Total surface area of 27 small cubes = 16,200 µm²

Figure 4.3

Isolating Organelles by Cell Fractionation

- Cell fractionation
  - Takes cells apart and separates the major organelles from one another
- The centrifuge
  - Is used to fractionate cells into their component parts

- The process of cell fractionation

APPLICATION Cell fractionation is used to isolate (fractionate) cell components, based on size and density.

TECHNIQUE First, cells are homogenized in a blender to break them up. The resulting mixture (cell homogenate) is then centrifuged at various speeds and durations to fractionate the cell components, forming a series of pellets.

Figure 6.5

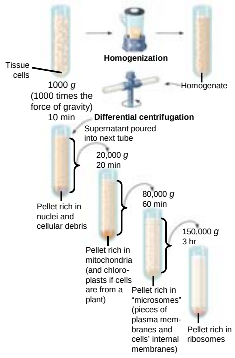


Figure 6.5

RESULTS In the original experiments, the researchers used microscopy to identify the organelles in each pellet, establishing a baseline for further experiments. In the next series of experiments, researchers used biochemical methods to determine the metabolic functions associated with each type of organelle. Researchers currently use cell fractionation to isolate particular organelles in order to study further details of their function.

Figure 6.5

Concept 6.2: Eukaryotic cells have internal membranes that compartmentalize their functions

- Two types of cells make up every organism
  - Prokaryotic
  - Eukaryotic

Comparing Prokaryotic and Eukaryotic Cells

- All cells have several basic features in common
  - They are bounded by a plasma membrane
  - They contain a semifluid substance called the cytosol
  - They contain chromosomes
  - They all have ribosomes

- Prokaryotic cells
  - Do not contain a nucleus
  - Have their DNA located in a region called the nucleoid

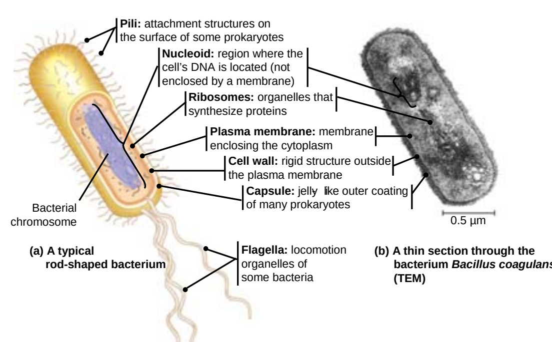
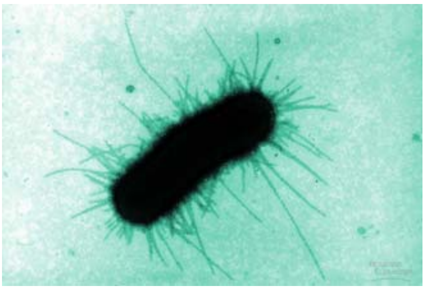


Figure 6.6 A, B

- Pili on a prokaryotic cell

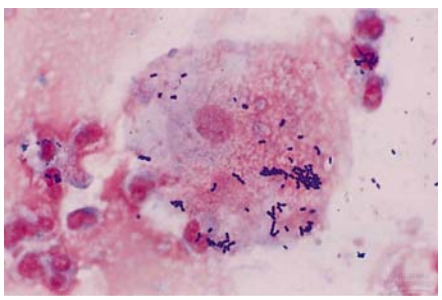


- Prokaryotic cell, *E. coli*

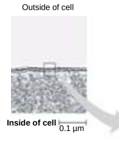
- Prokaryotic flagella

- Eukaryotic cells
  - Contain a true nucleus, bounded by a membranous nuclear envelope
  - Are generally quite a bit bigger than prokaryotic cells

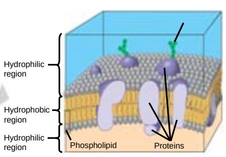
- Prokaryotic and eukaryotic cells compared



- The plasma membrane
  - Functions as a selective barrier
  - Allows sufficient passage of nutrients and waste



(a) TEM of a plasma membrane. The plasma membrane, here in a red blood cell, appears as a pair of dark bands separated by a light band.



(b) Structure of the plasma membrane

Figure 6.8 A, B

A Panoramic View of the Eukaryotic Cell

- Eukaryotic cells
  - Have extensive and elaborately arranged internal membranes, which form organelles
- Plant and animal cells
  - Have most of the same organelles

- A animal cell

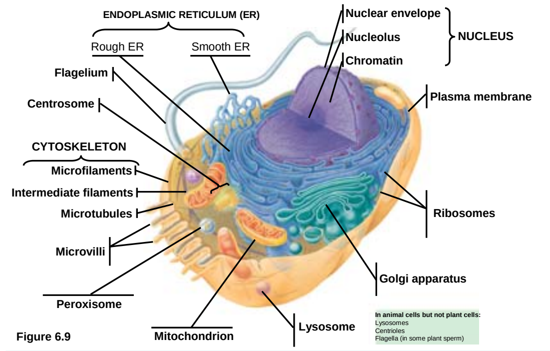


Figure 6.9

- *Paramecium*, an animal cell

- A plant cell

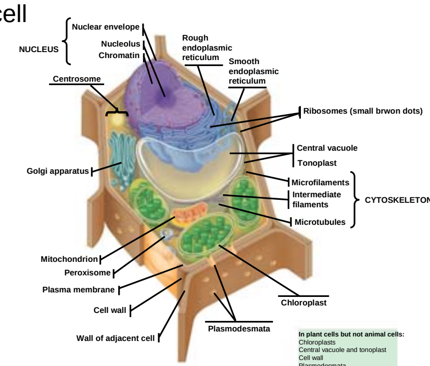
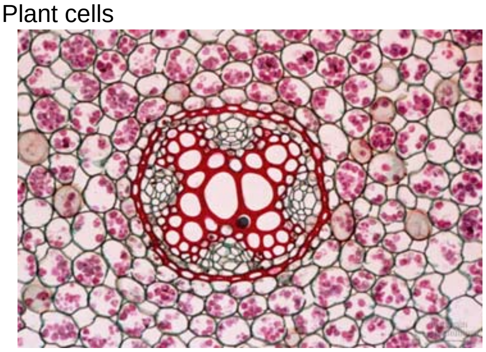
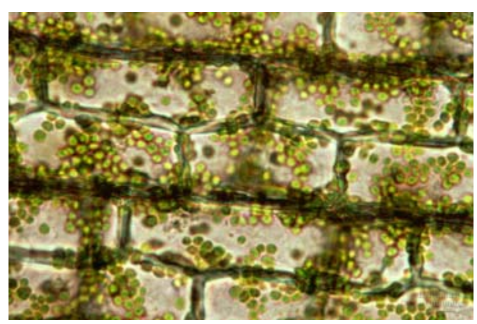


Figure 6.9

- Plant cells



- Chloroplasts in plant cells



Concept 6.3: The eukaryotic cell’s genetic instructions are housed in the nucleus and carried out by the ribosomes

- The nucleus
  - Contains most of the genes in the eukaryotic cell

- The nuclear envelope
  - Encloses the nucleus, separating its contents from the cytoplasm

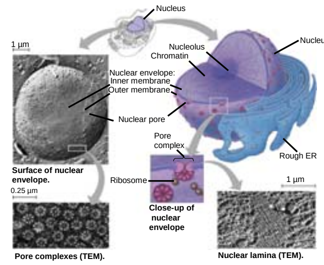


Figure 6.10

Ribosomes

- Carry out protein synthesis

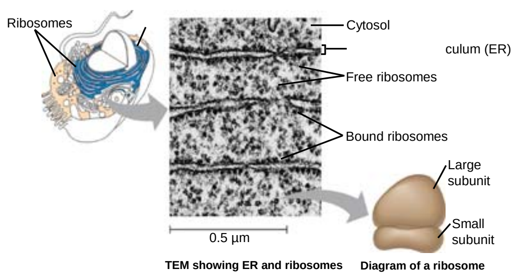


Figure 6.11

Concept 6.4: The endomembrane system regulates protein traffic and performs metabolic functions in the cell

- The endomembrane system
  - Includes many different structures

- The ER membrane
  - Is continuous with the nuclear envelope

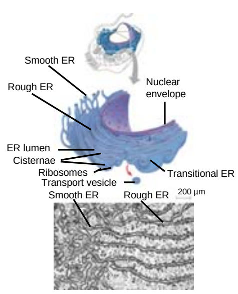


Figure 6.12

- There are two distinct regions of ER
  - Smooth ER, which lacks ribosomes
  - Rough ER, which contains ribosomes

Functions of Smooth ER

- The smooth ER
  - Synthesizes lipids
  - Metabolizes carbohydrates
  - Stores calcium
  - Detoxifies poison

Functions of Rough ER

- The rough ER
  - Has bound ribosomes
  - Produces proteins and membranes, which are distributed by transport vesicles

- Functions of the Golgi apparatus

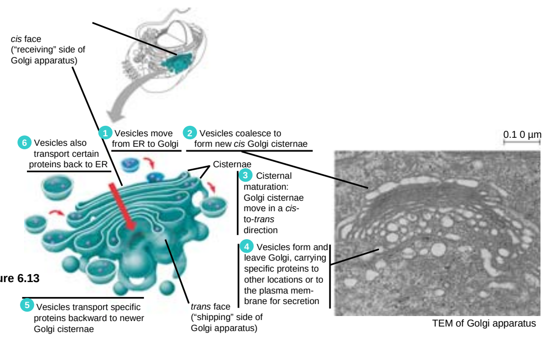


Figure 6.13

- Lysosomes carry out intracellular digestion by
  - Phagocytosis

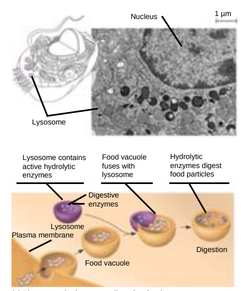


Figure 6.14 A

- Autophagy

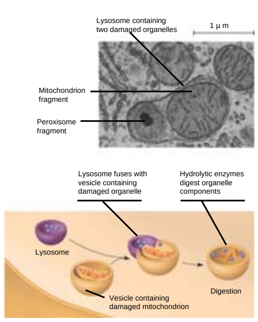


Figure 6.14 B

Vacuoles: Diverse Maintenance Compartments

- A plant or fungal cell
  - May have one or several vacuoles
- Food vacuoles
  - Are formed by phagocytosis
- Contractile vacuoles
  - Pump excess water out of protist cells

- Central vacuoles
  - Are found in plant cells
  - Hold reserves of important organic compounds and water

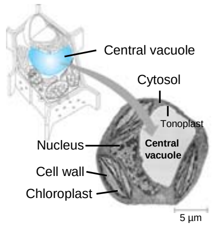


Figure 6.15

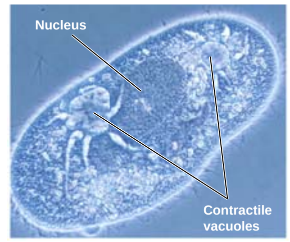


Figure 4.13B

- Relationships among organelles of the endomembrane system

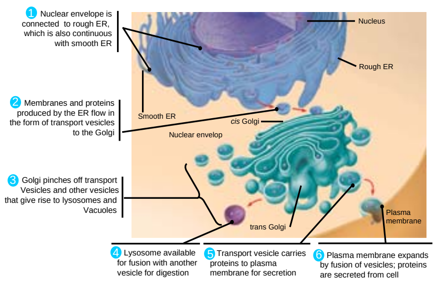


Figure 6.16

- Concept 6.5: Mitochondria and chloroplasts change energy from one form to another
- Mitochondria
  - Are the sites of cellular respiration
- Chloroplasts
  - Found only in plants, are the sites of photosynthesis

Mitochondria

- Two membranes
  - A smooth outer membrane
  - An inner membrane folded into cristae

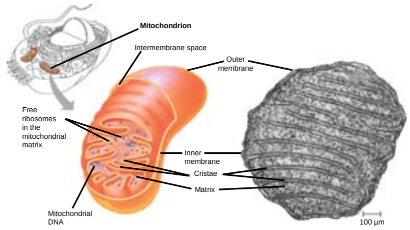


Figure 6.17

Chloroplasts: Capture of Light Energy

- The chloroplast
  - Is a specialized member of a family of closely related plant organelles called plastids
  - Contains chlorophyll

- Chloroplasts
  - Are found in leaves and other green organs of plants and in algae

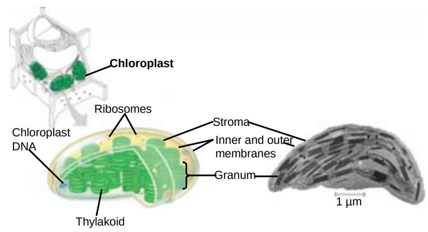


Figure 6.18

Peroxisomes: Oxidation

- Peroxisomes
  - Produce hydrogen peroxide and convert it to water

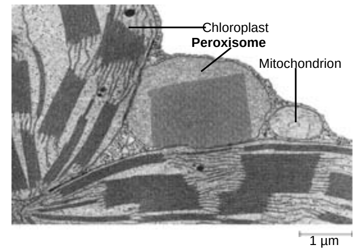


Figure 6.19

cytoskeleton

- organizes structures and activities in the cell
- Is a network of fibers extending throughout the cytoplasm

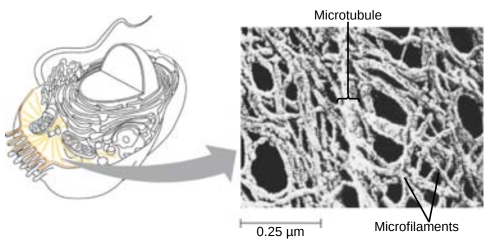
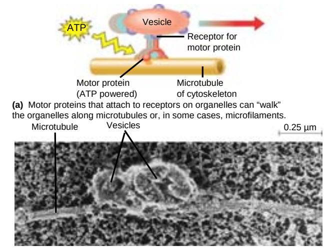


Figure 6.20

Roles of the Cytoskeleton: Support, Motility, and Regulation

- Cell motility utilizes motor proteins



(b) Vesicles containing neurotransmitters migrate to the tips of nerve cell axons via the mechanism in (a). In this SEM of a squid giant axon, two vesicles can be seen moving along a microtubule. (A separate part of the experiment provided the evidence that they were in fact moving.)

Figure 6.21 A, B

- There are three main types of fibers that make up the cytoskeleton

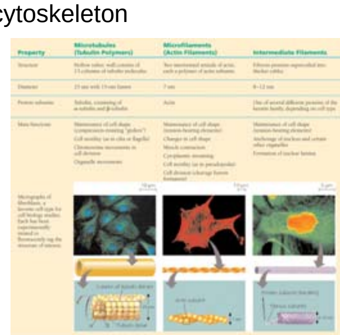


Table 6.1

Microtubules

- Microtubules
  - Shape the cell
  - Guide movement of organelles
  - Help separate the chromosome copies in dividing cells

Centrosomes and Centrioles

- The centrosome is a "microtubule-organizing center" & contains a pair of centrioles

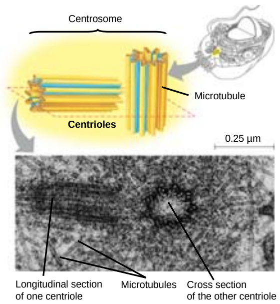


Figure 6.22

Cilia and Flagella

- Cilia and flagella
  - Contain specialized arrangements of microtubules
  - Are locomotor appendages of some cells

- Flagella beating pattern

(a) Motion of flagella. A flagellum usually undulates, its snakelike motion driving a cell in the same direction as the axis of the flagellum. Propulsion of a human sperm cell is an example of flagellatelocomotion (LM).

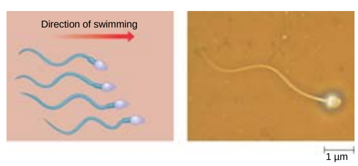


Figure 6.23 A

- Ciliary motion

(b) Motion of cilia. Cilia have a back-and-forth motion that moves the cell in a direction perpendicular to the axis of the cilium. A dense nap of cilia, beating at a rate of about 40 to 60 strokes a second, covers this *Colpidium,* a freshwater protozoan (SEM).

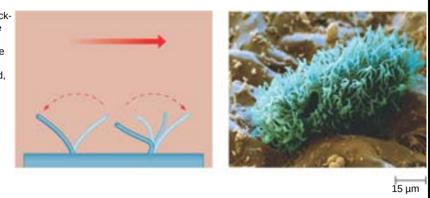


Figure 6.23 B

- Cilia and flagella share a common ultrastructure

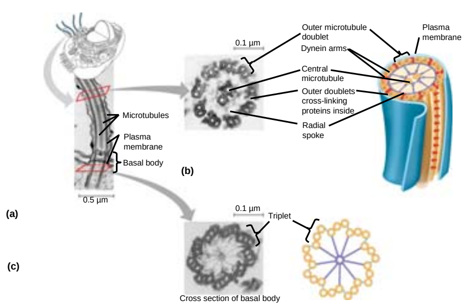
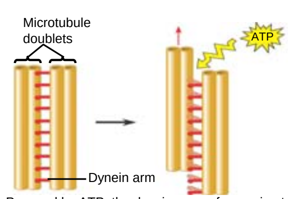


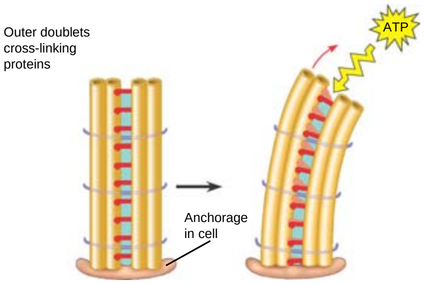
Figure 6.24 A-C

- The protein dynein
  - Is responsible for the bending movement of cilia and flagella



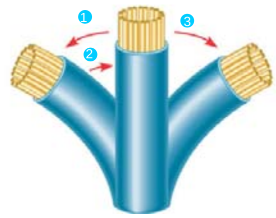
(a) Powered by ATP, the dynein arms of one microtubule doublet grip the adjacent doublet, push it up, release, and then grip again. If the two microtubule doublets were not attached, they would slide relative to each other.

Figure 6.25 A



(b) In a cilium or flagellum, two adjacent doublets cannot slide far because they are physically restrained by proteins, so they bend. (Only two of the nine outer doublets in Figure 6.24b are shown here.)

Figure 6.25 B



(c) Localized, synchronized activation of many dynein arms probably causes a bend to begin at the base of the Cilium or flagellum and move outward toward the tip. Many successive bends, such as the ones shown here to the left and right, result in a wavelike motion. In this diagram, the two central microtubules and the cross-linking proteins are not shown.

Figure 6.25 C

Microfilaments (Actin Filaments)

- Microfilaments
  - Are built from molecules of the protein actin

- Are found in microvilli

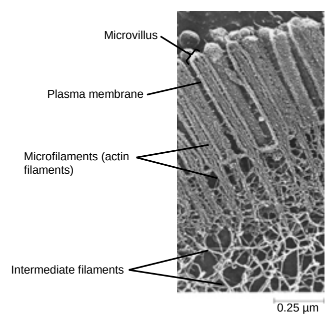


Figure 6.26

- Microfilaments that function in cellular motility
  - Contain the protein myosin in addition to actin

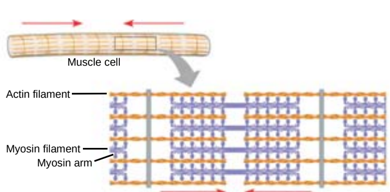


Figure 6.27 A (a) Myosin motors in muscle cell contraction.

- Amoeboid movement
  - Involves the contraction of actin and myosin filaments

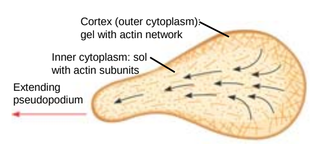


Figure 6.27 B (b) Amoeboid movement

- Cytoplasmic streaming
  - Is another form of locomotion created by microfilaments

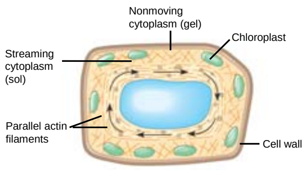


Figure 6.27 C **(b) Cytoplasmic streaming in plant cells**

Intermediate Filaments

- Intermediate filaments
  - Support cell shape
  - Fix organelles in place

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

Plant cell walls

- Are made of cellulose fibers embedded in other polysaccharides and protein
- May have multiple layers

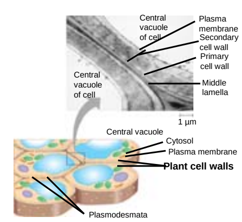


Figure 6.28

The Extracellular Matrix (ECM) of Animal Cells

- The ECM
  - Is made up of glycoproteins and other macromolecules

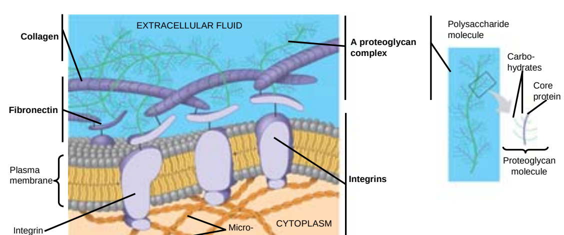


Figure 6.29

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

Intercellular Junctions

- Plants: plasmodesmata
  - Are channels that perforate plant cell walls

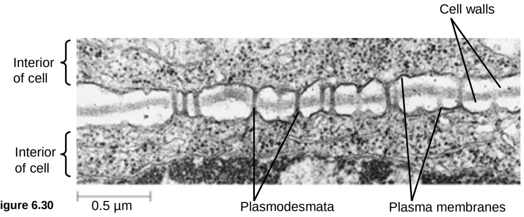


Figure 6.30

Animals: Tight Junctions, Desmosomes, and Gap Junctions

- In animals, there are three types of intercellular junctions
  - Tight junctions
  - Desmosomes
  - Gap junctions

- Types of intercellular junctions in animals

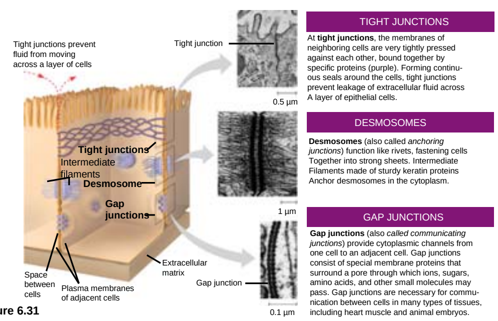


Figure 6.31

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

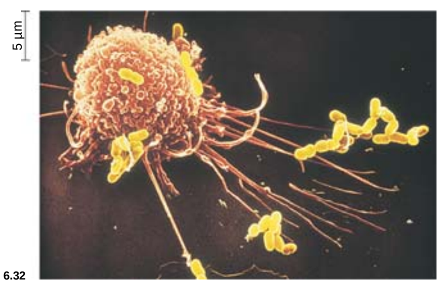


Figure 6.32