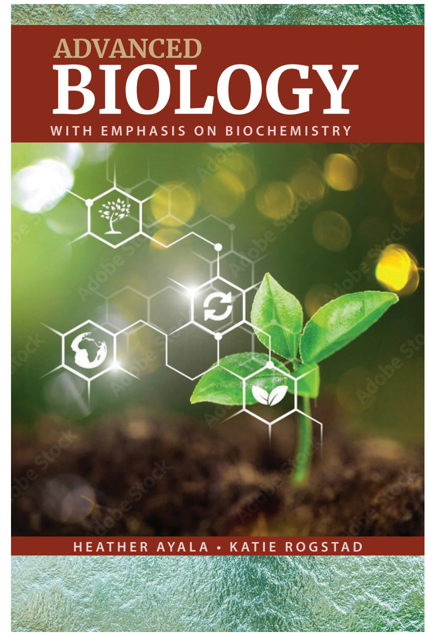
Advanced Biology

All Keys and Sample Answers



Thank you for using *Advanced Biology*. This document contains sample answers to all questions in the text, on quizzes, and on exams.

The sample answers in this document are provided to aid in situations in which the adult teacher responsible for conducting the course does not possess a background in this subject, or in which a student is studying independently. The written answers provided here are only samples and should not be considered the only correct responses to the questions.

In environments where there are multiple students in a class or group, it is recommended that students form their own answers to chapter exercises in complete sentences as a homework assignment. These should be graded for completion only, not accuracy. Then in the group setting, students bring their preliminary answers to class where they collaborate with each other and the teacher to improve their answers. The final product is a useful study tool developed by the group. In such a setting, there is little need for the written answers in the present document, but it is provided for the many home study situations in which there is no collaborative group.

Additional information about how this course should be conducted is provided in the textbook introduction and in documents on the Digital Resources download. A full presentation of strategies and techniques for mastery-learning can be found *From Wonder to Mastery*, available at classicalacademicpress.com.

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Advanced Biology: All Keys and Sample Answers

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Chapter Exercises

Chapter 1 Exercises

SECTION 1.1

1. Distinguish between truth and scientific facts.

Truth is the way things really are. Truth is known by direct observation or by revelation from God (and by valid reasoning or logic from true premises). A scientific fact is a statement based on evidence from many experiments or observations that is correct so far as we know. Because we are constantly learning new things about the world, scientific facts can and do change.

2. Write three true statements and three factual statements (that are correct so far as we know).

Comment: There is an infinitude of correct answers for this question. They key is that all truth claims must originate from Scripture or from direct observation.

Example truths:

Jesus rose from the dead.

God is love.

I am a male.

Example facts:

All matter is composed of atoms.

Air consists of about 80% nitrogen and 20% oxygen.

The earth orbits the sun.

3. Distinguish between theories, hypotheses, and experiments.

A theory is a mental model or representation that accounts for a large number of scientific facts in an organized way. Hypotheses are informed predictions, based on a particular scientific theory. Hypotheses are tested and supported (or not supported) by observations and experiments.

4. Explain how the Cycle of Scientific Enterprise works.

Currently known scientific facts are gathered together as part of a cohesive theory that explains most or all of these facts. A widely accepted theory may be understood as our best current explanation for a body of data (facts). The theoretical understanding of the natural world then allows scientists to make predictions about what would happen in as-yet untested circumstances. These informed predictions are called hypotheses. A hypothesis is tested by an experiment. The experiment provides evidence that either supports or does not support the hypothesis. If supported, the theory is strengthened. If the hypothesis is not supported, further tests must be done, perhaps with revised experimental methods. If the experiments continue to fail to support a hypothesis, then the theory is weakened and must be reevaluated. If enough evidence disfavoring a theory is collected, then a revised theory may be needed. Occasionally, a theory must be thrown out altogether and replaced. As time progresses, the cycle proceeds on and on, hopefully giving us facts and theories that are closer and closer to the truth about reality.

5. Make a table listing the three types of microscopes discussed in the this chapter. For each, include columns with the following information: 1) how the image is obtained, 2) range of magnification, 3) degree of resolution, 4) types of structures that can be observed, and 5) description of the resulting image.

	how image is obtained	magnification	resolution	types of structures that can be observed	description of image
compound light microscope	uses two lenses to form an image the same way a telescope does	40–1000×	200 nm	cells and microorganisms (living)	images of cells don't have much detail
scanning electron microscope	uses a beam of electrons to form the image from signals produced by interaction between electrons and sample	about 100 times higher than light microscope, so 100,000×	2 nm	cells and much smaller structures (nonliving)	detailed, 3-D, black and white image of cells
transmission electron microscope	not described	higher than the SEM	smaller than 2 nm	cells and organelles	2-D, black and white image of cells and organelles

6. For each of the seven common measurements/metric prefixes listed in Table 1.1, identify two additional applications to actual objects or phenomena in nature.

Comment: There is an infinitude of correct answers for this question. Examples:

kilo: mass of humans (80 kg); distance between cities (80 km)

centi: length of shoestring (50 cm); volume of beverage can (37 cL)

milli: length of fingernail (10 mm); mass of ibuprophen tablet (200 mg)

micro: thickness of human hair (40 μm); thickness of sheet of paper (200 μm)

nano: wavelength of visible light (500 nm); wavelength of ultraviolet light (300 nm)

angstrom: distance between atoms (10 Å); wavelength of X-rays (1 Å)

pico: wavelength of gamma rays (1 pm); width of small molecule (100 pm)

7. Compare the micron and the angstrom (i.e., calculate their ratio).

$\frac{1\times10^{-6}\text{ m}}{1\times10^{-10}\text{ m}}=10{,}000$. The micron is 10,000 times larger than the angstrom.

SECTION 1.2

8. List and briefly describe the six characteristics of life.

1. Living things are composed of cells and operate on many levels of organization. Living things are made of matter, and are arranged in a highly organized, complex, purposeful format. The most fundamental level of organization that displays all the characteristics of life is the cell.

2. Living things metabolize. Living things use materials from the environment and excrete waste, the process of metabolism. Waste products are broken down and used again. Energy is continually supplied from the sun, converted, and used by organisms, which produce waste heat in the process.

3. Living things grow, develop, and reproduce. Organisms proceed through various life stages, typically of increasing complexity, until maturity is reached and the organism is able to reproduce. Organisms proceed through various life stages, typically of increasing complexity, until maturity is reached and the organism is able to reproduce.

4. Living things use and transmit genetic information. Living things share a common genetic code, or instruction manual for

life. These instructions dictate how an organism functions and are passed on to offspring.

5. Living things respond. Living things have some sort of sensory system, by which they respond to light, sound, motion, or other stimuli. They process the information received and respond accordingly.

6. Living things adapt to their environments. Populations of organisms adapt to a changing environment, as each generation favors survival of organisms with the most suitable traits.

9. Make a table listing the levels of biological organization. For each level, list a defining characteristic.

Level	Characteristic
atom	composed of protons, electrons, and neutrons; fundamental unit of matter
simple molecule	composed of just a few atoms; comprise compounds encountered in everyday life
biomolecule	composed of hundreds or thousands of atoms
organelle	small parts of cells that perform specific functions
cell	the fundamental unit of life; the lowest level of organization that can be considered alive
tissue	specialized cells working together to perform a specific function
organ	tissues working together to perform a specific function
organism	an individual living being; comprised of many coordinated organ systems
population	composed of multiple individuals of same species living in a particular region
community	composed of multiple interacting populations in a particular region
ecosystem	composed of both living and nonliving things, interacting in their environment
biosphere	composed of all life on earth

10. Explain why a cell is the simplest level of organization considered to be alive.

The cell is the lowest level of biological organization that exhibits all six of the characteristics of life.

11. Other than those discussed in the book, give an example of a cell type, tissue, organ, and organism. Make sure that each example is a component of the level of organization above it.

Comment: Many examples are possible. Example:

Cell type: heart cells

Tissue: the muscle tissue of the heart

Organ: Heart

Organism: Human

12. Write a paragraph distinguishing between producers, consumers, and decomposers.

Producers harness the sun's energy, storing it in molecules that can be eaten and used by other organisms. Consumers eat plants and other animals, reusing the matter and stored energy for their own purposes. Finally, decomposers, such as mushrooms, secrete special biomolecules that break down excreted waste products or the remains of dead organisms, allowing those molecules to be used again.

13. Compare and contrast sexual and asexual reproduction.

When living things reproduce, they pass their genetic code on to their offspring by one of two processes of reproduction—asexual or sexual. In asexual reproduction, a single-celled organism makes a copy of its DNA and then divides into two identical daughter cells. Thus, asexual reproduction results in genetically identical offspring. In sexual reproduction, two parents each contribute half their DNA to the resulting progeny. The result is a genetically unique individual.

14. Briefly trace the developmental process of a human being, from conception through death.

A person begins as a single cell—the joining of a sperm and an egg with a unique genetic code. At that point, the cell begins to grow and divide (a process called *mitosis*), becoming two cells, then four, then eight. As the process of growth and cell division continues, certain cells begin to specialize their roles. Some cells are set on a path to become blood cells, others are destined to become brain cells, and so on. As time progresses, the expressed genes in each cell begin to dictate how they are arranged within the body. The growing baby begins to look more and more human-like, with a head, a face, a torso, two arms and two legs. Dramatic growth and differentiation of cells continues for about nine months, until the baby's lungs are ready to breathe oxygen, and then the baby is born. The baby gradually gains the ability to roll over, crawl, walk, and talk. As the child reaches school age, she learns to read and write. She reaches physical milestones, such as losing baby teeth and gaining permanent ones. Eventually, the child reaches puberty, initiating a series of changes by which she becomes physically capable of sexual reproduction. All the while, the person gains increasingly complex reasoning abilities. She can now visualize abstract concepts, as she studies subjects in increasing depth throughout her high school career and beyond. Development continues throughout adulthood. Around middle age, signs of aging appear—such as graying hair, diminishing eyesight, and menopause in women. Eventually, the person dies.

15. Besides those mentioned in the book, think of three examples of an organism responding to a stimulus. For each example, explain what the stimulus is, how the organism senses it, and how the organism appropriately responds.

Comment: Many answers are possible. Examples:

A mouse hears a sound with its ears, perhaps associated with a potential threat, and runs into a hole or hiding place.

A hawk sees a mouse with its eyes and dives toward the mouse to catch it.

A plant responds to the stimulus of hot weather by closing pores in its leaves to prevent water loss.

Bacteria exhibit chemotaxis, the ability to sense concentrations of molecules, then they swim toward or away from them.

16. Define homeostasis, giving an example of an organism exhibiting homeostasis.

Homeostasis is an organism's maintenance of various continuous stimulus/response processes so that the organism remains within life-sustaining limits. Like a thermostat controlling the temperature in a building, to maintain homeostasis organisms monitor pH, salt concentration, temperature, nutrient levels, and a whole host of other parameters—adjusting their responses to these conditions so that the body remains in an acceptable, life-sustaining range. Maintaining homeostasis is a particularly complex manifestation of the stimulus/response characteristic of life. An example is a person sweating (or a dog panting) in order to maintain body temperature within appropriate limits.

17. Define adaptation, giving an example of a population adapting to changing environmental conditions.

Adaptation is the response of a population to changing environmental conditions over several generations. This process of adaptation depends upon genetic variability among the members of the population. Variable traits that give survival advantage increase in the population. An example is the size of bird beaks that become larger or smaller over several generations as food sources (seeds) become harder or softer due to drought or other conditions.

SECTION 1.3

18. Compare and contrast the theories of Aristotle and Redi.

Aristotle thought organisms could randomly come into existence through spontaneous generation. In experiments with rotting meat and maggots, Francesco Redi showed that organisms don't spontaneously generate randomly. Maggots on rotting meat don't emerge in meat by spontaneous generation. Instead, they are the offspring of flies laying eggs in the rotting meat. Redi's work led to his dictum omne vivum ex vivo—every living thing from a living thing.

19. Compare and contrast the experiments of Needham and Spallanzani. How were their theories different from those of Aristotle and Redi?

John Needham boiled mutton gravy in sealed tubes and afterward observed microorganisms in the tubes, observations that seemed to support spontaneous generation. Lazzaro Spallanzani replicated this experiment, but used hermetically sealed tubes and boiled the gravy for longer, arguing that Needham didn't boil his gravy long enough to kill the microorganisms in the gravy. Spallanzani did not observe microorganisms in his tubes after boiling. Needham countered that Spallanzani's long boiling killed the "life force" in the air that is necessary to generate new life. Needham's life force was a new idea that was not part of Aristotle's thinking. Spallanzani held the same view as Redi.

20. Describe the experiments and conclusions of Louis Pasteur.

Louis Pasteur resolved the debate by using a specially designed swan-necked flask that allowed air into the flask but kept out dust. He performed three experiments. In the first, he broke off the neck of the flask and observed that microorganisms form after a few days. In the second, he left the flask after boiling for months with no appearance of microorganisms. In the third, he tipped over the flask after it had sat for months so the liquid inside came in contact with the edge of the opening. Microorganisms were then observed to grow inside in just a few days. This set of experiments strongly supports Redi's biogenic theory, that all life comes from previously existing life.

21. What experimental modifications did John Tyndall make, and how did his results strengthen biogenic theory?

During the course of his experiments, John Tyndall discovered that bacteria could live in heat-resistant hay spores, making it possible for the bacteria to survive the boiling process. The problem was solved by applying a new regimen of alternately heating and cooling a sample. But the discovery showed how easy it is for bacteria to remain in a sample and contaminating it unless vigorous methods were used to kill them all. Tyndall's work strengthened biogenic theory by showing that when life did emerge, there was already other life there in the first place.

22. Distinguish between Bastian's term *archebiosis* and Huxley's term *abiogenesis*. How are these two terms different from the term *spontaneous generation*?

The term archebiosis refers to life routinely emerging from nonliving matter, but doing so according to natural laws. This is slightly different from spontaneous generation, where life emerges randomly, not necessarily following any natural laws. Biogenesis is the prevailing theory today—that life always comes from life. T.H. Huxley coined the term abiogenesis to refer to the single instance long ago when the first life emerged from nonliving matter. At present, no one knows how this might have occurred, although clearly it did.

Chapter 2 Exercises

SECTION 2.1

1. What is hydrogen bonding? What kinds of atoms participate in hydrogen bonding and under what conditions?

When a hydrogen atom is chemically bonded to a highly electronegative element, such as oxygen, nitrogen, or fluorine, this results in a partial positive charge on the hydrogen and a partial negative charge on the electronegative atom. The charge imbalance produces a highly polar molecule that readily bonds with other polar molecules.

2. How do van der Waals interactions occur? What kinds of molecules participate in these kinds of interactions?

The weakest intermolecular interactions are the Van der Waals forces, which occur between molecules that are mildly polar or nonpolar. In molecules that are nonpolar, there can still be small random fluctuations in charge that lead to a fleeting, temporary, partial charge. These random fluctuations are caused by the electrons being momentarily denser on one side of the molecule. If this fleeting partial charge occurs, it can induce a momentary partial charge in a neighboring molecule, and then the neighbor's neighbor, and so on as electrons rush towards a neighboring partial positive charge. However, because these interactions are quickly formed and quickly dispersed, they are not nearly so strong as hydrogen bonds. However, they do account for interactions between nonpolar molecules, and can exhibit strength when present in large numbers.

3. What is cohesion? Adhesion? Using these two terms, briefly describe how water flows upward in trees and other plants against the force of gravity.

Cohesion is the tendency for molecules of the same kind to stick together. Water's hydrogen bonding tendencies cause it to be highly cohesive. You can also observe cohesion by slightly overfilling a glass of water and noticing how the water bows upwards without spilling over. In this case, the cohesive forces between water molecules overcome the force of gravity. While cohesion describes how water sticks to itself, adhesion refers to water's tendency to stick to other substances or objects. Trees and other plants use cohesion and adhesion working together in a rather magnificent way. In order to survive, a tree must pull large amounts of water from its roots up to its leaves on a daily basis. Whereas humans and other animals have hearts to pump blood all over the body, trees have no such organ. In a process called transpirational pull (part of cohesion-tension theory), water actually pulls on itself and on the inner tissue of the tree (the xylem) to cause the bulk flow of water in large amounts. A large oak tree moves about 110 gallons of water (the amount of water held in an extra-large bathtub) from roots to leaves every day.

4. Explain why water striders are able to walk on water.

Related to cohesion is surface tension. Because water molecules tend to stick together, the surface of water has a special resistance to being broken. This resistance, or surface tension, is commonly seen when insects such as water striders literally walk on the water without breaking the surface.

5. How does adhesion affect the way one takes a volume reading with a graduated cylinder or a buret?

Adhesion refers to water's tendency to stick to other substances or objects. In glassware such as burets and graduated cylinders, some water creeps up the sides of the glass, forming a curved surface called a meniscus. The presence of a meniscus means that a special measurement technique is required. In order to obtain an accurate reading, you must position yourself so the meniscus is at eye level and read the water level at the bottom of the meniscus.

6. Define specific heat capacity. What are two ways that water's specific heat capacity benefits life (at the organism and ecosystem levels)?

The specific heat capacity of a substance is the amount of heat required to raise the temperature of one gram of the substance by one degree Celsius. Because of hydrogen bonding in water, much more heat is required to raise its temperature than almost all other substances.

This property is extremely important for life—both at the organism and ecosystem levels of organization. Individual organisms cycle matter and energy through many thousands of chemical reactions. In the process of these reactions, large amounts of heat are released. Because cells have such a high water content, most of this heat is safely absorbed without appreciably raising the body temperature of the organism. This is just one way that organisms can maintain homeostasis—keeping body temperature within a very narrow range that is necessary for life. At the ecosystem level, large bodies of water such as oceans resist changes in atmospheric temperature. This provides a stable environment for marine life.

7. Consider a planet having high levels of H_2S (hydrogen sulfide) instead of H_2O (water). Do you think life could exist there? Why or why not? Explain your answer in terms of hydrogen bonding and resulting properties. Hint: the electronegativities of hydrogen, oxygen, and sulfur are 2.20, 3.44, and 2.58, respectively.

The electronegativity of oxygen is far higher than that of hydrogen. The big difference produces a polar molecule that engages in hydrogen bonding. Sulfur's electronegativity is a lot closer to that of hydrogen. Thus, the H_2S molecule is not nearly as polar as the H_2O molecule is. Since the hydrogen bonding of water leads to many properties that are critical for life, it is highly unlikely that life could exist in an H_2S environment.

8. Describe how the unique density properties of water support life.

In the case of water, ice is actually less dense than liquid water. Whereas in liquid water the molecules are constantly tumbling over one another, engaging in and moving away from hydrogen bonding with other molecules, ice forms a stable hydrogen bonding pattern. The ideal geometry of these bonds forces the water molecules to sit farther apart than they do as a liquid. This means molecules take up more space in solid ice. As a result, ice is less dense than water and floats.

This property is very important for maintaining life. In cold winter weather, lakes freeze over and because ice floats, only the top of the lake freezes. This top layer of ice then shields the liquid water underneath from the brutal winter temperatures, preventing freezing of the entire lake. Fish and other aquatic life are able to survive in the liquid underneath. Additionally, when the ice melts in the spring, a phenomenon called spring overturn occurs. As ice melts, it becomes dense cold liquid water and falls to the bottom of the lake. As this denser water falls, it pushes the warmer water originally at the bottom up to the top. This process circulates nutrients and oxygen and is essential for the health of all life within the lake.

9. Consider a nonpolar substance such as oil. Is water able to dissolve it? Explain, in terms of electrostatic interactions, why this is the case.

Comment: This is not specifically addressed in the text in Section 2.1. From the description of water's ability to dissolve polar and ionic substances, students are expected to speculate that the insolubility of oil must have something to do with oil molecules being nonpolar. This is, in fact, correct. As stated in the first paragraph under Lipids in Section 2.3.3: The lipids is a class of molecules that are hydrophobic (water-fearing). These molecules consist mainly of carbon and hydrogen and are nonpolar. Their electrons are shared and distributed evenly around the molecule, so that no partially charged regions are created. Water is not able to dissolve molecules in this class.

10. Describe the process by which water dissolves a salt crystal at the molecular level.

If you place a spoonful of table salt in a cup of water, the polar water molecules begin to pull apart the salt crystal, ion by ion. Since water has both partial negative and partial positive charges, these are attracted to their opposite charges in ions in the crystal. The attraction is so strong that it overcomes the crystal structure present in the salt. Once the salt completely dissociates—that is, comes completely apart and dissolves—each ion is surrounded by water molecules.

SECTION 2.2

11. What are the six most abundant elements found in living organisms? What additional element is a significant part of the composition of the human body and why?

The acronym CHNOPS is often used to summarize the six elements that are the basic building blocks for all biological molecules—carbon, hydrogen, nitrogen, oxygen, phosphorus, and sulfur. Even though calcium is not in the CHNOPS list, its abundance in the human body exceeds that of phosphorus and sulfur. This is because calcium comprises 39% of the atoms in our bones.

12. Do some research on the abundance of elements in the composition of the earth. How does this compare to the percentage of elements in living things?

Percentages in the table below are from the CRC, listed in a table on Wikipedia.

element	abundance in humans	element	abundance in Earth's crust
hydrogen	62%	oxygen	46%
oxygen	24%	silicon	28%
carbon	12%	aluminum	8%

nitrogen	1.1%	iron	5.6%
calcium	0.22%	calcium	4%
phosphorous	0.22%	sodium	2%
sulfur	0.038%	magnesium	2.3%
sodium	0.037%	potassium	2%
potassium	0.03%	titanium	0.6%
chlorine	0.024%	hydrogen	0.1%

These two lists are rather different. Both include oxygen, hydrogen, calcium, sodium, and potassium in the top 10 elements. But the percentages are wildly different. Hydrogen, for example, is the most abundant element in the body, and the least abundan element in the Earth's top ten.

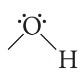
SECTION 2.3

13. Why is the element carbon a major component of biological molecules?

Carbon atoms have four valence electrons, the electrons in the valence shell available to participate in chemical bonding. This means that carbon has the opportunity to form up to four covalent bonds with other elements or with other carbon atoms. Carbon is able to form single, double, and triple covalent bonds, in which one, two, or three pairs of electrons are shared. Additionally, carbon atoms can bond together in straight chains, branched chains, or rings. Carbon is thus an extremely versatile element and forms the basis for almost all biologically relevant molecules.

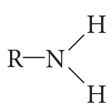
14. Draw the following functional groups: hydroxyl, amino, carboxyl, phosphate. Describe their unique properties.

hydroxyl



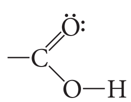
Hydroxyl is a polar functional group, which means it exhibits hydrogen bonding with water.

amino



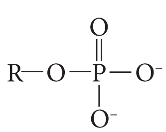
Amino groups are capable of accepting a third hydrogen atom under certain conditions, which means they are weakly basic molecules. Aminos, like carboxyls, play an important role in the formation of peptide bonds between amino acids.

carboxyl



Carboxyls tend to give up the hydrogen atom in aqueous environments, which means they are acids. They also play an important role in the formation of covalent bonds between the amino acids of proteins.

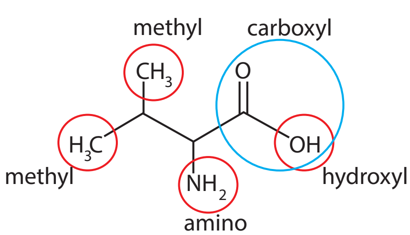
phosphate



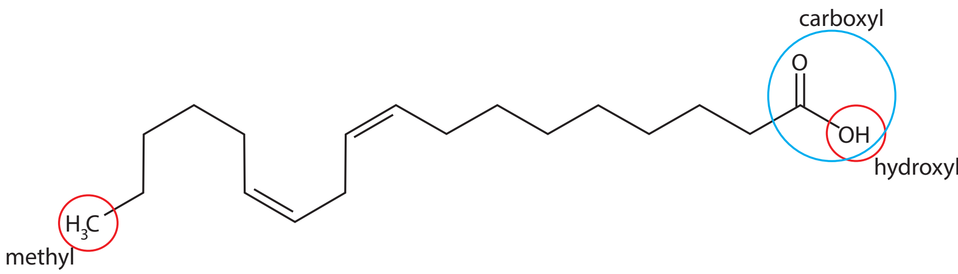
Phosphate is a negatively charged, polar functional group commonly found in DNA, ATP, and phospholipids.

15. Sketch the following molecules on your own paper. Then circle and label as many different functional groups as you can.

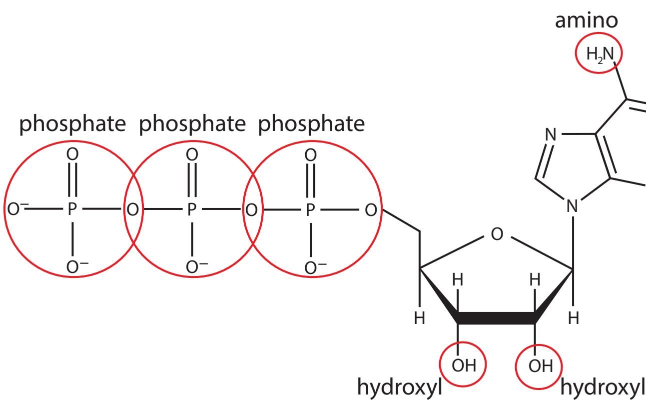
a. valine



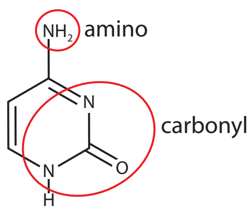
b. linoleic acid



c. ATP



d. cytosine



16. Describe the chemical structure of a simple sugar.

The monomers of carbohydrates are called simple sugars or monosaccharides (meaning single sugar). These sugars are generally composed of a ring with five or six carbon atoms and an oxygen atom, and an OH group attached to each carbon atom. Three common sugars are glucose, galactose, and fructose, which differ in their placement of OH groups relative to one another and the shape of their rings.

17. Describe the four major types of carbohydrates. What is the nature of each one's chemical structure? What are the roles of these carbohydrates in biology?

Starch is a polymer of glucose, formed as a mixture of two types of chains: amylose and amylopectin. Amylose is a straight-chain molecule; amylopectin is a branched-chain molecule. Starch is the major dietary source of glucose, and is found in rice, bread, potatoes, and similar foods. Our bodies break down starch in a hydrolysis reaction.

Glycogen is a branched-chain polymer of glucose, found mainly in the liver and muscles. Its purpose is to store glucose for future energy usage.

Cellulose is a straight-chain polymer of glucose, in which the glucose monomers are bonded in a different orientation than they are in dietary starch. This orientation allows hydrogen bonding to occur between neighboring strands, resulting in an extremely strong fiber that gives strength to plants and trees. Cellulose is a major component of celery, making it very difficult to chew. The human body is not able to digest cellulose, so celery has little caloric value. (It does, however, contribute many helpful compounds such as vitamins and antioxidants.)

Chitin is composed of glucose monomers linked together in the same indigestible manner as those of cellulose. However, one of the OH groups on each glucose monomer is replaced by an acetyl amine group. These groups allow for hydrogen bonding between chains, giving chitin the ability to form a strong, flexible, two-dimensional sheet. This makes chitin the perfect material for the exoskeletons of insects and crustaceans, as well as the cell wall of some fungi.

18. Compare and contrast carbohydrates and lipids.

The lipids is a class of molecules that are hydrophobic (water-fearing). These molecules consist mainly of carbon and hydrogen and are nonpolar. Their electrons are shared and distributed evenly around the molecule, so that no partially charged regions are created. Water is not able to dissolve molecules in this class. All the carbohydrates include ring structures of five or six atoms in the monomers the molecules are composed of. Additionally, the numbers of carbon and oxygen atoms in the carbohydrates are roughly equal. There are no ring structures in two of the three classes of lipids. In all lipids the numbers of carbon atoms are far greater than the numbers of oxygen atoms in the molecules.

19. Describe the three major classes of lipids in terms of their chemical structures and roles in the cell.

Triglycerides consist of three fatty acids—carbon-hydrogen chains—attached to a glycerol molecule. Lipids in the form of triglycerides are used in animals to store energy for long-term use. In saturated fatty acids, all the carbon-carbon bonds are single bonds. This results in straight carbon chains that pack tightly together. Because of the tight packing, these fats are solids at room temperature. Animal fats, such as butter or bits of fat that you may trim from a piece of meat, are composed of saturated fats. In unsaturated fats, one or more double bonds are present between the carbon atoms in the chain. The double bonds kink the carbon chain so that it bends, preventing the fats from being very close to one another. As a result, unsaturated fats tend to be liquids at room temperature; those that are are called oils. Unsaturated fats are often plant-derived. Olive oil and vegetable oil used for cooking are examples of unsaturated fats.

Phospholipids consist of only two fatty acids bound to a glycerol, with the third spot being taken by a phosphate group. These fats have the property of being hydrophobic at one end (where the fatty acids are) and hydrophilic at the other end (where the phosphate group is). The result is that this molecule can form a lipid bilayer, the major component of the cell membrane.

Steroids are small molecules of fused carbon rings. Cholesterol is a component of the cell membrane. Two other steroid molecules are testosterone and estrogen. These are the sex hormones that control some of the functions specific to males and females.

20. Describe the chemical structure of an amino acid. Identify and label the functional groups.

Each amino acid has an identical backbone, consisting of a central carbon atom, an NH_2 group on one end, and a COOH group on the other, so the generic amino acid formula can be written $R\text{-}CH(NH_3)COOH$. The difference between the amino acids is the “R” group, the side chain. Some amino acid side chains are hydrophobic, some hydrophilic. Some are small, some are bulky. Some are acidic, some are basic. Some are positively charged, some negatively charged. Some can even covalently bond with others. All in all, the amino acids have a vast array of physical and chemical properties, making them the perfect components for producing the proteins needed to perform the huge number of functions that occur in the bodies of complex organisms such as ourselves.

21. Structurally speaking, how do amino acids join together to create proteins?

Proteins are formed by chains of amino acids, connecting the NH_2 (amino group) of one amino acid to the COOH (carboxyl group) of the next.

22. List and describe the four main groups of amino acids. Give an example of an amino acid from each group.

nonpolar side chains: these include glycine, alanine, valine

polar side chains: these include serine, threonine, cysteine

acidic: there are two of these—aspartic acid, glutamatic acid

basic: there are three of these—lysine, arginine, histidine

23. Explain how the different amino acids give a protein its specific structure.

A protein’s amino acid sequence determines its three-dimensional structure, and its structure determines its function.

The making of a protein molecule begins with a single, straight chain of amino acids—a polypeptide. The sequence of amino acids present in this single chain defines the protein's primary structure. Once the polypeptide is assembled, or even while it is being assembled, it begins folding into a 3-D structure that gives it machine-like abilities.

The secondary structure refers to some common 3-D structures that can occur in parts of a polypeptide chain. Two types of secondary structure are the alpha helix and beta sheet, both of which rely on regular patterns of hydrogen bonding within the chain of amino acids. In the alpha helix, every backbone N—H group hydrogen bonds to the backbone C = O group four monomers earlier in the same chain, creating a helical structure. In the beta sheet, hydrogen bonding occurs between the same two groups located on separate, parallel strands, creating a flat structure.

Tertiary structure describes the fully formed 3-D structure of a single polypeptide chain. The final shape is the product of many different chemical interactions between the R side chains. These interactions include covalent bonds, ionic bonds, hydrogen bonding, and Van der Waals interactions.

Quaternary structure is reserved for those proteins whose functions depend on several individual polypeptides, called subunits, interacting with one another to perform the final function. These subunits often associate with one another through hydrogen bonding or Van der Waals interactions.

24. Describe six major roles for proteins in the cell.

Enzymes An enzyme is a catalyst—a molecule that speeds up a chemical reaction without itself being consumed. Your body is a fantastic chemical factory of many thousands of chemical reactions—those that turn food into energy, those that build up tissue, those that control growth and development, and many others. In order that these reactions don't run out of control, every chemical reaction has an enzyme that controls it. These enzymes bind to a particular chemical, called a substrate, place it in just the right direction to react with another substrate, and then release a newly formed product, ready to begin the process again. Without an enzyme to help, most chemical reactions in the body would simply take too long, being too energetically unfavorable to occur. Enzymatic control of chemical reactions means that every process can be finely tuned, helping the body to maintain homeostasis.

Transporters Many substances must cross cell membranes in order to keep the body running smoothly. Proteins act as transporters to facilitate this process. Additionally, red blood cells must carry oxygen from your lungs to every cell in the body. The oxygen is transported by the protein hemoglobin, which is present in red blood cells.

Signaling Proteins Cell membranes have a number of proteins that relay signals from other cells to the interior. Other proteins may form a complex cascade of signaling pathways, such that all parts of the body or the cell remain in communication.

Structural Proteins Proteins are the structural components in the body. These include collagen in the extracellular matrix; keratin in hair, nails, and intermediate filaments; and other proteins in the cytoskeleton filaments extending throughout the interior of all cells and giving them their shape.

Motor Proteins Proteins enable our bodies to move. These proteins include myosin for muscle contraction, kinesin for vesicle transport, and dynein for cell division.

Regulatory Proteins Proteins such as antibodies, hormones, and receptors regulate and control processes throughout the body.

25. Make a table defining the four levels of protein structure: primary, secondary, tertiary, and quaternary.

primary structure	The making of a protein molecule begins with a single, straight chain of amino acids known as a polypeptide. The sequence of amino acids present in this single chain defines the protein's primary structure.
secondary structure	Once a protein has the necessary amino acids, it begins to fold into a 3-D structure that gives it machine-like abilities. The secondary structure refers to some common 3-D structures that can occur in parts of a polypeptide chain. Two types of secondary structure are the alpha helix and beta sheet, both of which rely on regular patterns of hydrogen bonding between the groups in the amino acids.
tertiary structure	Tertiary structure describes the fully formed 3-D structure of a single polypeptide chain. The final shape is the product of many different chemical interactions. These interactions include covalent bonds, ionic bonds, hydrogen bonding, and van der Waals interactions.

quaternary structure	Finally, quaternary structure is reserved for those proteins whose functions depend on many individual proteins, called subunits, interacting with one another to perform the final function. These subunits often associate with one another through hydrogen bonding or Van der Waals interactions.

26. Explain what happens to a protein if it is placed in an environment with an excessively high temperature.

Without finely tuned conditions, including maintaining temperature within a certain range, proteins fall apart, or denature—they lose their 3-D shape, resulting in a loss of function.

27. Describe the basic features of DNA's structure.

The monomers present in DNA are nucleotides. A nucleotide consists of three parts: a phosphate group, a five-carbon sugar, and a nitrogenous base. In the case of DNA, the sugar is deoxyribose. The nitrogenous bases can be one of four molecules: guanine, cytosine, adenine, or thymine (G, C, A, and T). Each nucleotide attaches to another, forming the phosphate-sugar backbone of the DNA molecule. A strand many nucleotides long will often form—even up to the millions. There are two strands of nucleotide bases in the molecule. The bases in the two strands are paired together by a very specific hydrogen bonding pattern.

28. Name the four bases found in DNA and indicate how they base-pair with one another.

The bases are guanine, cytosine, adenine, and thymine—G, C, A, and T. Wherever there is guanine on one strand, it pairs (via three hydrogen bonds) to a cytosine on the opposite strand. Adenine pairs with thymine (two hydrogen bonds). This complementarity gives DNA all kinds of advantages, including redundancy, so that even when repeatedly copied the genetic information maintains stability over long periods of time. The two strands in the DNA can also briefly separate so that the code can be copied and its information sent to other parts of the cell.

29. What type of bonding or interaction do DNA bases use to achieve complementary base pairing? Why do you think the structures of these bases are suited for this type of bonding?

Hydrogen bonding connects the bases in the pairs. The G–C bond involves three hydrogen bonds; the A–T bond involves two hydrogen bonds. Hydrogen bonding requires hydrogen atoms bonded to nitrogen, oxygen, or fluorine. All the attachment points of the bases in DNA are either a hydrogen atom bonded to nitrogen in the molecule, or nitrogen or oxygen atoms in the molecules (to which hydrogens attach).

30. Compare and contrast the structures of DNA and RNA.

RNA is similar to DNA but differs in three key ways. First, the sugar in RNA is ribose. Ribose is also a 5-carbon sugar, having an extra OH group that deoxyribose lacks. Second, RNA has four bases like DNA. Three of them are identical (adenine, guanine, and cytosine), and one of them is different, thymine being replaced by uracil. Uracil and thymine connect with adenine in the same way through hydrogen bonding. Third, while DNA exists in a stable double strand, RNA is often single stranded or folded into various 3-D shapes.

31. What are base-stacking interactions?

Base-stacking interactions are pushing and pulling forces between bases due to their being stacked on top of each other in the spiraling molecule. The bases lie quite flat on top of each other—they stack, like the crackers in a pack of crackers. Research now shows that the base-stacking interactions may even be more significant in holding the DNA strands together than the hydrogen bonding between base pairs.

REVIEW QUESTIONS

32. List the six characteristics of life.

1. Living things are composed of cells and operate on many levels of organization. Living things are made of matter, and are arranged in a highly organized, complex, purposeful format. The most fundamental level of organization that displays all the characteristics of life is the cell.

2. Living things metabolize. Living things use materials from the environment and excrete waste, the process of metabolism. Waste products are broken down and used again. Energy is continually supplied from the sun, converted, and used by organisms, which produce waste heat in the process.

3. Living things grow, develop, and reproduce. Organisms proceed through various life stages, typically of increasing complexity, until maturity is reached and the organism is able to reproduce. Organisms proceed through various life stages, typically of increasing complexity, until maturity is reached and the organism is able to reproduce.
4. Living things use and transmit genetic information. Living things share a common genetic code, or instruction manual for life. These instructions dictate how an organism functions and are passed on to offspring.
5. Living things respond. Living things have some sort of sensory system, by which they respond to light, sound, motion, or other stimuli. They process the information received and respond accordingly.
6. Living things adapt to their environments. Populations of organisms adapt to a changing environment, as each generation favors survival of organisms with the most suitable traits.

33. Describe three types of microscopes. What types of structures can be visualized with a light microscope?

The compound light microscope uses two lenses to form an image the same way a telescope does. This instrument produces images of cells and microorganisms (including living ones) with magnifications of up to 40,000× and resolutions down to 200 nm.

The scanning electron microscope uses a beam of electrons to form a 3-D image from signals produced by interaction between electrons and sample. Magnification is about 100 times greater then the light microscope.

The transmission electron microscope produces 2-D images with better resolution than the SEM.

34. Compare and contrast light and electrons as used for visualizing biological specimens.

Light can produce images down to about the size of the cell. Electrons can produce images of much smaller structures.

35. Define the terms resolution, magnification, and contrast.

Resolution is a measure of how clearly the image of an object appears. Mathematically, it is the measure of the minimum distance that two objects can be separated and still be viewed as distinct objects.

Magnification is defined as the ratio of an image size to the object's actual size.

Contrast refers to how well the image stands out from the background.

36. Are light microscopy or electron microscopy appropriate tools for studying biomolecules? Why or why not?

The size of biomolecules is down in the nanometer range. This is far smaller than the structures that can be imaged using a light microscope. However, Both SEM and TEM technologies can image structures of this size.

Chapter 3 Exercises

SECTION 3.1

1. Describe the observations made by Hooke and van Leeuwenhoek with their microscopes.

In 1665, English scientist Robert Hooke observed cork under a crude microscope. Hooke observed small chambers in a cork sample and noted that they resembled the wax cells of a honeycomb. This structure led him to coin the biological term cell. Hooke was probably observing dead, hollowed out cell walls of the bottle cork. Observation of living cells had yet to occur. In 1676, Dutch draper Antonie van Leeuwenhoek designed a more powerful microscope with a single spherical lens. He began making observations of pond water, blood, and sperm. Looking at these fluids under the microscope, he saw tiny, moving microorganisms and animal cells that he called animalcules,

2. How did the quality of Hooke's and van Leeuwenhoek's microscopes affect their observations?

Van Leeuwenhoek's microscopes used more powerful lenses. This enabled him to see smaller structures.

3. Explain how the observations of Dutrochet and Dumortier contributed to cell theory.

Henri Dutrochet made extensive microscopic observations of plant tissues, describing their structure as being composed of cells. In 1824, he was the first to describe the cell as the fundamental unit of structure and physiology in plants. He even boiled leaves in nitric acid so as to observe how the cells broke apart into individual units. In 1832, Belgian scientist Barthélemy Dumortier made observations on the silkweed plant, showing cells at the end of a filament dividing into two identical cells. Dumortier's writings are significant in that his careful observations led him to conclude that new cells are formed by the division of pre-existing cells, and that this cell division accounts for the growth of the entire organism.

Most scientists of the day adhered to the idea that cells could arise *de novo* from a mixture of simpler parts or decayed matter. Dumortier carried out observations showing that new cells formed from previously existing cells, findings that contradicted the prevailing theory.

4. What conclusions did Schleiden and Schwann make?

Apparently unaware of Dutrochet's work, in 1838 Matthais Schleiden declared that all plants are made of cells, based on his own observations. He compared notes with his friend Theodor Schwann, who had made similar conclusions regarding his own observations of animal cells. Together they deduced that all living things must be composed of cells. These findings were published in 1839 and gained wide acceptance. As a result, Schleiden and Schwann traditionally get credit for the idea that all living things have cells as their fundamental unit.

Interestingly, Schleiden and Schwann supported the predominant theory of the day regarding cellular origin, believing that cells could freely and spontaneously form from their component parts, according to a crystallization-like process, though these ideas were contradicted by the previous work of Dumortier. It would take further work for Dumortier's ideas—the beginning of our current cell theory—to gain scientific acceptance.

5. Write paragraphs comparing the contributions of Dutrochet and Dumortier with those of Schleiden and Schwann. Who came first? Which scientists were aware of the others? Who should receive the most credit for their accomplishments? Why are some of these scientists were more recognized than others?

Dutrochet, who was French, was the first to describe the cell as the fundamental unit of structure and physiology in plants, publishing in 1824. Dumortier, who was Belgian, concluded that new cells are formed by the division of pre-existing cells, publishing in 1832. This was the first proposal of this idea, now universally accepted.

Schleiden and Schwann, both German, also concluded that cells were the fundamental unit of structure in plants, extending the idea to animals and thus including all organisms. They apparently unaware of the earlier work of Dutrochet, eight years earlier. However, they did not embrace Dumortier's idea that all cells come from cells, holding to the older and more widely accepted view that cells could arise spontaneously to form from their component parts.

The text does not describe exactly why Schleiden and Schwann came to be credited for originating the idea that all living things are composed of cells. It could have to do with the fact that they were working in Germany, as opposed to Belgium and France where Dutrochet and Dumortier were working. This difference in countries may also relate to the journals in which these scientists published. It may be that the German ones (or wherever it was that Schleiden and Schwann published) were more widely read. It could also be due to the previously held reputations of Schleiden and Schwann, if they were more widely known. It could also have to do with national rivalry or international politics.

6. Discuss the ideas that Virchow popularized. Who originally proposed these ideas? Why is Virchow is historically given credit?

In 1855, German physician Rudolph Virchow popularized the idea that all cells come from other cells. He was widely respected in the medical community, so his voice carried weight. He was promoting ideas propounded in 1852 by Polish-German scientists Robert Remak, whose own research supported this theory. And as written above, the first to put this idea forward was Henri Dutrochet, in 1824. It was because of Virchow's prior reputation that he is often given credit for this insight. His association with this aspect of cell theory was also strengthened by the catchy phrase he coined: *omnis cellula e cellula* (every cell from a cell).

7. How do the tenets of cell theory support or discredit those of biogenic theory? Explain.

One of the basic tenets of biogenic theory is Francesco Redi's famous conclusion, *omne vivum ex vivo*, or every living thing from a living thing. The cell is the basic unit of life, the smallest structure possessing all six of the characteristics of life. If cells could arise from nonliving matter, the idea that all life comes from life would be discredited. Since the basic units of life all come from other cells which are also the basic units of life, the tenets of cell theory definitely support those of biogenic theory.

8. What ideas of Schleiden and Schwann were later discredited?

Schleiden and Schwann held to the view that cells could spontaneously arise from their component parts.

9. Compare and contrast the Latin phrases *omnis cellula e cellula* and *omne vivum ex vivo*. What do these statements reveal regarding the nature of life?

The two phrases mean every cell from a cell and every living thing from a living thing. The lowest level of biological organization that is alive is the cell. Cells are alive, all cells come from other cells, and thus all living things come from other living things.

10. Given what you know about the histories of cell theory and biogenic theory, speculate about what each scientist that contributed to cell theory might have thought regarding spontaneous generation. Did they support or oppose it? After you have made your hypothesis, do some searching on the Internet to see if you were correct.

Hooke: No information is given in the text about what Hooke may have thought about the origin of life.

van Leeuwenhoek: No information is given in the text about what van Leeuwenhoek may have thought about the origin of life. However, since he observed animalcules under his microscope, he may have been led to think that life arose from life, and that he thus opposed spontaneous generation. This would be a reasonable guess.

Dutrochet: Dutrochet was well-read in Redi. He also first suggested that cells always come from other cells. It seems likely that he would have opposed spontaneous generation.

Dumortier: Dumortier first observed cells dividing to form identical cells, and his cell theory includes two main ideas: that cells always come from other cells, and that cell division accounts for the growth of the entire organism. It seems likely that he would have opposed spontaneous generation.

Mohl: Mohl's publications were similar to (but later than) Dumortier's. But he was a German, and the Germans (see below) seem to support spontaneous generation of cells, and thus possibly of life, as well.

Schleiden: Schleiden and Schwann, both German, held to the view that cells could spontaneously arise from their component parts. It seems reasonable to assume that they also inclined toward supporting spontaneous generation.

Schwann: Schleiden and Schwann, both German, held to the view that cells could spontaneously arise from their component parts. It seems reasonable to assume that they also inclined toward supporting spontaneous generation.

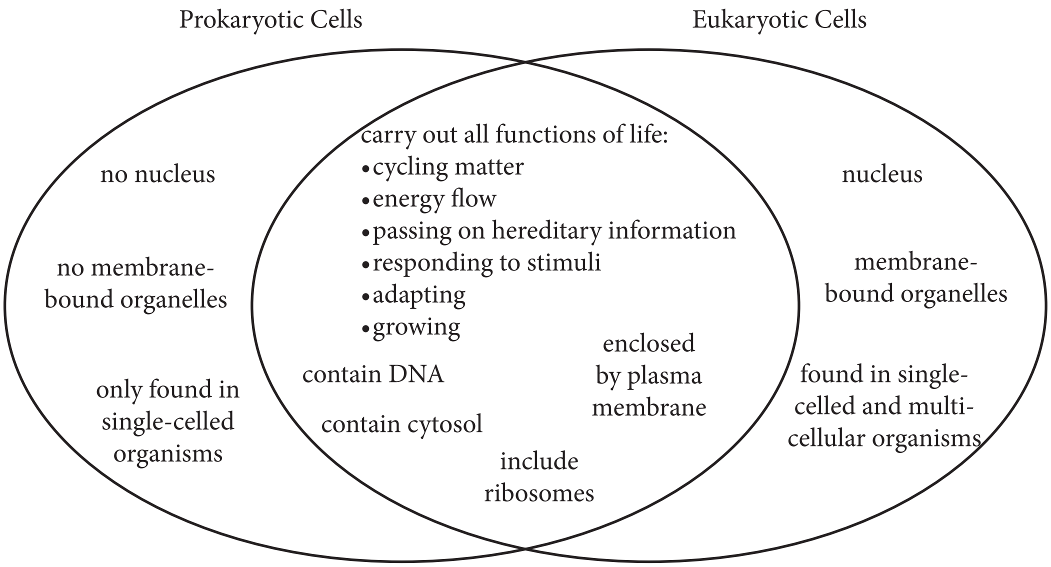
Remak: The text tells us explicitly that Remak thought spontaneous generation to be highly improbable.

Virchow: Virchow was the one who popularized Remak's work. It seems likely he would have felt as Remak did, that spontaneous generation was highly improbable.

11. What is an emergent property? Explain how cells possess emergent properties and how this fact points toward an intelligent Creator.

An emergent property is a characteristic that is much greater than the sum of its components. Each level of biological organization has emergent properties not present in the level below it. Cells can cycle matter, achieve energy flow, and reproduce. A simple mixture of biomolecules cannot. Mixing some DNA, proteins, and lipids together cannot account for the marvelous complexity of a cell—a cell that is precisely arranged to conduct thousands of metabolic reactions and to carry out each and every function of life. The highly complex, elegantly designed nature of the cell points to an intelligent creator.

12. Make a Venn diagram showing the properties of prokaryotic and eukaryotic cells (including those that are shared and those that are not).



SECTION 3.2

13. Make a copy of the table in the box The Range of Cellular Sizes, found in Section 3.2. Perform the calculations described in the box to complete the table. Then use your best thinking and speculation to address the following questions:

Cell Type	Diameter (D, µm)	Radius (r, µm)	Volume (V, µm^3)	Surface Area (A, µm^2)	A:V ratio
oocyte	197	98.5	4,000,000	120,000	0.03
adipocyte	105	52.3	600,000	34,000	0.06
lymphocyte	7.3	3.6	200	160	0.8
erythrocyte	5.8	2.9	100	110	1.1

a. How does the function of the oocyte relate to its surface area-to-volume ratio?

The oocyte must store large quantities of nutrients to nourish the growing embryo. This function is not dependent on the surface area of the membrane but is facilitated by the large volume of the cell. Large volumes are beneficial for storage cells because fewer overall cells can store the necessary amount of material. Additionally, nuclei and other organelles are kept to a minimum.

b. Compare the surface area-to-volume ratio of the adipocyte to that of the oocyte. How are the functions of these two cells similar and suited to a low surface area-to-volume ratio?

The A:V ratio of the adipocyte is twice that of the oocyte, but both are very small. Both the fat cell and the egg cell serve to store molecules for future use.

c. Discuss the roles of the lymphocyte and the red blood cell. Why is a high surface area-to-volume ratio essential to carry

out these roles?

The lymphocyte uses receptors on its surface to detect and attack foreign material. The erythrocyte uses its plasma membrane for diffusion of oxygen and carbon dioxide. Higher surface area benefits cells whose primary functions make use of the plasma membrane. In this case, the primary functions do just that.

d. In these calculations, we are assuming all the cells are spherical. In reality, the red blood cell is shaped more like a donut, with indentations on both sides. Does this modification increase or decrease the surface area? Why are high surface area and low volume important for a red blood cell?

Indentations in the red blood cell, making it donut-shaped, serve to increase the overall surface area of the membrane. The more membrane that is available, the more oxygen and carbon dioxide can diffuse across and be transported throughout the body.

e. Consider a cell as large as an oocyte. How easy or difficult do you think it would be for molecules that diffuse across the plasma membrane to reach the deep interior of the cell?

A molecule that diffuses across the membrane of the oocyte would not easily reach the interior, as the cell has a very large volume and radius. Conversely, the interior of a red blood cell is much more easily accessible, as the cell has a small volume and radius.

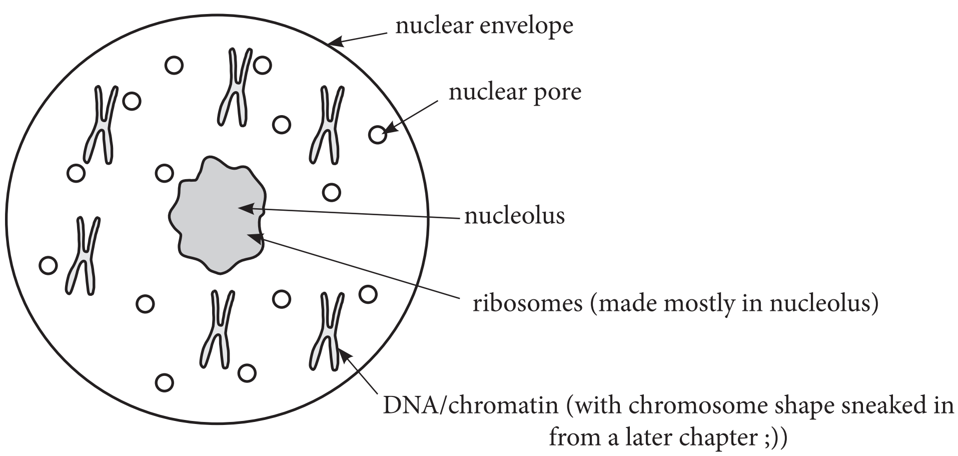
14. Distinguish between the terms cytosol and cytoplasm.

The region of the cell between the plasma membrane and the cell nucleus, including the suspended organelles, is the cytoplasm. The fluid in the cytoplasm is the cytosol.

15. Explain how cell specialization supports the needs of complex organisms.

Cell specialization is an important feature necessary for the survival of more complex organisms. The cells in the heart steadily contract and relax so that blood continuously pumps throughout your body, whereas red blood cells specialize in delivering oxygen and nutrients to each and every cell. White blood cells fight against infection, while liver cells detoxify various harmful substances. Meanwhile, neurons are firing away in the brain, making new connections with one another as we read and learn. Each cell type has the right combination of organelles to carry out its particular role. There are over 200 types of cells in the human body and around 30–40 trillion total cells.

16. Draw and label a diagram showing the nucleus. Indicate both its structure and function. Include: nuclear envelope, nuclear pores, DNA/chromatin, nucleolus, and ribosomes.



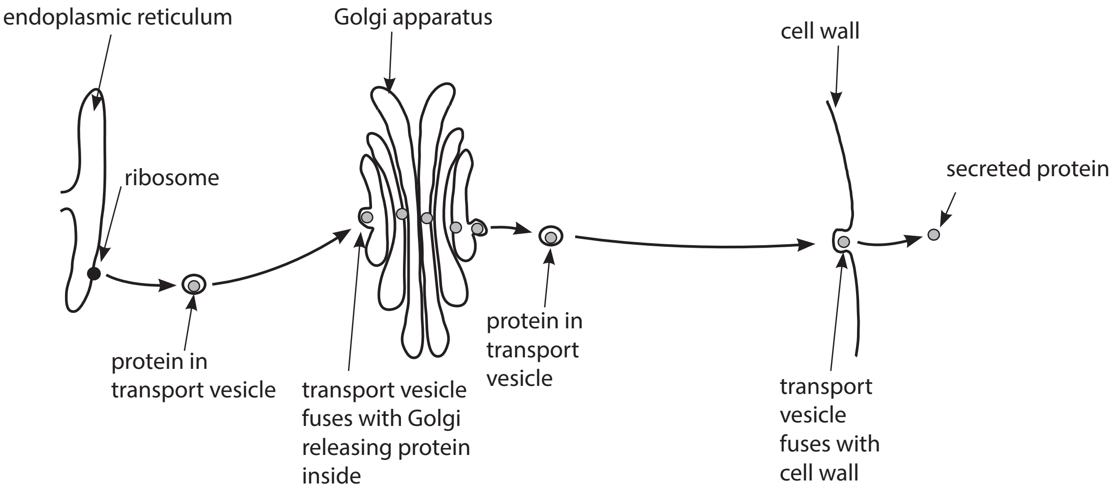
17. Compare and contrast the composition and roles of the smooth and rough endoplasmic reticulum.

There two types of endoplasmic reticulum—rough and smooth. Rough ER has numerous ribosomes embedded within its membrane. Here, proteins are synthesized that may be later secreted or bound within a membrane themselves. Smooth ER lacks ribosomes, making it the site for non-protein biosynthesis. Lipids, phospholipids, and steroids are all synthesized there. Additionally, smooth ER is the site for detoxification of drugs and other harmful compounds.

18. Describe the structure and role of the Golgi apparatus.

Once a protein is synthesized by a ribosome attached to the rough ER, it is transported to the Golgi apparatus. The Golgi apparatus is composed of membranes structured like a stack of completely separate membrane compartments. The purpose of the Golgi apparatus is to modify, package, and transport proteins. The Golgi's stack of membranes has a receiving end and a shipping end. When a protein is synthesized by ribosomes in the rough ER, it is typically released in a vesicle. A membrane-enclosed protein (transport vesicle) arriving from the ER fuses with the receiving membrane of the Golgi and proceeds through each membrane. The enclosed protein may be modified with a chemical telling the cell where it should go, or some other type of chemical modification. Once the modified protein reaches the end of the Golgi apparatus, it is enclosed in the membrane of a secretory vesicle. A secretory vesicle is an enclosed membrane that carries proteins or other molecules outside the Golgi.

19. Draw a picture or flowchart showing the path taken by a newly formed protein destined for secretion, starting with the rough ER and proceeding through the Golgi, vesicle, and then exiting the cell. Include as much detail as you can.



20. Compare and contrast the roles of vacuoles and lysosomes.

Vacuoles and lysosomes are both membrane-bound containers in cells. Vacuoles sometimes serve as storage containers for water or other small molecules in animal cells. In plant cells, the central vacuole takes up most of the space in the cell. This organelle stores water and a number of other molecules, exerting pressure on the cell from the inside. This pressure serves to make the plant rigid. The central vacuole can also store toxic molecules. These toxic substances can keep plant-eating predators away. Additionally, the vacuole protects the rest of the cell from coming into contact with the toxins. Many plants also store colored pigments in the central vacuole.

In animal cells, lysosomes are more important than vacuoles. Lysosomes are membrane-bound sacs of digestive enzymes, often in an acidic environment. These enzymes serve several purposes. In single-celled organisms, the lysosome serves as a sort of stomach, breaking apart food particles so that the building blocks can serve the needs of the cell. In white blood cells, lysosomes digest invading bacteria or viruses that these immune-system cells engulf. Most animal cells use lysosomes as the clean-up crew, recycling worn-out organelles to prevent buildup and so that the molecular building blocks can be used again.

21. Do an Internet search on lysosomal storage diseases, and choose one not mentioned in the book. Describe the symptoms of the disease you chose, and form a hypothesis describing how those symptoms might be caused by a malfunction of the lysosome.

Answer to this item is the product of the student's own Internet search.

22. Compare and contrast the structure and function of the chloroplasts and mitochondria.

The chloroplasts and mitochondria are two organelles in the cell involved in energy production. Chloroplasts are present only in plant cells and in many types of algae. Chloroplasts are the solar power plants of the cellular world. They harness energy from sunlight, converting it into chemical potential energy stored in sugar molecules. This process is called photosynthesis. The chloroplast is surrounded by two membranes—the inner and outer membrane. Inside sit membrane-bound structures called thylakoids. These flattened, sac-like thylakoids are stacked into groups called grana (singular granum) The grana are basically stacks of biological solar panels. A single chloroplast may have between 10 and 100 grana. Photosynthesis occurs within the membranes of the thylakoids. Surrounding these structures is a thick fluid called stroma, containing chloroplast DNA, ribosomes, and enzymes.

Chloroplasts use the energy from sunlight to convert atmospheric CO_2 into the simple sugar glucose. In so doing, electromagnetic radiation is stored in the chemical bonds of the glucose molecule, ready to be used by the cell. However, energy stored in glucose is not in a form the cell can immediately use and must be transformed into ATP, the energy currency of the cell.

Many of those energy-converting chemical reactions take place in the mitochondria. Mitochondria are present in most cell types. Like chloroplasts, mitochondria have two membranes—an inner and an outer. However, unlike chloroplasts, the inner membrane of the mitochondrion is highly folded. The folded structure greatly increases the available surface area of this membrane, allowing more space for the membrane-bound enzymes that carry out the ATP-generating chemical reactions.

23. Most cells have mitochondria, whereas only plant and algae cells have chloroplasts. Given this fact, how might non-photosynthetic cells obtain their glucose to convert into ATP?

It is transported to the cells in the blood.

24. How do chloroplasts and mitochondria differ from other organelles? Name as many ways as you can think of.

Chloroplasts and mitochondria are bound by a double membrane. Ribosomes are not bound by a membrane.

There are functional differences—chloroplasts and mitochondria are for energy production. The nucleus contains the DNA, used by the ribosomes to make proteins. The ER and Golgi apparatus are involved in synthesis, storage, and transport of many types of biomolecules. Vacuoles store water in plants and give the plant structural strength. Lysosomes digest invading bacteria and recycle other worn-out organelles.

25. Reproduce the following table on your own paper and fill in the required information, listing the appropriate details for the three components of the cytoskeleton.

Cytoskeleton Component	Microtubules	Intermediate Filaments	Microfilaments
Type of protein monomer	tubulin	vimentin	actin
Width of fiber	25 nm	10 nm	7 nm
Major roles in the cell	cell division (centriole); directing the movement of external cellular structures, such as cilia and flagella; directing the movement of organelles and other components within the cell	internally support the cell, forming a protective cage around the nucleus and supporting the other organelles	allow for muscle contraction; in single-celled amoebas, direct the blob-like movement of the entire organism

26. Compare and contrast the cell walls of bacteria, fungi, and plants.

In plants, this extracellular structure is composed largely of the carbohydrate cellulose. Fungal cell walls are composed of chitin. Bacterial cell walls are typically composed of peptidoglycan, a structure of cross-linked carbohydrates and proteins.

27. How does the cell wall provide support?

The cell wall keeps the cell from swelling to the point of bursting. It also protects the cell from outside structural damage. The cell wall can interconnect with adjacent cells, giving an organism a solid, rigid shape (especially in the case of plants and some fungi).

28. Describe the structure and purpose of the extracellular matrix in animal cells.

This matrix serves to hold cells together to form tissues in the body and protects the cell membrane. The ECM is composed of glycoproteins and the protein collagen.

29. What are junctions and how do they function in cells?

Junctions are special protein structures that provide structural stability and facilitate communication between cells. There are three types of cell junctions. Tight junctions prevent leaks in places such as the intestines. Desmosomes hold tough muscle or skin tissues together. Gap junctions facilitate rapid communication between coordinated cells.

SECTION 3.3

30. Describe the chemical structure of the plasma membrane. How does this structure make the membrane semipermeable?

The plasma membrane is composed of many phospholipid molecules lined up side by side in a double layer. Phospholipids consist of two fatty acids bound to a glycerol molecule, with the third spot being taken by a phosphate group. These fats are hydrophobic at the end where the fatty acids are and hydrophilic at the end where the phosphate group is. This structure enables this molecule to form a double layer—the lipid bilayer—the major component of the cell membrane.

This crowd of phospholipids in the lipid bilayer is called a fluid-mosaic. The term fluid is used because the phospholipids move about throughout the layer (the 2-D space of the membrane), just as people in a crowd are free to work their way through to the other side, without affecting the relatively tight packing in the overall area.

The peculiar composition of the cell membrane is explained by the solubility of the molecules involved. Polar molecules interact with water and nonpolar molecules (such as the fatty acids in lipids) repel water. The structure of the lipid bilayer makes an effective barrier between the inside (cytoplasm) and the outside (extracellular environment) of the cell. The polar phosphate groups of the lipids are facing both the inside cytoplasmic and the outside extracellular sides, where aqueous solutions or suspensions are present. Meanwhile, the nonpolar fatty acids face one another in the interior of the bilayer.

Because of this structure, the cell membrane controls which molecules enter or exit the cell. Some small, nonpolar molecules can pass directly through the membrane, just as a small child is able to traverse quickly through a crowd. Larger or more polar molecules tend to require a special protein channel through which to travel.

31. How do active and passive transport differ?

Transport across the cell membrane that requires the use of energy to power the process is active transport. Transport that requires no input energy is passive transport.

32. Compare and contrast the three main modes of passive transport.

There are three types of passive transport—simple diffusion, facilitated diffusion, and osmosis. Simple diffusion is the process by which small, nonpolar molecules travel directly though the plasma membrane. Gases such as O_2 and CO_2 diffuse directly across the plasma membrane of red blood cells—from areas of high concentration to low concentration. These nonpolar molecules are not repelled by the nonpolar environment of the lipid bilayer and are small enough to sneak through the crowd of much larger phospholipid molecules.

Larger and more polar molecules require a sheltered passageway through the lipid bilayer. This type of transport is called facilitated diffusion. Ions and polar molecules such as glucose must travel through special protein channels specific to them.

Water molecules are comparable in size to O_2 and CO_2 but their highly polar nature makes them unsuited for travel across the nonpolar interior of the plasma membrane. Instead, they flow through membrane-bound protein channels called aquaporins. However, because water is the solvent in biological systems rather than the solute, it has its own type of passive transport: osmosis. Osmosis is the process of water molecules seeking to equalize concentrations of solutes on either side of a membrane. Water flows toward the side where the higher solute concentration is, thus diluting it until both sides of the membrane have equal concentration of that solute.

33. A scientist prepares a beaker with a semipermeable membrane separating two halves. The membrane allows the passage of sucrose. The scientist places a 3% solution of sucrose on right side and a 1% solution on the left. What type of passive transport takes place and in what direction do the molecules flow? How do the final volumes on either side of the membrane compare?

Diffusion; sucrose diffuses towards the left side until both sides achieve equal concentration. Final volumes are equal.

34. Now, imagine the same scenario as presented in question 33, only this time the membrane is impermeable to sucrose. What type of passive transport occurs and in which direction do the molecules flow? How do the final volumes on either side of the membrane compare?

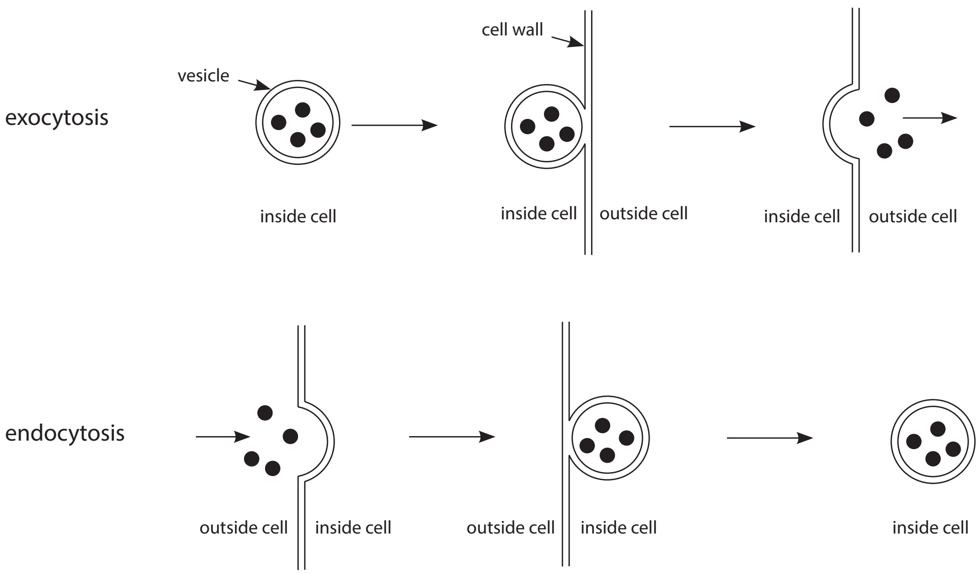
Osmosis; water flows towards the right side until both sides achieve equal concentration. The volume of solution on the right is higher than that on the left.

35. List and describe the three main types of active transport.

There are three major types of active transport: primary active transport, secondary active transport, and bulk transport. Primary active transport involves an ATP-dependent membrane-bound pump. This membrane protein uses ATP to pump sodium ions out of the cell and potassium ions in—both against their concentration gradients. In secondary active transport, energy input comes from molecules being transported down an electrochemical gradient rather than a concentration gradient. An electrochemical gradient occurs when there is a difference in charge across a plasma membrane due to the presence of positive or negative ions. The difference in charge enables molecular transport to be electrically-powered rather than ATP-powered. Bulk transport is reserved for structures that are too big or too numerous to use a transmembrane protein channel. Bulk transport occurs through the related processes of exocytosis and endocytosis.

36. Draw diagrams showing the mechanisms of exocytosis and endocytosis.

Both endocytosis and exocytosis exploit the fluid properties of the plasma membrane. Because the phospholipids are not covalently bound to one another, membrane-bound vesicles can easily fuse with the plasma membrane, allowing all its phospholipids to become part of the outer membrane and releasing its contents in the process.



37. Describe the three types of endocytosis.

First, phagocytosis occurs when an immune cell or unicellular organism completely engulfs a smaller cell. Second, pinocytosis brings in fluid from the outside the cell. Third, receptor-mediated endocytosis uses signaling molecules on the outside of the cell membrane that bind with specific ligands—ions or functional groups bound to central metal atoms. The receptor-ligand complex is brought into the cell and processed through a series of vesicles. Clathrin proteins form the coated pit on the exterior of the vesicle (interior of the plasma membrane).

SECTION 3.4

38. Describe the five main compartments of the eukaryotic cell and their overall functions.

1. The first group of structures deals with genetic expression. This includes the nucleus, nucleolus, and ribosomes. Together, these organelles enable the cell to copy the DNA, and also to transform the DNA into proteins through the process of gene expression.

2. The second is the endomembrane system. This collection of membrane-bound organelles includes the endoplasmic reticulum, Golgi apparatus, and various vesicles and vacuoles. This group of structures is largely responsible for the manufacturing of proteins and lipids that are used in the cell. It also provides a means for transporting and exporting these products outside the cell.

3. The third group of structures are those associated with energy production within the cell. These organelles include chloro-

plasts, found in plant and algae cells, and mitochondria.

4. Fourth is the cytoskeleton of the cell. This network of proteins not only provides a structural scaffolding that gives the cell its shape and structure, but also enables the transportation of vesicles within the cell and the movement of the cell.

5. Fifth are those structures which are external to the cell, such as the cell wall in plants, fungi, and protists, as well as the extracellular matrix of animal cells. Let's look at an example of how all these different compartments work together in a living cell.

39. Trace the path of a phospholipid from its synthesis to its final location on the cell plasma membrane.

The lipid is made within the smooth endoplasmic reticulum, transferred in a secretory vesicle to the Golgi apparatus, then transferred by another secretory vesicle to the plasma membrane.

40. What is the theory of endosymbiosis? What evidence supports this idea?

Current evolutionary theory proposes a mechanism by which more complex eukaryotic cells developed from simpler prokaryotic cells. The endosymbiotic theory proposes that billions of years ago a prokaryotic cell phagocytized a proteobacterium (also a prokaryote). These two prokaryotic cells developed a symbiotic relationship in which the engulfed cell adapted to live inside the archaeal host cell. Over time, it developed into the mitochondrion. In a second event, the host cell engulfed a photosynthetic bacterial cell which developed into the chloroplast. There are several pieces of evidence used to support this theory. First, the mitochondrion and chloroplast both have double membranes. During phagocytosis, the host cell encloses the inner cell in a membrane-bound vesicle, resulting in a secondary membrane surrounding the primary bacterial plasma membrane. Second, both mitochondria and chloroplasts have their own circular DNA and ribosomes, similar to those contained in bacterial cells. Finally, mitochondria and chloroplasts, like bacteria cells, use binary fission to divide. The theory proposes that the membrane around the nucleus and the other membrane-bound organelles, such as the Golgi and endoplasmic reticulum, resulted from the plasma membrane folding into the cell. In addition, the cell enlarged: parts of the plasma membrane began to fold inward, forming networks of membrane-bound structures that increased the overall surface area of the growing cell. Eventually, these membranous structures pinched off and developed into what we now know as the endomembrane system.

REVIEW QUESTIONS

41. List and describe six requirements for life.

1. Living things are composed of cells and operate on many levels of organization. Living things are made of matter, and are arranged in a highly organized, complex, purposeful format. The most fundamental level of organization that displays all the characteristics of life is the cell.

2. Living things metabolize. Living things use materials from the environment and excrete waste, the process of metabolism. Waste products are broken down and used again. Energy is continually supplied from the sun, converted, and used by organisms, which produce waste heat in the process.

3. Living things grow, develop, and reproduce. Organisms proceed through various life stages, typically of increasing complexity, until maturity is reached and the organism is able to reproduce. Organisms proceed through various life stages, typically of increasing complexity, until maturity is reached and the organism is able to reproduce.

4. Living things use and transmit genetic information. Living things share a common genetic code, or instruction manual for life. These instructions dictate how an organism functions and are passed on to offspring.

5. Living things respond. Living things have some sort of sensory system, by which they respond to light, sound, motion, or other stimuli. They process the information received and respond accordingly.

6. Living things adapt to their environments. Populations of organisms adapt to a changing environment, as each generation favors survival of organisms with the most suitable traits.

42. List and describe the levels of biological organization. What emergent properties to do cells possess that biomolecules or organelles do not?

atom	the fundamental unit of matter
simple molecule	atoms joined together by sharing or transferring of electrons

biomolecule	a large molecule made of many repeating small molecules joined together
organelle	groups of different biomolecules that work together to perform a function within the cell
cell	the fundamental unit of life, composed of multiple organelles, DNA in the nucleus, all inside the cell membrane. These parts work together to perform all the functions of life.
tissue	many cells of the same type that work together
organ	various tissues that work together to perform a particular job in the body
organism	an individual living being
population	a group of organisms of the same species living in a particular region
community	multiple, interacting populations in a particular region
ecosystem	a community of living things interacting with nonliving components of their environment
biosphere	all life on earth

43. Trace the history of biogenic theory and explain how the Cycle of Scientific Enterprise was at work throughout.

Aristotle thought organisms could randomly come into existence through spontaneous generation. In experiments with rotting meat and maggots, Francesco Redi showed that organisms don't spontaneously generate randomly, leading to his dictum omne vivum ex vivo—every living thing from a living thing. John Needham boiled mutton gravy in sealed tubes and afterward observed microorganisms in the tubes, observations that seemed to support spontaneous generation. Lazzaro Spallanzani replicated this experiment, but used hermetically sealed tubes and boiled the gravy for longer, arguing that Needham didn't boil his gravy long enough to kill the microorganisms in the gravy. Spallanzani did not observe microorganisms in his tubes after boiling. Needham countered that Spallanzani's long boiling killed the "life force" in the air that is necessary to generate new life. Needham's life force was a new idea that was not part of Aristotle's thinking. Spallanzani held the same view as Redi. Louis Pasteur resolved the debate by using a specially designed swan-necked flask that allowed air into the flask but kept out dust. He performed three experiments that strongly support Redi's biogenic theory, that all life comes from previously existing life. John Tyndall's work strengthened biogenic theory by showing that when life did emerge, there was already other life there in the first place.

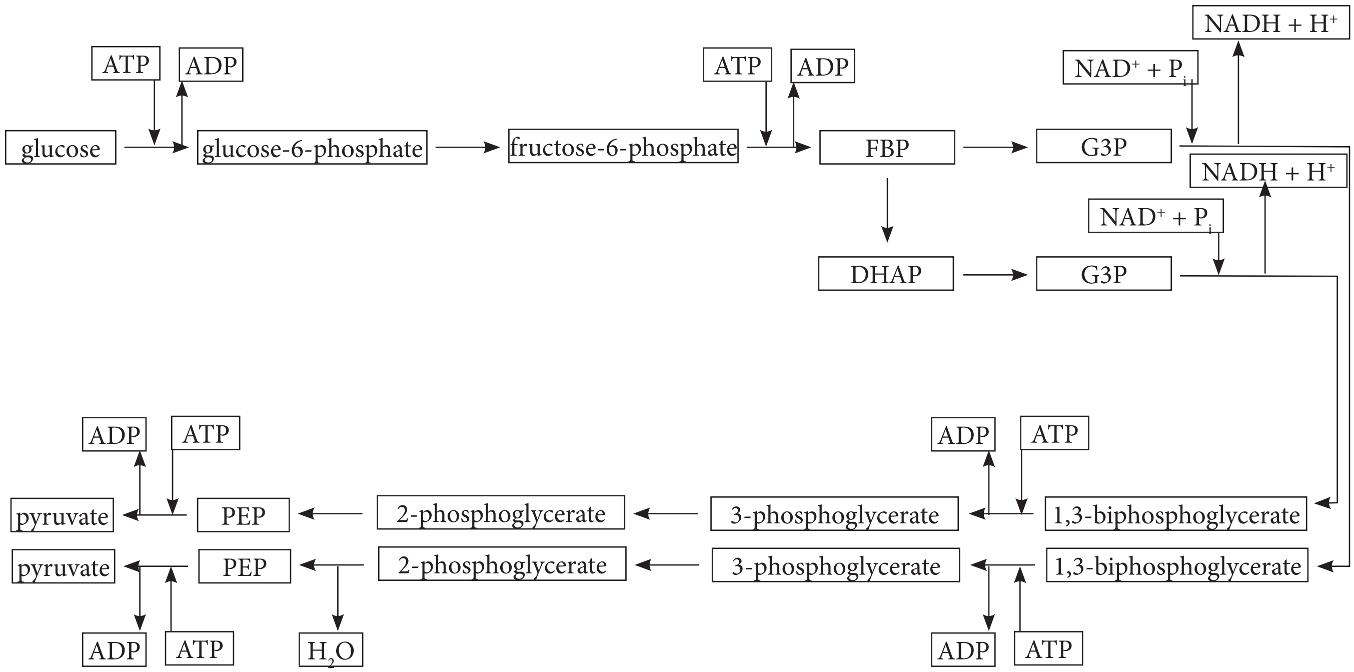
44. Name and describe properties of water that are essential to life.

cohesion	hydrogen bonding causes water molecules to stick to each other
surface tension	produced by hydrogen bonding causing water molecules to stick to each other
adhesion	hydrogen bonding causes water molecules to stock to other substances
high specific heat capacity	the amount of heat required to raise the temperature of one gram of a substance by 1°C
large temp range	large range between freezing and boiling, so water exists routinely in all three major phases
unusual density pattern	density increases during cooling, but then decreases just before freezing
dissolves many substances	called the universal solvent

45. Name the four major classes of biomolecules. For each one, give an example of a particular biomolecule and its role in the cell (or a particular organelle), e.g., proteins serve as channels in the plasma membrane.

Comment: There are many possible examples for the four major types of molecules.

carbohydrates
Example: starch, the major dietary source of glucose
Example: glycogen, the storage molecule for glucose
Example: cellulose, source of dietary fiber
Example: chitin, forms the exoskeletons of insects and crustaceans



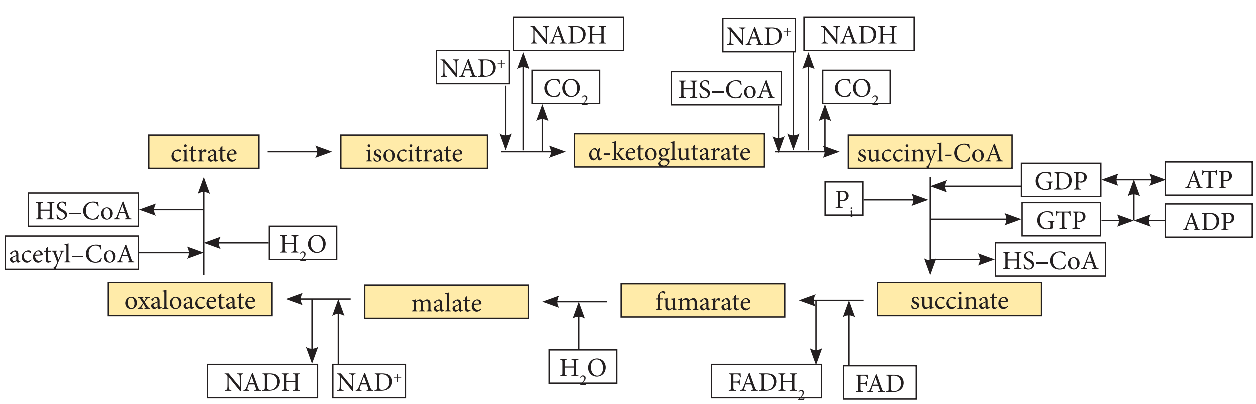
14. Explain the central dogma of biology.

The central dogma of biology states: The information in DNA flows from DNA to new DNA, DNA to RNA, and from RNA to protein, but cannot flow from protein to anywhere else. Once information has been embedded in a protein, it cannot get out.

The central dogma is intended to be a statement about biological information flow, particularly about the irreversibility of information flow once that information has made it down to the protein level where it is embedded in the sequence of amino acids comprising the protein. Information flows from DNA to new DNA during replication, from DNA to RNA during transcription, and from RNA to protein during translation. Organisms do not access genetic information from proteins themselves.

15. Describe the citric acid cycle.

The citric acid cycle breaks down acetyl-CoA into CO_2, produces two ATP and four CO_2 per molecule of glucose going into glycolysis, and produces six NADH and two $FADH_2$ electron transporters per molecule of glucose going into glycolysis. Molecules, inputs, and outputs are as follows:



16. Describe the role of the Golgi apparatus.

Once a protein is synthesized by a ribosome attached to the rough ER, it is transported to the Golgi apparatus. The Golgi apparatus is composed of membranes structured like a stack of completely separate membrane compartments. The purpose of the Golgi apparatus is to modify, package, and transport proteins. The Golgi's stack of membranes has a receiving end and a shipping end. When a protein is synthesized by ribosomes in the rough ER, it is typically released in a vesicle. A membrane-enclosed protein (transport vesicle) arriving from the ER fuses with the receiving membrane of the Golgi and proceeds through

Course Lesson List **Advanced Biology** **Fall Semester**

Lesson Number	Activity or Topic	Text Key	Assignment	Notes
1	Opening day: Review syllabus and how to study for mastery by practicing.			
2	Truth, facts, theories, hypotheses, Cycle of Scientific Enterprise	1.1.1-1.1.3		
3	Instruments and measurement	1.1.4	1.1 exercises	
4	ACAB Activity 1: Making Observations			ACAB = *The Apprentice's Companion for Advanced Biology*, available from Novare Science and Classical Academic Press
5	Quiz 1 (1.1.1-1.1.3) Life vs non-life	1.2.1		Quiz 1
6	Cellular structure and levels of organization	1.2.2		
7	ACAB Activity 2: The Cycle of Scientific Enterprise	1.1.1-1.1.3		
8	Living things: metabolize; grow, develop, reproduce	1.2.3-1.2.4		
9	Living things: use/transmit genetic info, respond, adapt	1.2.5-1.2.7	1.2 exercises	
10	Quiz 2 (1.2.1-1.2.2) ACAB Activity 3: Introduction to Microscopes	1.3.4		Quiz 2
11	Discussion			
12	History of biogenic theory; Modern Vocabulary	1.3.1-1.3.4	1.3 exercises	
13	Discussion			
14	Test Chapter 1			Test Chapter 1
15	Intermolecular interactions	2.1.1		
16	Structure and properties of water	2.1.2		
17	ACAB Activity 4: Making Solutions	2.1	2.1 exercises	
18	Quiz 3 (2.1.1-2.1.2) Elements of life	2.2	2.2 exercises	Quiz 3
19	ACAB Activity 5: Melting Points of Two Solutions	2.1		
20	Functional groups	2.3.1		
21	Monomers and polymers	2.3.2		
22	Carbohydrates, lipids, proteins	2.3.3		
23	Discussion			
24	Amino acids	2.3.4		
25	Proteins and nucleic acids	2.3.5	2.3 exercises Review Exercises	
26	Quiz 4 (2.2-2.3.3) ACAB Activity 6: Properties of Water	2.2		Quiz 4
27	Discussion			
28	Test Chapter 2			Test Chapter 2
29	History of cell theory	3.1.1		
30	Tenets of cell theory; prokaryotic and eukaryotic cells	3.1.2-3.1.3	3.1 exercises	
31	Cell size, genetic expression (nucleus, ribosomes)	3.2.1-3.2.2		
32	Endomembrane system	3.2.3		
33	Quiz 5 (3.1.1-3.1.3) Energy production	3.2.4		Quiz 5
34	Cytoskeleton, extracellular features, cell membrane	3.2.5-3.3.1	3.2 exercises	
35	Discussion			
36	ACAB Activity 7: Introduction to Cells	3.2		
37	Quiz 6 (3.2.1-3.2.5) Passive transport	3.3.2		Quiz 6
38	Passive and active transport	3.3.2-3.3.3		
39	Cell compartmentalization, endosymbiosis	3.3.4	3.3 exercises Review Exercises	
40	Discussion and ACAB Activity 8: Diffusion	3.3.2		
41	ACAB Activity 9: Osmosis	3.3.2		
42	Discussion			
43	Test Chapter 3			Test Chapter 3
44	Energy, chemical reactions, ATP, enzymes	4.1.1-4.1.4	4.1 exercises	
45	ACAB Activity 10: Calorimetry	4.1, 4.2		
46	Production of ATP	4.2.1		
47	ACAB Activity 11: Enzymes	4.1.4		
48	Quiz 7 (4.1.1-4.1.4) Cellular respiration—overview	4.2.2		Quiz 7
49	Cellular respiration	4.2.2		

50	Cellular respiration	4.2.2		
51	Fermentation, anaerobic respiration, other metabolism	4.2.3-4.2.4	4.2 exercises	
52	Discussion			
53	ACAB Activity 12: Fermentation			
54	Photosynthesis: Light and the E/M spectrum, chlorophyll	4.3.1		
55	Quiz 8 (4.2.1-4.2.2) Light-dependent reactions	4.3.2		Quiz 8
56	Calvin cycle; adaptations	4.3.3-4.3.4	4.3 exercises Review Exercises	
57	Discussion			
58	Test Chapter 4			Test Chapter 4
59	ACAB Activity 13: Photosynthesis			
60	Cell signaling, stages, reception	5.1-5.2.1	5.1 Exercises	
61	Signal transduction, cell response and regulation	5.2.2-5.2.3	5.2 Exercises	
62	The cell cycle, DNA structure and bonding details	5.3.1-5.3.2		
63	Synthesis (DNA replication)	5.3.3.		
64	Synthesis (DNA replication)	5.3.3.		
65	Quiz 9 (5.2) Discussion			
66	Mitosis and cytokinesis	5.3.4		
67	Mitosis and cytokinesis	5.3.4		
68	ACAB Activity 14: Observing Mitosis			
69	Regulation of the cell cycle	5.3.5	5.3 exercises Review Exercises	
70	Quiz 10 (5.3.3) Discussion			Quiz 10
71	Discussion			
72	Test Chapter 5			Test Chapter 5
73				

Course Lesson List **General Biology** **Spring Semester**

Lesson Number	Topic	Text Key	Assignment	Notes
1	Asexual & sexual reproduction; Meiosis	6.1.1		
2	Meiosis	6.1.2		
3	Genetic diversity	6.1.3		
4	ACAB Activity 15: Looking at Meiosis	6.1.2	6.1 exercises	ACAB = *The Apprentice's Companion for General Biology*, available from Novare Science and Classical Academic Press
5	Quiz 11 (6.1.1-6.1.2) Chromosomal basis of sex	6.2.1		Quiz 11
6	Nondisjunction, chromosomal abnormalities	6.2.2	6.2 exercises	
7	Mendel	6.3.1		
8	Laws of segregation and independent assortment	6.3.2		
9	Discussion			
10	Punnett squares	6.3.3		
11	ACAB Activity 16: Inheritance: Following Mendel	6.3.1		
12	Pedigrees	6.3.4		
13	Non-Mendelian inheritance	6.3.5	6.3 exercises Review Exercises	
14	ACAB Activity 17: Blood Typing			
15	Quiz 12 (6.3.3-6.3.4) Discussion			Quiz 12
16	Text Chapter 6			Test Chapter 5
17	History of DNA discovery	7.1.1		
18	Discovery of DNA structure	7.1.2		
19	DNA structure, histones, nucleosomes, chromosomes	7.2.1-7.2.2		
20	ACAB Activity 18: Extracting DNA	7.1.2		
21	RNA structure and history	7.2.3	7.2 exercises	
22	Quiz 13 (7.1) Discussion			Quiz 13
23	Transcription	7.3.1		
24	Transcription	7.3.1		
25	Translation	7.3.2		
26	Translation	7.3.2		
27	Post-translational modification and regulation	7.3.3	7.3 exercises	
28	ACAB Activity 19: Gene Expression			
29	Quiz 14 (7.3) Discussion			Quiz 14
30	Gene mutations	7.4.1		
31	Chromosomal mutations	7.4.2	7.4 exercises	
32	Recombinant DNA technology	7.5.1		
33	Gene editing	7.5.2		
34	RNA vaccines	7.5.3	7.5 exercises Review Exercises	
35	ACAB Activity 20:			
36	ACAB Activity 21:			
37	Discussion			
38	Test Chapter 7			Test Chapter 7
39	AP Exam practice			
40	Ecology, nutrient cycling	8.1, 8.2.1	8.1 exercises	
41	Nutrient cycling	8.2.1		
42	ACAB Activity 22: Plant Response to Pollutants			
43	Biomes	8.2.2		
44	Biomes	8.2.2	8.2 exercises	
45	ACAB Activity 23: Soil Testing	8.2		
46	Discussion			
47	Trophic levels and food webs	8.3.1		
48	Populations	8.3.2		
49	Quiz 15 (8.2) Keystone species	8.3.3		Quiz 15
50	Ecological succession	8.3.4		
51	Symbiotic relationships	8.3.5	8.3 exercises	
52	ACAB Activity 25: Owl Pellet Dissection	8.3		
53	ACAB Activity 25: Owl Pellet Dissection	8.3		
54	Quiz 16 (8.3) Discussion			Quiz 16
55	Human population	8.4.1		

56	ACAB Activity 24: Population Calculations	8.4.1		
57	Habitat destruction	8.4.2		
58	Waste production	8.4.3		
59	Human stewardship	8.4.4	8.4 exercises Review Exercises	
60	Discussion			
61	Test Chapter 8			Test Chapter 8
62	AP Exam practice			
63	Selection	9.1.1		
64	Genetic drift and gene flow	9.1.2	9.1 exercises	
65	Discussion			
66	Quiz 17 (9.1) ACAB Activity 26: Natural Selection			Quiz 17
67	Population genetics: introduction	9.2.1		
68	Hardy-Weinberg equilibrium	9.2.2		
69	Understanding the Hardy-Weinberg equation	9.2.3	9.2 exercises	
70	Quiz 18 (9.2.1-9.2.2) Species	9.3.1		Quiz 18
71	Reproductive isolation	9.3.2		
72	Patterns of speciation; time	9.3.3-9.3.4	9.3 exercises Review Exercises	
73	Discussion			
74	Test Chapter 9			Test Chapter 9
75	AP Exam practice			
76	Intro to evolution	10.0, 10.1.1		
77	Definitions used in evolutionary theory	10.1.2		
78	Early history	10.1.3		
79	Charles Darwin	10.1.4		
80	The modern synthesis	10.1.5	10.1 exercises	
81	Quiz 19 (10.0-10.1) Discussion			Quiz 19
82	Evidence for macroevolution	10.2.1		
83	Evidence for macroevolution	10.2.1		
84	Quiz 20 (10.2) Discussion			Quiz 20
85	Evo-devo	10.2.2		
86	History of life on Earth	10.2.3		
87	Patterns and challenges in life's history	10.2.4		
88	Human origins	10.2.5	10.2 exercises Review Exercises	
89	Discussion			
90	Test Chapter 10			Test Chapter 10
91				

First and Last Name___________________________________

Advanced Biology Chapter 5 Exam

Answer questions in complete sentences using correct spelling and grammar. Point values are shown in parentheses.

1. What was Earl Sutherland's contribution to our understanding of cell communication? (10)

2. Describe the three stages of signal transduction. (20)

3. Describe how a phosphorylation cascade works. (10)

4. Describe the initiation and process of DNA replication. (20)

5. List and describe the five stages of mitosis. (10)

6. Describe the cell cycle. (10)

7. Describe the four major groups of amino acids and give an example of each. (10)

8. Describe the purpose and process of the Krebs cycle. Include a list of the inputs and outputs. (10)

First and Last Name___________________________________

Advanced Biology Quiz 9: Chapter 5 (5.2)

Point values for each item are shown in parentheses. Write all responses in complete sentences, using correct spelling and grammar.

1. List and describe the three stages of cell signaling. (50)

2. Write brief definitions for each of the following terms. (50)

   a. signal-transduction pathway

   b. ligand

   c. receptor

   d. second messenger

   e. transcription factor