HONORS PACKET INSTRUCTIONS

The following are guidelines in order for you to receive FULL credit for this bio packet:

1. Read and take notes on the packet in full
2. Answer the multiple choice questions correctly and JUSTIFY your answer
   Example Question: "Which of the following organelles is involved in photosynthesis?
      a) *The mitochondria*
      b) *The endoplasmic Reticulum*
      c) *The liver*
      d) *The chloroplast*

   Example answer: The correct answer is D because the cholorplast is an organelle that contains chlorophyll a pigment directly associated with Absorbing light from the sun. the other organelles listed have other functions throughout the cell, and the liver isn't an organelle at all.
3. Complete the essay response

you do not have to print out the packet in order to take notes and complete the quiz

See wynn for questions!

Review Chapter 1: The Cell

Basic Unit of Life

According to cell theory, the cell is the basic unit of life. All living organisms are either single-celled or multicellular; multicellular organisms have many cells that are specialized to carry out different functions. Cells come in two basic types: *prokaryotic* and *eukaryotic*.

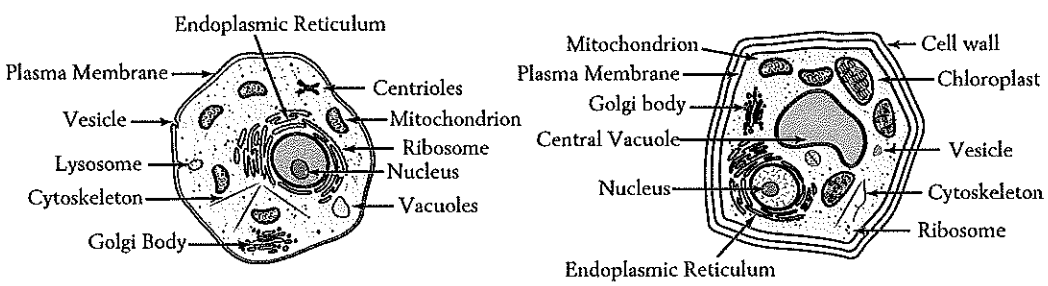
Prokaryotic Cells

Prokaryotic cells are the smallest and simplest cells. They include a plasma membrane and the jelly-like cytosol. Unlike eukaryotes, prokaryotes do not contain membrane-bound organelles. They do, however, have ribosomes, the tiny particles that assemble proteins from the genetic information in the cell's chromosome. A prokaryote's simple, circular chromosome is contained in the cytoplasm, allowing the prokaryote to divide by the simple process of binary fission. Most prokaryotes have a rigid cell wall surrounding the plasma membrane.

Eukaryotic Cells

A eukaryotic cell is larger and more complex than a prokaryotic cell. Its cytoplasm contains membrane-bound organelles, and its genetic material is contained in a nucleus. A eukaryotic cell has the following structures:

- *Cytoskeleton.* This scaffold, made up of tubulin and actin proteins, gives structure and support to the cell. The centrosome is an area that organizes microtubules, and a pair of centrioles may be observed in some cell types (for example, animal cells).
- *Nucleus.* The nucleus contains the cell's genetic material, which consists of long, linear deoxyribonucleic acid (DNA) strands. The strands are wrapped around histone proteins, which coil to form chromosomes. Chromosomes contain the genetic instructions for assembling proteins.



Eukaryotic Cell (Animal) Eukaryotic Cell (Plant)

- *Endoplasmic reticulum and Golgi body.* Internal membranes enclose the nucleus and make up the endoplasmic reticulum (ER) and Golgi body, or apparatus. The ER consists of a network of membranes surrounding the nucleus. Rough ER is studded with tiny ribosomes, structures made up of ribonucleic acid (RNA) and protein. The ER is where proteins, cell membranes, and other biological molecules, such as hormones and lipids, are synthesized. Proteins are then enclosed in vesicles, which are small sacs that bud off a membrane, forming a sphere. A vesicle transports the material contained inside it, and can merge with another membrane elsewhere in the cell to deposit its cargo. In the case of proteins, the vesicles transport them to the Golgi body.

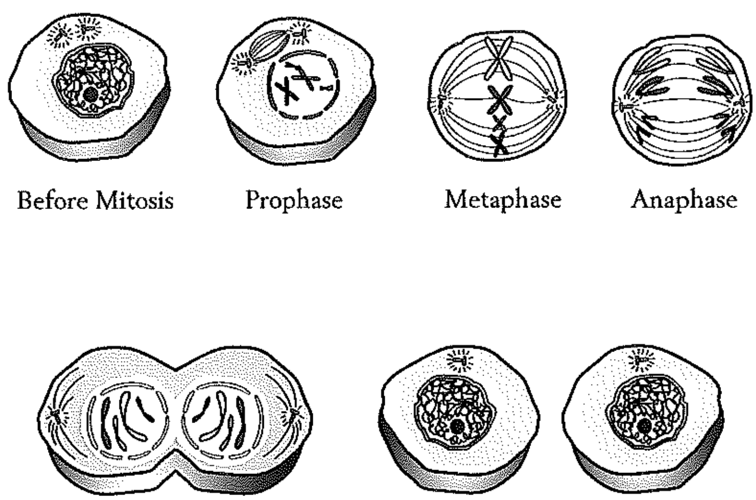
- *Ribosomes.* Ribosomes are tiny, non-membrane-bound structures made up of protein and RNA. They carry out protein synthesis. In eukaryotes, ribosomes are bound to the ER and are also found floating in the cytoplasm. (Note that prokaryotes also contain ribosomes.)
- *Lysosomes and vacuoles.* Lysosomes are similar to vesicles and contain enzymes that digest, or break down, large molecules. Vacuoles are vesicles of varying sizes that store food or water in the cytoplasm. For example, plant cells often contain a large, central vacuole that stores water and other materials.
- *Mitochondria.* Cells contain many of these organelles, which convert the energy stored in food to small molecules called adenosine triphosphate (ATP). Mitochondria have an external membrane and a highly folded internal membrane, which is important in cellular respiration.
- *Chloroplasts.* These organelles carry out photosynthesis in the cells of eukaryotic producers, such as plants and algae. Their chlorophyll gives producers their characteristic green color. Other plasts may contain starches or pigments.
- *Cell wall.* Some eukaryotic cells are surrounded and supported by cell walls. The presence and make-up of the cell wall is a key characteristic in the classification of organisms.

Mitosis and Cytokinesis

With their large chromosome numbers, eukaryotic cells must undergo mitosis before the cells can divide. Mitosis is the replication of the eukaryotic nucleus and results in two nuclei containing identical genetic information. Eukaryotes species have a characteristic diploid number of paired homologous chromosomes. In sexual reproduction, one homolog from each pair is inherited from each parent.

Before mitosis even begins, the cell has replicated its DNA, with each chromosome forming two identical sister chromatids. However, the number of chromosomes has not doubled because the sister chromatids are joined at the centromeres; they will separate in mitosis. Mitosis proceeds in stages that can be remembered by the mnemonic PMAT: Please Make Another Two.

- *Prophase.* Before mitosis, the chromosomes are in an uncondensed state. In prophase, they condense, and the nuclear membrane breaks down. Spindle fibers emerge from the centrioles, which move to opposite poles of the cell.
- *Metaphase.* The spindle fibers attach to the centromeres of each chromosome, aligning them along the central metaphase plate. Each sister chromatid is attached to a spindle fiber from one centriole.
- *Anaphase.* The centromeres holding sister chromatids together now detach. Sister chromatids separate and are pulled to opposite poles of the cell by the shortening spindle fibers.



Before Mitosis Prophase Metaphase Anaphase

Telophase Cytokinesis

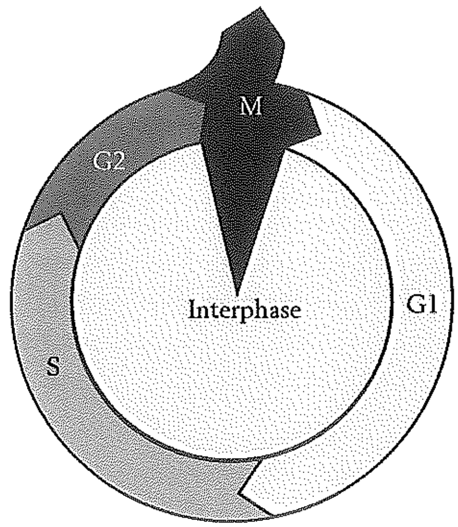
- *Telophase.* Now that the sister chromatids have separated, the cell contains two full sets of identical chromosomes. In telophase, a nuclear membrane re-forms around each set, creating a cell with two nuclei. Mitosis is now complete.

- *Cytokinesis*. The division of a cell into two daughter cells can proceed once mitosis is complete. Often, it even begins during telophase. In cells that lack a cell wall, a cleavage furrow forms around the center, constricting the cell and pinching it to form two new cells. In cells with cell walls, a cell plate forms between the two nuclei. This will make up part of the cell wall of the two daughter cells.

The Cell Cycle

Mitosis and cytokinesis make up a very small fraction of the cell cycle, called the *M (mitotic) phase*. The majority of a cell's lifetime is spent in interphase, throughout which the cell grows. Interphase consists of three stages:

- *G1*. A newly formed eukaryotic cell starts out in the G1 ("first gap") phase, during which it grows and accumulates the raw materials needed to replicate its DNA and organelles.
- *S*. In S phase, the synthesis phase, the cell replicates its organelles in preparation for cell division. S phase is also when the chromosomes double their genetic material, forming sister chromatids. (Keep in mind that the chromosome number does not double; sister chromatid pairs are still joined and so are considered single chromosomes.)
- *G2*. In G2 ("second gap") phase, the cell continues to grow in preparation for mitosis and cytokinesis (M phase). The two gap phases are so called because the cell is neither replicating DNA nor dividing.



G1: The cell grows and prepares to replicate its DNA

S: The cell replicates its DNA, creating sister chromatids

G2: The cell grows and prepares for cell division

M: Mitosis and Cytokinesis

Checkpoints throughout the cell cycle ensure that DNA is copied correctly and that each new cell receives a complete set of chromosomes. In a multicellular organism, the cell cycle is tightly controlled to ensure that cells do not continue to divide indefinitely. Cancer tumors form due to a disruption of the cell cycle in which cells inherit abnormal numbers of chromosomes (called *aneuploidy*) and/or continue to divide even when external conditions are crowded.

Review Questions

1. Which of these cell structures contains one or more membranes?

   I. Ribosome
   II. Plasma membrane
   III. Endoplasmic reticulum
   IV. Golgi body

   A. II only
   B. IV only
   C. I and II
   D. I, II, and III
   E. II, III, and IV

2. Cyanobacteria are photosynthetic prokaryotes. Which organelles do cyanobacteria cells contain?

   I. Chloroplasts
   II. Nucleus
   III. Ribosomes

   A. I only
   B. II only
   C. III only
   D. I and II only
   E. I and III only

3. A cell normally contains 54 chromosomes. During which phases of mitosis does the cell contain 108 chromosomes?

   I. Anaphase
   II. Metaphase
   III. Prophase
   IV. Telophase

   A. I and IV
   B. II and III
   C. II and IV
   D. I, II, and III
   E. I, II, and IV

4. A cell contains multiple nuclei with identical genetic information. This cell most likely formed by going through

   A. multiple rounds of mitosis, but no cytokinesis
   B. multiple rounds of the M phase, but no rounds of the S phase
   C. multiple rounds of cytokinesis, but no rounds of mitosis
   D. multiple rounds of the cell cycle, but no rounds of mitosis
   E. multiple rounds of the S phase, but no other phases of the cell cycle

5. What is the correct sequence of these events in the cell cycle?

   I. Nuclear membrane dissolves.
   II. Cell size increases.
   III. Two daughter cells form.
   IV. DNA replicates.

   A. I, IV, II, III
   B. I, IV, III, II
   C. II, I, IV, III
   D. II, IV, I, III
   E. IV, II, III, I

Answer Explanations

1. **E.** The ER, plasma membrane, and Golgi body of a eukaryotic cell consist of membrane composed of a phospholipid bilayer. In contrast, the ribosome is not a membrane-bound organelle.

2. **C.** Cyanobacteria are prokaryotes, and so do not contain membrane-bound organelles such as chloroplasts or a nucleus. All prokaryotes, however, do contain ribosomes.

3. **A.** The sister chromatids making up each of the 54 chromosomes separate in anaphase and move to opposite poles of the cell in telophase. In these two phases, the cell contains 108 distinct chromosomes.

4. **A.** A single cell with multiple nuclei must have undergone multiple rounds of mitosis, which is the replication of the nucleus. It did not, however, undergo cytokinesis, which is the division of a eukaryotic cell to form two daughter cells.

5. **D.** In the G1 and G2 phases of the cell cycle, a newly formed cell grows. It replicates its DNA in the S phase. In mitosis, the nuclear membrane dissolves as the nucleus is replicated. After mitosis, cytokinesis forms two identical daughter cells.

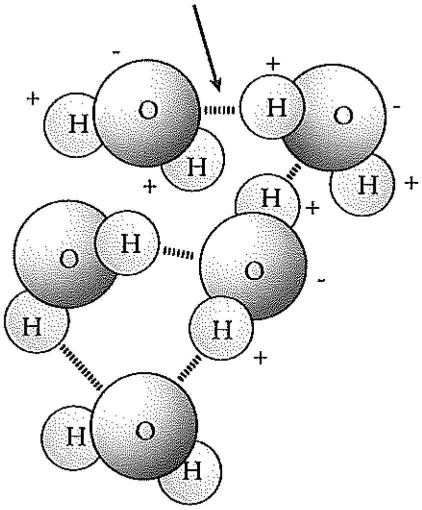
Review Chapter 2: Water, Cell Membranes, and Transport

Water

Because much of life consists of, takes place in, and depends upon water, understanding the special properties of this small molecule is essential. Water is a good solvent for ionic and polar covalent compounds.

Ionic and *covalent* are two basic types of chemical bonds. Ionic bonds form when atoms gain or lose electrons. When dissolved in water, these compounds dissociate to form *ions*, which are atoms or molecules that carry a charge. For example, the sodium ion, Na^+, has lost an electron and carries a positive charge of 1. The calcium ion, Ca^{2+}, carries a positive charge of 2. Chlorine, Cl^-, has an extra electron and carries a negative charge of 1. In contrast, covalent bonds form when two atoms share electrons. Covalent compounds, such as glucose, do not dissociate or carry a charge in water.

In some molecules (such as water), the atoms do not share the electrons equally. Some atoms are more attracted to the bonding electrons, which tend to be found closer to those atoms than to others. This results in the atom having a partial negative or partial positive charge. This is called a *polar covalent bond*, and these molecules are known as polar molecules. Water is a polar molecule: the oxygen atom has a partial negative charge, and each hydrogen atom has a partial positive charge.

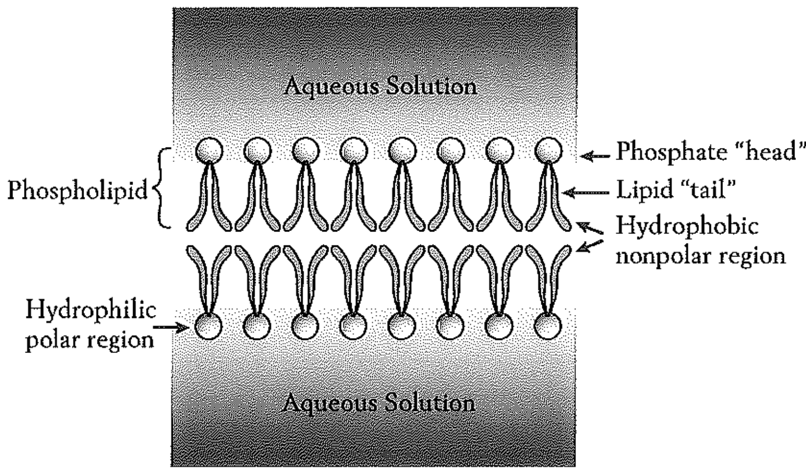


The polar nature of the water molecule is responsible for water's unique properties. Water molecules participate in hydrogen bonding interactions, both with each other and with other substances. The partially negative oxygen atoms attract the partially positive hydrogen atoms of other water molecules. As a result, water has high *cohesion*. This leads to water's high surface tension, demonstrated when insects are able to walk on water without sinking.

Water also has high *adhesion*, or the ability to attract other surfaces and substances. This is important for water's capillary action. Also, water can dissolve both ionic compounds and many covalent compounds, making it the universal solvent. Lipids, whose molecules are not polar at all, do not interact with water molecules and therefore do not dissolve easily in water. Lipids are termed *hydrophobic*, or water avoiding.

The Plasma Membrane

The plasma membrane is a phospholipid bilayer; it is made up of two layers of phospholipid molecules. A phospholipid has a *hydrophilic* (water-seeking) "head" and a hydrophobic "tail." When these molecules are layered with the hydrophobic tails sandwiched between the hydrophilic heads, the membrane is stable in an aqueous (water) environment.



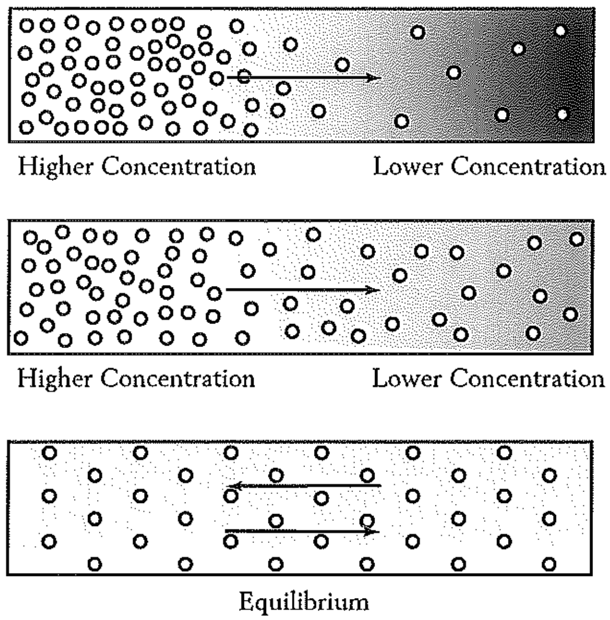
The cell membrane is semipermeable or selectively permeable. Some substances may cross freely; others cannot. Small, hydrophobic molecules easily pass through the phospholipid bilayer. Ions or polar molecules cannot cross this layer easily; even water diffuses through the phospholipid bilayer very slowly.

However, ions and polar molecules do have assistance to help them pass through the cell membrane. The fluid mosaic model depicts proteins floating in the "sea" of phospholipids. These proteins transport molecules across the membrane and are essential for allowing ions, polar molecules, and larger molecules to enter and exit the cell.

Movement of Substances across Cell Membranes

The cell membrane is primarily responsible for allowing substances to enter and exit the cell. Methods of cell transport are divided into two broad categories, depending whether the cell needs to expend energy: *passive* transport and *active* transport.

Passive transport depends on a concentration gradient existing across the membrane. A concentration gradient occurs when a substance exists in different concentrations in adjacent locations, even if no membrane is involved. Over time, ions, molecules, or atoms move "down" the concentration gradient, from an area of greater concentration to an area of lesser concentration. This movement, called *diffusion*, occurs "for free," meaning that no energy or work needed to be expended. Diffusion continues until the concentration is equal throughout (equilibrium), at which point no *net* movement occurs.



Suppose a cell membrane sits in the middle of a concentration gradient. If the concentration is lower inside the cell, the substance will diffuse into the cell. If the concentration is higher inside the cell, the substance will diffuse out of the cell.

However, because the cell membrane is semipermeable, not all substances may move down a gradient, across the membrane. In some cases, cell membrane proteins act as transport channels that allow these substances to cross. No energy is required; the channel protein simply provides an entry point in this process, called *facilitated diffusion.* Facilitated diffusion is therefore a form of passive transport.

Suppose there is no concentration gradient surrounding a cell membrane. In that case, a cell must expend energy to move substances across the membrane in active transport. Active transport is carried out by cell membrane proteins that pump ions or other molecules against their concentration gradients. For example, cells require a higher concentration of sodium (Na^+) ions outside the cell membrane and a higher concentration of potassium (K^+) ions inside. The cell must continually pump these ions against ("up") their concentration gradients.

Osmosis: The Diffusion of Water

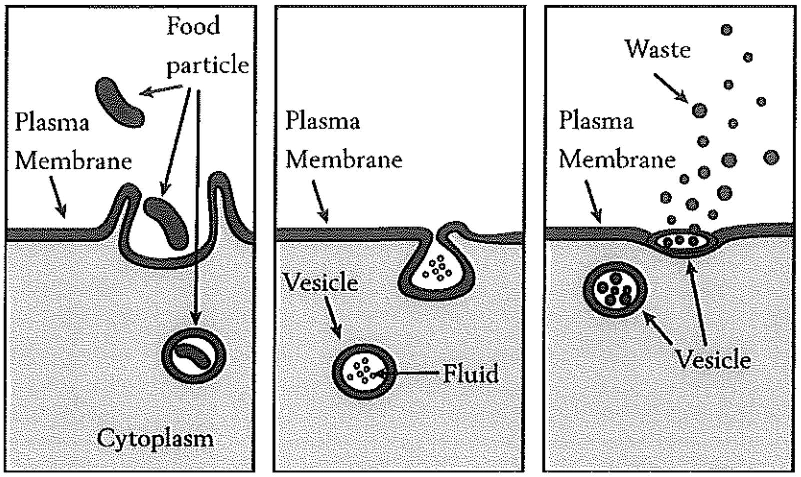
While a dissolved substance, or *solute*, moves "down" a concentration gradient, water moves in the opposite direction of the solute. Osmosis is the diffusion of water across a selectively permeable membrane. All cells must maintain proper water balance, and the surrounding liquid affects osmosis into or out of the cell. This, in turn, depends on the concentration of solutes that **cannot** cross the membrane.

The tonicity of the fluid surrounding a cell affects its water balance. A cell in an *isotonic* solution, or one that has equal tonicity to the cell's cytoplasm, experiences no net change in water balance. In a *hypertonic* (higher-concentration) solution, on the other hand, water will move out of the cell, causing it to shrink. In cells with cell walls, the plasma membrane pulls away from the wall in a process called *plasmolysis*.

In a *hypotonic* (lower-concentration) solution, water will move into the cell. The excess water causes a cell without walls to lyse, or burst. In contrast, a cell with walls becomes turgid (rigid) in hypotonic surroundings, because the wall can withstand the turgor pressure of the water. This causes plants to become firm when watered.

Transport of Larger Materials

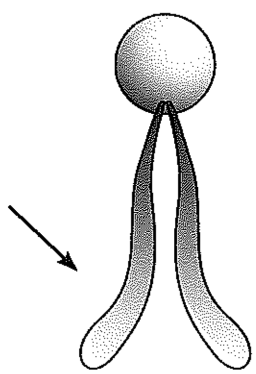
Large particles or quantities of liquid are moved across the cell membrane by processes involving vesicle formation: *endocytosis* and *exocytosis*. In endocytosis, the cell membrane surrounds a particle outside of the cell and pinches off to form a vesicle. The vesicle transports the acquired material through the cytoplasm. Two forms of endocytosis are phagocytosis, in which the cell takes in a large particle, and pinocytosis, in which the cell takes in surrounding fluid instead of particles. Exocytosis is the reverse process: a vesicle inside the cell fuses with the cell membrane, ejecting its contents outside of the cell. Because they require energy, these processes are forms of active transport.



Phagocytosis Pinocytosis Exocytosis

Review Questions

1. Which of these BEST describes the part of the molecule shown?



A. It is hydrophilic.
B. It forms the outer layer of the plasma membrane.
C. It is composed of phosphate atoms.
D. It contains nonpolar covalent bonds.
E. It is capable of hydrogen bonding.

2. A plant cell is placed in a hypotonic solution. As a result, the cell will

   A. lyse
   B. swell but remain intact
   C. shrivel
   D. remain unchanged
   E. take up solutes

3. A solute cannot move into a cell by crossing the phospholipid bilayer of the membrane. It can, however, enter through a membrane protein. The fact that solute molecules are entering the cell MOST LIKELY indicates that

   A. energy is being expended by the cell
   B. the solute is moving against its concentration gradient
   C. the solute molecules are hydrophilic
   D. the cell is in a hypotonic solution
   E. solute concentration is higher inside than outside the cell

4. How can a water molecule BEST be described?

   I. It is nonpolar.
   II. It has an equal electron distribution.
   III. It is able to form hydrogen bonds.

   A. I only
   B. II only
   C. III only
   D. I and II
   E. I and III

Answer Explanations

1. **D.** The lipid tails of a phospholipid molecule are indicated. This region of the phospholipid is hydrophobic (water avoiding), lacks phosphate

atoms, contains nonpolar covalent bonds, and does not participate in hydrogen bonding. It forms the inner layer of the plasma membrane.

2. **B**. A plant cell placed in a hypotonic solution will take up water and swell. However, it will not burst because the rigid cell wall can withstand the turgor pressure of the water. This process keeps plants upright.

3. **C**. The fact that solute molecules are entering a cell via a membrane protein does not necessarily mean that the cell is expending energy (active transport), that the solute is moving against its concentration gradient (which requires energy), or that the solute concentration is greater inside the cell than outside (implying that the solute is moving against its concentration gradient). If the cell were in a hypotonic solution, solutes would tend to move out of the cell while water moved into it. Facilitated diffusion uses membrane protein to allow polar, hydrophilic molecules or ions into the cell. These solutes cannot pass through the nonpolar, hydrophobic inner layer of the cell membrane.

4. **C**. Water is polar, meaning that it has an unequal distribution of electrons. This helps it to form hydrogen bonds.

Chapter 3: **Cellular and Molecular Biology**

- Biological Chemistry
- Water and Its Properties
- Functional Groups
- Carbohydrates
- Lipids (Fats and Oils)
- Proteins
- Enzymes
- Nucleic Acids
- How Cells Get Energy and Make ATP
- Glycolysis
- Fermentation
- Aerobic Respiration
- Photosynthesis
- The Genome and Gene Expression
- DNA Structure
- DNA Replication
- The Genetic Code
- Mutations
- Recombinant DNA Technology
- RNA
- Translation
- Cell Structure and Organization
- Viruses

One way to solve a puzzle is to put together the pieces in larger and larger assemblies until the entire puzzle is complete. Biologists try to gain understanding about living systems in a similar way, by studying life at many levels and then putting all of the pieces together in one complete picture. Looking at biology from this perspective, the behavior of molecules is observed to explain the workings of cells, which in turn explain the function of tissues, organs, and organisms. From there, we can explain populations and ecosystems, and the changes in life through time—called evolution—that have created the great diversity of life on earth today.

In this chapter we present the molecules of life and the workings of the cell. This will form the foundation for later chapters concerning organisms, genetics, ecology, and evolution. By the final chapter, it will be possible to view life not as a set of isolated facts, but as a rich interconnected network. This perspective should create a deep understanding that fosters improved problem-solving and test-taking through the application of general concepts. It should also provide an appreciation for the unity of life in all its many facets, viewed from many different perspectives. Life is one thing and many things. It all depends on how you look at it.

BIOLOGICAL CHEMISTRY

Life is, at one level, an extremely sophisticated form of chemistry. Living organisms, whether they are rose plants or goldfish, are composed primarily of a few common types of molecules. The tissues within organisms play many different roles, but contain the same chemical building blocks throughout.

SPONCH

At the elemental level, all life is composed primarily of carbon, hydrogen, oxygen, nitrogen, phosphorous and sulfur, with traces of other elements such as iron, iodine, magnesium, and calcium that are also essential for life. Salts such as sodium chloride are also essential components of life, but since they do not contain carbon they are known as *inorganic compounds*. Chemicals that contain carbon are called *organic compounds*, and include the major types of biological molecules found in all organisms, including proteins, lipids, carbohydrates, and nucleic acids. Before we explore these molecules, let's look at a vastly important and seldom appreciated inorganic molecule of life: water.

WATER AND ITS PROPERTIES

ONE OF A KIND

Water is the only compound that exists in the Earth's natural environment as a solid, a liquid, and a gas.

Life is not possible without water. The presence of liquid water allowed life to evolve and to persist on earth. The unique properties of water that allow it to play this role are based on the way the water molecule is put together.

The water molecule is *polar*, meaning it has a positively charged side and a negatively charged side. Each water molecule is composed of an atom of oxygen with two hydrogens attached at an angle. Oxygen draws the electrons in the molecule toward itself, giving itself a partial negative charge, while the hydrogens are partially positive. The water molecule as a whole is not charged, but since the molecule is bent, its unequal charge distribution makes one end positive and the other end negative. This makes H_2O a "polar covalent" molecule. ("Covalent" means the atoms share electrons, holding the molecule together.) This unequal distribution of charge is called a *dipole moment*. When water molecules are together in a beaker, they interact with each other, with the partial positive and negative charges attracting each other, interactions called *hydrogen bonds*.

The strong hydrogen bonds between water molecules give water its many special properties. These bonds between water molecules that hold the molecules together give water structure and take a lot of energy to break. Hydrogen bonds give water a great deal of cohesion and surface tension compared to other liquids, allowing trees to transport water from their roots all the way to their leaves in a single long column of water. Bonds between water molecules also mean that it takes a great deal of energy to heat water and to make it boil compared to other liquids. Remember, heat in a liquid or gas is carried in the movement of the molecules: More heat means more rapid movement of molecules. When you add heat energy to water, the energy must break hydrogen bonds between molecules before it can increase their movement to increase the temperature of the water. Liquid hydrocarbons, like octane, in contrast, have very low boiling points because the molecules in the liquid are held together very weakly and when heat is added, the molecules easily move about rapidly (heat) and leave the liquid (boil). The great deal of energy that water requires to heat or boil means that our body temperature is stable and we can cool ourselves through evaporation using sweat. Water's ability to absorb heat also means that water remains liquid over a range of temperatures common on our planet.

Another handy feature of water is that the solid form of water, ice, is less dense than its liquid form. The water molecules in ice are held apart from each other in a crystalline lattice of hydrogen bonds, while in water they move about more loosely and pack together more closely. As a result, ice is less dense than water, and ice therefore floats on top of water. One of the many benefits derived from this property is that in winter, water freezes on top of lakes first and insulates the layers below from further cooling and freezing, allowing life to prosper in the water beneath the ice. If ice were denser than liquid water, then lakes would freeze from the bottom up and freeze solid.

One more feature of water that is important to life is its ability to dissolve many different things. Water molecules are polar, but they are not charged. Water is particularly good at dissolving other polar molecules, and at dissolving charged molecules such as salts. One class of compounds water is less able to dissolve are nonpolar molecules like hydrocarbons, which do not form hydrogen bonds with water molecules. Life involves chemical reactions between molecules dissolved in water, so the ability of water to dissolve things is essential to life.

POLAR PROPERTIES

The unique properties of water all relate to its polar nature and hydrogen bonding.

Solutions in Water

Life involves molecules in solution, but what does it mean if we say something is "in solution"? When we dissolve sugar in water, and the crystals disappear, what happens to the molecules in the crystals? Solids in crystals contain organic or inorganic molecules packed together and interacting with one or more types of bonds. If the molecules are polar, then they interact with each other in the crystal through polar covalent bonds. Water can also form dipole-dipole interactions with these molecules, displacing their interactions with each other and allowing the molecules to leave the crystal to float surrounded by water molecules. As more and more molecules of sugar leave the crystal in this way, the crystal disappears, with the sugar molecules dissolved in water to form a solution.

In a solution, the substance that does the dissolving is called the *solvent* (water, in the example above), and the molecules that are dissolved are called the *solute* (sugar). Since solutions and solutes are important in biology, we will talk a little more about measurements and calculations of solutions and about special classes of solutes called acids and bases.

Most biological reactions occur in water with solutes. Concentration is measured by *molarity*, which is the number of moles of solute in one liter. A mole is 6 x 10^{23} molecules of a substance, and has a specific weight called the molecular weight. For example, the molecular weight of salt, NaCl, is about 58.5 grams per mole. Therefore, to obtain one mole of NaCl, 58.5 grams must be weighed out. One mole of one substance has the same number of molecules as a mole of another substance even if it does not have the same weight. The unit of concentration used in chemistry and biology is *molar* (M). A one-molar (1 M) solution contains one mole of solute in one liter of solution. To make a one-liter solution with one mole of NaCl, we would weigh out 58.5 grams of NaCl and completely dissolve it in water. Then we would bring the total volume to one liter and this would be a one-molar (1 M) solution of NaCl.

Acids and Bases: *Acids* and *bases* are particularly important types of solutes in biology. There are a few different ways that people define acids and bases. For our purposes, an acid is defined as a proton donor and a base is a proton acceptor. A proton (H^+) is a hydrogen atom stripped of its single electron, leaving a positively charged proton. One famous example of a strong acid is hydrochloric acid: HCl. Chlorine atoms have a relatively weak affinity for hydrogen atoms, and in HCl they are held together not covalently but by ionic bonds. Water can easily dissolve HCl to form H^+ and Cl^-. In this case, since HCl donates its proton, it is an acid. In the reverse reaction, Cl^- would accept a proton to form HCl again, making Cl^- a base in this reverse reaction. However, Cl^- has very little affinity for H^+ ions, making it a weak base, and meaning that the reverse reaction is not favored.

ACID RAIN

Acid rain forms when industrial wastes lower the pH of rainwater. It has a pH that is 25 times more acidic than normal rain. Acid rain causes considerable damage to the environment.

$$\text{Equation: } HCl \rightarrow H^+ + Cl^-$$

Another example of an acid is water itself. H_2O can dissociate to donate a proton, forming H^+ and OH^- (see equation). Not only can water be an acid, but water can also be a base, acting as a proton acceptor. The H^+ donated by one water molecule can be accepted by another one to form H_3O^+.

$$\text{Water as an acid: } H_2O \rightarrow H^+ + OH^-$$

$$\text{Water as a base: } H^+ + H_2O \rightarrow H_3O^+$$

A substance that reduces the hydrogen ion concentration in a solution is known as a base. This dissociation of the base results in more OH^- ions than H^+ ions. An example of this is NaOH, a strong base that favors dissociation into sodium and hydroxide ions. The hydroxide ions in solution react with protons to reduce the acidity of the solution.

$$\text{Equation: } NaOH \rightarrow Na^+ + OH^-$$

Other bases reduce H^+ ion concentration directly by accepting H^+ ions into themselves. Ammonia is an example of a base that will bind a hydrogen ion from the solution.

$$\text{Equation: } NH_3 + H_2O \rightarrow NH_4^+ + OH^-$$

Either case will result in a reduction of the H^+ concentration, a decrease in acidity, and an increase in basicity. Solutions with a relatively high concentration of OH^- are called basic solutions.

of cell, while Rudolph Virchow proposed in 1855 that cells arise only from other cells. The *cell theory* based on these ideas unifies all biology at the cellular level and may be summarized as follows:

- All living things are composed of cells.
- All chemical reactions of life occur in cells or in association with cells.
- Cells arise only from preexisting cells.
- Cells carry genetic information in the form of DNA. This genetic material is passed from parent cell to daughter cell.

Prokaryotic versus Eukaryotic Cells

DON'T MIX THESE UP ON TEST DAY

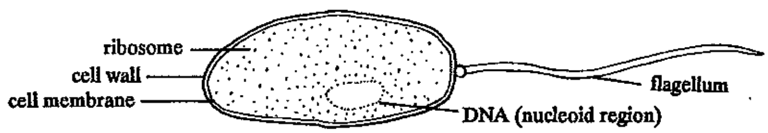
Prokaryotes have no nucleus and no membrane-bound organelles, but do have ribosomes; and most have cell walls made up of peptidoglycans.

Eukaryotes have a nucleus, membrane-bound organelles, and ribosomes. Examples include protists, fungi, plants, and animals. Fungi and plant eukaryotic cells have cell walls made of cellulose.

Prokaryotic Cells

Prokaryotes include bacteria and cyanobacteria (blue-green algae), unicellular organisms with a simple cell structure. These organisms have an outer lipid bilayer cell membrane, but do not contain any membrane-bound organelles, unlike their cousins the eukaryotes. Prokaryotes have no true nucleus and their genetic material consists of a single circular molecule of DNA concentrated in an area of the cell called the nucleoid region.

Prokaryotes may also contain plasmids: small, circular, extrachromasomal DNAs containing few genes. Plasmids replicate independently from the rest of the genome and often incorporate genes that allow the prokaryotes to survive adverse conditions. Bacteria also have a cell wall, cell membrane, cytoplasm, ribosomes, and, sometimes, flagella that are used for locomotion. Respiration in prokaryotes occurs at the cell membrane, since there are no other membranes present at which a proton gradient could be created for ATP synthesis to take place.

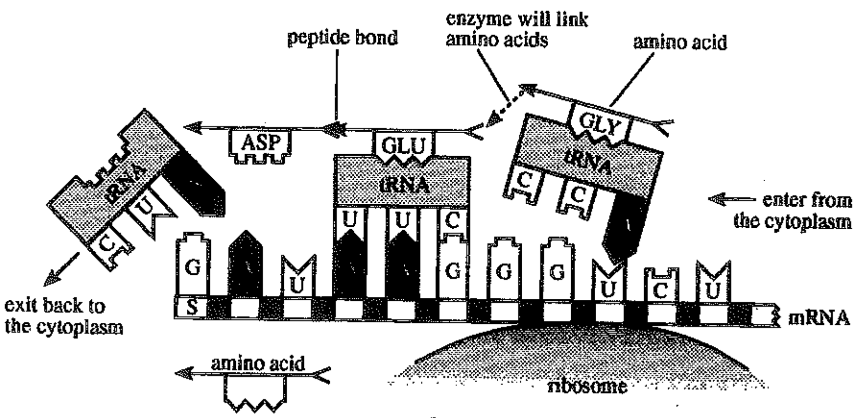


Prokaryotic Cell

Eukaryotic Cells

All multicellular organisms (you, a tree, or a mushroom) and all unicellular protists (amoeba or paramecia) are composed of *eukaryotic cells*. A eukaryotic cell is enclosed within a lipid bilayer cell membrane, as are prokaryotic cells. Unlike prokaryotes, however, eukaryotic cells contain organelles, membrane-bound structures within the cell with specific functions isolated in separate compartments. The separation of the organelle membrane and interior from the rest of the cell allows organelles to perform distinct functions isolated from other activities, which is not possible in prokaryotes. This prevents incompatible processes from mixing together, allows step-wise processes to be more strictly regulated, and can make processes more efficient by making them happen in a single constrained place. The *cytoplasm* is the liquid inside the cell surrounding the organelles.

anticodon matching the mRNA codon, the next amino acid will be transferred from the bound tRNA to the end of the protein chain.



Translation

With each step in protein synthesis, the ribosome matches another tRNA to the correct mRNA codon, adds the next amino acid to the end of the protein chain, forms a peptide bond in the growing polymer, and releases the used tRNA back to the cytoplasm. The used tRNA will be recycled by the addition of the correct amino acid once again. When the ribosome reaches a stop codon in the mRNA, it stops translation and releases the mRNA. The mRNA can then be translated again or chewed into pieces by enzymes that degrade mRNA in the cell.

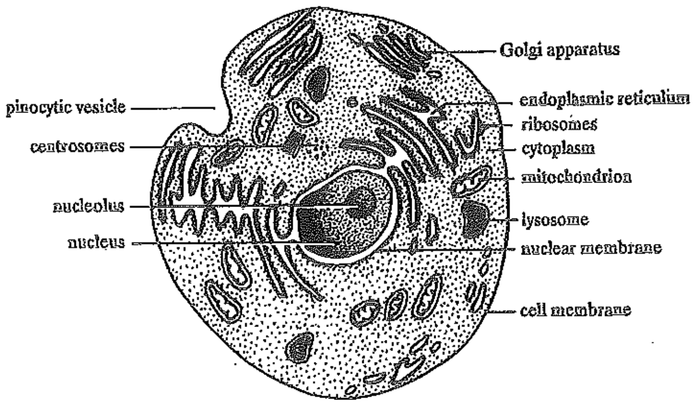
In eukaryotes, translation can occur either on ribosomes in the cytoplasm or on ribosomes bound to the rough endoplasmic reticulum (ER), depending on where signals on the newly forming protein direct it to go. Proteins that will live in the cytoplasm are translated by ribosomes in the cytoplasm. Proteins that are destined for the ER, Golgi, or the plasma membrane or that are to be secreted from the cell are synthesized by ribosomes bound to the rough ER. When the protein is synthesized, it is inserted into the ER through the ER membrane. The protein sequence tells the ER where to send the protein. From the ER, the newly synthesized proteins are packaged into small spheres of membrane called vesicles. These vesicles move from the ER to the Golgi, where the proteins are further modified, then on to the plasma membrane where they are either secreted or remain as transmembrane proteins.

CELL STRUCTURE AND ORGANIZATION

Cell Theory

The role of the cell in modern biology is so inherent in the way we view life that its importance is easy to overlook. Cells were unknown until the development of the microscope in the seventeenth century allowed scientists to see cells for the first time. In 1838, Matthias Schleiden and Theodor Schwann proposed that all life was composed

Although both animal and plant cells are eukaryotic, they differ in a number of ways. For example, plant cells have a cell wall and chloroplasts, while animal cells do not. Centrioles, located in the centrosome area, are found in animal cells but not in plant cells.



Eukaryotic Cell

Summary of Cell Properties:

Structure	Nucleus?	Genetic Material?	Cell Wall?	Cell Membrane?
Eukaryote	Yes	DNA	Yes/No	Yes
Prokaryote	No	DNA	Yes	Yes

Structure	Membrane Organelles?	Ribosomes?
Eukaryote	Yes	Yes
Prokaryote	No	Yes*

* Ribosomes in prokaryotes are smaller and have a different subunit composition than those in eukaryotes.

Plasma Membrane

The *plasma membrane* is not an organelle but is an important component of cellular structure. The plasma membrane (also called the *cell membrane*) encloses the cell and exhibits *selective permeability*; it regulates the passage of materials into and out of the cell. To carry out the biochemical activities of life, life must retain some molecules inside the cell and keep other material out of the cell. This is what the selective permeability of the membrane provides.

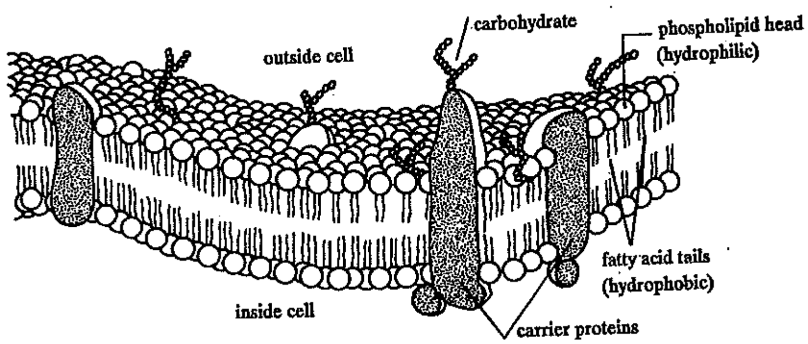
According to the *fluid mosaic model*, the cell membrane consists of a *phospholipid bilayer*. Phospholipids have both a water-loving (hydrophilic) polar phosphoric acid region and a hydrophobic fatty acid region. If they are mixed with water, phospholipids will spontaneously organize themselves into a lipid bilayer structure in which the hydrophilic regions are found on the exterior surfaces of the membrane, facing water, while the hydrophobic regions are found on the interior of the membrane, facing each other.

HISTORY OF THE CELL MEMBRANE

As early as 1895, scientists began to create models of cell membranes. But it wasn't until 1972 that S. J. Singer and Garth L. Nicolson proposed that the cell membrane was a phospholipid bilayer with fluid movement within the plane of the membrane.

The lipid bilayer membrane contains phospholipids, cholesterol, and proteins as major components. In a lipid bilayer membrane, lipids and many proteins can freely move sideways within the plane of the membrane. Because of this fluid motion of material in the membrane, this model of membrane structure is called the fluid mosaic model. Cholesterol molecules embedded in the hydrophobic interior contribute to the membrane's fluidity. Proteins interspersed throughout the membrane may be partially or completely embedded in the bilayer; one or both ends of the protein may extend beyond the membrane on either side.

How does the membrane create selective permeability, restricting the flow of material into and out of the cell? The lipid membrane itself is one factor responsible for the control of material into and out of the cell, in addition to proteins in the membrane. With the membrane itself, the hydrophobic interior of the membrane prevents charged or very polar molecules from diffusing across the membrane, although noncharged or small molecules such as water, oxygen, and carbon dioxide diffuse freely through the membrane. The proteins within the membrane also allow material to pass in and out of the cell. Cell membrane proteins contain both ion channels that act as selective pores for ions and receptors that bind signaling molecules outside of the cell and send signals into the cell. They also carry out the functions of cell adhesion and nutrient transport.



The Plasma Membrane

STUDY TIP

On Test Day, you should have the function of every organelle down cold. If you do, it's likely that you will be rewarded with a higher score!

Organelles

Eukaryotic cells have specialized membrane-bound structures called *organelles* that carry out particular functions for the cell. Organelles include the nucleus, endoplasmic reticulum, Golgi apparatus, lysosomes, microbodies, vacuoles, mitochondria, and chloroplasts. The lipid bilayer membranes that surround organelles also regulate and partition the flow of material into and out of these compartments, just as the plasma membrane does for the cell with its exterior environment.

Nucleus

One of the largest organelles of the cell is the *nucleus*. The nucleus is the site in which genes in DNA are read to produce messenger RNA (transcription), mRNA is spliced, and the DNA genome is replicated when the cell divides. Other activities such as glycolysis and protein synthesis are excluded from the nucleus. The nucleus is surrounded by a two-layer *nuclear membrane* (or nuclear envelope) that maintains a nuclear environment distinct from that of the cytoplasm. Nuclear pores in this membrane allow selective two-way exchange of materials between the nucleus and cytoplasm, importing some proteins into the nucleus that are involved in transcription, mRNA splicing, and DNA replication, and keeping out other factors such as those involved in glycolysis and translation. The nucleus contains the DNA genome complexed with proteins called *histones* involved in packaging DNA and regulating access to genes. DNA packaged with histones is called *chromatin* and forms chromosomes, the highest level of structure in the genome, in which each chromosome contains a fully packaged and immensely long molecule of DNA containing many different genes. The activity of chromosomes in cell division and the role this plays in heredity are discussed in chapter 5, Classical Genetics.

NUCLEUS:

- DNA replication
- Transcription
- Splicing

(Translation occurs in the cytoplasm.)

A dense structure within the nucleus in which ribosomal RNA (rRNA) synthesis occurs is known as the *nucleolus*.

Ribosomes

Ribosomes are not membrane-bound organelles but are relatively large complex structures that are the sites of protein production and are synthesized by the nucleolus. They consist of two subunits, one large and one small; each subunit is composed of rRNA and many proteins. Free ribosomes are found in the cytoplasm, while bound ribosomes line the outer membrane of the endoplasmic reticulum. Prokaryotes have ribosomes that are similar in function to eukaryotic ribosomes, although they are smaller.

MNEMONIC

Remember:

The roughness of the endoplasmic reticulum is determined by ribosomes!

Endoplasmic Reticulum

The *endoplasmic reticulum* (ER) is a network of membrane-enclosed spaces connected at points with the nuclear membrane. The network extends in sheets and tubes through the cytoplasm. If this network has ribosomes lining its outer surface, it is termed *rough endoplasmic reticulum* (RER); without ribosomes, it is known as *smooth endoplasmic reticulum* (SER). The ER is involved in the transport of proteins in cells, especially proteins destined to be secreted from the cell. SER is involved in lipid synthesis and the detoxification of drugs and poisons, while RER is involved in protein synthesis. Proteins that are found in the cytoplasm are made by free ribosomes. Proteins that are secreted, found in the cell membrane, the ER, or the Golgi, are made by ribosomes on the RER. Proteins synthesized by the bound ribosomes cross into the *cisternae* (the interior) of the RER. Small regions of ER membrane bud off to form small, round, membrane-bound vesicles that contain newly synthesized proteins. These cytoplasmic vesicles are transported next to the Golgi apparatus.

A CLOSER LOOK

Endoplasmic refers to something that is within the cytoplasm, while *reticulum* is derived from a Latin word that means "network."

Golgi Apparatus

The *Golgi* is a stack of membrane-enclosed sacs. It receives vesicles and their contents from the ER and modifies proteins (through glycosylation, the process of modifying

> **THINK OF IT THIS WAY**
>
> It may help to visualize the *Golgi apparatus* as the warehouse of the cell, a place where proteins are packaged for shipment.
>
> The *lysosome* serves as the "stomach" of the cell—both the lysosome and the stomach have acidic pHs.

proteins with carbohydrate chains, for example). Next, it repackages them into vesicles and ships the vesicles to their next stop, such as lysosomes, or the plasma membrane. In cells that are very active in the secretion of proteins, the Golgi is particularly active in the distribution of newly synthesized material to the cell surface. Secretory vesicles, produced by the Golgi, release their contents to the cell's exterior by the process of exocytosis.

Lysosomes

Lysosomes contain hydrolytic enzymes involved in intracellular digestion, degrading proteins and structures that are worn out or not in use. Maximally effective at a pH of 5, these enzymes are enclosed within the lysosome, which has an acidic environment distinct from the neutral pH of the cytosol (the fluid portion of the cytoplasm). Lysosomes fuse with endocytic vacuoles, breaking down material ingested by the cells. They also aid in renewing a cell's own components by breaking them down and releasing their molecular building blocks into the cytosol for reuse.

A cell in injured or dying tissue may rupture the lysosome membrane and release its hydrolytic enzymes to digest its own cellular contents. This is referred to as *autolysis*, and is not common in adult organisms.

Microbodies

Microbodies can be characterized as specialized containers for metabolic reactions. The two most common types of microbodies are *peroxisomes* and *glyoxysomes*. Peroxisomes contain oxidative enzymes that catalyze a class of reactions in which hydrogen peroxide is produced through the transfer of hydrogen from a substrate to oxygen. These microbodies break fats down into small molecules that can be used for fuel; they are also used in the liver to detoxify compounds, such as alcohol, that may be harmful to the body. Glyoxysomes, on the other hand, are usually found in the fat tissue of germinating seedlings. They are used by the seedling to convert fats into sugars until the seedling is mature enough to produce its own supply of sugars through photosynthesis.

Vacuoles

Vacuoles are membrane-enclosed sacs within the cell. They are formed after endocytosis and can fuse with a lysosome to digest their contents. Contractile vacuoles in freshwater protists pump excess water out of the cell. Plant cells have a large central vacuole called the tonoplast that is part of their endomembrane system. In plants, the tonoplast functions as a place to store organic compounds, such as proteins, and inorganic ions, such as potassium and chloride. Wastes can be stored here as well.

Mitochondria

Mitochondria are sites of aerobic respiration within the cell and are important suppliers of energy. Each mitochondrion has an outer and inner phospholipid bilayer membrane. The outer membrane has many pores and acts as a sieve, allowing molecules through on the basis of their size. The area between the inner and outer membranes is known as the intermembrane space. The inner membrane has many convolutions called *cristae*, as well as a high protein content that includes the proteins of the electron transport chain. The area bounded by the inner membrane is known as the *mitochondrial matrix* and is the site of many of the reactions in cell respiration, including electron transport, the Krebs cycle, and ATP production. For more information about the role of mitochondria in energy metabolism, see the earlier portion of this chapter.

QUICK QUIZ

What do *mitochondria* and *chloroplasts* do?

Answer: Chloroplasts capture light energy and use it to make glucose. Mitochondria extract energy from glucose to make ATP.

Mitochondria are somewhat unusual in that they are semiautonomous; they contain their own circular DNA and ribosomes, which enable them to produce some of their own proteins, and they self-replicate through binary fission. They are believed to have developed from early prokaryotic cells that evolved a symbiotic relationship with the ancestors of eukaryotes and still retain vestiges of this earlier independent life. This hypothesis for the evolution of the eukaryotic cell is called the endosymbiotic theory.

Chloroplasts

Chloroplasts are found only in algal and plant cells. With the help of one of their primary components, chlorophyll, they function as the site of photosynthesis. They contain their own DNA and ribosomes, exhibit the same semiautonomy as mitochondria, and are also believed to have evolved via symbiosis. For more information, see the earlier portion of this chapter.

Cytoskeleton

The cell is not a blob of gelatin enclosed by a membrane bag. The cell has shape, and in some cases actively moves and changes its shape. The cell gains mechanical support, maintains its shape, and carries out cell motility functions with the help of the *cytoskeleton*, composed of *microtubules*, *microfilaments*, *intermediate fibers*, and chains and rods of proteins, each with distinct functions and activities.

Microtubules. *Microtubules* are hollow rods made of polymerized tubulin proteins. When polymerized, microtubules radiate throughout the cells and provide it with support and a framework for organelle movement within the cell. *Centrioles* and the *mitotic spindle,* which direct the separation of chromosomes during cell division, are composed of microtubules.

Cilia and Flagella. *Cilia* and *flagella* are specialized arrangements of microtubules that extend from certain cells and are involved in cell motility. Prokaryotic flagella are entirely distinct in structure from eukaryotic flagella.

Microfilaments. Cell movement and support are maintained in part through the action of solid rods composed of actin subunits; these are termed *microfilaments*. Muscle contraction, for example, is based on the interaction of actin with myosin in muscle cells. Microfilaments are involved in cell movement and in changing cell shape; they are active, for instance, in the contraction phase of cell division and in amoeboid movement.

Intermediate Fibers. These structures are a collection of fibers involved in the maintenance of cytoskeletal integrity. Their diameters fall between those of microtubules and microfilaments.

Membrane Transport Across the Plasma

It is crucial for a cell to control what enters and exits it. In order to preserve this control, cells have developed the mechanisms described in this section.

Permeability—Diffusion Through the Membrane

Traffic through the membrane is extensive, but the membrane is selectively permeable; substances do not cross its barrier indiscriminately. A cell is able to retain many small molecules and exclude others. The sum total of movement across the membrane is determined by *passive diffusion* of material directly through the membrane and selective transport processes through the membrane that require proteins.

Most molecules cannot passively diffuse through the plasma membrane. The hydrophobic core of the membrane impedes diffusion of charged and polar molecules. Hydrophobic molecules such as hydrocarbons can readily diffuse through the membrane, however. The ability of cells to get oxygen to fuel electron transport depends on the ability of oxygen to diffuse through membranes into the cell and for carbon dioxide to passively diffuse back out again through the cell membrane and into the bloodstream. Although it is polar, water is also able to readily diffuse through the membrane. If two molecules are equally soluble, then the smaller molecule will diffuse through the plasma membrane faster. Small, polar, uncharged molecules can pass through easily, but the lipid bilayer is not permeable to large, uncharged polar molecules such as glucose. It is also relatively impermeable to all ions, even small ones such as H^+ and Na^+, in part because of the large sphere of water molecules around an ion that hydrates it.

Transport Proteins

Molecules that do not diffuse through the membrane can often get in or out of the cell with the aid of proteins in the membrane. Hydrophilic substances avoid contact with the lipid bilayer and still traverse the membrane by passing through *transport proteins*. There are three types of transport proteins: uniport, symport, and antiport. Uniport proteins carry a single solute across the membrane. Symport proteins translocate two different solutes simultaneously in the same direction; transport occurs only if both solutes bind to the proteins. Antiport proteins exchange two solutes by transporting one into the cell and the other out of the cell.

Diffusion/Passive Transport

Diffusion is the net movement of dissolved particles down their concentration gradients, from a region of higher concentration to a region of lower concentration. *Passive diffusion* does not require proteins since it occurs directly through the membrane. Since molecules are moving down a concentration gradient, no external energy is required.

Facilitated Diffusion

The net movement of dissolved particles down their concentration gradient—with the help of carrier proteins in the membrane—is known as *facilitated diffusion*. This process does not require external energy. Ion channels are one example of membrane proteins involved in facilitated diffusion, in which the channel creates a passage through the membrane for ions to flow down their concentration gradient. These ions will not flow through the membrane on their own. Some ion channels are always open for ions to flow through them, while other ion channels open only in response to some stimuli, such as a change in the voltage across the membrane or the presence of a molecule like a neurotransmitter.

DON'T MIX THESE UP ON TEST DAY

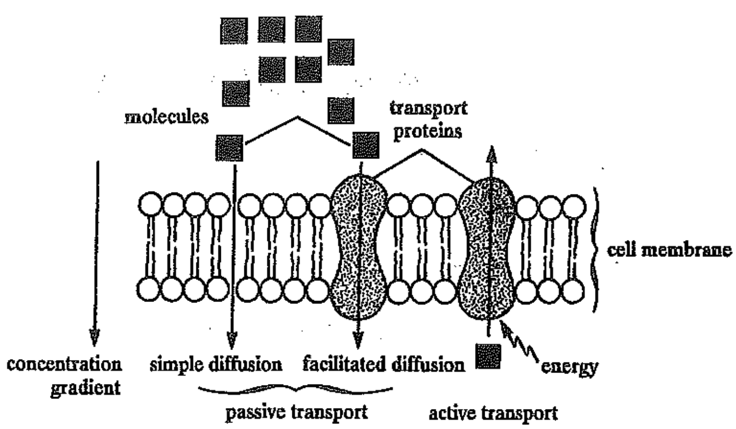
Passive transport:
- Moves with the gradient
- Requires no protein
- Requires no external energy

Facilitated diffusion:
- Moves with the gradient
- Requires a protein
- Requires no external energy

Active transport:
- Moves against the gradient
- Requires a protein
- Requires external energy

Active Transport

Active transport is the net movement of dissolved particles against their concentration gradient with the help of transport proteins. This process requires external energy, and is necessary to maintain membrane potentials in specialized cells such as neurons. The most common forms of energy to drive active transport are ATP or a concentration gradient of another molecule. Active transport is used for uptake of nutrients against a gradient.



Movement Across Membranes

Osmosis

Osmosis is the simple diffusion of water from a region of lower solute concentration to a region of higher solute concentration. Water flows to equalize the solute concentrations. If a membrane is impermeable to a particular solute, then water will flow across the membrane until the differences in the solute concentration have been equilibrated. Differences in the concentration of substances to which the membrane is impermeable affect the direction of osmosis.

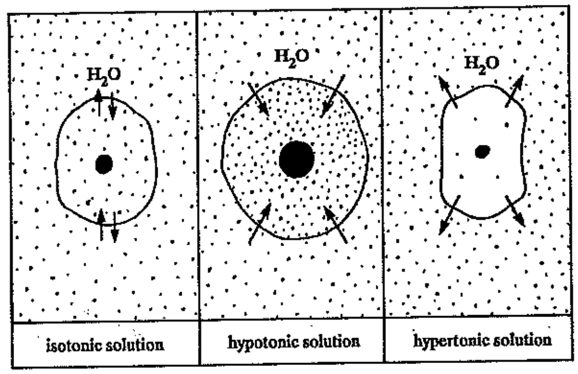
DON'T MIX THESE UP ON TEST DAY

In a *hypotonic* solution, a cell will swell until it looks like an O, and eventually burst.

In a *hypertonic* solution, a cell will shrivel.

In an *isotonic* solution, a cell will remain the same size.

Water diffuses freely across the plasma membrane. When the cytoplasm of the cell has a lower solute concentration than the extracellular medium, the medium is said to be *hypertonic* to the cell; water will flow out, causing the cell to shrink. On the other hand, when the cytoplasm of a cell has a higher solute concentration than the extracellular medium, the medium is *hypotonic* to the cell, and water will flow in, causing the cell to swell. If too much water flows in, the cell may lyse. Red blood cells, for example, lyse when put into distilled water. Finally, when solute concentrations are equal inside and outside, the cell and the medium are said to be *isotonic*. There is no net flow of water in either direction.

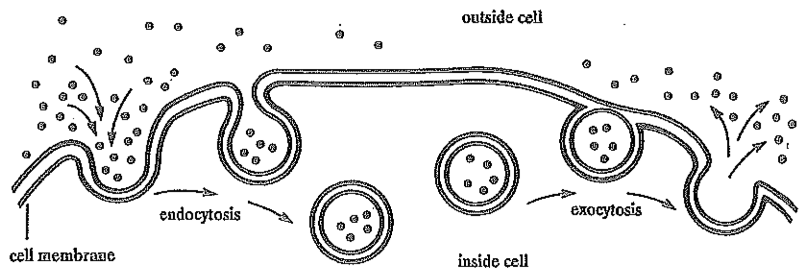


Osmosis

Endocytosis/Exocytosis

Endocytosis is a process in which the cell membrane is invaginated, forming a vesicle that contains extracellular medium. Specifically, *pinocytosis* is the ingestion of liquids or small particles, while *phagocytosis* is the term assigned to the engulfing of large particles. In the latter, particles may first bind to receptors on the cell membrane before being engulfed.

These processes differ from *exocytosis*, which occurs when a vesicle in the cell fuses with the cell membrane and releases its contents to the outside. This fusion of the vesicle with the cell membrane can play an important role in cell growth and intercellular signaling. Exocytosis is used by cells to release secreted proteins into their exterior environment, for example. In both endocytosis and exocytosis, the material inside the vesicle never actually crosses the cell membrane but is enclosed within the membrane of the vesicle and kept separate from the cytoplasm. Endocytosis is usually mediated by cell-surface receptors that are internalized along with the membrane vesicle.



Endocytosis and Exocytosis

VIRUSES

Viruses are small packages of nucleic acid in a protein coat that replicate themselves in cells. Viruses are not cells, have no cytoplasm, and carry out no biochemical activity of their own. They are completely dependent on living within a cell to carry out metabolic processes and replicate. For these reasons, viruses are not generally considered to be living organisms. Although viruses are not living, the mechanisms they use to alter the cell cycle and other cellular processes have revealed a great deal about the mechanisms that cells use to perform the same functions.

There are a great variety of viruses. They all have a similar basic structure, however, with a nucleic acid genome in the viral interior surrounded by a protein coat called the *capsid*. The protein coat protects the genome from the external environment and helps the viral genome to attach to cells and get into the cells. The capsid is usually formed from units of one or a few proteins that repeat. The structure of the virus forms either a long tubular helix with the genome in the middle or a geometric icosahedral structure. Many animal viruses have a lipid bilayer coat called the envelope that surrounds the capsid. Viruses without the envelope are called *naked*. One of the central features common to viruses is their great economy of genetic information, since their protein package is very small and can contain only a limited amount of genetic material. Viruses have very few base pairs in their genome that do not code for a gene product, and some that code for more than one gene product.

To enter a cell, a virus binds to receptors in the plasma membrane using specific envelope proteins on the surface of the virus. The cellular proteins that the virus recognizes are common cellular proteins that the virus has adapted to recognize. The expression of the cellular proteins determines the types of cells and tissues that a virus can infect. Once a virus binds to the cellular receptors, either it enters the cell by fusion of its envelope with the plasma membrane to release the viral capsid and genome into the cytoplasm, or the virus is internalized by endocytosis.

The viral genome can be either DNA or RNA, double- or single-stranded, linear or circular. RNA viruses have smaller genomes than DNA viruses. The lack of proofreading of RNA leads to a very rapid rate of evolution in RNA viruses. All viruses use the cellular machinery for translation to produce viral proteins for the viral capsid and other viral proteins.

VERSATILE VIRUSES

Viruses possess the characteristics of life only when they've infected a living host cell. Some examples of the wide range of diseases caused by viruses are:

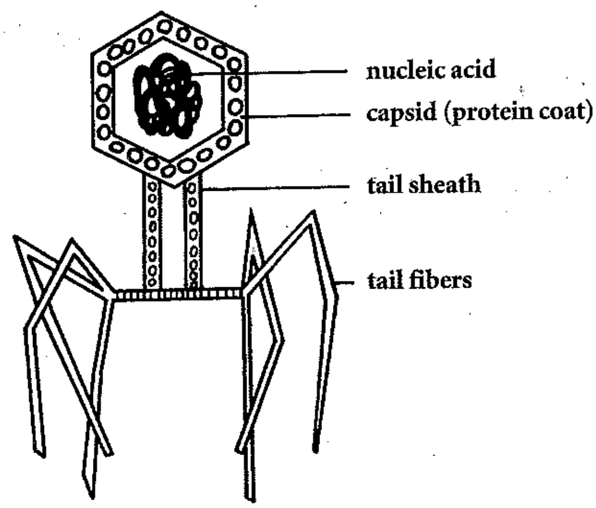
- Chickenpox (caused by varicella zoster)
- AIDS (HIV)
- Colds (rhinoviruses)
- Cold sores (herpes simplex virus I)

Bacteriophage Life Cycle

Bacteriophages are viruses that infect bacteria. They typically have complex tail assemblies composed of virus proteins that bind to the bacterial cell wall and inject the phage genome through the cell wall into the bacteria. Once in the bacteria, the viral genome can enter either a lytic cycle or a lysogenic cycle.

In the lytic cycle, the phage commandeers the cellular biosynthetic machinery to produce new copies of the viral genome and to make more virus. As viral proteins accumulate, they self-assemble spontaneously. When the host cell is full of new virus, the virus produces an enzyme to degrade the bacterial cell wall and burst the cell, releasing the newly synthesized viruses to infect neighboring bacterial cells.

In the lysogenic cycle, however, the phage does not begin to produce viral gene products but integrates its genome into the bacterial genome, where it remains hidden. In response to changing conditions in the cell, the phage can later excise itself and enter the lytic cycle.



Bacteriophage Virus Structure

CELLULAR AND MOLECULAR BIOLOGY QUIZ

1. Which of the following processes utilizes proofreading to increase its accuracy?
   (A) Transcription
   (B) DNA replication
   (C) Recombination
   (D) Peptide bond formation
   (E) Electron transport

2. Which of the following is NOT an organelle?
   (A) Nucleus
   (B) Golgi apparatus
   (C) Lysosome
   (D) Chlorophyll
   (E) Chloroplast

3. Which of the following are correctly associated?
   (A) RNA: thymine
   (B) DNA: uracil
   (C) RNA: replication
   (D) mRNA: picks up amino acids
   (E) RNA: ribose sugars

4. What is the BEST evidence that genes encode the amino acid sequence of proteins?
   (A) Proteins are macromolecules.
   (B) RNA directs amino acid synthesis.
   (C) The amino acid sequence of polypeptides is changed by gene mutation.
   (D) DNA serves as a template for RNA.
   (E) mRNA is found in the ribosome.

5. The tRNA anticodon for the amino acid valine is CAA (reading 3' to 5'). What is the mRNA codon for valine (reading 5' to 3')?
   (A) TTG
   (B) GGU
   (C) CCA
   (D) CCG
   (E) GUU

6. The source of oxygen given off in photosynthesis is
   (A) water.
   (B) carbon dioxide.
   (C) glucose.
   (D) starch.
   (E) chlorophyll.

7. Which of the following is NOT a lipid derivative?
   (A) Waxes
   (B) Steroids
   (C) Carotenoids
   (D) Albumins
   (E) Lecithin

8. Which is NOT a characteristic of proteins?
   (A) They contain genetic information.
   (B) They can act as hormones.
   (C) They can catalyze chemical reactions.
   (D) They act in cell membrane trafficking.
   (E) They can bind foreign materials.

THINGS TO REMEMBER

- Water's polar properties
- The pH scale
- Structure of basic biological molecules
- Role of enzymes
- Cellular respiration
- Glycolysis
- Krebs cycle
- Electron transport
- Photosynthesis
- DNA replication
- RNA transcription and translation
- Cell structure
- Virus structure and activity

9. The rough endoplasmic reticulum differs from the smooth endoplasmic reticulum due to the presence of
   (A) lysosomes.
   (B) ribosomes.
   (C) mitochondria.
   (D) Golgi apparatus.
   (E) histones.

10. Which of the following is found in eukaryotes but NOT in prokaryotes?
    (A) Ribosomal RNA
    (B) Plasma membrane
    (C) Nuclear membrane
    (D) Ribosomes
    (E) None of the above

11. Which of the following statements regarding photosynthesis is NOT true?
    (A) The light cycle occurs only during exposure to light.
    (B) The dark cycle occurs only in the absence of light.
    (C) ATP is produced during the light cycle.
    (D) During the dark cycle, sugars are produced.
    (E) Red and blue light are optimal for photosynthetic function.

12. Which of the following statements about the Krebs cycle is NOT true?
    (A) The Krebs cycle occurs in the matrix of the mitochondrion.
    (B) The Krebs cycle is linked to glycolysis by pyruvate.
    (C) The Krebs cycle is the single greatest direct source of ATP in the cell.
    (D) Citrate is an intermediate in the Krebs cycle.
    (E) The Krebs cycle produces nucleotides such as NADH and $FADH_2$.

13. Cells that are involved in active transport, such as cells of the intestinal epithelium, utilize large quantities of ATP. In such cells, there are
    (A) high levels of adenylate cyclase activity.
    (B) many polyribosomes.
    (C) many mitochondria.
    (D) high levels of DNA synthesis.
    (E) many lysosomes.

14. The process by which a cell engulfs large particulate matter is called
    (A) pinocytosis.
    (B) exocytosis.
    (C) cytokinesis.
    (D) phagocytosis.
    (E) osmosis.

15. The basis for the pairing of the two strands of DNA in the double helix is
    (A) covalent bonding.
    (B) ionic bonding.
    (C) hydrogen bonding.
    (D) hydrophobic interactions.
    (E) tertiary structure.

16. Which of the following statements about enzymes is NOT true?
    (A) The activity of enzymes is unaffected by genetic mutation.
    (B) Enzymes may interact with nonprotein molecules in order to engage in biological activity.
    (C) Enzymes optimally operate at a particular pH.
    (D) Enzymes optimally operate at a particular temperature.
    (E) Enzymes are almost always proteins.

17. Which of the following is a correct association?
    (A) Mitochondria: transport materials from the nucleus to the cytoplasm
    (B) Lysosome: digestive enzyme for intracellular use
    (C) Endoplasmic reticulum: selective barrier for the cell
    (D) Ribosome: electron transport chain
    (E) Polysome: group of Golgi complexes

18. Which of the following is in a different chemical category than the others?
    (A) Cytosine
    (B) Thymine
    (C) Arginine
    (D) Guanine
    (E) Uracil

19. Which of the following statement about viruses is NOT true?
    (A) Their genetic material may be DNA or RNA.
    (B) The virus may replicate in a bacterial host.
    (C) The virus may replicate in a eukaryotic host.
    (D) The virus may replicate autonomously in the absence of a host.
    (E) The protein coat of the virus does not enter a host bacterial cell.

20. In the speculation concerning the origins of life, one theory states that purines, pyrimidines, sugars, and phosphates combined to form
    (A) nucleotides.
    (B) nucleosides.
    (C) carbohydrates.
    (D) fats.
    (E) proteins.

HONORS BIO ESSAY RESPONSE

Respond to the following prompt using complete sentences. Diagrams, flow charts, sketches and images should only be used to enhance your written response.

Life on earth is made possible because of certain characteristics of water, choose 1-4 properties of water and…

A. For each characteristic that you choose, identify and define the property (Liquid/solid/gas, polar/non polar/, types of chemical bond it occupies… etc)
B. Describe one example of how the property affects the functioning of living organisms.