UNIT 2

The Cell

Chapter 6

A Tour of the Cell

Key Concepts

6.1 To study cells, biologists use microscopes and the tools of biochemistry

6.2 Eukaryotic cells have internal membranes that compartmentalize their functions

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

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

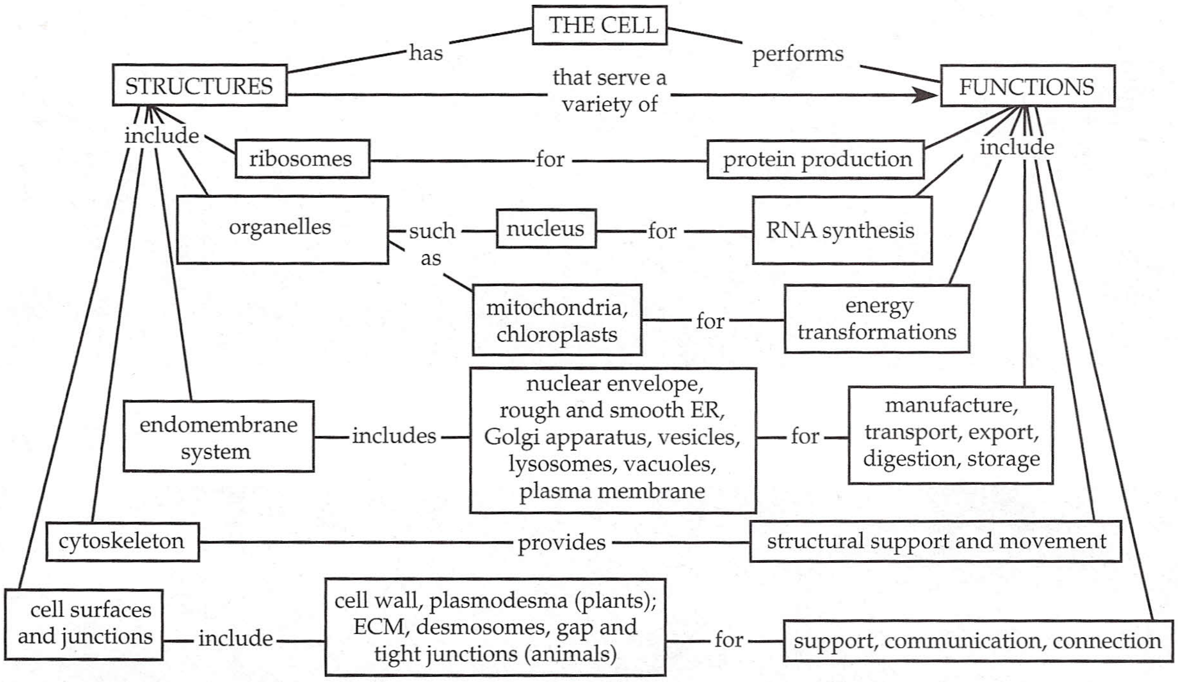
6.5 Mitochondria and chloroplasts change energy from one form to another

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

6.7 Extracellular components and connections between cells help coordinate cellular activities

Framework

The cell is the fundamental unit of life. The complexities in the processes of life are reflected in the complexities of the structure of the cell. It is easy to become overwhelmed by the number of new vocabulary terms for this array of cell organelles and membranes. The following diagram provides an organizational framework for the wealth of detail found in "a tour of the cell."



Chapter Review

The cell is the basic structural and functional unit of all living organisms. In the hierarchy of biological organization, the capacity for life emerges from the structural order of the cell. All cells are related through common descent, but evolution has shaped diverse adaptations.

6.1 To study cells, biologists use microscopes and the tools of biochemistry

Microscopy The glass lenses of **light microscopes (LMs)** refract (bend) the visible light passing through a specimen such that the projected image is magnified. *Magnification* is the ratio of the size of this projected image to the real size of the object. *Resolution* is a measure of how clear an image is, and is determined by the minimum distance two points must be separated to be distinguished. The resolution of the light microscope is limited by the shortest wavelength of visible light, so that details finer than 0.2 μm (micrometers = 10^{-3} mm) cannot be resolved. Staining of specimens and using techniques such as fluorescence, phase-contrast, and confocal microscopy improve visibility by increasing contrast between structures that are large enough to be resolved.

Most subcellular structures, including membrane-enclosed **organelles,** cannot be resolved by the light microscope. Cells were discovered by Robert Hooke in 1665, but their ultrastructure was largely unknown until the development of the **electron microscope (EM)** in the 1950s. The electron microscope focuses a beam of electrons through the specimen. The short wavelength of the electron beam allows a resolution of about 2 nm (nanometers = 10^{-3} μm), a hundred times greater than that of the light microscope.

In a **scanning electron microscope (SEM),** an electron beam scans the surface of a specimen usually coated with a thin gold film, exciting electrons from the specimen, which are detected and translated into an image on a video screen. This image appears three-dimensional.

In a **transmission electron microscope (TEM),** a beam of electrons is passed through a thin section of a specimen stained with atoms of heavy metals. Electromagnets, acting as lenses, then focus the image onto a screen or film.

Modern cell biology integrates *cytology* with *biochemistry* to understand relationships between cellular structure and function.

INTERACTIVE QUESTION 6.1

a. Define cytology.

b. What do cell biologists use a TEM to study?

c. What does an SEM show best?

d. What advantages does light microscopy have over both TEM and SEM?

Cell Fractionation **Cell fractionation** is a technique that separates organelles and other structures of a cell so that they can be identified and their functions studied. Cells are broken apart and the homogenate is separated into component fractions by centrifugation at increasing speeds.

6.2 Eukaryotic cells have internal membranes that compartmentalize their functions

Comparing Prokaryotic and Eukaryotic Cells All cells are bounded by a plasma membrane, which encloses a semifluid medium called **cytosol.** All cells contain chromosomes and ribosomes.

Only members of the domains Bacteria and Archaea have **prokaryotic cells,** which are cells with no nucleus or membrane-enclosed organelles. The DNA of prokaryotic cells is concentrated in a region called the **nucleoid.** **Eukaryotic cells** have a true nucleus enclosed in a nuclear envelope and numerous organelles suspended in cytosol. **Cytoplasm** refers to the entire region between the nucleus and the plasma membrane, and also to the interior of a prokaryotic cell.

Most bacterial cells range from 1 to 10 μm in diameter, whereas eukaryotic cells are 10 times larger, ranging from 10 to 100 μm.

The small size of cells is dictated by geometry and the requirements of metabolism. Area is proportional to the square of linear dimension, while volume is proportional to its cube. The **plasma membrane** surrounding every cell must provide sufficient surface area for exchange of oxygen, nutrients, and wastes relative to the volume of the cell.

INTERACTIVE QUESTION 6.2

a. Describe the molecular structure of the plasma membrane.

b. If a eukaryotic cell has a diameter that is 10 times that of a bacterial cell, proportionally how much more surface area would the eukaryotic cell have?

c. Proportionally how much more volume would it have?

A Panoramic View of the Eukaryotic Cell Membranes compartmentalize the eukaryotic cell, providing local environments for specific metabolic functions and participating in metabolism through membrane-bound enzymes. Like the plasma membrane, internal membranes are composed of a bilayer of phospholipid molecules associated with diverse proteins.

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

The Nucleus: Information Central The **nucleus** is surrounded by the **nuclear envelope,** a double membrane perforated by pores that regulate the movement of materials between the nucleus and the cytoplasm. The inner membrane is lined by the **nuclear lamina,** a layer of protein filaments that helps to maintain the shape of the nucleus.

Most of the cell's DNA is located in the nucleus, where it is organized into units called **chromosomes,** which are made up of a complex of DNA and proteins called **chromatin.** Each eukaryotic species has a characteristic chromosomal number. Individual chromosomes are visible only when condensed in a dividing cell.

The **nucleolus,** a dense structure visible in the nondividing nucleus, synthesizes ribosomal RNA and combines it with protein to assemble ribosomal subunits, which then pass through nuclear pores to the cytoplasm.

Ribosomes: Protein Factories **Ribosomes** are composed of protein and ribosomal RNA. Most of the proteins produced on *free ribosomes* are used within the cytosol. *Bound ribosomes,* attached to the endoplasmic reticulum or nuclear envelope, usually make proteins that will be included within membranes, packaged into organelles, or exported from the cell.

INTERACTIVE QUESTION 6.3

How does the nucleus control protein synthesis in the cytoplasm?

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

The **endomembrane system** of a cell consists of the nuclear envelope, endoplasmic reticulum, Golgi apparatus, lysosomes, vacuoles, and the plasma membrane. These membranes are all related either through direct contact or by the transfer of membrane segments by membrane-bound sacs called **vesicles.**

The Endoplasmic Reticulum: Biosynthetic Factory The **endoplasmic reticulum (ER)** is continuous with the nuclear envelope and encloses a network of interconnected tubules or compartments called cisternae. Ribosomes are attached to the cytoplasmic surface of **rough ER; smooth ER** lacks ribosomes.

Smooth ER serves diverse functions in different cells: Its enzymes are involved in phospholipid and steroid (including sex hormone) synthesis, carbohydrate metabolism, and detoxification of drugs and poisons. Barbiturates, alcohol, and other drugs increase a liver cell's production of smooth ER, thus leading to an increased tolerance (and thus reduced effectiveness) for these and other drugs. Smooth ER also functions in storage and release of calcium ions during muscle contraction.

Proteins intended for secretion are manufactured by membrane-bound ribosomes and then threaded into the lumen of the rough ER. Many are covalently bonded to small carbohydrates to form **glycoproteins.** Secretory proteins are transported from the rough ER in membrane-bound **transport vesicles.**

Rough ER manufactures membranes for the cell. Enzymes built into the membrane assemble phospholipids, and membrane proteins formed by bound ribosomes are inserted into the ER membrane. Transport vesicles transfer ER membrane to other parts of the endomembrane system.

The Golgi Apparatus: Shipping and Receiving Center The **Golgi apparatus** consists of a stack of flattened sacs. Vesicles that bud from the ER join to the *cis* face of a Golgi stack, adding to it their contents and membrane. According to the *cisternal maturation model,* Golgi products are processed and tagged as the cisternae themselves progress from the *cis* to the *trans* face. Glycoproteins often have their attached carbohydrates modified. The Golgi of plant cells manufacture some polysaccharides, such as pectins. Golgi products are sorted into vesicles, which pinch off from the *trans* face of the Golgi apparatus. These vesicles may have surface molecules that help direct them to the plasma membrane or to other organelles.

Lysosomes: Digestive Compartments **Lysosomes** are membrane-enclosed sacs of hydrolytic enzymes used by animal cells to digest macromolecules. Lysosomes provide an acidic pH for these enzymes.

In some protists, lysosomes fuse with food vacuoles to digest material ingested by **phagocytosis.** Macrophages, a type of white blood cell, use lysosomes to destroy ingested bacteria. Lysosomes also recycle a cell's own macromolecules by engulfing damaged organelles or small bits of cytosol, a process known as *autophagy.*

Vacuoles: Diverse Maintenance Compartments **Food vacuoles** are formed as a result of phagocytosis. **Contractile vacuoles** pump excess water out of freshwater protists. A large **central vacuole** is found in mature plant cells, surrounded by a vacuolar membrane (tonoplast) and enclosing a solution called cell sap. This vacuole stores organic compounds and inorganic ions for the cell. Dangerous metabolic by-products and poisonous or unpalatable compounds, which may protect the plant from predators, may also be contained in the vacuole. Plant cells increase in size with a minimal addition of new cytoplasm as their vacuoles absorb water and expand.

The Endomembrane System: A Review As membranes move from the ER to the Golgi and then to other organelles, their compositions, functions, and contents are modified.

6.5 Mitochondria and chloroplasts change energy from one form to another

Cellular respiration, the metabolic processing of fuels to produce ATP, occurs within the **mitochondria** of eukaryotic cells. Photosynthesis occurs in the **chloroplasts**

INTERACTIVE QUESTION 6.4

Name the components of the endomembrane system shown in this diagram and list the functions of each of these membranes.

a.

b.

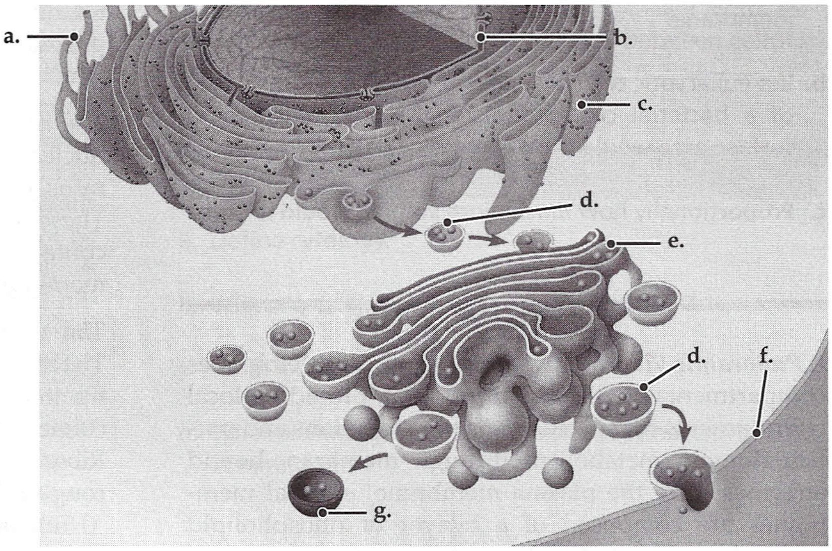
c.

d.

e.

f.

g.



of plants and algae, which produce organic compounds from carbon dioxide and water by absorbing solar energy. The membrane proteins of mitochondria and chloroplasts are made by ribosomes either free in the cytosol or contained within these organelles. They also contain a small amount of DNA that directs the synthesis of some of their proteins.

Mitochondria: Chemical Energy Conversion Two membranes, each a phospholipid bilayer with unique embedded proteins, enclose a mitochondrion. A narrow intermembrane space exists between the smooth outer membrane and the convoluted inner membrane. The folds of the inner membrane, called **cristae,** create a large surface area and enclose the **mitochondrial matrix.** Many respiratory enzymes, mitochondrial DNA, and ribosomes are housed in this matrix. Other respiratory enzymes and proteins are built into the inner membrane.

Chloroplasts: Capture of Light Energy **Plastids** are plant organelles that include amyloplasts, which store starch; chromoplasts, which contain pigments; and chloroplasts, which contain the green pigment chlorophyll and function in photosynthesis.

Chloroplasts are bounded by two membranes separated by a thin intermembrane space. Inside the inner membrane is a fluid called the **stroma** surrounding a membranous system of flattened sacs called **thylakoids,** inside of which is the thylakoid space. Photosynthetic enzymes are embedded in the thylakoids, which may be stacked together to form structures called **grana.** Chloroplast DNA, ribosomes, and many enzymes are contained in the stroma.

INTERACTIVE QUESTION 6.5

Sketch a mitochondrion and a chloroplast and label their membranes and compartments.

Peroxisomes: Oxidation **Peroxisomes** are oxidative organelles filled with enzymes that function in a variety of metabolic pathways, such as breaking down fatty acids for energy or detoxifying alcohol and other poisons. An enzyme that converts hydrogen peroxide (H_2O_2), a toxic by-product of these pathways, to water is also packaged into peroxisomes. *Glyoxyomes,* found in plant seeds, contain enzymes that convert fatty acids to sugars for growing seedlings.

INTERACTIVE QUESTION 6.6

Why are peroxisomes not considered part of the endomembrane system?

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

Roles of the Cytoskeleton: Support, Motility, and Regulation The **cytoskeleton** is a network of protein fibers that give mechanical support, function in cell motility (of both internal structures and the cell as a whole), and transmit mechanical signals from the cell's surface to its interior. The cytoskeleton interacts with special proteins called **motor proteins** to produce cellular movements.

Components of the Cytoskeleton The three main types of fibers involved in the cytoskeleton are *microtubules, microfilaments,* and *intermediate filaments.*

All eukaryotic cells have **microtubules,** which are hollow rods constructed of columns of globular proteins called tubulins. Microtubules change length through the addition or subtraction of tubulin dimers. In addition to providing the supporting framework of the cell, microtubules serve as tracks along which organelles move with the aid of motor molecules.

In many animal cells, microtubules grow out from a region near the nucleus called a **centrosome.** A pair of **centrioles,** each composed of nine sets of triplet microtubules arranged in a ring, is associated with the centrosome and replicates before cell division. Yeast and plant cells lack centrosomes and must have some other microtubule-organizing center.

Cilia and **flagella** are locomotor extensions of some eukaryotic cells. Cilia are numerous and short; flagella occur one or two to a cell and are longer. Many protists use cilia or flagella to move through aqueous media. Cilia or flagella attached to stationary cells of a tissue move fluid past the cell. Cilia may act to transmit environmental signals to the cell's nucleus.

Both cilia and flagella are composed of two single microtubules surrounded by a ring of nine doublets of microtubules (a nearly universal "9 + 2" arrangement), all of which are enclosed in an extension of the plasma membrane. A **basal body,** structurally similar to a centriole, anchors the tubules in the cell. ATP drives the sliding of the microtubule doublets past each other as arms, composed of motor proteins called **dyneins,** alternately attach to adjacent doublets, pull down, release, and reattach. In conjunction with anchoring cross-linking proteins and radial spokes, this action causes the bending of the flagellum or cilium.

Microfilaments, probably present in all eukaryotic cells, are solid rods consisting of a twisted double chain of molecules of the globular protein **actin.** Also called actin filaments, microfilaments function in support, forming a network just inside the plasma membrane (in the cytoplasmic layer called the **cortex**) and the core of small cytoplasmic extensions called microvilli.

In muscle cells, thousands of actin filaments interdigitate with thicker filaments made of the protein **myosin.** The sliding of actin and myosin filaments past each other causes the contraction of muscles.

Actin and myosin also interact in localized contractions such as cleavage furrows in animal cell division and amoeboid movements. Actin subunits reversibly assemble into microfilaments and then networks, driving the conversion of cytoplasm from sol to gel during the extension and retraction of **pseudopodia.** Actin filaments interacting with myosin may propel cytoplasm forward into pseudopodia. **Cytoplasmic streaming** in plant cells appears to involve both actin–myosin interactions and sol–gel conversions.

Intermediate filaments are intermediate in size between microtubules and Microfilaments and are more diverse in their composition. Intermediate fibers appear to be important in maintaining cell shape. The nucleus is securely held in a web of intermediate filaments, and the nuclear lamina lining the inside of the nuclear envelope is composed of intermediate filaments.

INTERACTIVE QUESTION 6.7

Fill in the following table to organize what you have learned about the components of the cytoskeleton. You may wish to refer to the textbook for additional details.

Cytoskeleton	Structure and Monomers	Functions
Microtubules	a.	b.
Microfilaments (actin filaments)	c.	d.
Intermediate filaments	e.	f.

6.7 Extracellular components and connections between cells help coordinate cellular activities

Cell Walls of Plants Plant **cell walls** are composed of microfibrils of cellulose embedded in a matrix of polysaccharides and protein.

The **primary cell wall** secreted by a young plant cell is relatively thin and flexible. Microtubules appear to guide the path of cellulose synthase, determining the pattern of cellulose fibril deposition and thus, the direction of cell expansion. Adjacent cells are glued together by the **middle lamella,** a thin layer of polysaccharides (called pectins). When they stop growing, some cells secrete a thicker and stronger **secondary cell wall** between the plasma membrane and the primary cell wall.

INTERACTIVE QUESTION 6.8

Sketch two adjacent plant cells, and show the location of the primary and secondary cell walls and the middle lamella.

The Extracellular Matrix (ECM) of Animal Cells Animal cells secrete an **extracellular matrix (ECM)** composed primarily of glycoproteins. **Collagen** forms strong fibers that are embedded in a network of proteoglycan complexes. **Proteoglycans** consist of a small core protein with many attached carbohydrate chains. Cells may be attached to the ECM by **fibronectins** and other glycoproteins that bind to **integrins,** receptor proteins that span the plasma membrane and bind, via other proteins, to microfilaments of the cytoskeleton. Thus, information about changes inside and outside the cell can be exchanged through a mechanical signaling pathway involving fibronectins, integrins, and the microfilaments of the cytoskeleton. Signals from the ECM appear to influence the activity of genes in the nucleus.

Intercellular Junctions **Plasmodesmata** are channels in plant cell walls through which the plasma membranes of bordering cells connect, thus linking most cells of a plant into a living continuum. Water, small solutes, and even some proteins and RNA molecules can move through these channels.

There are three main types of intercellular junctions between animal cells. At *tight junctions,* proteins hold adjacent cell membranes tightly together, creating an impermeable seal across a layer of epithelial cells. *Desmosomes* (also called *anchoring junctions*) are reinforced by intermediate filaments and rivet cells into strong sheets. *Gap junctions* (also called *communicating junctions*) are cytoplasmic connections that allow for the exchange of ions and small molecules between cells through protein-lined pores.

INTERACTIVE QUESTION 6.9

Return to your sketch of plant cells in Interactive Question 6.8 and draw in a plasmodesma.

The Cell: A Living Unit Greater Than the Sum of Its Parts The compartmentalization and the many specialized organelles typical of cells exemplify the principle that structure correlates with function. The intricate functioning of a living cell emerges from the complex interactions of its multiple parts.

Word Roots

centro- = the center; **-soma** = a body (*centrosome:* structure present in the cytoplasm of all animal cells, important during cell division)

chloro- = green (*chloroplast:* the site of photosynthesis in plants and algae)

cili- = hair (*cilium:* a short hair-like cellular appendage with a microtubule core)

cyto- = cell (*cytosol:* a semifluid medium in a cell in which are located organelles)

-ell = small (*organelle:* a small membrane-enclosed structure with a specialized function found in the cytoplasm of eukaryotic cells)

endo- = inner (*endomembrane system:* the system of membranes within a cell that includes the nuclear envelope, endoplasmic reticulum, Golgi apparatus, lysosomes, vacuoles, and the plasma membrane)

eu- = true (*eukaryotic cell:* a cell that has a true nucleus)

extra- = outside (*extracellular matrix:* the substance in which animal tissue cells are embedded)

flagell- = whip (*flagellum:* a long whip-like cellular appendage that moves cells)

glyco- = sweet (*glycoprotein:* a protein covalently bonded to a carbohydrate)

lamin- = sheet/layer (*nuclear lamina:* a netlike array of protein filaments that maintains the shape of the nucleus)

lyso- = loosen (*lysosome:* a membrane-enclosed sac of hydrolytic enzymes that a cell uses to digest macromolecules)

micro- = small; **-tubul** = a little pipe (*microtubule:* a hollow rod of tubulin protein in the cytoplasm of almost all eukaryotic cells)

nucle- = nucleus; **-oid** = like (*nucleoid:* the region where the genetic material is concentrated in prokaryotic cells)

phago- = to eat; **-kytos** = vessel (*phagocytosis:* a form of cell eating in which a cell engulfs a smaller organism or food particle)

plasm- = molded; **-desma** = a band or bond (*plasmodesmata:* an open channel in a plant cell wall)

pro- = before; **karyo-** = nucleus (*prokaryotic cell:* a cell that has no nucleus)

pseudo- = false; **-pod** = foot (*pseudopodium:* a cellular extension of amoeboid cells used in moving and feeding)

thylaco- = sac or pouch (*thylakoid:* a series of flattened sacs within chloroplasts)

tono- = stretched; **-plast** = molded (*tonoplast:* the membrane that encloses a large central vacuole in a mature plant cell)

trans- = across; **-port**= a harbor (*transport vesicle:* a membranous compartment used to enclose and transport materials from one part of a cell to another)

ultra- = beyond (*ultracentrifuge:* a machine that spins test tubes at the fastest speeds to separate liquids and particles of different densities)

vacu- = empty (*vacuole:* sac that buds from the ER, Golgi, or plasma membrane)

Structure Your Knowledge

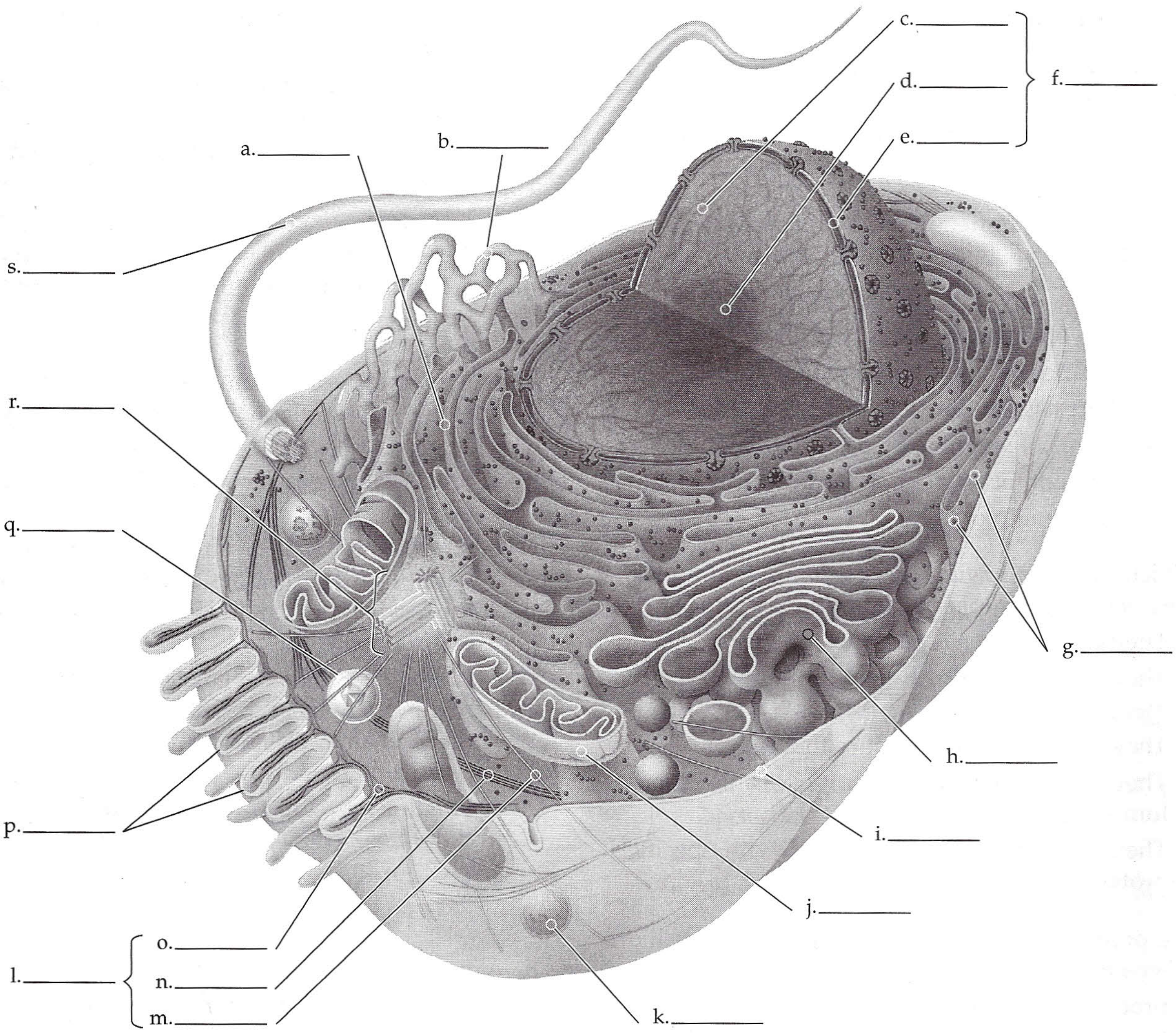
1. The following table lists the general functions performed by an animal cell. List the cellular structures associated with each of these functions.

Functions	Associated Organelles and Structures
Cell division	**a.**
Information storage and transferal	**b.**
Energy conversions	**c.**
Manufacture of membranes and products	**d.**
Lipid synthesis, drug detoxification	**e.**
Digestion, recycling	**f.**
Conversion of H_2O_2 to water	**g.**
Structural integrity	**h.**
Movement	**i.**
Exchange with environment	**j.**
Cell to cell connections	**k.**

2. This table lists structures that are found in plant cells but not animal cells. Fill in the functions of these structures.

Plant Cell Structures	Functions
Cell wall	**a.**
Central vacuole	**b.**
Chloroplast	**c.**
Amyloplast	**d.**
Plasmodesmata	**e.**

3. Label the indicated structures in this diagram of an animal cell.



4. Create a diagram or flowchart in the space below to trace the development of a secretory product (such as a digestive enzyme) from the DNA code to its export from the cell.

Test Your Knowledge

MULTIPLE CHOICE: *Choose the one best answer.*

1. Which of the following is/are not found in a prokaryotic cell?
   a. ribosomes
   b. plasma membrane
   c. mitochondria
   d. a and c
   e. a, b, and c

2. Resolution of a microscope is
   a. the distance between two separate points.
   b. the sharpness or clarity of an image.
   c. the degree of magnification of an image.
   d. the depth of focus on a specimen's surface.
   e. the wavelength of light.

3. Which of the following is *not* a similarity among the nucleus, chloroplasts, and mitochondria?
   a. They contain DNA.
   b. They are bounded by two phospholipid bilayer membranes.
   c. They can divide to reproduce themselves.
   d. They are derived from the endoplasmic reticulum system.
   e. Their membranes are associated with specific proteins.

4. The pores in the nuclear envelope provide for the movement of
   a. proteins into the nucleus.
   b. ribosomal subunits out of the nucleus.
   c. mRNA out of the nucleus.
   d. signal molecules into the nucleus.
   e. all of the above.

5. The ultrastructure of a chloroplast could be seen with the best resolution using
   a. transmission electron microscopy.
   b. scanning electron microscopy.
   c. phase-contrast light microscopy.
   d. cell fractionation.
   e. fluorescence microscopy.

6. Which of the following is *incorrectly* paired with its function?
   a. peroxisome—contains enzymes that break down H_2O_2
   b. nucleolus—produces ribosomal RNA, assembles ribosome subunits
   c. Golgi apparatus—processes, tags, and ships cellular products
   d. lysosome—food sac formed by phagocytosis
   e. ECM (extracellular matrix)—supports and anchors cells, communicates information with inside of cell

7. The cells of an ant and an elephant are, on average, the same size; an elephant just has more cells. What is the main advantage of small cell size?
   a. Small cells are easier to organize into tissues and organs.
   b. A small cell has a larger plasma membrane surface area than does a large cell, facilitating the exchange of sufficient materials with its environment.
   c. A small cell has a smaller cytoplasmic volume relative to its surface area, which helps to ensure the exchange of sufficient materials across its plasma membrane.
   d. Small cells require less oxygen than do large cells.
   e. The cytoskeleton of a large cell would have to be so large that cells would be too heavy.

8. A growing plant cell elongates primarily by
   a. increasing the number of vacuoles.
   b. synthesizing more cytoplasm.
   c. taking up water into its central vacuole.
   d. synthesizing more cellulose.
   e. producing a secondary cell wall.

9. The innermost portion of the cell wall of a plant cell specialized for support is the
   a. primary cell wall.
   b. secondary cell wall.
   c. middle lamella.
   d. plasma membrane.
   e. plasmodesmata.

10. Contractile elements of muscle cells are
    a. intermediate filaments.
    b. centrioles.
    c. microtubules.
    d. actin filaments (microfilaments).
    e. fibronectins.

11. Microtubules are components of all of the following *except*
    a. centrioles.
    b. the spindle apparatus for separating chromosomes in cell division.
    c. tracks along which organelles can move using motor molecules.
    d. flagella and cilia.
    e. the cleavage furrow that pinches apart cells in animal cell division.

12. Of the following, which is probably the most common route for membrane flow in the endomembrane system?
    a. rough ER → Golgi → lysosomes → nuclear membrane → plasma membrane
    b. rough ER → transport vesicles → Golgi → vesicles → plasma membrane
    c. nuclear envelope → rough ER → Golgi → smooth ER → lysosomes
    d. rough ER → vesicles → Golgi → smooth ER → plasma membrane
    e. smooth ER → vesicles → Golgi → vesicles → peroxisomes

13. Proteins to be used within the cytosol are generally synthesized
    a. by ribosomes bound to rough ER.
    b. by free ribosomes.
    c. by the nucleolus.
    d. within the Golgi apparatus.
    e. by mitochondria and chloroplasts.

14. Plasmodesmata in plant cells are similar in function to
    a. desmosomes.
    b. tight junctions.
    c. gap junctions.
    d. the extracellular matrix.
    e. integrins.

15. In an animal cell fractionation procedure, the first pellet formed would most likely contain
    a. the extracellular matrix.
    b. ribosomes.
    c. mitochondria.
    d. lysosomes.
    e. nuclei.

Use the cells described below to answer, for questions 16–20, the following question:

In which cell would you expect to find . . .

a. muscle cell in the thigh muscle of a long-distance runner
b. pancreatic cell that manufactures digestive enzymes
c. macrophage (white blood cell) that engulfs bacteria
d. epithelial cell lining digestive tract
e. ovarian cell that produces estrogen (a steroid hormone)

16. the most tight junctions?

17. the most lysosomes?

18. the most smooth endoplasmic reticulum?

19. the most bound ribosomes?

20. the most mitochondria?

SUGGESTED ANSWERS TO STRUCTURE YOUR KNOWLEDGE

1. The primary structure of a protein is the specific, genetically coded sequence of amino acids in a polypeptide chain. The secondary structure involves the coiling (α helix) or folding (β pleated sheet) of the protein, stabilized by hydrogen bonds along the polypeptide backbone. The tertiary structure involves interactions between the side chains (R groups) of amino acids and produces a characteristic three-dimensional shape for a protein. Quaternary structure occurs in proteins composed of more than one polypeptide chain.
2. **a.** amino acid (glycine)
   b. fatty acid
   c. nitrogenous base, purine (adenine)
   d. glycerol
   e. phosphate group
   f. sugar (pentose, ribose)
   g. sugar (triose)

1. b, d	**3.** c, e, f	**5.** c	**7.** e, f
2. a	**4.** f, g	**6.** a	**8.** b

ANSWERS TO TEST YOUR KNOWLEDGE

Matching:

1. A	**4.** C	**7.** B	**10.** A
2. B	**5.** C	**8.** C	
3. D	**6.** D	**9.** A	

Multiple Choice:

1. e	**6.** b	**11.** c	**16.** a	**21.** d
2. c	**7.** c	**12.** d	**17.** c	**22.** a
3. a	**8.** a	**13.** b	**18.** b	**23.** d
4. e	**9.** d	**14.** c	**19.** c	**24.** e
5. c	**10.** c	**15.** d	**20.** b	

CHAPTER 6: A TOUR OF THE CELL

INTERACTIVE QUESTIONS

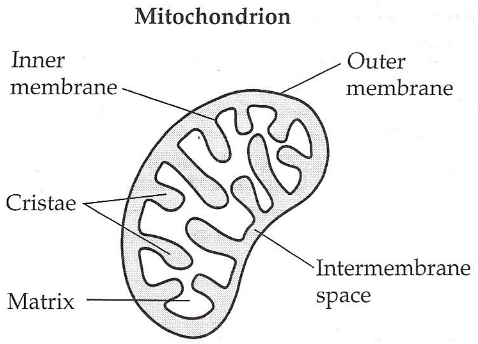
6.1 **a.** the study of cell structure
b. the internal ultrastructure of cells
c. the three-dimensional surface topography of a specimen
d. Light microscopy enables the study of living cells and may introduce fewer artifacts than do TEM and SEM.

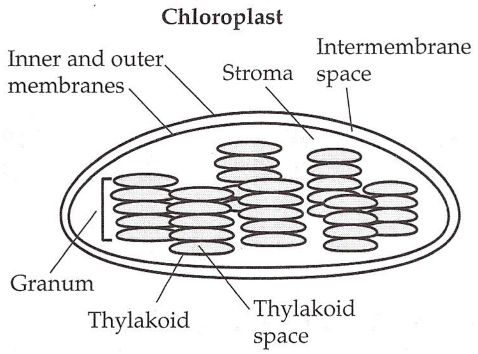
6.2 **a.** a phospholipid bilayer with the hydrophobic tails clustered in the interior and the phosphate heads facing the hydrophilic outside and inside of the cell; proteins are embedded in and attached to the membrane
b. 10^2, or 100 times the surface area
c. 10^3, or 1,000 times the volume

6.3 The genetic instructions for specific proteins are transcribed from DNA into messenger RNA (mRNA), which then passes into the cytoplasm to complex with ribosomes where it is translated into the primary structure of proteins.

6.4 **a.** smooth ER—in different cells may house enzymes that synthesize lipids; metabolize carbohydrates; detoxify drugs and alcohol; store and release calcium ions in muscle cells
b. nuclear envelope—double membrane that encloses nucleus; pores regulate passage of materials
c. rough ER—attached ribosomes produce proteins that enter cisternae; produces secretory proteins and membranes
d. transport vesicle—carries products of ER and Golgi apparatus to various locations
e. Golgi apparatus—processes products of ER; makes polysaccharides, packages products in vesicles targeted to specific locations
f. plasma membrane—selective barrier that regulates passage of materials into and out of the cell
g. lysosome—houses hydrolytic enzymes to digest macromolecules

6.5

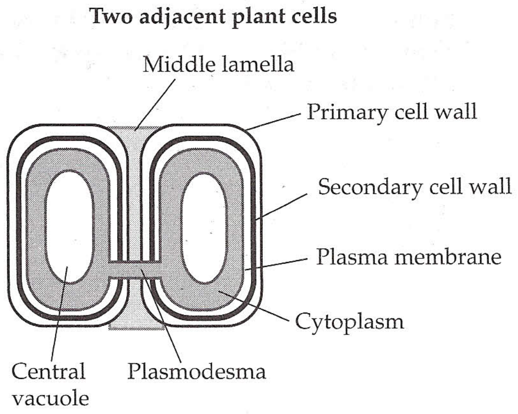




6.6 Peroxisomes do not bud from the endomembrane system, but grow by incorporating proteins and lipids from the cytosol; they increase in number by dividing.

6.7 **a.** hollow tube, formed from columns of tubulin dimers; 25-nm diameter
b. cell shape and support (compression resistant), tracks for moving organelles, chromosome movement, beating of cilia and flagella
c. two twisted chains of actin molecules; 7-nm diameter
d. muscle contraction, maintain (tension bearing) and change cell shape, pseudopod movement, cytoplasmic streaming, sol-gel transformations
e. supercoiled fibrous proteins of keratin family; 8–12 nm
f. reinforce cell shape, anchor nucleus; nuclear lamina

6.8



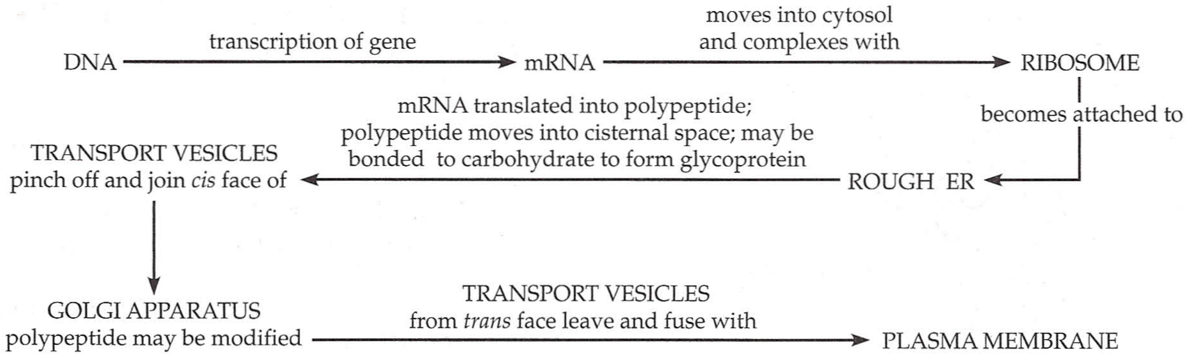
SUGGESTED ANSWERS TO STRUCTURE YOUR KNOWLEDGE

1. **a.** nucleus, chromosomes, centrioles, microtubules (spindle), microfilaments (actin-myosin aggregates pinch apart cell)
b. nucleus, chromosomes, DNA → mRNA → ribosomes → enzymes and other proteins
c. mitochondria
d. ribosomes, rough and smooth ER, Golgi apparatus, transport vesicles
e. smooth ER (peroxisomes also detoxify substances)
f. lysosomes, food vacuoles
g. peroxisomes
h. cytoskeleton: microtubules, microfilaments, intermediate filaments; extracellular matrix
i. cilia and flagella (microtubules), microfilaments (actin) in muscles and pseudopodia
j. plasma membrane, transport vesicles
k. desmosomes, tight and gap junctions, ECM

2. **a.** structural support, middle lamella glues cells together
b. storage, waste disposal, protection, growth
c. photosynthesis, production of sugars
d. starch storage
e. cytoplasmic connections between cells

3. **a.** rough endoplasmic reticulum
b. smooth endoplasmic reticulum
c. chromatin
d. nucleolus
e. nuclear envelope
f. nucleus
g. ribosomes
h. Golgi apparatus
i. plasma membrane
j. mitochondrion
k. lysosome
l. cytoskeleton
m. microtubules
n. intermediate filaments
o. microfilaments
p. microvilli
q. peroxisome
r. centrosome (contains a pair of centrioles)
s. flagellum

4.



ANSWERS TO TEST YOUR KNOWLEDGE

Multiple Choice:

1. c	**3.** d	**5.** a	**7.** c	**9.** b	**11.** e	**13.** b	**15.** e	**17.** c	**19.** b
2. b	**4.** e	**6.** d	**8.** c	**10.** d	**12.** b	**14.** c	**16.** d	**18.** e	**20.** a

CHAPTER 7: MEMBRANE STRUCTURE AND FUNCTION

INTERACTIVE QUESTIONS

7.1 **a.** phosphate head—hydrophilic
b. phospholipid bilayer
c. hydrocarbon tail—hydrophobic
d. hydrophobic region of protein
e. hydrophilic region of protein

7.2 In hybrid human/mouse cells, membrane proteins rapidly intermingle (Frye and Edidin experiment).

7.3 transport, enzymatic activity, signal transduction, intercellular joining, cell–cell recognition, attachment to cytoskeleton and ECM

7.4 Ions and larger polar molecules, such as glucose, are impeded by the hydrophobic center of the plasma membrane's lipid bilayer. Passage through the center of a lipid bilayer is not fast even for small, polar water molecules.

7.5 Side A initially has fewer free water molecules; side B initially has more. More water molecules are clustered around the glucose in the 1 *M* solution than around the fructose and sucrose whose combined concentration is 0.9 *M*. Water will move by osmosis from side B to A.

7.6 **a.** The protists will gain water from their hypotonic environment.
b. They may have membranes that are less permeable to water and contractile vacuoles that expel excess water.

7.7 **a.** isotonic **b.** hypotonic

7.8 Although it may speed diffusion, facilitated diffusion is still passive transport because the solute is moving down its concentration gradient; the process is driven by the concentration gradient and not energy expended by the cell.

7.9 Three sodium ions are pumped out of the cell for every two potassium ions pumped in, resulting in a net movement of positive charge from the cytoplasm to the extracellular fluid.

7.10 **a.** Human cells use receptor-mediated endocytosis to take in cholesterol.
b. LDL receptor proteins in the plasma membrane are defective, and low-density lipoproteins cannot bind and be transported from the blood into the cell.